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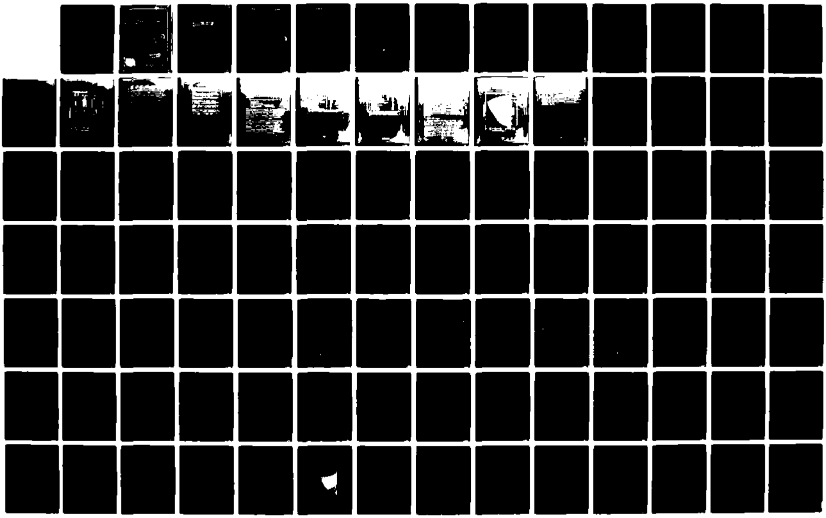

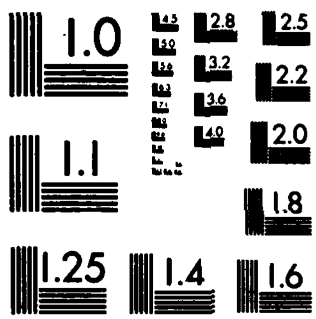

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A METHOD FOR CALCULATING INDUSTRIAL MOBILIZATION REQUIREMENTS WHICH INCORPORATES PRODUCTION PROCESS TIMES

VOLUME I

MAIN REPORT

Paul McCoy

October 1982

Prepared for

Office of the Under Secretary of Defense for Research and Engineering

INSTITUTE FOR DEFENSE ANALYSES
PROGRAM ANALYSIS DIVISION

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This paper presents a new economic model for assessing the industrial requirements generated by increased production for defense during a mobilization or due to a surge in requirements during peacetime. The model's procedure combines an input-output analysis of the direct and indirect requirements associated with defense production with information on processing times in each industry. In this way, one can determine not only the magnitude of production surges but also the time of peak activity in each industrial sector. (continued)

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The model is used to simulate increases of 50 to 200 percent in the level of overall defense spending. Two sorts of bottlenecks are identified--the first involving industries where peak requirements exceed capacity and the second, where cumulated processing times exceed the preparation period envisioned in the scenario.

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Contract MDA 903 79 C 0202
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FOREWORD

The analytic model presented in this paper was created by Dr. Paul McCoy. When Dr. McCoy left employment with IDA, I assumed responsibility for maintaining the IDA study effort in industrial mobilization. Miss Eileen Doherty (PAD editor) and I have edited this paper for publication.

The substance of the paper is unchanged from Dr. McCoy's preliminary draft; however, certain material was excluded and the appendices transferred to a second volume for easier handling by the reader.

R William Thomas

Dr. R. William Thomas

PREFACE

This paper was prepared by the Institute for Defense Analyses (IDA) for the Office of the Under Secretary of Defense Research and Engineering/Acquisition Policy (OUSDRE/AP) under Contract MDA 903 79 C 0202, Task Order No. T-190, dated April 1981.

The purpose of the study was to present an economic model for assessing the industrial requirements generated by increased production for defense during a mobilization or due to a surge in requirements during peacetime. The IMPMOD model's procedure combines an input-output analyses of the direct and indirect requirements associated with defense production with information on processing times in each industry. By so doing, one can determine the magnitude of production surges and the timing of peak activity in each industrial sector. The model simulates increases of 50 to 200 percent in the level of overall defense spending. Two sorts of bottlenecks are identified--the first involving industries where peak requirements exceed capacity, and the second, where cumulative processing times exceed the preparation period envisioned in the scenario.

This publication is issued in fulfillment of the contract.

ACKNOWLEDGMENTS

I wish to express my appreciation to Mr. John DuBreuil of the Office of the Director for Materiel Acquisition Policy, OUSDRE, who initiated the study, provided overall direction, and gave advice and assistance on a continual basis.

Many other people assisted by providing data and suggesting improvements. Particularly helpful have been Dr. James Bell, Dr. David Blond, Dr. Herschel Kanter, Lt. Col. Thomas Moore, Dr. Michael O'Brien, and Dr. R. William Thomas.

Paul McCoy

Paul McCoy by LWT

CONTENTS

VOLUME I

VOLUME II

APPENDICES

FIGURES

VOLUME I

VOLUME II

TABLES

VOLUME I

VOLUME II

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The purpose of this study effort was to develop [illegible] for identifying key sectors of the U.S. industrial base which would most constrain a major force expansion. The study sets forth a method for calculating defense industrial requirements in a major force expansion and illustrates the methodology through analyses of alternative levels of defense spending. This research was prompted by growing concern that, as world tensions rise, the capacity of our defense industrial base would be a major constraint on necessary force expansion.

The Under Secretary of Defense for Research and Engineering is assigned responsibility for acquisition management. This study addresses the mobilization capacity potential of the U.S. economy for increases varying from 50 to 200 percent in defense spending. Figure S-1 displays the expansion levels in terms of billions of 1981 dollars and percent of GNP for FY 1985 through FY 1990. Such expansion would imply defense spending levels (as a percent of GNP) comparable to the Korean War period and slightly greater than that of the Vietnam War period, but far less than that of World War II.

Chapter I

INTRODUCTION

A. BACKGROUND

Direct planning and funding by the Department of Defense for U.S. production facilities that support the manufacture of defense items has declined since the end of the Vietnam War. This has been caused by increasingly constrained defense budgets and increased emphasis on military readiness which directs dollars from investment in production facilities. Between fiscal years 1976 and 1979, budgeted funding for ammunition procurement doubled while funding for the ammunition production base, which comprises half of DoD-owned production facilities, was reduced by almost one-half.

In the recent past many articles and studies have claimed that the defense industrial base has deteriorated and is in danger of further deterioration in the coming years. Two examples of these studies are the Report of the Defense Industrial Base Panel of the Committee on Armed Services, House of Representatives [1], and the Defense Science Board 1980 Summer Study on Industrial Responsiveness [2]. Both studies point out the lengthening production lead times and increased costs for defense items which are symptomatic of capacity constraints, particularly at the lower tiers of the production process.

The current Administration recognized these problems and has placed emphasis on improving the defense industrial base. Not only have additional moneys been allocated to support production facilities, but also for the first time DoD official statements and planning documents mention planning levels for production facilities based on supporting a force expansion above the approved force. The intent of this study is to develop a mechanism for identifying key problem areas in the U.S. industrial base which would most constrain a major force expansion.

B. CURRENT MODELS FOR MOBILIZATION PLANNING

There are three general methods which are currently used for mobilization planning of defense production capacity. The Critical Path Method is often used in lead time studies done by the Services for particular weapon systems. Examples are the studies done by and for the Army for large-caliber ammunition [11], for the TOW weapon system [8], and for the 155mm self-propelled howitzer [9]. Advantages of this approach are that very detailed components of the weapon system can be individually tracked and that time delays in the various stages of production can be explicitly analyzed. A primary disadvantage is that usually only one weapon system at a time is analyzed due to the data and computation demands of this procedure. In a major force expansion where many weapon systems are being produced, as well as all the other items needed by defense, the requirements for components common to more than one weapon system or defense item would be underestimated unless a lead time study was done for every item and the results were combined.

The second general method to analyze mobilization uses input-output models. The most recent input-output table published by the U.S. Department of Commerce aggregates the commodities produced by the U.S. economy into 485 groups. These data can be combined with macroeconomic models to develop forecasts of U.S. production requirements. Several such models have been developed specifically for defense studies [5,10]. The DEIMS system [10] is of particular interest. It combines up-to-date defense requirements data with one of the largest commercially available forecasting models. Advantages of using these models for defense force expansion studies are that comprehensive data, which account for all commodities used in our economy, are available, and that due to their continual use, these models are constantly being tested and improved. Disadvantages are that they still use aggregated commodity groupings which may be too large to identify possible bottlenecks, and they do not explicitly model time delays due to production or capacity expansion.

The third general method is to use a linear programming model. Such a model was developed for the Federal Emergency Management Agency [4]. The primary advantages of using linear programming is that constraints can be explicitly included in the model. The FEMA model predicts capacity expansion over time. Its disadvantages are that (1) it does not take into account production time delays and (2) that due to the computational complexity of solving the linear program, the model is based on broader commodity groupings than other procedures.

C. STUDY APPROACH

In response to the current Administration's concern about the capability of the U.S. defense production base, the Under Secretary for Research and Engineering was assigned the responsibility for planning surges in defense spending of 50 to 200 percent. These are the expansion levels that this study will address. Figure 1 displays the expansion levels in terms of dollars and as a percent of Gross National Product (GNP). Expansion levels of 50 to 200 percent would bring us to the level of defense spending (as a percent of Gross National Product) that occurred during the Korean War, would be a little larger than occurred during the Vietnam War, but would be far less than defense spending during World War II (45 percent of GNP).

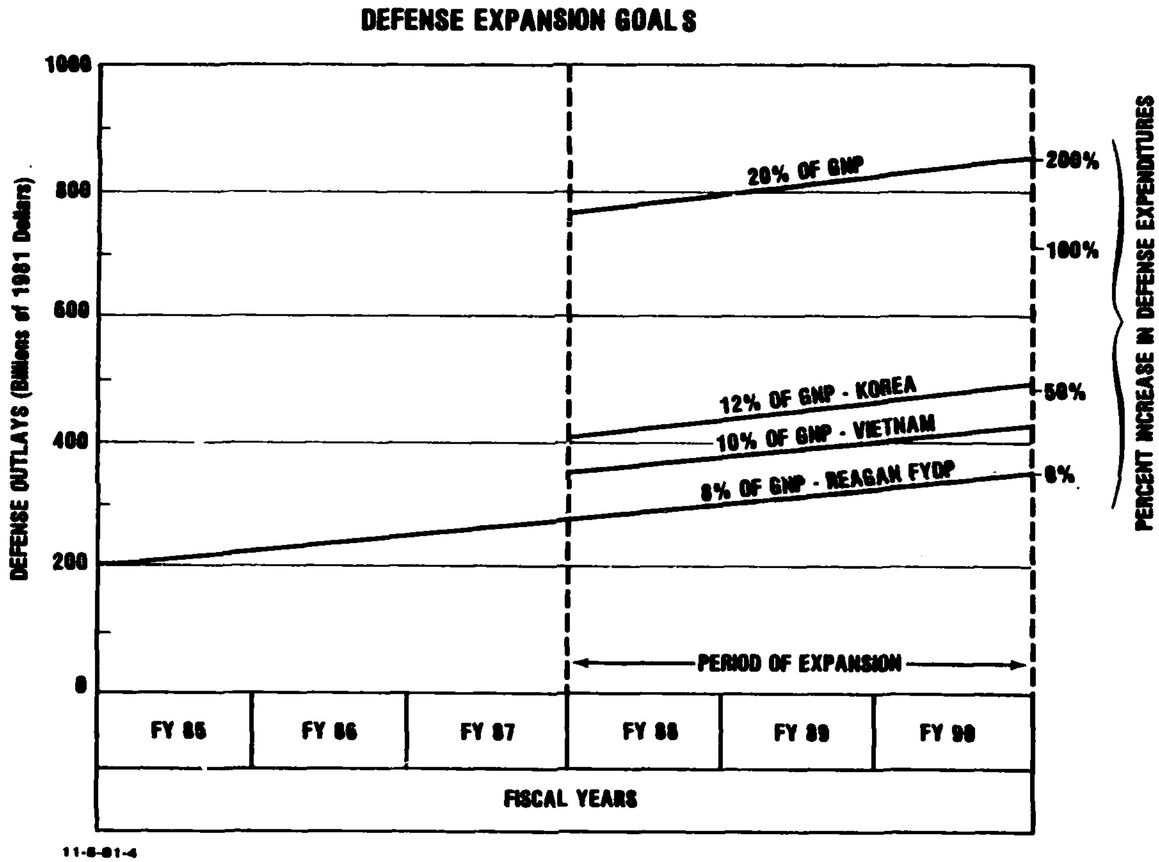

Figure 1. DEFENSE EXPANSION GOALS

Four major parameters must be specified in defining an industrial mobilization for defense. They are as follows:

- the amount of the surge (in terms of dollars or force structure units),
- the U.S. spending pattern during the mobilization (especially for defense),
- when the mobilization occurs (its start and finish times), and
- the delivery pattern of end items.

The expansion levels described earlier define the amount of the surge. Assumptions defining the remaining three parameters must also be made. In this study the U.S. spending pattern is defined for defense by the projected Five-Year Defense Plan (FYDP) for 1986, and for non-defense by estimated consumption in 1981. The industrial mobilization is assumed to occur within the next ten years (namely, FY 1981 to FY 1990). The delivery pattern of required defense end items is assumed to be evenly distributed over periods ranging from one week to five years.

The study presents a computer model which, for given values of the major parameters listed above, generates the following outputs:

- estimated production requirements and capacity,
- identification of those commodities whose production capacity would most constrain a force expansion,
- identification of those commodities which would be required first,
- a critical path network for any designated commodity, and
- assessment of the impact of reductions in production lead times.

The approach taken in developing the model was to combine the better features of the models currently available into a computationally feasible model which would generate the above outputs. Results are derived by running the model with a tentative set of data. The data set contains many rough estimates as little time was available for data collection, although the data set is sufficiently accurate to test the approach and indicate general results.

Chapter II

METHODOLOGY

A. GENERAL MODEL STRUCTURE

This study presents the Industrial Mobilization Planning Model (IMPMOD); its unique feature is that it combines the theoretical structures of critical path and input-output models. As will be explained in Section B, a commodity-to-commodity input-output model can be viewed as a collection of critical path networks (one network for the final demand of each commodity) where time delays for the arcs have been set at zero. Conversely, a critical path network for one defense end item can be viewed as a small component of a national input-output model but with added information about production time delays. IMPMOD generates time-phased industrial mobilization requirements using the comprehensive data base developed for input-output models together with production processing time delays typically used in critical path approaches.

In developing IMPMOD, compromises were made in order to build a model which was computationally feasible and used available data. The Department of Commerce's 1972 commodity-to-commodity input-output table was used as the model of U.S. production requirements. It has the advantage of being comprehensive in the sense that all commodities produced in the U.S. are accounted for. On the negative side, even though this table is the most detailed available with 485 individual commodities, it may be too aggregated to identify many industrial bottlenecks. IMPMOD was programmed so that, as more detailed production data are gathered, they can be readily integrated into the model. A second compromise was to devote almost all the computational work towards developing defense requirements. Non-defense requirements during the industrial mobilization period must also be estimated in order to draw conclusions about capacity requirements. The DEIMS system does a particularly good job of this. In IMPMOD, non-defense production requirements are essentially inputs--in this study we used Department of Commerce peacetime projections, although one could have used DEIMS projections just as well. The last major compromise made in developing IMPMOD was to base time delays entirely on production processing times--not to include time delays due to capacity limitations. It was felt that in a defense mobilization, the timing delays due to production lead times would be felt before those due to capacity expansion. Capacity expansion could be included in the model but would require additional programming.

The general structure of IMPMOD is similar to that of an input-output model like DEIMS although the calculation of indirect requirements is quite different (as is explained in the next section). The first three major inputs are the amount of the surge in defense spending (above peacetime funding), when the surge occurs, and the planned delivery schedule for defense end items. The fourth and last major input is the defense spending pattern which specifies precisely what commodities defense buys. We have used the pattern used in DEIMS which is based on the Five-Year Defense Plan (FYDP) spending estimates for FY 1986. IMPMOD develops a final demand vector for defense based on the amount of the surge and the defense spending pattern. It time-phases that final demand vector based on when the surge occurs and the planned end-item delivery schedule.

The resultant time-phased final demand vector is then passed through the input-output model described in Section B. The output is total defense surge requirements additionally time-phased due to production processing delays. At this point defense peacetime requirements and U.S. non-defense requirements are entered into the model. For each commodity, two numbers are required--the estimated requirement in 1981 and the projected annual growth. The estimated requirement that is entered can be only the direct requirement (and the model will calculate the additional indirect requirement) or both direct and indirect requirements added together. Also entered into the model at this point is estimated production capacity in 1981 and its projected annual growth. IMPMOD now plots a composite picture of total U.S. requirements over the mobilization period together with estimated U.S. capacity. It also will plot detailed critical path networks for designated commodities.

IMPMOD is programmed in FORTRAN and currently runs on a CDC 6400 computer, requiring 500,000 bytes of core memory, 1.6 million bytes of disk storage, and a Cal Comp plotter. Volume II, Appendix A contains a description of the program.

B. AN INTERNALLY DYNAMIC INPUT-OUTPUT MODEL

Dynamic input-output models typically time-phase total requirements in two ways. The first is to time-phase final demand (with particular emphasis on the investment component of final demand). The second is to adjust the input-output coefficients over time to reflect technological change. Note, however, that dynamic input-output models usually assume that all indirect requirements occur in the same time period as the direct requirement that generated them. For large surges in defense spending, this assumption may be particularly inappropriate as the time span between the required indirect commodities and delivery of the final end item may span several years due to production delays (e.g., two to four years for military aircraft and five to seven years for aircraft carriers and nuclear submarines). If the intended use of the analysis is to look for capacity bottlenecks, it is particularly important to know how requirements bunch up over time. For a particularly long lead-time item, capacity requirements for primary metal production may all occur very early in the production process while capacity requirements for final assembly may all occur very late in the production process. Assuming both direct and indirect requirements may be averaged over the same period (as is typically assumed in input-output models) distorts the comparison of requirements and capacity. This assumption precludes addressing the question of what capacity should be expanded first in an industrial mobilization. Figure 2 shows a hypothetical case involving two commodities--aircraft final assembly and nonferrous castings. The top half of Figure 2 shows the typical requirements distribution with no production delays, based on a direct requirement for aircraft in FY 1990. Both requirements for the end item and an indirect requirement for nonferrous castings are averaged over FY 1990. The bottom half of Figure 2 shows a possible requirements distribution when production processing delays are taken into account. As shown, the production of nonferrous casting must occur well before the final assembly of the required aircraft.

