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ANNUAL MATERIALS PLAN ANALYSIS TOOL II

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OPERATIONS RESEARCH AND ECONOMIC ANALYSIS OFFICE

DEPARTMENT OF DEFENSE

DEFENSE LOGISTICS AGENCY

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DLA-LO

FOREWORD

This report presents work done by the Defense Logistics Agency Operations Research Office. This study was made possible by the Administrator of the Defense National Stockpile Center, Ms. Marilyn Barnett, and her staff members Messrs. Richard Corder and Franklin Ringquist.

The Annual Materials Plan Analysis Tool I (AMPAT-I), developed under Project DLA-93-P10218, has previously automated the process of computing an optimal Annual Materials Plan. The resulting product from this study is an additional capability that enables the Defense Logistics Agency to model the major decision making processes that lead to the preparation of the Annual Materials Plan. These processes involve highly interrelated economic, political, industrial, and mathematical factors that have always defied adequate analytical representation until now. The Annual Materials Plan Analysis Tool II (AMPAT-II) supports the legislative responsibility of the Executive Branch to submit the Annual Materials Plan to Congress (Strategic and Critical Materials Stockpiling Act, 50 U.S.C 98, et seq). The Executive Branch has delegated preparation of the Annual Materials Plan to the Defense Logistics Agency, Defense National Stockpile Center.

ROGER C. ROY
Assistant Director
Policy and Plans

EXECUTIVE SUMMARY

At the request of the Defense National Stockpile Center (DNSC), the Defense Logistics Agency Operations Research Office developed the Annual Materials Plan Analysis Tool II (AMPAT-II). This uses the tools and concepts of applied mathematics and artificial intelligence to model the decision making processes that lead up to the computation of the Annual Materials Plan (AMP). These processes consider political, economic, and technical factors that involve many government agencies such as the Central Intelligence Agency and the Departments of State, Commerce, and Defense. Public law requires the President to submit the AMP to Congress each year, a responsibility that has been delegated to the Defense Logistics Agency for execution by the DNSC.

The decision making processes affecting the AMP have been largely developed and carried out by Mr. Richard Corder. Because he will retire from the DNSC in early 1993, the DNSC has compelled itself to obtain software that automates his knowledge. This is important because his successors--lacking an automated tool to guide their steps--may be defeated by the sheer complexity of the knowledge needed to develop an acceptably efficient AMP. AMPAT-I (Project DLA-93-P10218) has already automated the process of computing an optimal AMP, and AMPAT-II will automate the decision making processes that precede it.

Initially, it was planned to incorporate AMPAT-II into the existing software of AMPAT-I, thus providing an integrated operations research and artificial intelligence analysis tool. However, AMPAT-II grew so large that the two were kept separate: as the study progressed, other ways were found to represent the expert's knowledge. One such instance occurred when we approached knowledge engineering from a new direction, that being, allowing the user to identify basic components with which AMPAT-II then automatically builds the rule base. This new approach relied upon artificial intelligence software developed in January 1988 to address United States Air Force personnel matters.

This report marks the completion of a year-long effort that has developed two operations research/artificial intelligence analysis tools used to address the Annual Materials Plan. Both studies have leveraged new-to-DLA programming and analytical concepts to address the problems of decision making, concepts that are general enough for application to other unrelated studies undertaken by the operations research functions of DLA. In presenting the DNSC with the tools it needs to accomplish its mission, this study honors the objectives stated in the November 1990 "Artificial Intelligence Management Plan for the Defense Logistics Agency":

- Improve the quality, timeliness, and uniformity of mission accomplishments.

- Increase productivity of the work force and to improve effectiveness of Agency decision-making.

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SECTION 1
INTRODUCTION

1.1 BACKGROUND

The Annual Materials Plan (AMP) states how much of what materials to add, to remove, or upgrade in the Defense National Stockpile (DNS). The AMP also states when during the next three years such activity should occur. Materials found in the DNS are those which would be scarce in the opening years of a global conventional war that forces full economic mobilization of the United States. Public law creates the AMP which the President submits to Congress.

The AMP is a relatively short document but is tedious and time-consuming to create. It requires coordination with many federal agencies and is affected by legislation and politics. It requires understanding the economy and political stability of foreign supply sources, international supply and demand, and being able to forecast commodity prices, supply and demand. Although these factors are volatile and will always defy prediction, it is possible to mathematically model some important interactions.