In this section we present a method of time-phasing indirect requirements based on production processing times. In the first subsection, notation and a useful result from static input-output theory are given. In the second subsection we explain how the static model may be modified to handle production delays. In the final subsection we show that if a particular method of matrix inversion is used in solving the modified static model, the resulting solution is equivalent to viewing the modified model as a collection of critical path

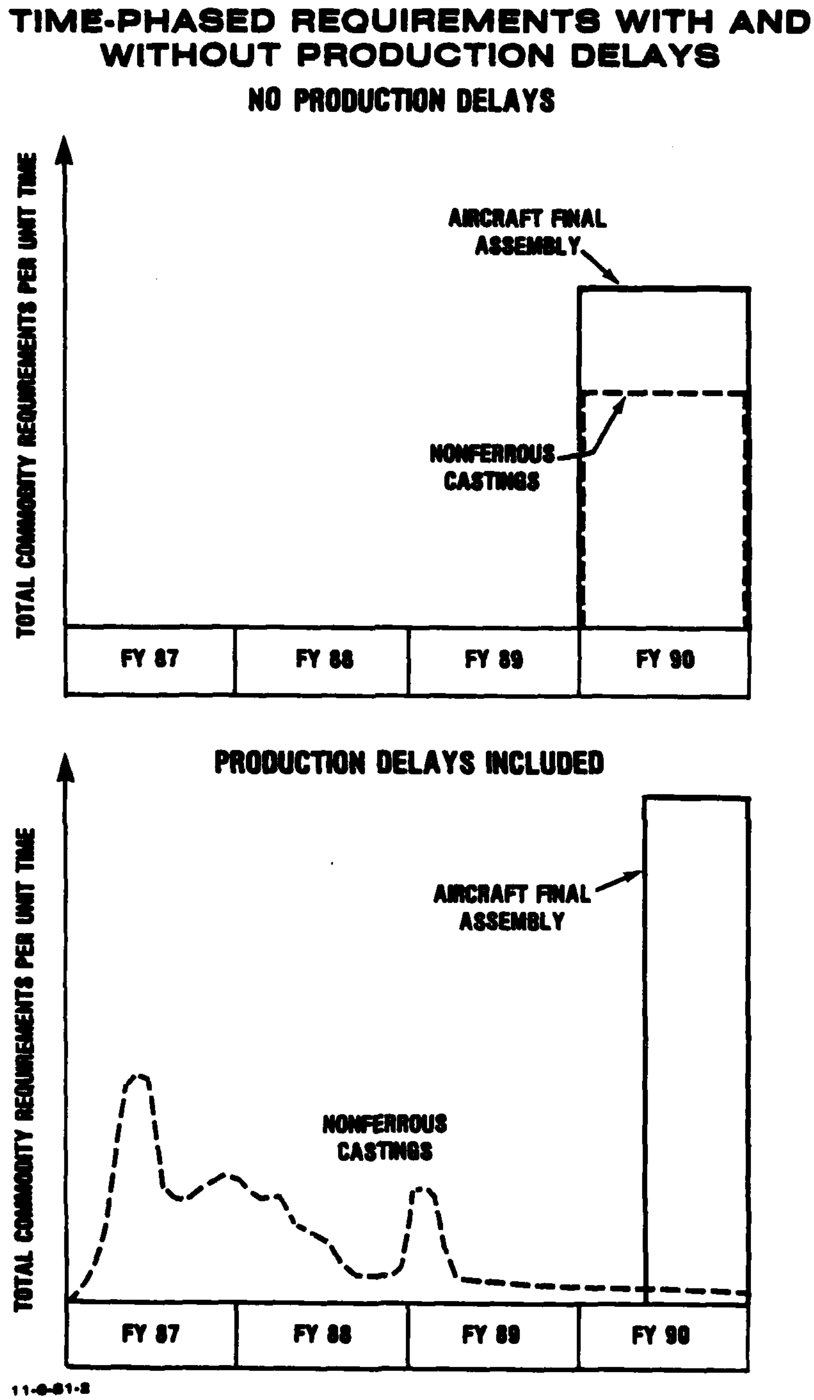

Figure 2. TIME-PHASED REQUIREMENTS WITH AND WITHOUT PRODUCTION DELAYS

networks--one for each commodity. From this formulation we derive a recursive solution algorithm which results in the most efficient solution procedure (the one used in IMPMOD). In this section we use as an example the input-output model actually used for the IMPMOD results reported in the following chapters. The model has 250 commodities with the industrial commodities at their lowest detail and the remainder aggregated as the two-digit SIC code level.

1. A Static Input-Output Model

Let the matrix A represent an NxN commodity-to-commodity input-output table.

Notation: N = number of commodities

$A = (a_{ij})$ is the NxN nonnegative matrix representing the input-output coefficients

$Z = (z_i)$ is the N vector representing final demands

$X = (x_i)$ is the N vector representing total requirements

Assumption 1:

$$a_{ij} \geq 0 \qquad \text{for all } i, j$$

and

$$\text{for some} \quad \varepsilon > 0, \ \sum_{i=1}^{N} a_{ij} \leq 1 - \varepsilon \quad \text{for all } j .$$

(Example: For the 250 Commodity Table, Primary Copper had the smallest value-added coefficient (0.098). Here ε is 0.098.)

We can now state a standard result in input-output theory.

Proposition 1: If Assumption 1 holds, then

$$(I-A)^{-1} = \sum_{n=0}^{\infty} A^n$$

Proof:

$$(I-A)\left(\sum_{n=0}^{m} A^n\right) = I-A^{m+1}$$

Using the $||\cdot||$ matrix norm

$$||A||_1 \equiv \max_{1\leq j\leq N} \sum_{i=1}^{N} |a_{ij}|$$

$$||A^{m+1}|| \leq ||A||^{m+1} \leq (1-\varepsilon)^{m+1} \to 0 \quad \text{as } m\to 0$$

thus

$$(I-A)^{-1} \text{ exists and equals } \sum_{n=0}^{\infty} A^n \qquad \text{Q.E.D.}$$

The standard input-output relationship is

$$X = AX+Z$$

which, by Proposition 1, yields

$$X = (I-A)^{-1}Z = \sum_{n=0}^{\infty} A^n Z \ . \tag{1}$$

(Example: For N=250, (I-A) has approximately 25,000 nonzero entries and is inverted directly quite easily by IMPMOD using LU decomposition.)

2. A Time-Phased Model Viewed as an Enlarged Static Model

Production processing times can be incorporated into the static input-output model by enlarging and slightly modifying the coefficient matrix.

Notation: T = number of time periods

$\lambda = (\lambda_i)$ is an N-vector representing commodity processing times

$$\bar{X} = \begin{bmatrix} x_1^1 \\ \cdot \\ \cdot \\ \cdot \\ x_1^T \\ x_2^1 \\ \cdot \\ \cdot \\ \cdot \\ x_N^T \end{bmatrix}$$ is a TN vector representing total requirements for each commodity i at every time t

$\bar{Z} = (Z_i)$ is a TN vector representing final demand composed of N elements Z_i each of which is a T vector

$$Z_i = \begin{bmatrix} z_i^1 \\ \cdot \\ \cdot \\ \cdot \\ z_i^T \end{bmatrix} \quad \text{with} \quad \begin{array}{ll} z_i^t = 0 & \text{for } T-\lambda_i < t \leq T \\ z_i^t = y_i^{t+\lambda_i} & \text{for } 1 < t \leq T-\lambda_i \\ z_i^t = \sum_{s=1}^{\lambda_i-1} y_i^s & \text{for } t=1 \end{array}$$

$\overline{A} = (G_{ij})$ is a TNxTN matrix composed of NxN elements G_{ij}, each of which is a TxT matrix.

$$
\begin{array}{cc}
 & \begin{array}{c} \text{column } \lambda_i \\ \downarrow \end{array} \\
G_{ij} = & \begin{bmatrix} a_{ij} & a_{ij} & \cdots & a_{ij} & 0 & \cdots & 0 \\ 0 & \cdots & & 0 & a_{ij} & & \vdots \\ & & & & & \ddots & 0 \\ \vdots & & & & & & a_{ij} \\ & & & & & & 0 \\ & & & & & & \vdots \\ 0 & & & \cdots & & & 0 \end{bmatrix}
\end{array}
$$

The effect of matrix G_{ij} is to lead the input requirement for commodity i by commodity j by the processing delay for commodity i (λ_i).

Notice that Assumption 1 holds for $\overline{A}$ since it holds for A.

Thus, Proposition 1 holds and we can use Equation (1) to get:

$$\overline{X} = (I-\overline{A})^{-1}\overline{Z} = \sum_{n=0}^{\infty} \overline{A}^n\overline{Z} \quad . \tag{2}$$

Total requirements, $\overline{X}$, can be calculated by using matrix inversion on the matrix $(I-\overline{A})$, although it may be quite large with TN rows and columns.

(Example: For N=250 and T=312 (weekly time periods for six years), $(I-\overline{A})$ has 78,000 rows and 7,800,000 non-zero elements which makes direct inversion very difficult.)

3. A Time-Phased Model Viewed as a Network Model

Direct inversion of the enlarged static model is very time-consuming. A more efficient solution procedure is developed below. The basic idea is that if the matrix inversion technique used to solve the enlarged static model is series expansion, then the model solution is equivalent to solving a large collection of critical path networks similar to those used in Service leadtime studies. To proceed further, we need the following definition:

Definition: A sequence of n commodities $(i_1, i_2, \ldots, i_n)$ is a *path of length n* if

$$a_{i_m i_{m+1}} > 0 \quad \text{for all m:} \quad 1 \leq m < n$$

Writing Equation (2) element by element we find:

$$x_i^t = \sum_{n=0}^{\infty} \{\bar{A}^n \bar{Z}\}_i^t$$

$$= \sum_{n=0}^{\infty} \left\{ \sum_{j=1}^{N} \sum_{\substack{\text{all paths} \\ \text{of length n} \\ (j,k_2,\ldots,k_{n-1},i)}} G_{ik_{n-1}} G_{k_{n-1}k_{n-2}} \cdots G_{k_2 j} Z_j \right\}^t \qquad (3)$$

$$x_i^t = \sum_{j=1}^{N} \sum_{\substack{\text{all paths} \\ (j,k_2,\ldots,k_{n-1},i)}} a_{ik_{n-1}} a_{k_{n-1}k_{n-2}} \cdots a_{k_2 j} y_j^s \qquad (4)$$

such that $\lambda_i + \sum_{m=2}^{n-1} \lambda_{k_m} + \lambda_j + t = s \quad (\geq s \text{ if } t=1)$.

Now notice that Equation (4) represents the solution calculations for a collection of critical path networks with nodes representing dollar flows and arcs representing time delays. Figure 3 shows one such network.

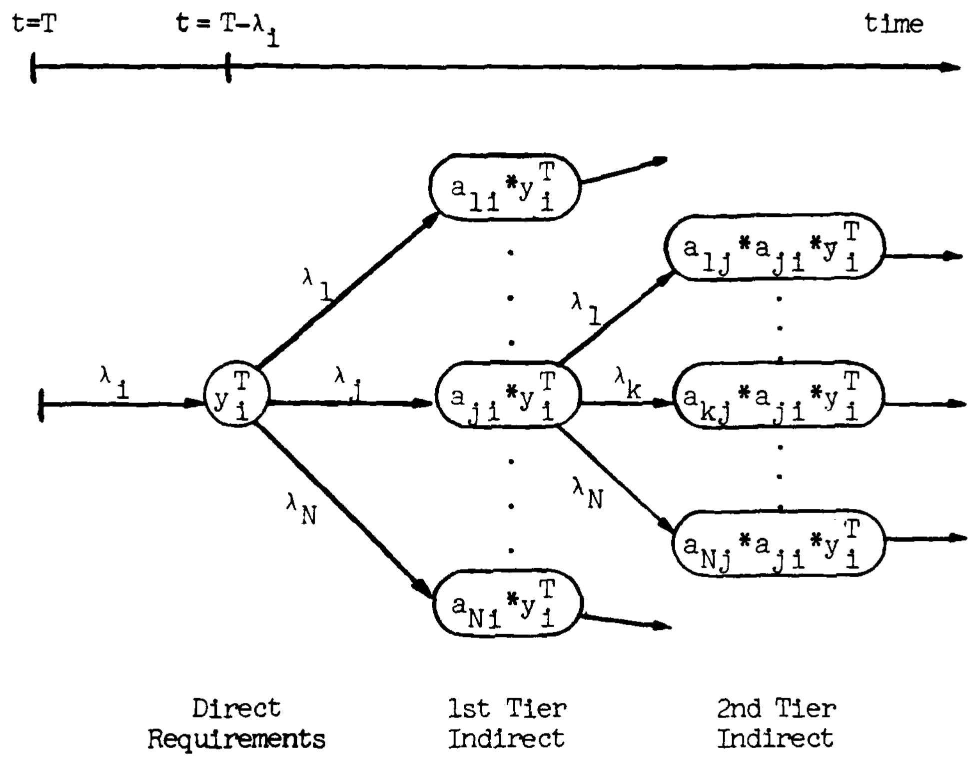

Figure 3. ASSOCIATED CRITICAL PATH NETWORK FOR COMMODITY i FOR FINAL DEMAND DELIVERED AT TIME T

We can make this easier to compute by turning Equation (4) into a backwards recursion so that the work done in calculating $\overline{X}_i^t$ for later values of t helps in calculating $\overline{X}_i^t$ for earlier values of t.

$$x_i^t = \sum_{j=1}^{N} a_{ij} x^{t+\lambda_i} + z_i^t \qquad \text{if } t > 1$$

$$x_i^1 = \sum_{j=1}^{N} \sum_{s=1}^{\lambda_i+1} a_{ij} x_j^s + z_i^1 \qquad \text{for } t=1 \ . \tag{5}$$

As the time horizon is fixed at T, we have assumed that all requirements which occur in time periods prior to t=1 are accounted for in the total requirement value for the first time period. Thus, total requirements for the time-phased and static models are equal when aggregated over time. Equation (5) is the solution procedure used in IMPMOD.

C. POSSIBLE EXTENSIONS

Many extensions are possible in making the model more realistic. As currently programmed, IMPMOD displays production capacity for each commodity but it has no impact on the time distribution of requirements. In reality, when requirements exceed capacity, queues will develop and production lead times will increase. IMPMOD could be modified so that when requirements exceed capacity in any time period, the production delay is increased by a wait time that allows all requirements to be met by existing capacity. Another extension in this same area is to explicitly model capacity expansion. In a mobilization, production capacity could be expanded. The expansion of facilities to increase capacity would require resources, and the production of these resources entails time delays identical to those already modeled in IMPMOD. A further extension is to allow different queue disciplines. One may want to place commodities used in the production of defense end items ahead of others in any queue that forms or even prioritize the defense items according to the Master Urgency List used by DoD to prioritize production in a mobilization.

Chapter III

DATA

A rather large data base was developed for use by IMPMOD. The intent was to collect the data needed to run IMPMOD from the best available sources, and where none existed, to use reasonable estimates. The purpose of this initial data base was to test out the model, to indicate the general nature of model results, and to estimate the work involved in creating a truly operational data base.

A. COMMODITIES AND ASSOCIATED INPUT-OUTPUT TABLE

The input-output table used in IMPMOD is the most recent and detailed table available. The table is based on the inter-industry transactions developed in the 1972 input-output study at the 496-industry level. The study was done by the Inter-industry Economics Division, Bureau of Economic Analysis, U.S. Department of Commerce [12], and became publicly available in 1979. We used the commodity-to-commodity table, feeling that the commodity classification was more appropriate for this study than the industry classification, particularly since we were including production processing times. We made no attempt to update the coefficients to reflect technological change beyond 1972; to do so would have required substantial programming effort and it was felt that for this initial test of the model, the non-updated table was adequate.

The input-output table, at its most detailed level, contains 485 commodities. Basically, their descriptions correspond to the four-digit Standard Industrial Code (SIC) classification levels described in Reference [13]. While it would be desirable to have much more detail for the industrial and military commodities, it was felt that the detail for consumer-oriented commodities could be sacrificed in order to decrease the computational demands on IMPMOD (it really is not necessary to distinguish between items like milk and cheese production). As a consequence, we aggregated many of the non-industrial commodities so that the total number we deal with in this study is 250. IMPMOD does this aggregation automatically (the process is described in Volume II, Appendix A). The new table has 22,459 non-zero coefficients while the unaggregated table has 56,046 coefficients.

Table 1 lists the aggregated commodities. ID. NO. is the industry identification number which defines the commodity. The VALUE-ADD column represents the total value-added coefficient for that commodity. NO. INPUTS is the number of direct inputs required in the production of the associated commodity. The last three columns are, respectively, estimated 1981 defense shipments, total U.S. shipments, and total U.S. production capacity. Their derivation will be explained later.

Table 1. IMPMOD COMMODITIES AND ESTIMATED REQUIREMENTS IN 1981 (MILLIONS OF 1981 DOLLARS)

INPUT/OUTPUT COMMODITIES - MILITARY END ITEMS

SEQ. NO.	ID. NO.	COMMODITY NAME	VALUE-ADD	NO. INPUTS	DEF. SHIP.	TOTAL SHIP.	CAPACITY
1	60.0100	AIRCRAFT	.449	115	11024.3	28200.0	56239.3
2	61.0100	SHIPBUILDING	.492	144	5408.9	8597.0	15962.6
3	13.0300	TANKS	.385	83	757.5	757.5	2204.9
4	13.0100	GUIDED MISSILES	.643	101	7344.2	9169.7	14522.2
5	13.0500	SMALL ARMS	.635	62	198.2	935.9	1768.2
6	13.0200	AMMUNITION	.397	114	3348.2	3450.9	53091.5
7	13.0600	SMALL ARMS AMMO	.457	52	520.8	1084.7	19468.3
8	13.0700	OTHER ORDNANCE	.611	95	1117.6	1388.3	3559.8

INPUT/OUTPUT COMMODITIES - TRANSPORTATION EQUIPMENT

SEQ. NO.	ID. NO.	COMMODITY NAME	VALUE-ADD	NO. INPUTS	DEF. SHIP.	TOTAL SHIP.	CAPACITY
9	59.0301	MOTOR VEHICLES	.272	127	1010.2	82800.0	92884.6
10	59.0200	TRUCK TRAILERS	.415	97	43.5	2333.0	3140.6
11	59.0100	TRUCK/BUS BODIES	.388	109	3.3	1870.0	3146.6
12	60.0200	AIR/MISSILE ENG.	.463	130	8301.8	13500.0	25506.1
13	60.0400	AIR/MISS. EQUIP.	.488	145	8114.0	11000.2	20424.7
14	61.0300	RAILROAD EQUIP.	.407	119	45.0	5988.4	7246.1
15	59.0302	VEHICLE PARTS	.442	177	867.3	50445.4	59698.7
16	61.0200	BOAT BUILDING	.385	112	16.3	3027.6	4866.4
17	61.0500	MOTORCYCLES/BIKE	.356	78	12.5	1381.5	1836.7
18	61.0601	CAMPERS	.267	92	.0	3157.7	4595.4
19	61.0602	MOBILE HOMES	.274	104	0.0	7764.5	13936.2
20	61.0700	TRANSPORT. EQUIP	.312	104	23.8	1924.4	3238.1

(Continued)

Table 1. (Continued)

INPUT/OUTPUT COMMODITIES - MACHINERY

SEQ. NO.	ID. NO.	COMMODITY NAME	VALUE-ADD	NO. INPUTS	DEF. SHIP.	TOTAL SHIP.	CAPACITY
21	43.0100	STEAM TURBINES	.520	115	237.5	2453.0	3182.8
22	43.0200	INT. COMB. ENGIN	.412	122	336.6	8431.6	11641.3
23	44.0001	FARM EQUIPMENT	.466	126	28.7	13500.0	25066.3
24	44.0002	GARDEN EQUIPMENT	.331	100	11.2	2893.5	4100.2
25	45.0100	CONSTRUCT. EQUIP	.446	136	232.8	17290.0	24826.7
26	45.0200	MINING EQUIPMENT	.465	101	22.8	2900.0	4164.1
27	45.0300	OILFIELD MACH.	.551	99	23.4	9375.0	12464.4
28	46.0100	ELEVATORS	.402	65	29.3	665.0	1136.8
29	46.0200	CONVEYORS	.525	103	18.8	2989.0	4527.6
30	46.0300	HOISTS/CRANES	.438	89	36.9	1225.0	1807.2
31	46.0400	IND. TRUCKS/TRAC	.458	93	39.7	2970.0	4504.9
32	47.0100	METAL CUTTING	.527	103	69.7	7594.0	11683.1
33	47.0200	METAL FORMING	.518	90	31.4	2240.0	3216.4
34	47.0300	SPECIAL DIES/TOO	.638	148	659.9	8745.0	13264.4
35	47.0401	POWER HAND TOOLS	.511	87	21.5	1529.1	2573.0
36	47.0402	ROLLING MILL MAC	.580	71	3.1	671.6	1148.1
37	47.0403	METALWORK MACH.	.548	87	26.3	1848.3	1590.1
38	48.0100	FOOD PROD. MACH.	.527	100	3.5	3362.0	5570.2
39	48.0200	TEXTILE MACH.	.540	79	6.8	1310.0	2312.7
40	48.0300	WOODWORK MACH.	.445	74	2.8	1120.5	1453.8
41	48.0400	PAPER IND. MACH.	.502	78	5.8	987.8	1541.7
42	48.0500	PRINTING MACH.	.524	92	13.4	2525.0	4183.4
43	48.0600	SPECIAL MACHINER	.497	147	88.2	532.0	830.3
44	49.0100	PUMPS/COMPRESSOR	.474	132	255.4	10130.0	14354.3
45	49.0200	BALL/ROLLER BEAR	.571	67	265.5	3950.0	4889.5
46	49.0300	BLOWERS/FANS	.471	110	71.0	1862.0	2948.9
47	49.0400	INDUST. PATTERNS	.707	54	31.8	577.7	715.0
48	49.0500	POWER TRANS. EQ.	.55[illegible]	123	214.0	3875.4	5564.6
49	49.0600	IND. FURN/OVENS	.474	69	6.2	1261.0	2089.2
50	49.0700	GENERAL MACH.	.454	120	93.7	2847.1	5196.7
51	50.0001	CARBURETORS	.573	100	49.8	2146.4	3081.9
52	50.0002	MACHINERY	.552	131	1030.2	8679.4	14162.1
53	51.0101	COMPUTING EQUIP.	.427	121	788.0	32800.0	47097.4
54	51.0102	ACCOUNTING MACH.	.439	85	9.2	1782.7	2742.6
55	51.0200	TYPEWRITERS	.515	63	7.6	1175.4	1861.4
56	51.0300	SCALES/BALANCES	.448	63	4.2	470.1	713.1
57	51.0400	OFFICE MACHINES	.474	100	21.1	1477.5	1829.0
58	52.0100	AUTO. MERCH. MAC	.404	63	1.4	774.5	1174.7
59	52.0200	COMM. LAUNDRY EQ	.445	66	5.5	455.6	1090.3
60	52.0300	REFRIG/HEAT EQUI	.426	140	242.9	13025.0	19796.2
61	52.0400	PUMPS	.466	67	.3	466.7	605.6
62	52.0500	SERVICE IND. MAC	.441	108	27.4	2163.1	3065.2
63	53.0100	INST. MEAS. ELEC	.517	92	516.4	3415.3	5572.8
64	53.0200	TRANSFORMERS	.449	88	125.0	2778.0	3988.9
65	53.0300	SWITCHGEAR APPAR	.493	105	114.4	5369.0	9177.8
66	53.0400	MOTORS/GENERATOR	.505	136	426.3	6880.0	9147.2
67	53.0500	INDUSTRIAL CONT.	.539	103	156.5	3955.0	6982.3
68	53.0600	WELDING APPARAT.	.451	88	82.6	1920.0	3627.5
69	53.0700	CARBON/GRAPHITE	.488	48	55.1	818.3	1036.8
70	53.0800	ELECT. IND. APP.	.472	94	34.0	1160.6	1487.9

(Continued)

Table 1. (Continued)

INPUT/OUTPUT COMMODITIES - MACHINERY

SEQ. NO.	ID. NO.	COMMODITY NAME	VALUE-ADD	NO. INPUTS	DEF. SHIP.	TOTAL SHIP.	CAPACITY
71	54.0000	HOUSEHOLD APPLIA	.423	129	57.2	16275.9	27307.4
72	55.0100	ELECT. LAMPS	.603	74	54.8	2580.3	3473.5
73	55.0200	LIGHTING FIXTURE	.429	119	89.9	3580.0	5072.9
74	55.0300	WIRING DEVICES	.533	128	221.4	5038.0	7535.5
75	56.0100	RADIO/TV SETS	.283	89	88.7	9034.9	14969.1
76	56.0200	RECORDS/TAPES	.385	44	6.2	1320.8	1497.3
77	56.0300	TELEPHONE/TELEGR	.486	101	457.4	11498.0	16081.1
78	56.0400	RADIO/TV COM. EQ	.531	150	9944.8	25100.0	40955.7
79	57.0100	ELECTRON TUBES	.521	81	403.0	2120.0	2750.7
80	57.0200	SEMICONDUCTORS	.556	103	1171.8	9720.0	12765.5
81	57.0300	ELECTRONIC COMP.	.452	143	2696.5	14495.0	20539.5
82	58.0100	STORAGE BATTERY	.408	62	55.8	2359.3	3176.0
83	58.0200	PRIM. BATTERIES	.498	45	37.4	780.8	1255.0
84	58.0300	X-RAY APPARATUS	.541	67	26.0	1038.7	1471.8
85	58.0400	ENGINE ELECT. EQ	.509	117	180.4	4455.1	5330.9
86	58.0500	ELECTRICAL EQUIP	.423	103	39.6	1204.6	1777.0

(Continued)

Table 1. (Continued)

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INPUT/OUTPUT COMMODITIES - FABRICATED METAL PRODUCTS
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SEQ. NO.	ID. NO.	COMMODITY NAME	VALUE-ADD	NO. INPUTS	DEF. SHIP.	TOTAL SHIP.	CAPACITY
87	39.0100	METAL CANS	.309	78	105.9	11860.0	19649.7
88	39.0200	METAL BARRELS	.346	70	61.3	1240.4	2154.5
89	40.0100	METAL SANIT. WAR	.485	67	12.8	650.0	864.2
90	40.0200	PLUMBING FITTING	.441	76	30.7	1740.0	2313.4
91	40.0300	HEATING EQUIP.	.415	103	52.1	2326.7	3132.1
92	40.0400	FAB. STRUCT. MET	.365	125	270.3	8500.0	11587.1
93	40.0500	METAL DOORS/TRIM	.393	108	81.9	4671.4	7186.8
94	40.0600	BOILER SHOPS	.419	147	225.6	8159.0	11715.4
95	40.0700	SHEET METAL WORK	.399	142	143.0	6544.7	10678.9
96	40.0800	ARCHITECTURAL MT	.401	89	43.5	1454.5	2116.8
97	40.0901	PREFAB. METAL BG	.364	75	16.7	1433.1	1837.3
98	40.0902	MISC. METAL WORK	.331	104	35.0	2423.1	3389.0
99	41.0100	SCREWS/BOLTS/NUT	.473	133	608.0	7572.3	11485.6
100	41.0201	AUTOMOTIVE STAMP	.461	125	133.1	12532.7	14670.4
101	41.0202	CROWNS/CLOSURES	.420	60	6.5	856.2	1562.7
102	41.0203	METAL STAMPINGS	.459	136	409.7	6388.6	9173.3
103	42.0100	CUTLERY	.504	55	7.3	997.9	1414.0
104	42.0201	HAND/EDGE TOOLS	.529	100	71.2	2791.1	4174.7
105	42.0202	HAND SAWA	.559	66	19.1	504.1	754.1
106	42.0300	HARDWARE	.533	117	213.8	7689.3	10350.9
107	42.0401	PLATING/POLISH.	.614	73	349.6	2509.2	3603.0
108	42.0402	METAL COATING	.455	86	137.1	1763.1	2674.3
109	42.0500	FAB. WIRE PROD.	.444	135	221.5	5947.1	9853.1
110	42.0700	STEEL SPRINGS	.418	77	13.6	885.7	1271.7
111	42.0800	PIPE/VALVES/FIT.	.489	138	267.9	9100.0	13611.1
112	42.1000	METAL FOIL/LEAF	.348	81	15.2	1254.4	1517.9
113	42.1100	FAB. METAL PROD.	.465	160	329.6	5328.4	8197.6

(Continued)

Table 1. (Continued)

INPUT/OUTPUT COMMODITIES - PRIMARY METAL MANUFACTURING

SEQ. NO.	ID. NO.	COMMODITY NAME	VALUE-ADD	NO. INPUTS	DEF. SHIP.	TOTAL SHIP.	CAPACITY
114	37.0101	BLAST FURN/MILLS	.374	159	3951.1	62253.4	74491.2
115	37.0102	ELECTRO/METAL PD	.313	72	112.3	1455.6	2062.6
116	37.0103	STEEL WIRE	.425	86	29.3	822.1	1120.7
117	37.0104	COLD FIN. STEEL	.212	42	5.0	133.3	175.1
118	37.0105	STEEL PIPE	.292	37	.8	67.0	96.2
119	37.0200	IRON FOUNDRIES	.552	158	642.6	14188.3	18409.3
120	37.0300	IRON FORGINGS	.431	149	413.3	4479.0	6346.7
121	37.0401	METAL HEAT TREAT	.649	50	99.6	1143.3	1620.0
122	37.0402	PRIM. METAL PD.	.391	83	174.6	1038.3	1553.0
123	38.0100	PRIMARY COPPER	.098	85	544.4	5730.0	7525.3
124	38.0200	PRIMARY LEAD	.178	53	122.3	930.0	1335.4
125	38.0300	PRIMARY ZINC	.217	52	144.3	435.0	532.3
126	38.0400	PRIM. ALUMINUM	.312	88	648.4	6576.1	8743.2
127	38.0500	PRIM. NONFERROUS	.208	78	420.9	2836.4	5007.5
128	38.0600	SEC. NONFERROUS	.186	40	23.0	274.8	455.3
129	38.0700	COPPER ROLLING	.216	102	447.7	7107.1	9688.3
130	38.0800	ALUMINUM ROLLING	.256	101	736.1	8719.3	10670.5
131	38.0900	NONFERROUS ROLL.	.226	85	277.8	2555.9	5856.4
132	38.1000	NONFERROUS WIRE	.280	118	470.2	10920.5	17818.9
133	38.1100	ALUMINUM CASTING	.482	91	293.5	2859.8	3710.6
134	38.1200	BRASS/BRONZE CAS	.439	76	49.0	1133.4	1695.2
135	38.1300	NONFERROUS CAST.	.430	71	288.2	1476.5	2446.3
136	38.1400	NONFERROUS FORG.	.369	60	268.1	710.3	956.1

(Continued)

Table 1. (Continued)

INPUT/OUTPUT COMMODITIES - OTHER MANUFACTURING

SEQ. NO.	ID. NO.	COMMODITY NAME	VALUE-ADD	NO. INPUTS	DEF. SHIP.	TOTAL SHIP.	CAPACITY
137	62.0100	ENG/SCI. INSTRUM	.536	114	1114.5	2791.8	4118.6
138	62.0200	MEASURING DEVICE	.562	129	244.4	4283.4	6150.5
139	62.0300	AUTO. TEMP. CONT	.571	92	45.1	1442.9	1987.9
140	62.0400	MEDICAL INSTRUM.	.557	111	46.3	2454.6	3433.0
141	62.0500	SURGICAL SUPPLY	.497	93	139.0	2835.1	4129.9
142	62.0600	DENTAL SUPPLIES	.463	64	10.0	893.5	1188.0
143	62.0700	WATCHES/CLOCKS	.383	85	200.9	2231.2	4620.8
144	63.0100	OPTICAL INSTRUM.	.555	88	125.3	1481.5	2127.2
145	63.0200	OPHTHALMIC GOODS	.582	58	38.0	1253.8	2177.8
146	63.0300	PHOTOGRAPHIC EQ.	[illegible]	117	760.6	12982.2	16448.0
147	64.0000	MISC. MANUFACT.	.390	143	304.0	27432.9	40470.1
148	14.0000	FOOD PRODUCTS	.278	101	2061.7	291688.3	461949.8
149	15.0000	TOBACCO MANUF.	.482	55	29.8	22335.3	32071.2
150	16.0000	FABRIC MILLS	.316	98	601.2	41635.3	56047.6
151	17.0000	MISC. TEXTILES	.270	100	185.2	14753.6	21765.1
152	18.0000	APPAREL	.338	98	421.3	72983.3	100765.9
153	19.0000	MISC. FAB. TEXT.	.324	104	402.2	13939.9	19752.9
154	20.0000	WOOD PRODUCTS	.382	133	995.9	52368.7	75196.1
155	21.0000	WOOD CONTAINERS	.353	51	117.6	1106.5	1547.6
156	22.0000	HOUSEHOLD FURN.	.404	104	76.4	17539.4	25184.8
157	23.0000	OTHER FURNITURE	.445	116	123.4	9212.2	13778.9
158	24.0000	PAPER PRODUCTS	.387	119	1038.7	46986.8	60239.5
159	25.0000	PAPERBOARD BOXES	.379	99	438.9	20621.0	30009.8
160	26.0000	PRINTING PUBLISH	.476	104	686.6	74865.0	98321.8
161	27.0100	INDUSTRIAL CHEM.	.433	154	1682.1	83390.0	116573.4
162	27.0201	NITROGENOUS FERT	.393	96	66.2	8200.0	10190.3
163	27.0202	MIXING FERTILIZE	.296	24	.2	31.1	44.7
164	27.0300	AGRICULT. CHEM.	.407	86	26.7	4400.0	5446.5
165	27.0401	GUM/WOOD CHEMICA	.374	59	15.8	736.7	1149.9
166	27.0402	ADHESIVES/SEAL.	.335	86	47.3	2324.1	3627.4
167	27.0403	EXPLOSIVES	.610	59	279.3	957.6	1539.1
168	27.0404	PRINTING INK	.341	75	30.5	1221.1	2121.8
169	27.0405	CARBON BLACK	.476	34	9.9	548.2	787.2
170	27.0406	CHEM. PREPARATIO	.396	127	244.4	5513.4	7421.9
171	28.0100	PLASTICS/RESINS	.357	104	387.3	18000.0	24852.1
172	28.0200	SYNTHETIC RUBBER	.376	83	68.7	2500.0	2895.8
173	28.0300	CELLULOSIC FIBER	.376	49	27.7	1616.1	1933.8
174	28.0400	ORGANIC FIBERS	.458	73	104.4	7152.8	8655.1
175	29.0000	DRUGS/CLEANING P	.402	133	220.4	47540.0	78764.5
176	30.0000	PAINTS	.350	96	325.4	10300.0	15623.8
177	31.0100	PETROLEUM REFIN.	.244	110	3861.4	69694.6	83395.2
178	31.0200	PAVING MIXTURES	.389	82	45.4	2238.2	4155.8
179	31.0300	ASPHALT COATINGS	.395	69	58.2	2205.2	3392.7
180	32.0100	TIRES/TUBES	.507	74	185.3	11000.0	13774.6
181	32.0200	RUBBER FOOTWEAR	.517	52	2.4	1238.3	2137.0
182	32.0301	RECLAIMED RUBBER	.524	40	2.4	123.3	174.7
183	32.0302	RUBBER PRODUCTS	.483	107	253.3	6222.0	8375.7
184	32.0400	PLASTIC PRODUCTS	.448	166	707.2	27297.1	37211.3
185	32.0500	RUBBER HOSE/BELT	.547	74	91.2	2125.0	2825.3
186	33.0001	LEATHER TANNING	.269	50	14.0	2539.2	4143.3

(Continued)

Table 1. (Continued)

INPUT/OUTPUT COMMODITIES - OTHER MANUFACTURING

SEQ. NO.	ID. NO.	COMMODITY NAME	VALUE-ADD	NO. INPUTS	DEF. SHIP.	TOTAL SHIP.	CAPACITY
187	34.0000	FOOTWEAR PRODUCT	.426	74	38.6	10969.2	16182.2
188	35.0100	GLASS PRODUCTS	.504	119	235.9	8537.8	11077.8
189	35.0200	GLASS CONTAINERS	.582	63	36.2	5355.0	6705.7
190	36.0100	CEMENT	.510	70	67.2	4620.0	5653.8
191	36.0200	BRICK/CLAY TILE	.579	68	14.1	1128.9	1266.4
192	36.0300	CERAMIC TILE	.585	41	9.1	389.3	427.8
193	36.0400	CLAY REFRACTORIE	.515	68	22.1	734.3	1275.5
194	36.0500	STRUCTURAL CLAY	.617	52	5.4	414.4	572.2
195	36.0600	PLUMBING FIXTURE	.595	63	10.1	575.0	688.0
196	36.0701	CHINA UTENSILS	.723	33	2.1	199.4	278.8
197	36.0702	EARTHEN. UTENSIL	.644	32	.1	144.2	242.7
198	36.0800	PORCELAIN ELECT.	.599	62	24.5	631.5	894.8
199	36.0900	POTTERY PRODUCTS	.658	46	4.1	357.0	486.7
200	36.1000	CONCRETE BLOCK	.435	64	26.9	1795.0	2722.6
201	36.1100	CONCRETE PROD.	.514	76	64.6	4655.0	8794.9
202	36.1200	READY-MIX CONC.	.367	82	119.6	10700.0	16004.3
203	36.1300	LIME	.439	61	23.4	578.8	724.8
204	36.1400	GYPSUM PRODUCTS	.455	63	21.0	1418.0	1542.5
205	36.1500	CUT STONE PROD.	.503	52	5.9	719.3	790.5
206	36.1600	ABRASIVE PROD.	.506	93	86.2	2188.8	3143.0
207	36.1700	ASBESTOS PROD.	.479	79	43.2	1836.1	2382.3
208	36.1800	GASKETS/PACKING	.561	86	67.6	1784.2	2432.2
209	36.1900	MINERALS	.457	.77	28.4	1133.0	1794.4
210	36.2000	MINERAL WOOL	.517	67	32.9	1791.6	2097.2
211	36.2100	NONCLAY REFRACT.	.514	57	30.9	978.1	1950.6
212	36.2200	MINERAL PROD.	.496	49	35.3	404.7	506.8

(Continued)

Table 1. (Continued)

INPUT/OUTPUT COMMODITIES - MINING/AGRICULTURE/CONSTRUCTION

SEQ. NO.	ID. NO.	COMMODITY NAME	VALUE-ADD	NO. INPUTS	DEF. SHIP.	TOTAL SHIP.	CAPACITY
213	1.0000	LIVESTOCK	.212	63	686.7	98418.4	0.0
214	2.0000	AGRICULTURAL PD.	.556	66	481.6	82183.5	0.0
215	3.0000	FORESTRY PD.	.655	64	181.8	5430.9	0.0
216	4.0000	FORESTRY SERVICE	.474	74	111.0	10035.3	0.0
217	5.0000	IRON ORE MINING	.423	67	286.2	3132.2	0.0
218	6.0100	COPPER MINING	.565	70	273.4	3768.0	0.0
219	6.0200	NONFERROUS MININ	.582	60	164.3	1573.0	0.0
220	7.0000	COAL MINING	.586	72	547.1	13157.9	0.0
221	8.0000	CRUDE PETROLEUM	.657	85	2289.3	40448.3	0.0
222	9.0000	STONE MINING	.597	95	155.2	7040.5	0.0
223	10.0000	CHEMICAL MINING	.553	74	29.2	1188.0	0.0
224	11.0000	NEW CONSTRUCTION	.424	139	3621.5	313521.5	0.0
225	12.0000	MAINT. CONSTRUCT	.580	130	3846.3	88061.1	0.0

(Continued)

Table 1. (Concluded)

INPUT/OUTPUT COMMODITIES - SERVICES

SEQ. NO.	ID. NO.	COMMODITY NAME	VALUE-ADD	NO. INPUTS	DEF. SHIP.	TOTAL SHIP.	CAPACITY
226	65.0100	RAILROADS	.617	105	1339.9	36229.5	0.0
227	65.0200	HIGHWAY PASS. TR	.627	88	329.1	17589.6	0.0
228	65.0300	MOTOR FREIGHT	.642	96	3347.1	72834.2	0.0
229	65.0400	WATER TRANSPORT.	.370	94	1601.9	17776.2	0.0
230	65.0500	AIR TRANSPORT.	.567	101	1342.5	33013.0	0.0
231	65.0600	PIPE LINES	.713	47	301.7	3908.2	0.0
232	65.0700	TRANSPORT. SERV.	.698	51	86.1	2925.7	0.0
233	66.0000	COMMUNICATIONS	.823	62	2145.6	74171.3	0.0
234	67.0000	RADIO/TV BROAD.	.619	4	.4	10.2	0.0
235	68.0100	ELECTRIC UTIL.	.562	84	2713.5	76500.7	0.0
236	68.0200	GAS UTILITIES	.392	90	1267.6	50374.3	0.0
237	68.0300	WATER UTILITIES	.596	71	294.0	14351.9	0.0
238	69.0100	WHOLESALE TRADE	.746	80	5961.1	251280.9	0.0
239	69.0200	RETAIL TRADE	.783	108	511.7	276665.5	0.0
240	70.0000	FINANCE/INSUR.	.564	67	1723.7	187384.8	0.0
241	71.0000	REAL ESTATE/RENT	.808	75	3819.3	423120.5	0.0
242	72.0000	HOTELS/PERS. SER	.573	98	1916.0	73283.7	0.0
243	73.0000	BUSINESS SERVICE	.650	135	9008.0	213275.8	0.0
244	74.0000	EATING/DRINKING	.432	59	2571.9	117871.6	0.0
245	75.0000	AUTO REPAIR	.470	74	897.4	59369.0	0.0
246	76.0000	AMUSEMENTS	.525	71	612.7	30772.4	0.0
247	77.0000	HEW SERVICES	.678	89	1174.8	205411.9	0.0
248	78.0100	POSTAL SERVICE	.831	60	631.1	19823.4	0.0
249	78.0400	OTHER GOV. ENT.	.581	75	27.4	3322.0	0.0
250	79.0300	OTH. STATE ENT.	.504	64	64.2	6769.8	0.0

B. PRODUCTION PROCESSING TIME

Numerous recent studies have collected data on order lead times for industrial commodities and have observed that lead times for numerous commodities have been rapidly growing over the last several years. Unfortunately, order lead times are not very useful in predicting what would happen in an industrial mobilization. Consider the following:

Process Time = Manufacture Time + Transportation Time

Order Lead Time = Process Time + Queue Time.