These interactions were modelled in a previous Defense Logistics Agency Operations Research Office (DLA-DORO) study (DLA-93-P10218). In October 1992, the Annual Materials Plan Analysis Tool I (AMPAT-I) was delivered to the Defense National Stockpile Center (DNSC). AMPAT-I was a PC-based analysis tool that solved a system of equations whose solution was essentially the AMP. However, AMPAT-I assumed that the values of certain variables had already been established by the user. It was recognized that modelling the decision making process that assigned these values would be just as necessary and challenging as creating AMPAT-I. This decision making process largely centered on estimating the maximum number of units that could be sold on world markets of a specific commodity, i.e., the commodity's maximum market activity.

1.2 PURPOSE

The purpose of this study is to enable the DNSC to automate the steps taken by its expert to determine the maximum market activity of a commodity.

1.3 OBJECTIVES

The general objectives of this study are to:

(1) Identify the mechanics of the decision processes and essential inputs that set the maximum market activity for commodities in the DNS.

(2) Use the appropriate tools and concepts from applied mathematics and artificial intelligence to model these processes.

(3) Subject to hardware restrictions, integrate resulting software into AMPAT-I which uses linear programming to mathematically build an AMP.

1.4 SCOPE

This study will only consider the expertise of the DNS expert on the AMP, Mr. Richard Corder, and that only those factors used by AMPAT-I will be included. This study will not evaluate competing market forecasting techniques to determine the best one(s) to use in AMPAT-II. Rather, a technique that the DNSC judges as adequate will be used.

SECTION 2
METHODOLOGY

2.1 CONDUCT BACKGROUND INTERVIEWS

In October 1992, analysts from DORO met with the DNSC expert on the AMP, Mr. Richard Corder. The purpose of the interview was to discuss his decision making processes that assign values to key variables used to build an AMP. The interview revealed three major areas of decision making:

(1) Forecasting market conditions for a commodity.

(2) Determining the maximum number of units of a commodity that the DNSC can sell on the commodity's world market, i.e., the commodity's market tolerance (this allows the DNSC to estimate how long lived its surplus in the commodity will be and the net revenue from sales).

(3) Identifying where and in what order all the materials used to create a stockpiled commodity appear in the commodity's production process.

The interview also revealed some surprising facts:

(1) There was no known central database--anywhere--that contained the production relationships for all stockpiled commodities. Independent investigation by the author confirmed this. Although the DNSC had wanted such a database for many years, it neither had the resources to develop one nor did it know how to understandably represent such information to a decision maker.

(2) The technique used to forecast the supply, demand, and price of a commodity was to simply average historical values and use this as the forecast throughout a ten-year planning horizon. Although the DNSC had not known about alternative forecasting methods, it was

clearly willing to try a different, hopefully better method.

2.2 IDENTIFY USES OF OPERATIONS RESEARCH AND ARTIFICIAL INTELLIGENCE METHODOLOGIES

It was seen that AMPAT-II would require the: use of statistical regression for forecasting; processing and merging potentially large databases that could not be kept entirely in memory; and a programming medium whose ability to represent rules would be more flexible than classical procedural languages such as FORTRAN.

The DNSC agreed to use linear regression as the forecasting technique for reasons explained later in this paper. In order to address the concerns of numerical calculations and of rule representation, it was decided to use the procedural language C for the former and the declarative artificial intelligence language PROLOG for the latter. Another attractive benefit of PROLOG was that it had the best tools available to the author with which to construct user interfaces.

2.3 LOCATE DATA SOURCES AND IDENTIFY NEEDED DATA

The sources of data used by AMPAT-II were various reports by the US Bureau of Mines, the Institute for Defense Analyses, and because there was no centralized database of production rules for stockpiled commodities, the collective knowledge of material specialists at the DNSC. The Bureau of Mines reports were already in use within the DNSC and the Institute for Defense Analyses data is detailed in Appendix A.

SECTION 3
DESCRIPTION OF THE ANNUAL MATERIALS PLAN ANALYSIS TOOL II (AMPAT-II)

3.1 GENERAL FUNCTIONALITY

AMPAT-II estimates how much of a stockpiled commodity could be sold without upsetting international commodity markets--the most difficult factor to determine in AMPAT-I. Done annually during a ten-year planning period, such estimates involve many factors which are addressed by separate AMPAT-II modules. These factors include forecasted supply and demand, guidelines that set the rate at which a commodity is sold, and the effect that shortages in other materials have upon the price of a given commodity. Once computed, these sales tolerances are used by AMPAT-I to compute an optimal AMP.