While Process Time is fairly independent of the state of the economy, the Queue Time component of Order Lead Time is very dependent upon the state of the economy. If the economy is booming or in an industrial mobilization, Queue Time may be quite long. On the other hand, if the economy is in recession or defense is rigidly exercising its Priority System, the Queue Time may be reduced for defense items. The correct way to predict Order Lead Time in a mobilization is to first collect Process Time data for each commodity and then to explicitly model the queue formation during mobilization. If requirements for a commodity exceed capacity at a particular time, then a queue would form according to some queue discipline (e.g., first-come-first-serve, Defense Priority System, etc.). As discussed in the previous chapter, IMPMOD does not now model queue formation, although it could with additional programming. The runs reported in this study use Process Time alone. Thus, results assumed capacity is unconstrained; if queuing were included, production times would increase.

Table 2 lists the estimated Process Times used for each of the 250 commodities. Individual estimates were made for 37 commodities, while for the remaining commodities, generic estimates were used. Due to lack of specific data, the generic estimates are pure guesses by the author. For the individual estimates, the value used was based on data obtained from the

Table 2. ESTIMATED COMMODITY PROCESS TIMES

ID. No.	Commodity	Process Time (weeks)	Source
37.0101	Blast Furn/Mills	5	Defense Materials System
37.0102	Electro/Metals Pd.	5	Defense Materials System
37.0103	Steel Wire	5	Defense Materials System
37.0104	Cold Fin. Steel	5	Defense Materials System
37.0105	Steel Pipe	5	Defense Materials System
37.0200	Iron Foundries	18	NAVSHIPSO
37.0300	Iron Forgings	17	NAVSHIPSO
37.0401	Metal Heat Treat	17	NAVSHIPSO
38.0700	Copper Rolling	9	Defense Materials System
38.0800	Aluminum Rolling	9	Defense Materials System
38.0900	Nonferrous Roll.	9	Defense Materials System
38.1000	Nonferrous Wire	9	Defense Materials System
38.1100	Aluminum Casting	8	NAVSHIPSO
38.1200	Brass/Bronze Cast.	11	NAVSHIPSO
38.1300	Nonferrous Cast.	11	Estimate
38.1400	Nonferrous Forg.	20	Defense Science Board
43.0100	Steam Turbines	72	NAVSHIPSO
43.0200	Int. Comb. Engine	44	NAVSHIPSO
49.0200	Ball/Roller Bear.	16	the Defense Industry
49.0300	Blowers/Fans	52	NAVSHIPSO
51.0101	Computing Equip.	16	Defense Science Board
56.0400	Radio/TV Com. Eq.	76	Aircraft Capacity Study
57.0100	Electron Tubes	25	Estimate
57.0200	Semiconductors	25	Defense Science Board
57.0300	Electronic Comp.	16	Defense Science Board
58.0100	Storage Battery	26	Defense Science Board
58.0200	Prim. Batteries	26	Defense Science Board
60.0100	Aircraft	94	Defense Science Board
60.0200	Air/Missile Eng.	82	Defense Science Board
60.0400	Air/Miss. Equip.	52	Defense Science Board
61.0100	Shipbuilding	104	Estimate
13.0100	Guided Missiles	20	Estimate
13.0200	Ammunition	4	Estimate
13.0300	Tanks	4	Estimate
13.0500	Small Arms	4	Estimate
13.0600	Small Arms Ammo.	4	Estimate
13.0700	Other Ordnance	4	Estimate

GENERAL ASSUMPTIONS FOR REMAINING COMMODITIES:

	Weeks
Mining	4
Agriculture	52
Services	1
Assembly Line Commodities	4
Assembly of Heavy Mach.	8
Fab. of Metal Products	8

listed source. The Defense Materials System [16] was the only source of true Process Times. The Defense Science Board [2], NAVSHIPSO [14], and the Aircraft Capacity Study [17] all contain Order Lead Time data. The estimate used for the Process Time was the smallest Order Lead Time reported in the last ten years, the implicit assumption being that sometime during that period Queue Time was zero.

C. DEFENSE REQUIREMENTS

Non-mobilization defense requirements for 1981 are listed in Table 1. They were calculated by IMPMOD by multiplying the defense purchase pattern listed in Table 3 by estimated defense outlays for FY 1981 and multiplying the resulting final demand vector by the inverted input-output matrix. Estimated outlays for FY 1981 were $158.6 billion.[1] The defense purchase pattern was developed for the DEIMS model and is based on the FY 1986 Five-Year Defense Plan spending pattern. For this purchase pattern, commodity spending is 55 percent of total outlays--the remainder is spent on government employee compensation. For the years beyond 1981, IMPMOD assumes that defense requirements increase in real terms at a seven percent annual rate.[2]

D. NON-DEFENSE CONSUMPTION

Estimates of total U.S. consumption for 1981, both defense and non-defense, are listed in Table 1. The estimate for non-defense consumption was based on Department of Commerce projections for 1981 [7]. Unfortunately, 1981 projections for some commodities were not available. For these commodities, IMPMOD calculated a crude projection by multiplying the 1972

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[1] Office of the Assistant Secretary of Defense (Public Affairs), *News Release*, No. 77-81, 4 March 1981.

[2] Herschel Kanter, "The Reagan Defense Budget," *Astronautics and Aeronautics*, May 1981.

Table 3. DEFENSE PURCHASE PATTERN

Sequence Number	Identification Number	Commodity Name	Defense Share
1	60.0100	Aircraft	.069106
2	61.0100	Shipbuilding	.033579
3	13.0300	Tanks	.007417
4	13.0100	Guided Missiles	.045644
5	13.0500	Small Arms	.001081
6	13.0200	Ammunition	.019040
7	13.0600	Small Arms Ammunition	.003214
8	13.0700	Other Ordnance	.007007
9	59.0301	Motor Vehicles	.006031
10	59.0200	Truck Trailers	.000270
11	59.0100	Truck/Bus Bodies	.000005
12	60.0200	Air/Missile Engines	.040090
13	60.0400	Air/Missile Equipment	.030225
14	61.0300	Railroad Equipment	.000005
15	59.0302	Vehicle Parts	.001350
16	61.0200	Boat Building	.000073
17	61.0500	Motorcycles/Bike	.000004
18	61.0601	Campers	.000000
19	61.0602	Mobile Homes	.000000
20	61.0700	Transportation Equipment	.000000
21	43.0100	Steam Turbines	.000574
22	43.0200	Internal Combustion Engines	.000691
23	44.0001	Farm Equipment	.000056
24	44.0002	Garden Equipment	.000001
25	45.0100	Construction Equipment	.000724
26	45.0200	Mining Equipment	.000011
27	45.0300	Oilfield Machinery	.000003
28	46.0100	Elevators	.000000
29	46.0200	Conveyors	.000046
30	46.0300	Hoists/Cranes	.000017
31	46.0400	Industrial Trucks/ Tractors	.000180
32	47.0100	Metal Cutting	.000120
33	47.0200	Metal Forming	.000045
34	47.0300	Special Dies/ Tools	.000175
35	47.0401	Power Hand Tools	.000039
36	47.0402	Rolling Mill Machinery	.000001
37	47.0403	Metalwork Machinery	.000059
38	48.0100	Food Production Machinery	.000005
39	48.0200	Textile Machinery	.000001
40	48.0300	Woodwork Machinery	.000006
41	48.0400	Paper Industry Mach.	.000001
42	48.0500	Printing Machinery	.000033
43	48.0600	Special Machinery	.000240
44	49.0100	Pumps/Compressors	.000345
45	49.0200	Ball/Roller Bearings	.000330
46	49.0300	Blowers/Fans	.000045
47	49.0400	Industrial Patterns	.000000
48	49.0500	Power Transportation Equipment	.000039
49	49.0600	Industrial Furnaces/ Ovens	.000011
50	49.0700	General Machinery	.000234
51	50.0001	Carburetors	.000000
52	50.0002	Machinery	.000306
53	51.0101	Computing Equipment	.003062
54	51.0102	Accounting Machinery	.000038
55	51.0200	Typewriters	.000021
56	51.0300	Scales/Balances	.000021
57	51.0400	Office Machines	.000094
58	52.0100	Automatic Merchandising Machinery	.000000
59	52.0200	Commercial Laundry Equipment	.000028
60	52.0300	Refrigeration/Heating Equipment	.000[illegible]25
61	52.0400	Pumps	.000001
62	52.0500	Service Industry Machinery	.000044
63	53.0100	Inst. Meas. Elec.	.002215
64	53.0200	Transformers	.000257
65	53.0300	Switchgear Apparatus	.000204
66	53.0400	Motors/Generators	.001374
67	53.0500	Industrial Controls	.000323
68	53.0600	Welding Apparatus	.000060
69	53.0700	Carbon/Graphite Prod.	.000042
70	53.0800	Electrical Industrial Apparatus, n.e.c.	.000067
71	54.0000	Household Appliances	.000059
72	55.0100	Electric Lamps	.000103
73	55.0200	Lighting Fixtures	.000047
74	55.0300	Wiring Devices	.000066
75	56.0100	Radio/Television Sets	.000234
76	56.0200	Records/Tapes	.000031
77	56.0300	Telephone/Telegraph	.002122
78	56.0400	Radio/Television Communications Equipment	.049415
79	57.0100	Electronic Tubes	.001695
80	57.0200	Semiconductors	.000733
81	57.0300	Electronic Comp.	.002413
82	58.0100	Storage Battery	.000245
83	58.0200	Prim. Batteries	.000216
84	58.0300	X-Ray Apparatus	.000046
85	58.0400	Engine Elec. Equipment	.000181
86	58.0500	Electrical Equipment	.000077
87	39.0100	Metal Cans	.000018
88	39.0200	Metal Barrels	.000046
89	40.0100	Metal Sanitation Hardware	.000000
90	40.0200	Plumbing Fittings	.000001
91	40.0300	Heating Equipment	.000043
92	40.0400	Fabricated Structural Metal	.000332
93	40.0500	Metal Doors/Trim	.000012
94	40.0600	Boiler Shops	.000661
95	40.0700	Sheet Metal Work	.000007
96	40.0800	Architectural Metal	.000006
97	40.0901	Prefabricated Metal Bg	.000000
98	40.0902	Miscellaneous Metal Work	.000040
99	41.0100	Screws/Bolts/Nuts	.000313
100	41.0201	Automotive Stampings	.000000
101	41.0202	Crowns/Closures	.000000
102	41.0203	Metal Stampings	.000026
103	42.0100	Cutlery	.000002
104	42.0201	Hand/Edge Tools	.000136
105	42.0202	Hand Saws	.000001
106	42.0300	Hardware	.000085
107	42.0401	Plating/Polishing	.000079
108	42.0402	Metal Coating	.000043
109	42.0500	Fabricated Wire Products	.000039
110	42.0700	Steel Springs	.000000
111	42.0800	Pipe/Valves/Fittings	.000334
112	42.1000	Metal Foil/Leaf	.000007
113	42.1100	Fabricated Metal Products	.000294
114	37.0101	Blast Furnace/Mills	.000323
115	37.0102	Electro/Metal Products	.000004
116	37.0103	Steel Wire	.000055
117	37.0104	Cold Finishing Steel	.000000
118	37.0105	Steel Pipe	.000000
119	37.0200	Iron Foundries	.000087
120	37.0300	Iron Forgings	.000000
121	37.0401	Metal Heat Treating	.000015
122	37.0402	Primary Metal Products	.000278
123	38.0100	Primary Copper	.000006
124	38.0200	Primary Lead	.000000
125	38.0300	Primary Zinc	.000000
126	38.0400	Primary Aluminum	.000076
127	38.0500	Primary Nonferrous	.000000
128	38.0600	Secondary Nonferrous	.000000
129	38.0700	Copper Rolling	.000012
130	38.0800	Aluminum Rolling	.000012

(Continued)

Table 3. (Concluded)

Sequence Number	Identification Number	Commodity Name	Defense Share
131	38.0900	Nonferrous Rolling	.000015
132	38.1000	Nonferrous Wire	.000118
133	38.1100	Aluminum Casting	.000015
134	38.1200	Brass/Bronze Casting	.000027
135	38.1300	Nonferrous Casting	.000000
136	38.1400	Nonferrous Forging	.000001
137	62.0100	Eng./Sci. Instruments	.005827
138	62.0200	Measuring Devices	.000708
139	62.0300	Automatic Temperature Controls	.000000
140	62.0400	Medical Instruments	.000267
141	62.0500	Surgical Supplies	.000627
142	62.0600	Dental Supplies	.000049
143	62.0700	Watches/Clocks	.000403
144	63.0100	Optical Instruments	.000284
145	63.0200	Ophthalmic Goods	.000170
146	63.0300	Photographic Equipment	.003796
147	64.0000	Miscellaneous Manufacturing, n.e.c.	.000553
148	14.0000	Food Products	.003755
149	15.0000	Tobacco Manufacturing	.000000
150	16.0000	Fabric Mills	.000337
151	17.0000	Miscellaneous Textiles	.000082
152	18.0000	Apparel	.001147
153	19.0000	Miscellaneous Fabric Textiles	.001774
154	20.0000	Wood Products	.000091
155	21.0000	Wood Containers	.000046
156	22.0000	Household Furniture	.000086
157	23.0000	Other Furniture	.000220
158	24.0000	Paper Products	.000420
159	25.0000	Paperboard Boxes	.000142
160	26.3000	Printing Publishing	.001104
161	27.0100	Industrial Chemicals	.002799
162	27.0201	Nitrogenous Fertilizer	.000009
163	27.0202	Mixing Fertilizer	.000000
164	27.0300	Agricultural Chemicals	.000023
165	27.0401	Gum/Wood Chemicals	.000000
166	27.0402	Adhesives/Sealants	.000005
167	27.0403	Explosives	.001279
168	27.0404	Printing Ink	.000000
169	27.0405	Carbon Black	.000000
170	27.0406	Chemical Preparations	.000508
171	28.0100	Plastics/Resins	.000092
172	28.0200	Synthetic Rubber	.000019
173	28.0300	Cellulosic Fiber	.000035
174	28.0400	Organic Fibers	.000050
175	29.0000	Drugs/Cleaning Products	.000588
176	30.0000	Paints	.000008
177	31.0100	Petroleum Refineries	.015691
178	31.0200	Paving Mixtures	.000000
179	31.0300	Asphalt Coatings	.000000
180	32.0100	Tires/Tubes	.000192
181	32.0200	Rubber Footwear	.000015
182	32.0301	Reclaimed Rubber	.000000
183	32.0302	Rubber Products	.000576
184	32.0400	Plastic Products	.000178
185	32.0500	Rubber Hose/Belts	.000073
186	33.0001	Leather Tanning	.000004
187	34.0000	Footwear Products	.000081
188	35.0100	Glass Products	.000086
189	35.0200	Glass Containers	.000000
190	36.0100	Cement	.000000
191	36.0200	Brick/Clay Tile	.000000
192	36.0300	Ceramic Tile	.000000
193	36.0400	Clay Refractories	.000000
194	36.0500	Structural Clay Prod.	.000000
195	36.0600	Plumbing Fixtures	.000000
196	36.0701	China Utensils	.000000
197	36.0702	Earthenware Utensils	.000000
198	36.0800	Porcelain Elect.	.000000
199	36.0900	Pottery Products	.000005
200	36.1000	Concrete Block	.000000
201	36.1100	Concrete Products	.000000
202	36.1200	Ready-Mix Concrete	.000000
203	36.1300	Lime	.000000
204	36.1400	Gypsum Products	.000000
205	36.1500	Cut Stone Products	.000001
206	36.1600	Abrasive Products	.000005
207	36.1700	Asbestos Products	.000041
208	36.1800	Gaskets/Packing	.000000
209	36.1900	Minerals	.000000
210	36.2000	Mineral Wool	.000000
211	36.2100	Non-Clay Refractories	.000000
212	36.2200	Mineral Products	.000000
213	1.0000	Livestock	.000069
214	2.0000	Agricultural Products	.000164
215	3.0000	Forestry Products	.000425
216	4.0000	Forestry Service	.000056
217	5.0000	Iron Ore Mining	.000000
218	6.0100	Copper Mining	.000000
219	6.0200	Nonferrous Mining	.000000
220	7.0000	Coal Mining	.000502
221	8.0000	Crude Petroleum	.000000
222	9.0000	Stone Mining	.000000
223	10.0000	Chemical Mining	.000000
224	11.0000	New Construction	.022634
225	12.0000	Maintenance Construction	.014568
226	65.0100	Railroads	.003394
227	65.0200	Highway Passenger Transportation	.000162
228	65.0300	Motor Freight	.011428
229	65.0400	Water Transportation	.006331
230	65.0500	Air Transportation	.003783
231	65.0600	Pipe Lines	.000961
232	65.0700	Transportation Services	.000000
233	66.0000	Communications	.006833
234	67.0000	Radio/Television Broadcasts	.000000
235	68.0100	Electric Utilities	.007801
236	68.0200	Gas Utilities	.001653
237	68.0300	Water Utilities	.000581
238	69.0100	Wholesale Trade	.014853
239	69.0200	Retail Trade	.000000
240	70.0000	Finance/Insurance	.000070
241	71.0000	Real Estate/Rent	.004679
242	72.0000	Hotels/Pers. Services	.006342
243	73.0000	Business Service	.021423
244	74.0000	Eating/Drinking	.003480
245	75.0000	Auto Repair	.001054
246	76.0000	Amusements	.002002
247	77.0000	HEW Services	.005507
248	78.0100	Postal Service	.001520
249	78.0400	Other Government Ent.	.000018
250	79.0300	Other State Ent.	.000093

input-output study purchase pattern by estimated GNP in 1981, and then multiplying the resultant final demand vector by the inverted input-output matrix. Projected defense consumption was then subtracted. The estimate of GNP for 1981 was $2861.7 billion.[1] For the years beyond 1981 it is assumed that consumption grows at an annual real rate of 2.9 percent.[2]

E. PRODUCTION CAPACITY

Table 1 lists 1981 production capacity estimates for all commodities except mining, agriculture, construction, and services. These estimates are based on a survey of plant capacity done by the Bureau of the Census [3]. The capacity level represents what is defined in Reference [3] as Practical Capacity, it being "the greatest level of output that can be achieved within the framework of a realistic work pattern." It is assumed that sufficient labor, materials, utilities, etc. are available to utilize the facilities currently in place. The latest detailed survey was done in 1978. The 1978 utilization percentages were updated to 1981 by multiplying each by the ratio of aggregate capacity utilization in 1981 to that in 1978. Aggregate capacity utilization was 84 percent in 1978 and 78 percent in 1981.[3]

One further adjustment was made to the capacity levels for three commodities. It was felt that the Census Survey did not take into account designated mobilization producers for defense end items. For tanks, large caliber ammunition, and small arms ammunition, the DoD mobilization capacity

[1] Eckstein, Leahy, Probyn, *Impact of Defense on the United States Economy--Macroeconomic Effects*, Data Resources, Inc., October 1980.