3.2 MAIN MENU

The greeting screen (Figure 3-1) is the point of entry to all modules of AMPAT-II. Each module is described in the following paragraphs below with fictitious numbers used in the figures as examples.

Annual Materials Plan Analysis Tool-II 1.0 (AMPAT-II)

F1 Help
F2 Modify Master Commodity List
F3 Create/Modify Historical Commodity Data
F4 Adjust/Forecast Commodity Data
F5 Compute Market Tolerance
F6 Review IDA Report
F7 Display Commodity Interrelationships
F8 Backup AMPAT-II Files to C:\AMPAT2\backup*.*
F9 Overview

Figure 3-1. AMPAT-II Greeting Screen

3.3 MODIFY MASTER COMMODITY LIST MODULE

This module allows the user to maintain a central database of commodities whose data are shared by AMPAT-I and AMPAT-II (Figure 3-2). These data values are the commodity's name, unit of measure, inventory, requirement, and current disposal authority.

```
FORMAT : Commodity; StandardUnit; Inventory; Requirement; Curr DispAuthority
EXAMPLE: bauxite, refractory; ST; 15232.32; 9235; 1900.23
Aluminum Metal; ST; 57588; 0; 0
Aluminum Oxide, Abras Grain; ST; 50786; 0; 0
Aluminum Oxide, Abras Grn. NSG; ST; 118; 0; 0
Aluminum Oxide, Fused Crude; ST; 249867; 0; 249867
Antimony; ST; 36004; 0; 36004
Antimony, NSG; ST; 7; 0; 7
Asbestos, Amosite; ST; 34005; 0; 34000
Asbestos, Amosite NSG; ST; 1; 0; 0
Asbestos, Chrysotile; ST; 9783; 0; 7700
Asbestos, Chrysotile, NSG; ST; 916; 0; 0
Asbestos, Crocidolite (DBA); ST; 36; 0; 36
Baddeleyite; SDT; 15991; 0; 0
Bauxite, Met. Grade, Jamaica; LDT; 12288824; 0; 12457740
Bauxite, Met. Grade, Surinam; LDT; 4908512; 0; 5299597
Bauxite, Refractory; LCT; 276067; 0; 207067
Beryllium Metal; ST; 353; 0; 0
Beryl Ore; ST; 16074; 0; 17729
Beryllium Copper Master Alloy; ST; 7387; 0; 7387
Bismuth; Lb; 1631406; 0; 300000
Cadmium; Lb; 6328570; 0; 6328570
Chromite, Chemical, SDT; 242414; 0; 0
Chromite, Metallurgical; SDT; 873122; 0; 0
          F10 Save and Return to MAIN     ESC Abort
```

Figure 3-2. Master Commodity List

3.4 CREATE/MODIFY HISTORICAL COMMODITY DATA MODULE

This module allows a user to create and maintain historical databases of prices, supply and demand, and the basis from which forecasted trends are made. This data comes from various Bureau of Mines and financial reports.

Because a user may want to maintain various commodity databases to suit many purposes, AMPAT-II allows the user to create a database having any number of commodities. When this module is entered, a menu appears from which the user chooses the database to modify. By hitting the escape key, the user may create a new file (Figure 3-3).

hit escape to abort

1.2MP	2.2MP	3.2MP
4.2MP	5.2MP	6.2MP
7.2MP	8.2MP	A.2MP

hit escape to abort

Name of new AMP File >> newone

Figure 3-3. AMPAT-II Historical Database Selection Menu

After a file has been chosen, another menu appears from which to choose the commodity to be modified or added (Figure 3-4). Commodities that already appear in the database are marked with an asterisk. After the commodity is chosen, its historical supply, demand, and price data appear (Figure 3-5). The user simply enters or modifies any value, may attach a narrative remark to the commodity for future reference purposes, or may delete the commodity from the database. The current price can be modified for use in other modules that use up-to-date prices. Pop-up help text (F1 key) is available for the user who needs to have the screen explained.