[2] Richard Kaufman, *A Simulation of the Economic Effects of President Reagan's Fiscal and Monetary Proposals 1981-1984*, Staff Study, Joint Economic Committee, U.S. Congress, 1981.

[3] *Survey of Current Business*, June 1980, p. 25, and March 1981, p. 31.

levels were used in setting the capacity levels. IMPMOD projects capacity levels beyond 1981 by assuming that they grow at a 2.9 percent annual rate, the assumption being that capacity grows at the same rate as GNP. A refinement of IMPMOD would be to use different expansion rates for each commodity. For this initial study only the aggregate rate was used.

Chapter IV

MODEL RESULTS

A. RESULTS DISPLAYING MODEL STRUCTURE

1. Critical Path Networks

IMPMOD has the capability of plotting a critical path network for each commodity. Figure 4 portrays the supplier networks for the aircraft industry. Plots for the eight commodities listed as military end items appear in Volume II, Appendix B. For these plots, six tiers of indirect commodity usage are displayed. In IMPMOD the network has an unlimited number of tiers, but at this level of commodity aggregation most production paths have cycled through to a basic commodity, such as mining, by the sixth tier. Each tier includes the 20 most significant commodities.[1] The commodities are arranged in ascending order of their contribution, in terms of dollar value, to the production of the end item.

Each box in the networks of Figures 4 through 6 contains the commodity name and three numbers; a line connects each box to a box in the previous tier. The line denotes that the commodity is directly required in the production of the commodity in the previous tier. As an example from Figure 4, the following sequence of commodities is such that each commodity is directly required in the production of the previous commodity:

- Aircraft,
- Aircraft/Missile Equipment,

[1]The calculations in IMPMOD include many more than these 20 commodities. For aircraft there are 115 commodities in the first tier, as calculated in IMPMOD, and the full 250 commodities in each of the remaining tiers.

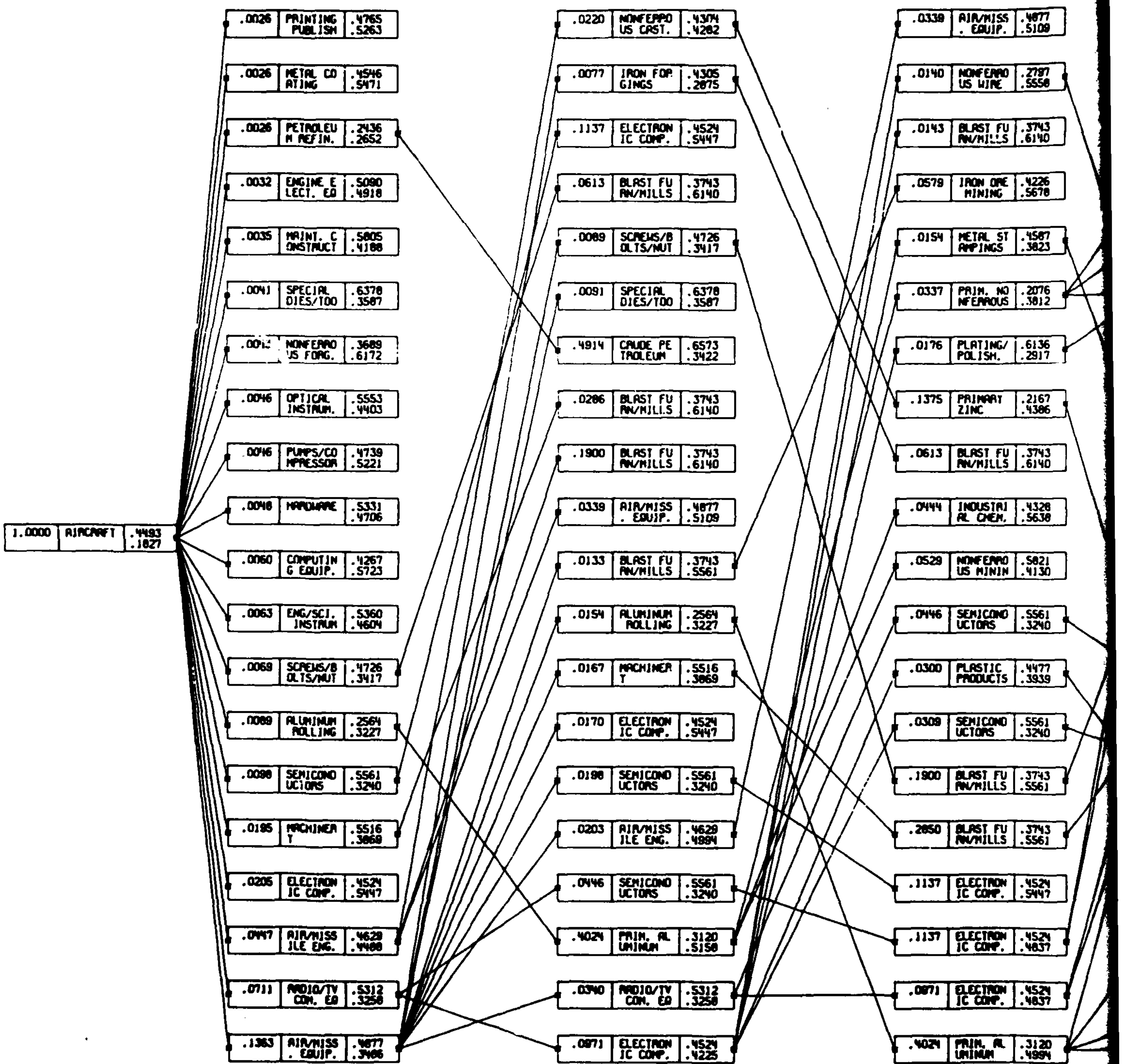
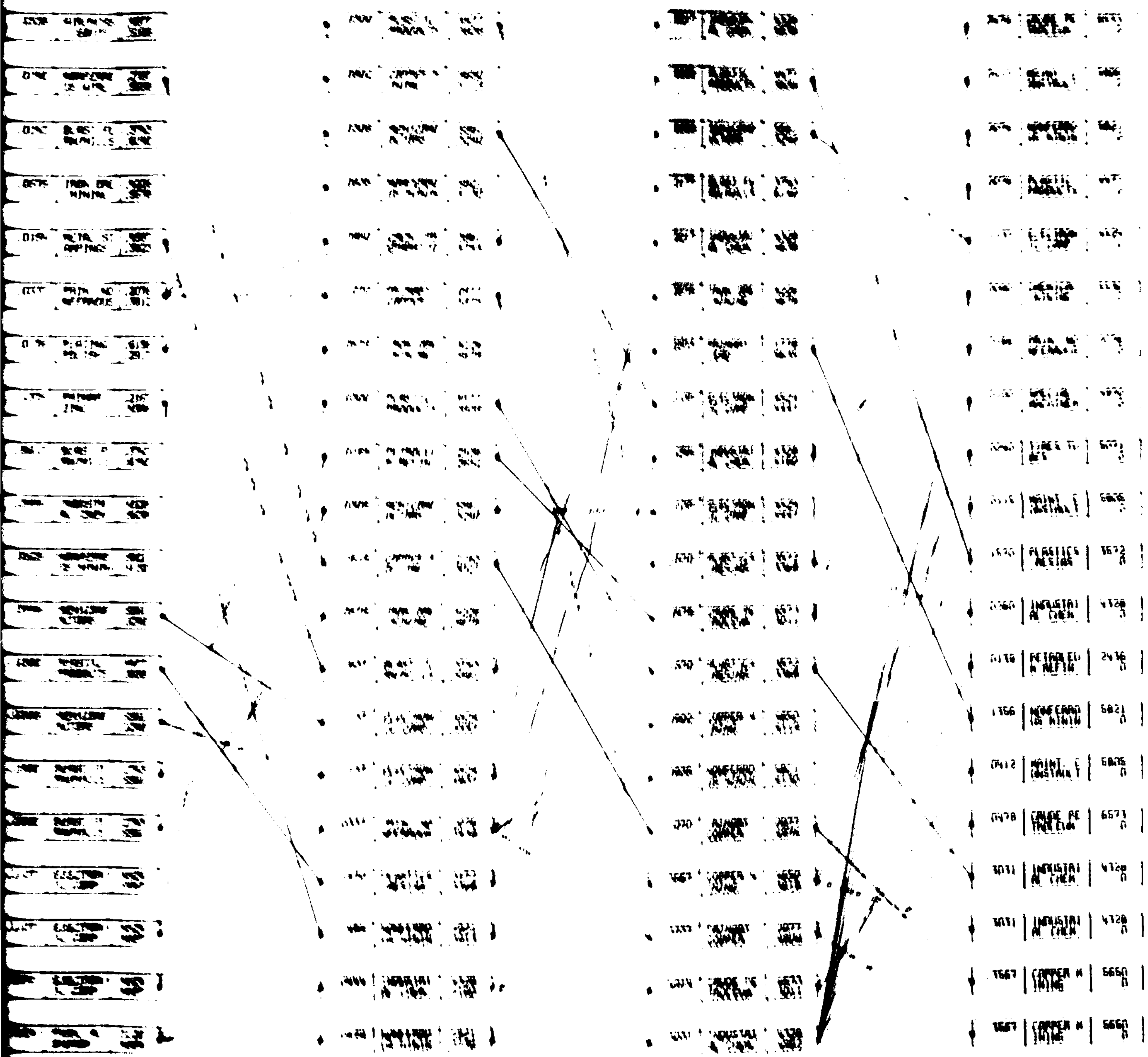


Figure 4. CRITICAL PATH NETWORK FO



PATH NETWORK FOR AIRCRAFT PRODUCTION

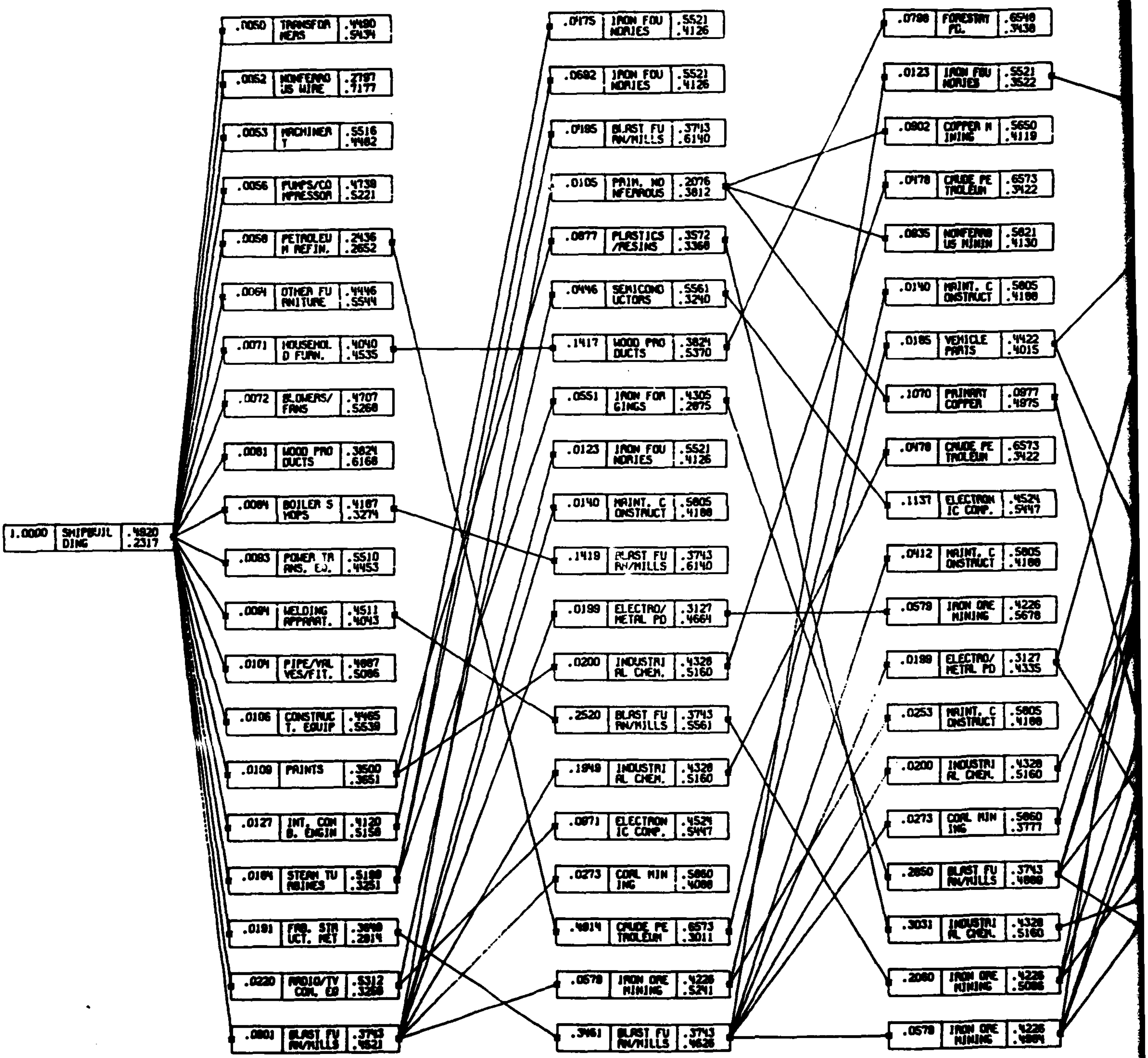
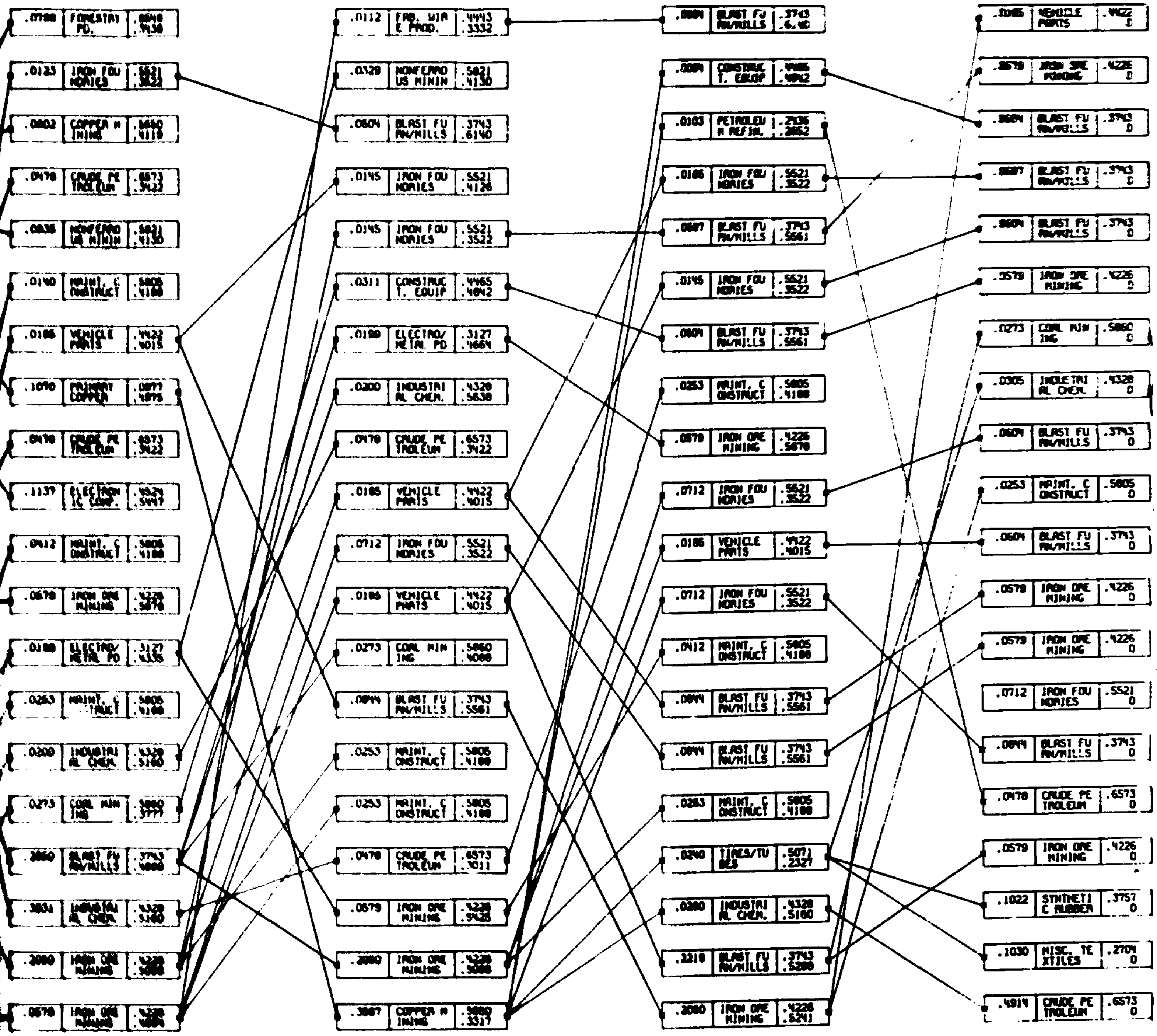