ESC saves/goto MAIN; C:\AMPAT2\A.2MP

*Aluminum Metal
Aluminum Oxide, Abras Grain
Aluminum Oxide, Abras Grn, NSG
Aluminum Oxide, Fused Crude
*Antimony
Antimony, NSG
Asbestos, Amosite
Asbestos, Amosite NSG
Asbestos, Chrysotile
Asbestos, Chrysotile, NSG
Asbestos, Crocidolite (DBA)
Baddeleyite
Bauxite, Met. Grade, Jamaica
Bauxite, Met. Grade, Surinam
Bauxite, Refractory
Beryllium Metal
Beryl Ore
Beryllium Copper Master Alloy
Bismuth
Cadmium
Chromite, Chemical
Chromite, Metallurgical NSG

(* indicates items currently in file)

Figure 3-4. Listing of Commodities in Chosen AMP File

Aluminum Metal (ST)
Current Price » 12.38

******************** UNADJUSTED HISTORY ********************

	.... Domestic		..... NonDomestic		
YEAR	Production	Consumption	Production	Consumption	Price/Unit
1977	9.0	9.0	9.0	9.0	3.0
1978	6.0	6.0	6.0	8.0	8.0
1979	13.0	14.0	15.0	16.0	16.0
1980	3.0	33.0	4.0	45.0	6.0
1981	8.0	9.0	9.0	9.0	9.0
1982	9.0	10.0	11.0	12.0	13.0
1983	9.0	8.0	9.0	9.0	9.0
1984	12.0	13.0	14.0	15.0	16.0
1985	4.0	5.0	6.0	7.0	7.0
1986	19.0	3.0	4.0	65.0	6.0
1987	2.0	3.0	5.0	6.0	67.0
1988	1.0	1.0	1.0	1.0	1.0
1989	3.0	56.0	4.0	4.0	4.0
1990	1.0	2.0	3.0	4.0	5.0
1991	7.0	6.0	5.0	8.0	3.0
1992	21.0	22.0	3.0	4.0	5.0

F1 Help F2 Store Item F3 Remarks F4 Delete Item ESC Quit

Figure 3.5. Historical Supply, Demand, and Price Screen

3.5 ADJUST/FORECAST COMMODITY DATA MODULE

Once a commodity's historical data has been established, the user may forecast its ten-year supply, demand, and price trends. AMPAT-II uses this history to do a linear regression. The user specifies which years to include in the regression and may adjust historical data in light of recent events, e.g., an adjustment made by the Bureau of Mines. The user may also adjust the forecast using information that cannot be considered analytically by the regression, e.g., the recent destruction of a commodity's refining capacity due to civil disturbance.

Upon entering this module, a menu appears from which the user chooses a database. The user then chooses the specific variable to forecast (Figure 3.6). Next, the user chooses the commodity from a menu that lists those found in the database (Figure 3.7). A screen then appears (Figure 3.8) to display the history for the commodity's variable. The user can then adjust the historical entry and include/exclude the entry (by toggling yes or no in the column headed "Keep").

Forecast (ESC quits)	
Domestic	Production
Domestic	Consumption
Nondomestic	Production
Nondomestic	Consumption
Prices	

Figure 3.6. Choosing the Variable to Forecast

Items w/Historical Data
Aluminum Metal
Antimony
Baddeleyite
Bauxite, Met. Grade, Jamaica
Bauxite, Met. Grade, Surinam
Bauxite, Refractory
Beryllium Metal

Figure 3.7. Items with Historical Data

Aluminum Metal (ST)
Domestic Production

Year	History	Adjustment	Keep	OutYear	Forecast	Adjustment
1977	9.0	10.0	Y	+1	6.8	-2.0
1978	6.0	0.0	N	+2	6.5	0.0
1979	13.0	0.0	Y	+3	6.2	0.0
1980	3.0	0.0	Y	+4	5.9	3.0
1981	8.0	0.0	Y	+5	5.6	0.0
1982	9.0	-4.0	Y	+6	5.3	0.0
1983	9.0	0.0	N	+7	5.0	0.0
1984	12.0	0.0	Y	+8	4.7	0.0
1985	4.0	12.0	Y	+9	4.4	0.0
1986	19.0	0.0	Y	+10	4.1	0.0
1987	2.0	0.0	Y			
1988	1.0	0.0	Y			
1989	3.0	0.0	Y			
1990	1.0	0.0	Y			
1991	7.0	-1.0	Y			
1992	21.0	0.0	Y			

F1 Help F2 Store Item F3 Remarks F4 Redo Forecast ESC Quit
F6 DProd F7 DConsumption F8 NProd F9 NConsumption F10 Prices

Figure 3.8. Forecasts Screen

After all adjustments are made, the user forecasts the ten-year trend by hitting the F4 key. The user may then accept or adjust the annual forecasts. Other available options are: attach remarks; store forecasts for use by other AMPAT-II modules; shift to another variable to forecast; and read pop-up help text that describes how the module works.