Figure 5. CRITICAL PATH NETWORK FOR



ICAL PATH NETWORK FOR SHIP PRODUCTION

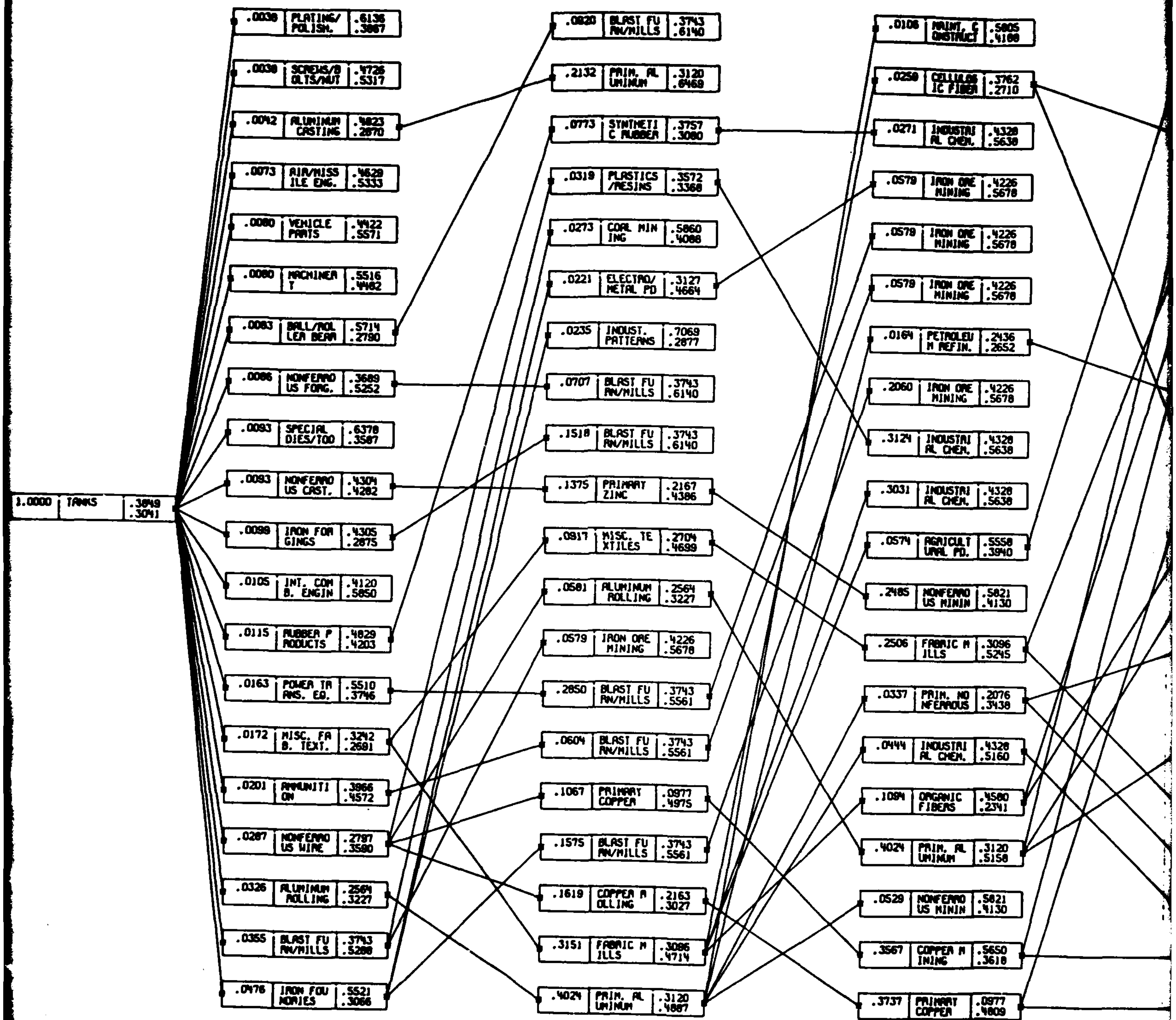
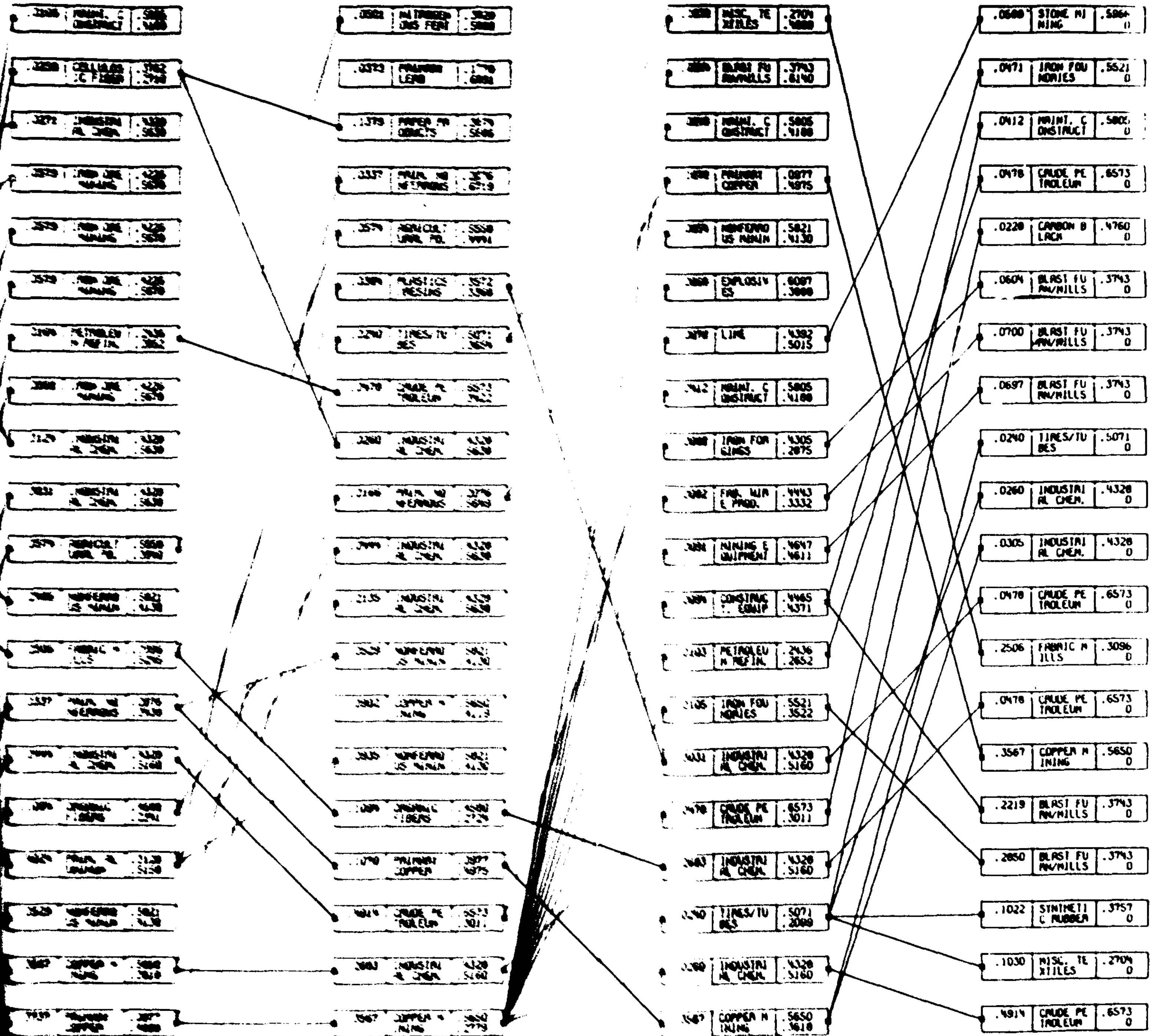


Figure 6. CRITICAL PATH NETWORK FOR TANK PR



AL PATH NETWORK FOR TANK PRODUCTION

- Aluminum Rolling,
- Primary Aluminum,
- Nonferrous Mining,
- Industrial Chemicals, and
- Crude Petroleum.

The number in the upper left corner is the number of dollars of the commodity required in the production of one dollar of the commodity preceding it in the previous tier. The number in the upper right corner is the amount of value-added in the production of the commodity. That number represents the fraction of a production dollar devoted to non-material items such as labor, profits, rents, and taxes. The number in the lower right corner is the number of dollars of commodities required in the production of one dollar of the boxed commodity that are not accounted for by lines emanating to commodities in the following tier. As an example, consider the third commodity in the first tier of Figure 4--Petroleum Refining. For every dollar spent on aircraft production, 0.0026 dollars is spent on buying products directly from petroleum refiners. For every dollar spent on refined products, 0.2436 dollars is spent on non-material items such as labor, profits, and rents while 0.4914 dollars is spent on crude petroleum and 0.2652 dollars is spent on other commodities.[1]

An interesting observation is to note that the lowest commodity in each tier contributes the most in terms of dollar value to the production of the end item. For aircraft, electronic components contribute the most in the second tier. For shipbuilding and small arms manufacturing, it is blast furnaces and steel mills.

[1]Networks for other principal defense end items appear in Volume II, Appendix B.

2. Individual Commodity Expansions

Figures 7, 8, and 9 show time-phased indirect requirements based on a surge in spending for three end item commodities--aircraft, ships, and tanks, respectively. In each case, one billion dollars in end item deliveries was required, with the figures showing the induced requirements for three supporting commodities over a period of 152 weeks prior to delivery of the end item. It is interesting to compare the critical path networks (Figures 4, 5, and 6) with the induced requirements. By doing so, one can see how requirements vary depending upon what tiers are required for the indirect commodity and what the associated time delays are. Surging one commodity is similar to the type of analysis done in lead time studies. IMPMOD is unique in the fact that it can surge all commodities simultaneously and time-phase the induced requirements.

B. REQUIREMENTS FOR INDUSTRIAL MOBILIZATION

In this section we describe the general model outputs. We start by describing the major parameter values used in making the model runs and then describe the resulting plots produced by IMPMOD.

1. Assumptions

As discussed in Chapter I, four major assumptions must be specified in defining the industrial mobilization. The first major assumption is the amount of the surge. For this study we ran two expansion levels. They represent a 50 and 200 percent increase in the defense budget. These levels bracket those assigned to the Under Secretary for Research and Engineering for mobilization planning. We arbitrarily chose three years as the duration of the expanded funding and used estimated outlays for defense for FY86 (which amounted to $240

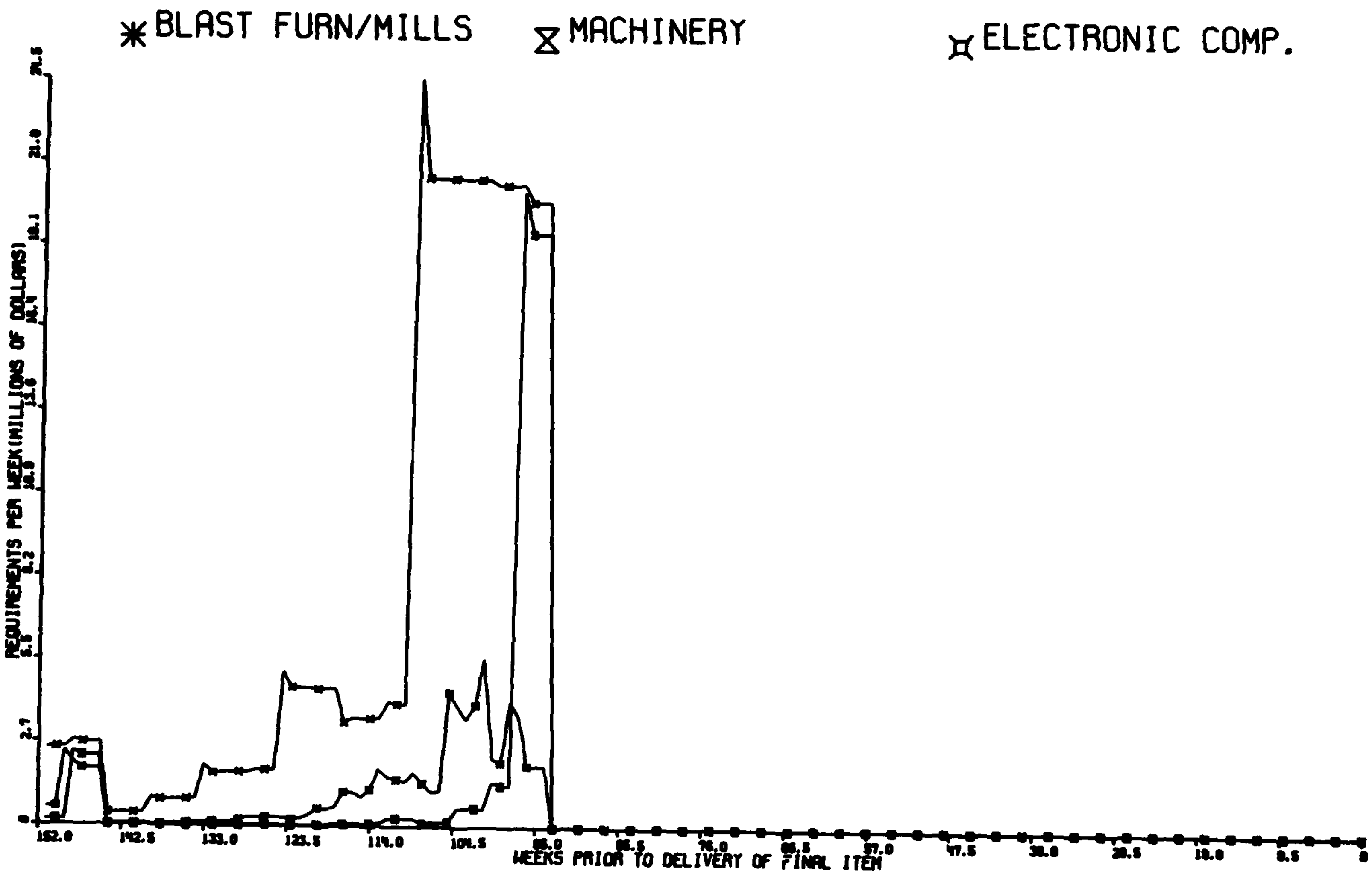


Figure 7. TIME-PHASED INDIRECT REQUIREMENTS FOR THE PRODUCTION OF AIRCRAFT

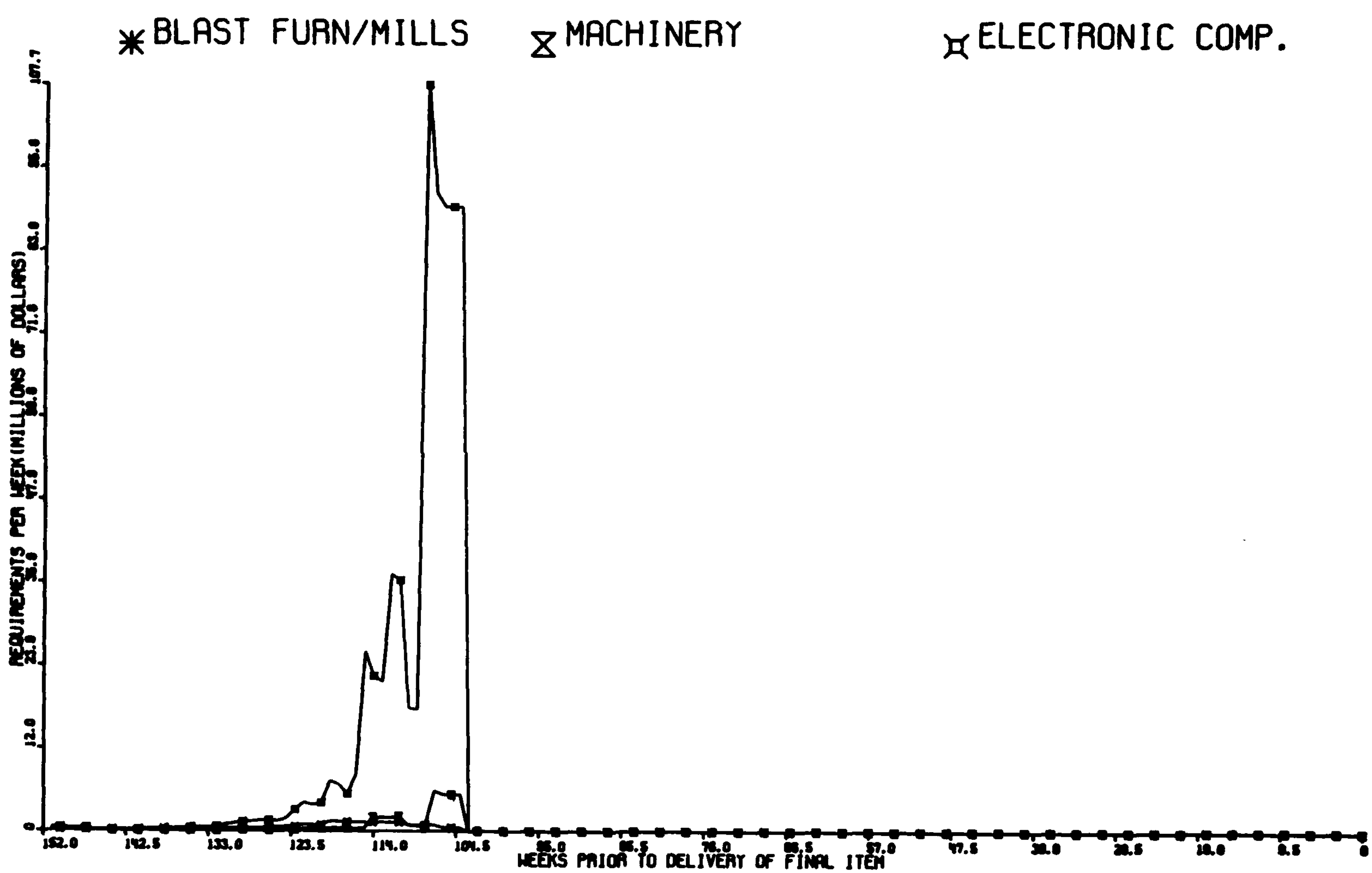


Figure 8. TIME-PHASED INDIRECT REQUIREMENTS FOR THE PRODUCTION OF SHIPS

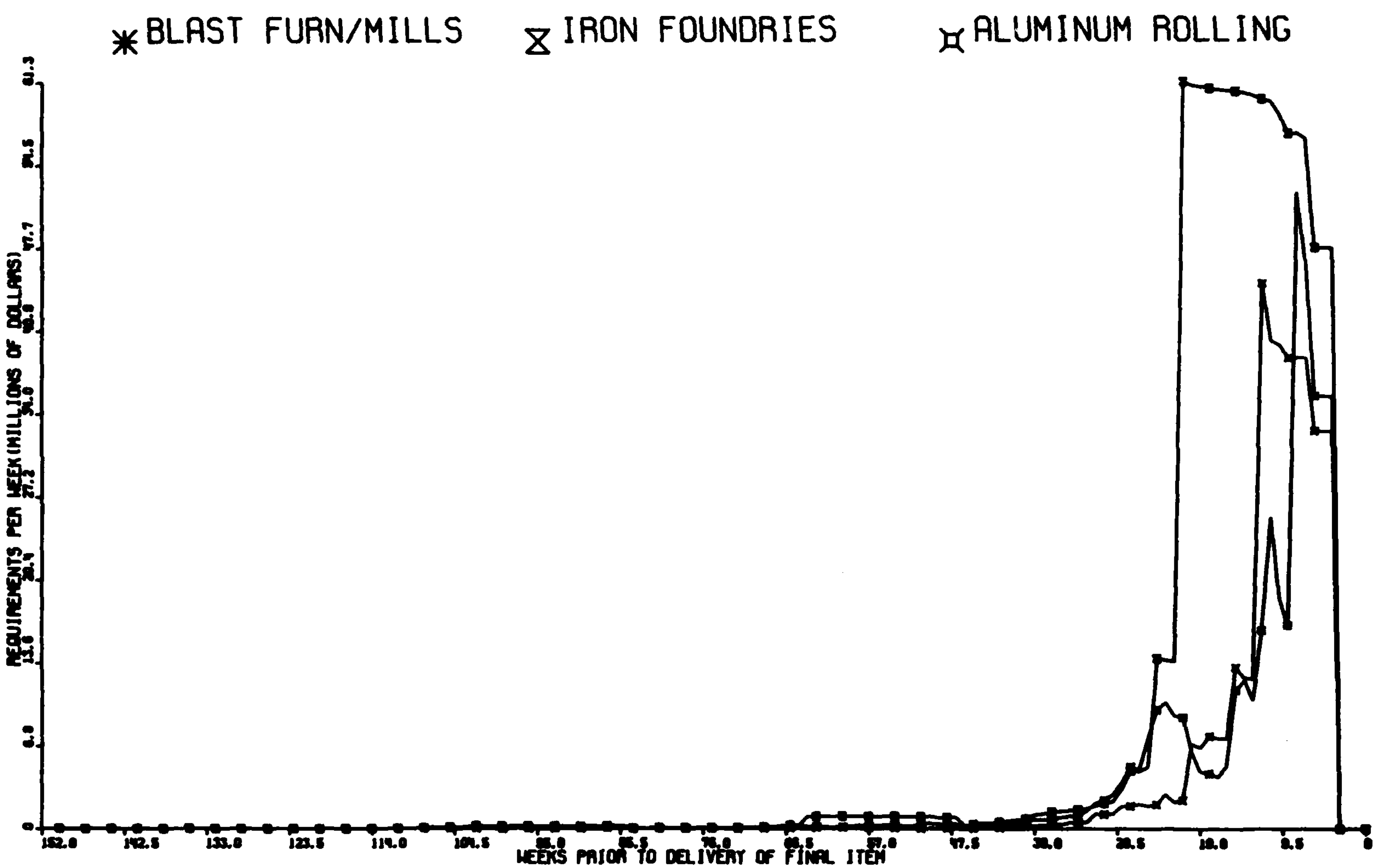


Figure 9. TIME-PHASED INDIRECT REQUIREMENTS FOR THE PRODUCTION OF TANKS

billion (1981 dollars))[1] as the basis for that expansion. The resulting total dollars are as shown in Table 4 below.

Table 4. ADDITIONAL OUTLAYS ASSOCIATED WITH SURGE IN PROCUREMENT

Expansion Level (Percent of FY86 Outlays)	Total Additional Spending Over Three Years (Billions of 1981 Dollars)
50	360
200	1,440

The second major assumption is the pattern of spending. Here we used the defense purchase pattern, shown in the budget estimate for FY86 in DoD's 1982-86 Five-Year Defense Plan. In our industrial mobilization we are implicitly assuming that DoD buys aircraft, ships, tanks, etc. in the same ratio as was planned for FY86. We have modified the purchase pattern in only one way--that is, all spending is directed to material items. Forty-five percent of the defense budget for FY86 was for government employee compensation; this includes civilian and military pay as well as a significant percentage for retirement benefits. In a mobilization it is not clear how employee compensation would increase. In the runs made in this study we have assumed that increased defense spending goes entirely towards buying material items and not towards buying a larger civilian or military work force. Thus the 50 and 200 percent expansion levels in total spending equate to 91 and 364 percent expansion levels in the procurement, research and development, operations and maintenance, and military construction categories.

[1]Office of the Assistant Secretary of Defense (Public Affairs), *News Release*, No. 77-81, March 4, 1981.

The third major assumption choice is when the mobilization occurs. Here we assumed a ten-year planning period (FY81 through FY90). End item deliveries must end by the final week of FY90 and induced requirements are calculated back through FY81.

The last major assumption is the end item delivery pattern. The expansion level and purchase pattern determine which and how much end item commodities are actually bought. A critical parameter is the timing of the delivery of these end items. If delivery is spread out over a long period of time, the maximum induced requirements will be minimized while the time span of induced requirements will be maximized. The opposite is true if the delivery period is very short. What this means is that if the U.S. must build up its forces quickly, then the delivery period must be short and the resulting production capacity requirements will be large. If the assumed time to build up the forces is longer, then production capacity requirements will not be as severe. In making the model runs we assumed three different delivery patterns. We assumed that (1) the same pattern applied for all commodities and (2) that delivery was uniform over a period ending in the last week in FY90. The three delivery periods were:

- one year (FY90)
- three years (FY88-90)
- five years (FY86-90).

A significant assumption made in plotting the results was that non-defense requirements were not reduced by the mobilization. In theory, defense requirements could replace non-defense consumption to some extent. The mechanism could be either specifically applied rationing or more general taxes. We chose not to reduce non-defense consumption since such a reduction was not observed during World War II, the Korean War, or the Vietnam War (see Reference [18], page 25). Historically, austerity has not been part of the American wartime experience except for the elimination of some nonessential consumption through controls and rationing geared to economize on critical materials.

2. Time-Phased Requirements and Production Capacity

Volume II, Appendix C contains time-phased requirements and estimated production capacity for 24 of the 250 industries included in the model. These 24 industries are those most affected by the defense surge. The selected commodities include 13 commodities where a 50 percent surge caused requirements to exceed estimated capacity. The remaining 11 commodities were selected to ensure inclusion of at least one commodity from each major industrial grouping as well as additional commodities in the key areas of Military End Items and Primary Metal Manufacturing. Plots for four of these commodities are shown in Figures 10 through 13. These four commodites--Guided Missiles, Tanks, Nonferrous Forgings and Primary Zinc--had requirements which most exceeded estimated capacity.

Four simulation runs were made for each commodity. The parameters for these runs were chosen so as to cover a reasonable range of expansion levels and end item delivery periods. The choice was to make three simulations at the 50 percent expansion level (defense surge of $360 billion) while setting the end item delivery period at one year, three years, and five years. One final plot was made at the 200 percent expansion level (defense surge of $1,440 billion) with a delivery period set at five years. Runs for additional expansion levels were not done since they can easily be derived from the 50 percent expansion level run. (A 100 percent expansion level run can be obtained simply by scaling the defense surge requirements by a factor of two.)

Each plot has four lines. Total U.S. requirements have been split into three categories (each represented by a line)--

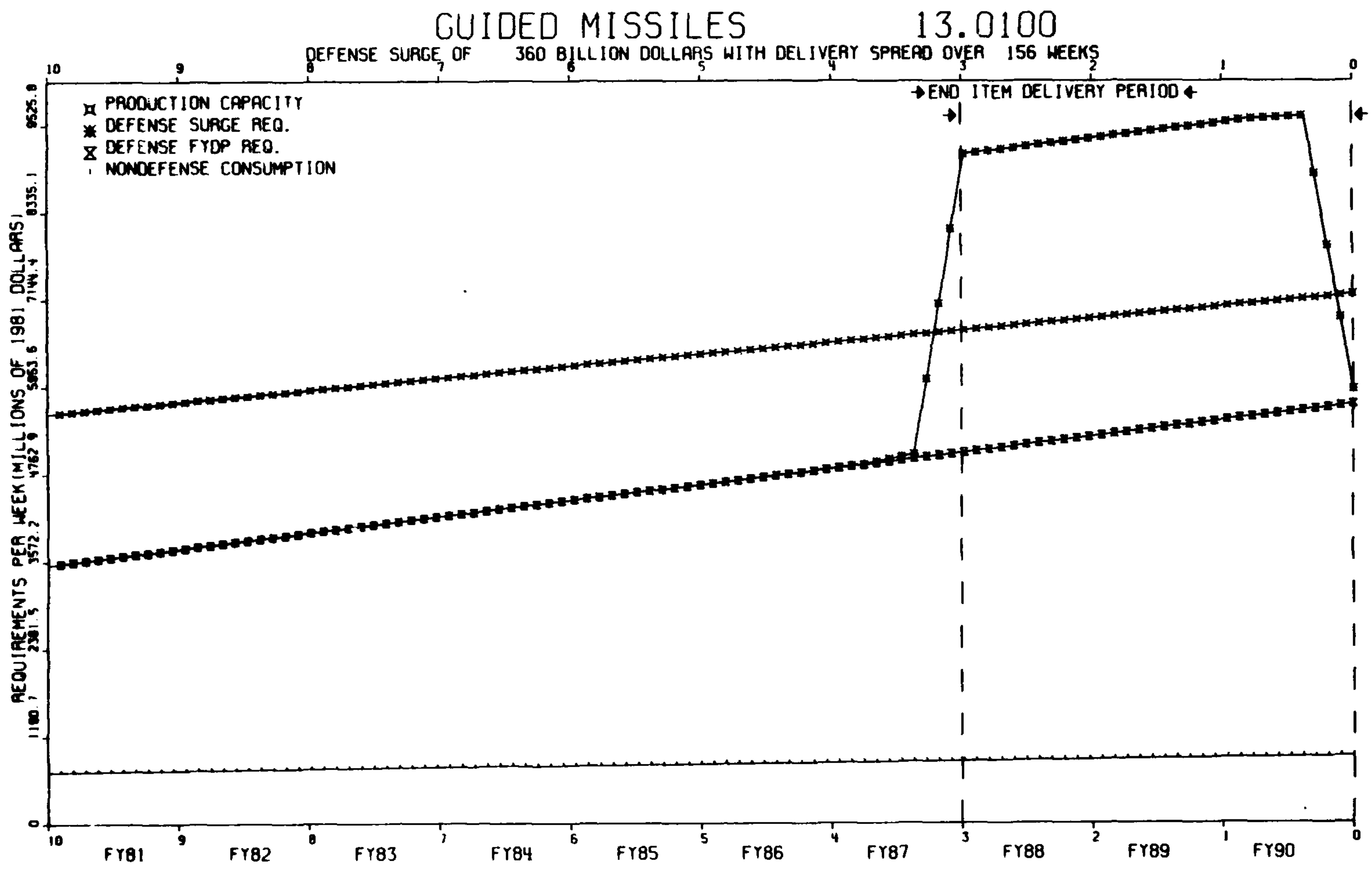


Figure 10. TOTAL REQUIREMENTS FOR GUIDED MISSILES BASED ON A DEFENSE SURGE OF $360 BILLION WITH DELIVERY SPREAD OVER 156 WEEKS

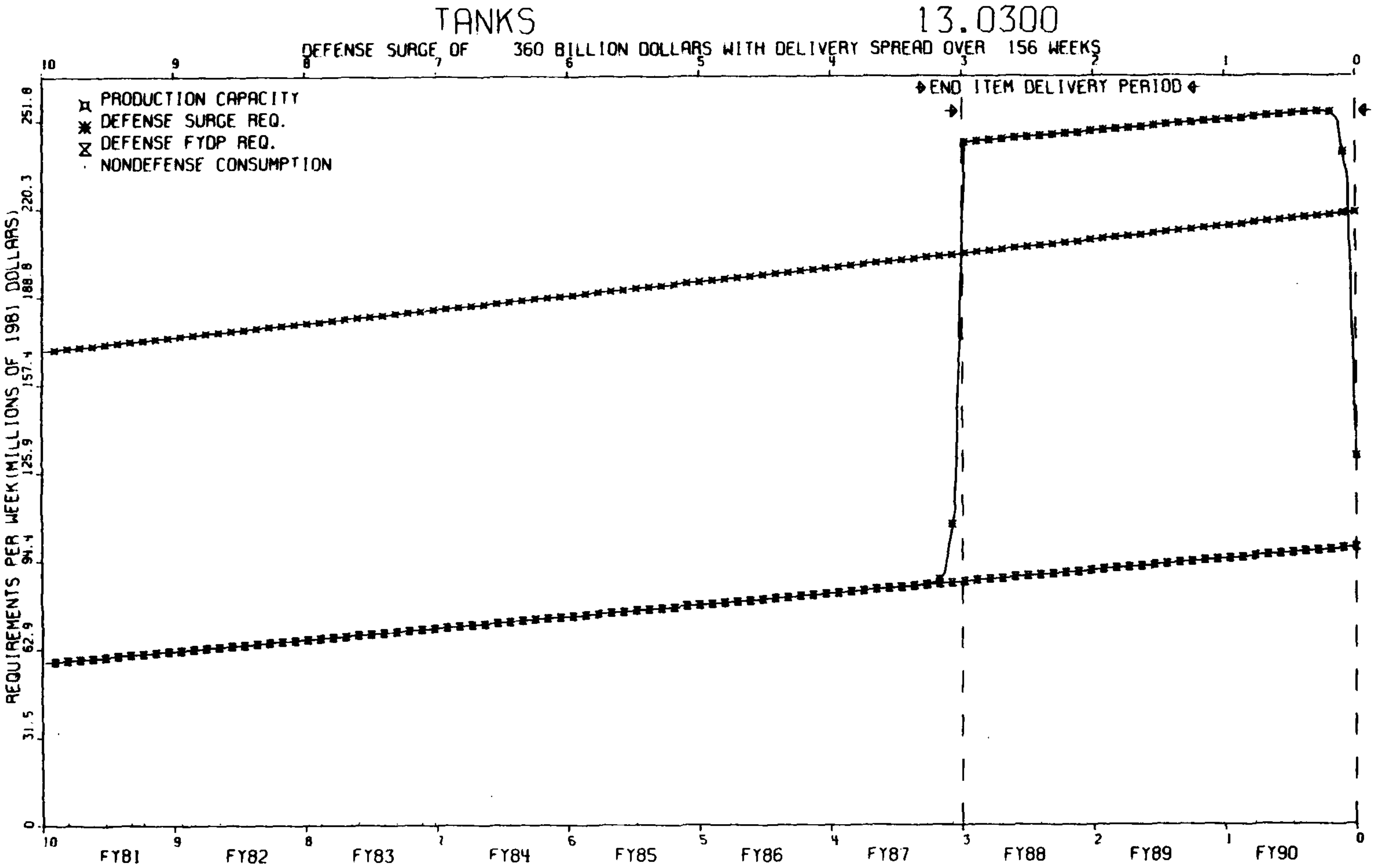


Figure 11. TOTAL REQUIREMENTS FOR TANKS BASED ON A DEFENSE SURGE OF $360 BILLION WITH DELIVERY SPREAD OVER 156 WEEKS

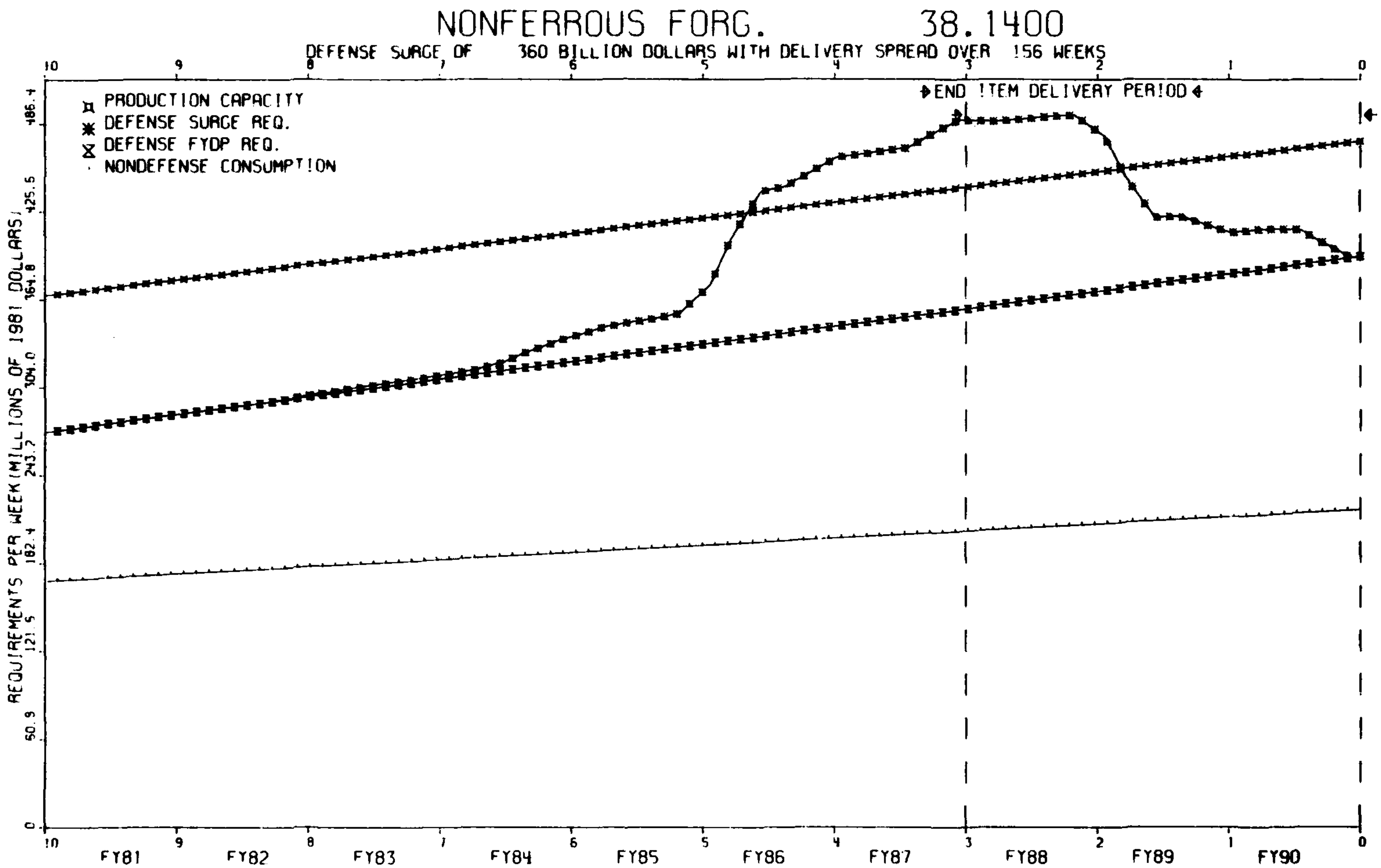


Figure 12. TOTAL REQUIREMENTS FOR NONFERROUS FORGINGS BASED ON A DEFENSE SURGE OF $360 BILLION WITH DELIVERY SPREAD OVER 156 WEEKS

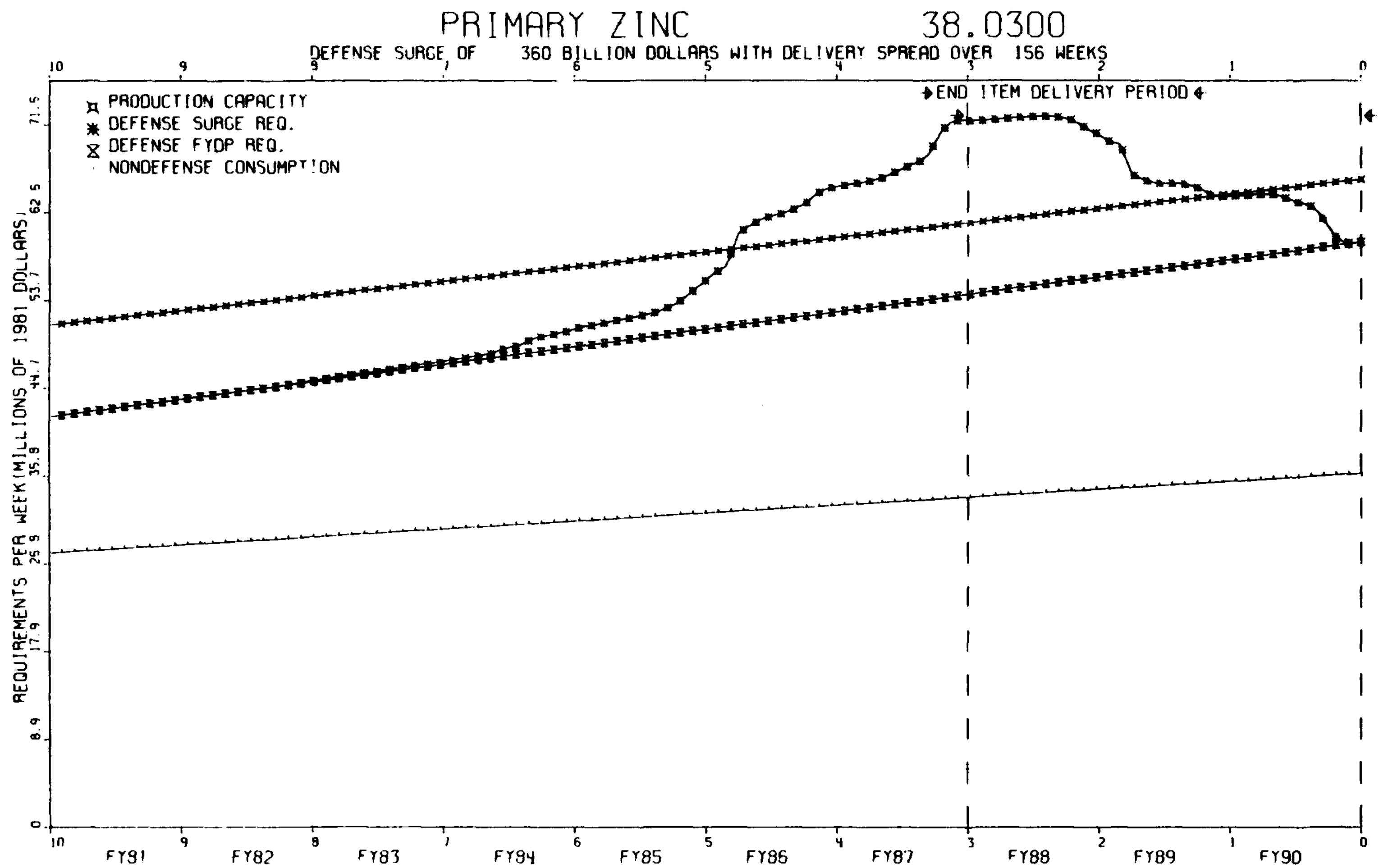


Figure 13. TOTAL REQUIREMENTS FOR PRIMARY ZINC BASED ON A DEFENSE SURGE OF $360 BILLION WITH DELIVERY SPREAD OVER 156 WEEKS

Nondefense Consumption, Defense FYDP Requirements, and Defense Surge Requirements. The fourth line represents production capacity. Both the capacity and requirement lines are in terms of millions of dollars in process per week. "In process" means that a commodity is counted as a requirement the week it is required for delivery as well as the previous weeks during its production. This allows a meaningful comparison between capacity and requirements. Nondefense Consumption represents commodity requirements needed to support non-defense U.S. consumption. Defense FYDP Requirements represent commodity requirements needed to support peacetime defense needs. The estimate is based on the Carter FYDP spending pattern for FY86 which has been scaled to Reagan's total planned spending for defense. Defense Surge Requirements represent the extra commodity requirements needed to reach the assumed defense expansion level. Production Capacity represents the maximum output obtainable from existing U.S. production facilities (though possible substitution is not taken into account).