As mentioned earlier, this module forecasts different commodity trends. Although many more sophisticated forecasting methods exist, AMPAT-II uses linear regression for several reasons. First, it represents an acceptable improvement over the practice of using the averaged historical data as the forecast. Second, developing an accurate method to forecast commodity prices is beyond the scope of this study and rests with seasoned commodities traders. Finally, another study by the Defense Industrial Supply Center's Artificial Intelligence and Operations Research Office (DISC-AO, Ms. Cheri Homaee) will train a neural network to forecast trends of stockpiled commodities. Upon completion of this study, the neural network can be used to forecast trends used in AMPAT-II.

3.6 COMPUTE MARKET TOLERANCE MODULE

This is the main module of AMPAT-II. It estimates how much of a stockpiled commodity can be sold without upsetting international commodity markets (the commodity's "market tolerance").

The expert rule that determines market tolerance is simple to state (five percent of domestic consumption plus an excess) but difficult to implement. Because the results of the formula must be ratified by the Open Market Committee--whose members come from several government agencies (State and Commerce Departments, CIA, DoD, and others)--before being used to build the formal AMP, the formula must respect these factors:

(1) Reduce the surplus in a stockpiled commodity as much as possible.

(2) Do not depress the price that the commodity's domestic producers command.

(3) Do not interfere with the commodity's international market.

(4) Respect trading policies set by the United States.

A commodity's market tolerance for a given year starts at five percent of that year's forecasted domestic consumption of the commodity. Five percent is the "safe" figure that long practice has proven to be politically acceptable with the Open Market Committee and elected officials. This base sales amount then rises only when both these conditions are satisfied in the given year:

(1) Domestic demand exceeds domestic supply (otherwise, selling of stockpiled commodities may further depress the price and hurt domestic producers).

(2) The surplus in a commodity either has a large dollar value (defends the sale when political interests move to block it) or a forecasted trend that warrants increased selling (e.g., if demand is expected to exceed supply for only the next 2 years, then sell while the market is good).

However, any such increase must not exceed some percentage of the domestic consumption (normally ten percent). Furthermore, the rate of increase from five percent to the upper cap may be gradual or rapid depending on what the political and market forces are that currently weigh upon planning.

When the market tolerance module of AMPAT-II is entered, the user first chooses the commodity database from which to compute market tolerances. Next, another menu allows the user to either compute market tolerance or decide whether a commodity warrants greater selling beyond its five percent base limit (Figure 3-9). There are two ways that the latter can be accomplished: dollar value of surplus; and marketable life span.

Display Dollar Value of All Commodities Bird's-Eye View of Marketability Lifetimes Compute Market Tolerance

Figure 3-9. Market Tolerance Pre-Menu

3.6.1 HI-SALE COMMODITY (DOLLAR VALUE OF SURPLUS) SUBMODULE

As stated earlier, a commodity may qualify for greater selling if the current dollar value of its surplus is relatively high. This is determined by comparing the current dollar value of its surplus to that of the other stockpiled surplus commodities.

Notionally, the commodities with the highest current dollar values are the ones that qualify to be sold at rates beyond the five percent base. AMPAT-II will determine the dollar value of each commodity in the database and rank order them from highest to lowest current dollar value (Figure 3-10). The user then identifies the "big ticket" items by hitting the return key on the appropriate items, an action which toggles an item's selection. When all the big ticket items have been chosen, the user hits the F10 key which in turn resets each commodity's "big ticket" flag to "yes" in the database. This will be used later in the market tolerance submodule. Also, the user may attach remarks to this submodule to explain why a given item was chosen if for reasons other than relatively high dollar value.