Of the four commodities shown in Figures 10 through 13, requirements for Guided Missiles and Tanks are almost entirely due to direct defense requirements, and as a consequence, the shape of their requirements curves are straightforward. On the other hand, requirements for Nonferrous Forgings and Primary Zinc are almost entirely due to indirect requirements, and it is here that the effect of IMPMOD's time-phasing can be seen. As an example, Figure 12 shows Nonferrous Forgings with a 50 percent defense expansion and a delivery period of one year. The first thing to note is that peacetime defense requirements consume about one-third of current production. The next thing to note is that requirements exceed capacity in FY88 and FY89. The Defense Surge Requirements curve represents the latest time that Nonferrous Forgings could be produced before causing a delay in the delivery of one or more defense end items. While excess requirements cannot be produced later in time, they can be produced earlier. Doing so would force one to start the industrial mobilization of Nonferrous Forgings sooner in time unless large inventories were available. It would also push earlier in time the requirements for any commodity required in the production of Nonferrous Forgings.

A major question is: What inference can be drawn from these results concerning which industrial mobilizations are feasible and which are not. Table 5 summarizes that data from the results of Volume II, Appendix C. The Maximum Surge Amount represents the largest expansion possible before requirements exceed capacity. The Minimum Surge Length represents the fewest number of years prior to the end of FY90 that industrial mobilization must begin. It is assumed that mobilization production must begin when surge requirements exceed ten percent of peacetime requirements. (The implicit assumption is that at this level all inventories have been exhausted.) Notice that as the delivery period increases, the Surge Amount and Length increases also. Thus, one can accommodate a larger defense surge if one is also willing to start it sooner. The most interesting feature of Table 5 is that the commodities which most constrain the defense surge, both in terms of capacity and duration, are invariant to the delivery period. These commodities are:

- Tanks,
- Guided Missiles,
- Primary Zinc,
- Nonferrous Forgings, and
- Engineering and Scientific Instruments.

Table 5. MOBILIZATION CONSTRAINTS FOR SELECTED COMMODITIES

Selected Commodities	1 Week Delivery Period		1 Year Delivery Period		3 Years Delivery Period		5 Years Delivery Period	
	Minimum Surge Length (Years)	Maximum Surge Amount (Billions $)	Minimum Surge Length (Years)	Maximum Surge Amount (Billions $)	Minimum Surge Length (Years)	Maximum Surge Amount (Billions $)	Minimum Surge Length (Years)	Maximum Surge Amount (Billions $)
1. Shipbuilding	2.0	220	2.0	220	2.0	350	2.0	600
2. Tanks	0.2	10	0.1	90	0.1	270	0.1	480
3. Guided Missiles	0.3	20	0.3	50	0.3	150	0.3	222
4. Ammunition	0.2	120	0.2	1,800	0.2	5400	0.2	7200
5. Small Arms Ammo	0.1	300	0.1	3,620	0.1	11,100	0.1	17,472
6. Other Ordnance	0.1	20	0.1	180	0.1	500	0.1	870
7. Air/Missile Eng.	3.1	300	3.0	310	2.5	350	2.0	650
8. Air/Miss. Equip.	3.0	150	3.0	160	2.6	320	2.5	450
9. Radio/TV Com. Eq.	3.2	250	3.0	280	2.3	400	2.0	720
10. Electron Tubes	2.0	90	1.9	180	1.8	400	1.5	720
11. Semiconductors	2.3	320	2.8	420	2.1	720	1.8	1,080
12. Plating/Polish.	2.2	250	3.0	640	2.2	900	1.8	1,200
13. Blast Furn/Mills	2.3	120	2.1	720	2.0	900	1.5	1,200
14. Prim. Metal Pd.	0.2	50	1.9	350	1.0	750	0.3	1,200
15. Primary Copper	2.5	180	2.2	720	2.0	1,080	1.1	1,200
16. Primary Lead	2.5	100	2.2	450	1.8	1,080	1.0	1,200
17. Primary Zinc	4.0	27	3.5	91	3.0	150	2.5	240
18 Primary Aluminum	2.3	300	2.2	720	2.1	900	1.8	1,400
. Aluminum Rolling	2.2	200	2.0	600	2.0	720	1.4	1,200
20. Aluminum Casting	2.2	180	2.5	480	1.7	800	1.5	1,200
21. Nonferrous Casting	3.3	150	3.1	450	2.0	1,080	1.6	1,400
22. Nonferrous Forg.	4.0	49	3.3	120	3.0	240	3.0	360
23. Eng/Sci. Instrum.	2.2	10	1.9	110	1.5	300	0.2	500
24. Explosives	0.2	20	0.2	180	0.2	600	0.2	900

Chapter V

CONCLUSIONS

In this final chapter we review the most significant assumptions made in generating the results of the previous chapter and discuss their impact. We then summarize the results of the study and discuss their implications concerning the mobilization capability of the U.S. economy. We conclude with a discussion of how IMPMOD might be used by DoD.

A. MAJOR ASSUMPTIONS AND LIMITATIONS

DoD must make planning and budgetary decisions based on how the U.S. economy will react in a mobilization. The motivation for the development of IMPMOD was to provide an analytic tool for making those decisions. The goal was to generate only a rough approximation to what might happen, as current economic models have a difficult time predicting how the economy will perform in peacetime, let alone during a defense mobilization.

Even though IMPMOD is a rather large program with a very large data base, it is extremely simplistic relative to the U.S. economy which it models. Many assumptions have been made in generating the results contained in this study. Assumptions were chosen so as to be most reasonable within the constraints of available data and programming effort. Table 6 contains the seven assumptions which, in the opinion of the author, most strongly affect the results.

The first assumption in Table 6 is Commodity Aggregation. The commodity categories are fairly aggregated. As an example, Nonferrous Castings includes many types of titanium and beryllium

Table 6. MAJOR ASSUMPTIONS

• Commodity Aggregation--All commodities in the U.S. economy can be treated as aggregated groups at the four-digit Standard Industrial Classification code level.
• Defense Purchase Pattern--In a future mobilization, DoD purchases will be in the same pattern as planned for FY 1986 in the Five-Year Defense Plan.
• Defense Delivery Pattern--All defense end items are delivered according to the same time-phased pattern during a mobilization.
• Non-defense Spending--Total non-defense spending is not reduced during the mobilization. Non-defense U.S. consumption is in the same pattern as experienced in 1981 and grows at the rate projected for GNP.
• Commodity Process Times--Production process times for individual commodities can be estimated based on the smallest order lead time observed over the past ten years.
• Commodity Queue Times--Commodity queue times can be neglected. In effect, capacity constraints are assumed to be non-binding in computing production delays.
• Production Capacity--The production capacity growth rate is unchanged during the mobilization.

castings. The possibility exists that for a particular type of casting, requirements exceed capacity, whereas for the aggregate, that is not the case. On the other hand, the data for the aggregate commodity can be viewed as a bound. If the aggregate commodity requirement exceeds capacity, there will be problems for one or more particular commodities. As an example, suppose that there are N types of Nonferrous Castings:

$$\mathrm{Req} = \sum_{i=1}^{N} \mathrm{Req}_i$$

$$\mathrm{Cap} = \sum_{i=1}^{N} \mathrm{Cap}_i \quad .$$

- If Req > Cap, then $\mathrm{Req}_i > \mathrm{Cap}_i$ for some type of Nonferrous Casting i.
- If Req $\leq$ Cap, then $\mathrm{Req}_i > \mathrm{Cap}_i$ may or may not occur. (The wider the gap between total requirements and capacity, the less likely the chance of capacity problems for individual items.)

Commodities can be disaggregated, as explained in Chapter II, but doing so would require a substantial amount of additional data.

In a specific mobilization, defense spending patterns will almost surely differ from the FYDP plan. In a conventional scenario, non-nuclear forces would probably be built up faster than nuclear forces. It would be most appropriate to run IMPMOD with a range of spending patterns, but it is felt that the FYDP plan is a good first run. Similarly, the delivery patterns for different defense items will almost surely differ in a real mobilization with short lead time items, with those required first delivered first. Without having time to collect additional data, we chose a uniform delivery pattern. The bias of this assumption is probably to skew requirements towards the end of the mobilization period. Non-defense spending will also likely be different from 1981 spending patterns, though exactly how is difficult to predict.

The estimates for the commodity process times are probably the poorest data in the model. This was caused by the fact that very little process time data are collected, and in some commodity categories such as Shipbuilding, process times vary greatly within the category. For this reason, the estimates used here should be reviewed and sensitivity runs made. IMPMOD does not model commodity queue times. In reality, if requirements exceed capacity, then some commodity requirements will have to wait in a queue. IMPMOD, as currently programmed, flags the fact that requirements exceed capacity but does not increase production delays because of it. The bias created by this assumption is probably to increase requirement peaks but shorten the time span during the mobilization period.

The final assumption listed in Table 6 is that IMPMOD does not model the fact that production capacity can be expanded during a mobilization--incurring time delays and requiring commodity inputs. The bias introduced by this assumption is to underestimate capacity later on in the mobilization period while also underestimating some commodity requirements early in the mobilization period.

B. MOBILIZATION CAPABILITY OF THE U.S. ECONOMY

An important question is: What commodities would first constrain an industrial mobilization based on a military expansion? There are two ways of answering this question. Table 7 shows the ten commodities which would most exceed estimated production capacity. For these commodities one might want to concentrate efforts to encourage capacity expansion. Table 8 shows the ten commodities with the earliest surge in requirements. For Primary Zinc one must increase production four and one-half years prior to final delivery of the defense end items or have on hand a substantial inventory. For these commodities, one might want to concentrate efforts on encouraging inventory buildup or actually include these items in the Stockpile of Strategic and Critical Materials.

Table 7. THE TEN COMMODITIES MOST CONSTRAINED BY EXISTING PRODUCTION CAPACITY (BASED ON A ONE-YEAR DELIVERY PERIOD)

Commodity	Maximum Expansion Before Capacity is Reached[1]
1. Guided Missiles	7
2. Tanks	13
3. Primary Zinc	13
4. Engineering and Scientific Equipment	15
5. Nonferrous Forgings	17
6. Aircraft/Missile Equipment	22
7. Electron Tubes	25
8. Explosives	25
9. Other Ordnance	25
10. Radio/Television Communications Equipment	39

[1]Expressed as a percentage of estimated capacity in 1986.

Table 8. THE TEN COMMODITIES WITH THE EARLIEST SURGE IN REQUIREMENTS (BASED ON A ONE-YEAR DELIVERY PERIOD)

Commodity	Lead Time Before Surge in End-Item Delivery Occurs[1]
1. Primary Zinc	3.5
2. Nonferrous Forgings	3.3
3. Nonferrous Castings	3.1
4. Aircraft/Missile Engines	3.0
5. Aircraft/Missile Equipment	3.0
6. Radio/Television Communications Equipment	3.0
7. Plating and Polishing	3.0
8. Semiconductors	2.8
9. Aluminum Castings	2.5
10. Primary Aluminum	2.2

[1]Years. Thus, an increase in primary zinc production is required 3.5 years before delivery of the additional defense end items which (directly or indirectly) use the zinc.

There are four commodities common to both lists:

- Primary Zinc,
- Nonferrous Forgings,
- Aircraft and Missile Equipment, and
- Radio, Television, and Communications Equipment.

These commodities deserve special attention. A first step would be to make sure that our aggregation assumptions have not led us astray. It could happen that a particular commodity is used in the production of commercial items but not defense items; since we are dealing with aggregates we could end up surging a commodity that is not used by defense. A first check can be made by looking back at the critical path networks of Chapter IV. Of the eight defense end items with networks, three use Primary Zinc:

- Tanks--through Nonferrous Castings,
- Aircraft--through Aircraft Engines,
- Small Arms Ammunition--through Copper Rolling and Primary Copper.

A more detailed check might entail a Department of Commerce study of that commodity.

An interesting question is: What production tier most constrains U.S. mobilization capacity? Is it commodities in the lower production tiers or end item assembly itself? In the past, DoD has directly funded end-item production capacity, and the U.S. Government has stockpiled commodities at the lowest tiers (primarily raw materials). Many people have expressed concern about the adequacy of production capacity between these two extremes. Tables 7 and 8 show that commodities representing most of the production tiers are in the list of commodities which most constrain a mobilization. End-item commodities head the list most constrained by production capacity, and primary commodities head the list with the earliest surge requirements. The primary commodities, such as Primary Zinc and Nonferrous Forgings, probably deserve the most attention as these commodities would be required first in a mobilization and there would be little time to expand capacity or build up inventories.

Figure 14 summarizes the results. Given the assumptions we have made, it shows which defense expansions are feasible with existing production capacity and which are not feasible. If we must have completed end-item deliveries within five years (read the Five-Year Surge curve), then a defense surge of $90 billion above FYDP spending can be accommodated if the delivery period is one year. If the delivery period is

FEASIBLE DEFENSE EXPANSIONS

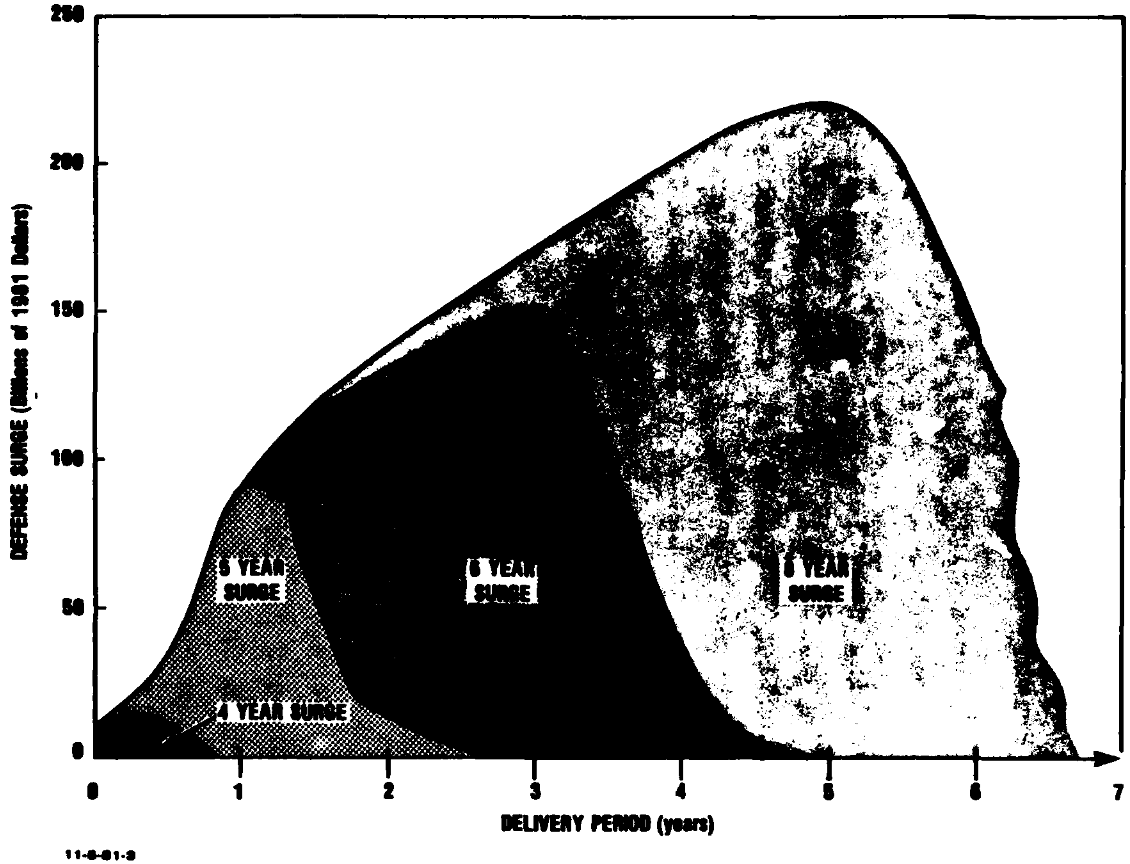


Figure 14. FEASIBLE DEFENSE EXPANSIONS

either longer or shorter, the size of the feasible defense surge decreases sharply. The Figure also shows that if the time span allowed for the mobilization is lengthened, the feasible region increases. The curves were constructed such that above any curve the requirements of at least one commodity exceeds its production capacity (below the curve none do). In general, end-item commodities, such as Guided Missiles and Tanks, define the shape of the left side of each curve, while primary commodities, such as Primary Zinc and Nonferrous Forgings, define the right side. Allowing capacity expansion would probably significantly increase the left side of each curve but would probably not affect the right side.

C. USES OF IMPMOD

IMPMOD is the only model (of which the author is aware) that is both comprehensive and takes into account production processing delays. Both of these factors are very important in mobilization planning. On the other hand, IMPMOD is based on many assumptions which are handled better by other models, and a potential user must make a judgment as to which factors he feels are most important in answering his questions. For large surges in defense spending, the author feels that IMPMOD is the best model to use for identifying areas of the U.S. industrial base which would most constrain such a surge. For small surges, or when the delivery period is stretched out over a long period of time, production delays are not as significant and other models may be adequate to compute industrial requirements.

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Volume I -- Main Report

A METHOD FOR CALCULATING INDUSTRIAL MOBILIZATION REQUIREMENTS WHICH INCORPORATES PRODUCTION PROCESS TIMES

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