Big Ticket Item (Y)es/(N)o	$Value (descending)
Aluminum Metal »N	712939
Antimony »N	445009
Bauxite, Met. Grade, Surinam »N	225010
Baddeleyite »N	107009
Bauxite, Met. Grade, Jamaica »N	93787
Beryllium Metal »N	91000
Bauxite, Refractory »N	57000

RETURN toggle (black) item status F3 Remarks F10 update ESC to quit

Figure 3-10. Accelerated Sales Based on Current Dollar Value Submodule

3.6.2 HI-SALE COMMODITY (MARKETABLE LIFE SPAN) SUBMODULE

As stated earlier, a commodity may also qualify for greater selling if favorable market conditions are short lived, i.e., domestic demand exceeds domestic supply for only the next few years. This submodule lists all the commodities in the chosen database and displays a legend aside each that describes the ten-year trend (Figure 3-11). If the user feels that a commodity's legend suggests a short marketable life span, then the user simply hits the return key on the commodity to toggle its selection. After the appropriate commodities have been chosen, the user hits the F10 key to update the "marketable life span" flags in the database. Like the "big ticket" flags, the marketable life span flags will be used in the submodule that computes market tolerance for each commodity.

How is a legend read? A legend consists of ten characters--one for each year in the planning horizon--where the first character represents the first year. A blank means that the forecasted domestic supply in that year exceeds its domestic demand. Otherwise, a character means that domestic demand exceeds domestic supply. A '+' means that the gap between supply and demand (in the given year) is greater than that for the previous year. A '-' means that the gap has narrowed, and a '.' means no change. Thus, a commodity with a string of pluses is one with a good market and so there may not be an overriding need to dispose of this commodity beyond its five percent rate. Likewise, a commodity with all minuses may indicate the same even though its market is narrowing. In this case, the user will want to study the commodity in greater detail. A commodity whose legend starts off with two characters followed by all blanks is one whose market may shortly disappear, and so may need to be disposed of at a rate exceeding the base five percent.

```
        Forecasted Year
                Big Ticket Item (Y)es/(N)o      1 2 3 4 5 6 7 8 9 0
                       Aluminum Metal »N        + - + + + + - + + -
                             Antimony »N        + + + + + + + . . .
          Bauxite, Met. Grade, Surinam »Y       + + - - - - - - - .
                          Baddeleyite »N        . . . . . . . . . .
          Bauxite, Met. Grade, Jamaica »N       + + + + + + + + + -
                      Beryllium Metal »Y        - - -
                   Bauxite, Refractory »Y       + -       .


blank:  domestic consumption < domestic Production
  +  :  net increase in consumption over production since previous year
  -  :  net decrease in consumption over production since previous year
  .  :  no net change in consumption over production since previous year

        RETURN toggle (black) item status  F3 Remarks  F10 update  ESC to quit
```

Figure 3-11. Accelerated Sales Based on Marketable Life Span Submodule

3.6.3 COMPUTATION OF MAXIMUM MARKET TOLERANCE SUBMODULE

After the user has determined whether to sell the commodity beyond its base rate, the stage is set to compute the maximum amount of the commodity that can be sold on international commodity markets. This is the submodule around which AMPAT-II revolves.

Upon entering this submodule, a menu appears from which the user chooses the commodity whose annual market tolerances are to be found. Next, a screen appears to display the essential data and logical factors used to compute the market tolerances (Figure

3-12). These are displayed for each year in the ten-year planning horizon. Other options available from this screen include pop-up help text, storing the data, attaching remarks, and recomputing the tolerances after an entry has been changed.

Screen entries fall into three categories:

(1) Static (cannot be modified unless done so in another module)

(2) Manual (may be manually changed on-screen)

(3) Computed (derived from the static and manual entries already set)

The supply, demand, and price data are static because they were forecasted in a previous module: an entry equals the actual forecast from the regression plus any adjustment-to-forecast. The MARKET TOLERANCE and MAXIMUM ACTIVITY are computed entries: the former uses the rule used to compute market tolerance (Appendix B) while the latter equals this tolerance plus any adjustment that the user makes in light of known or foreseeable events.

The other entries can be changed manually and the effects of any changes recomputed by hitting the F4 key. The "Big Ticket" entries allow the user to establish whether the commodity should be disposed of beyond its base rate in that year. If so, the user enters "Y" for yes, otherwise "N" for no. However, if a manually established value conflicts with the theoretical value determined by the "big ticket" and "marketable life span" flags of the two previous sub modules, then the yes/no flag will flash.

The other entries which can be manually changed are the base and maximum sales rate for that year, the speed at which the increase occurs (Cap Ratio), and the adjustment to the theoretical market tolerance. The Cap Ratio simply allows adjustment of the disposal rate of the commodity, which is always constrained to be between the Base and Cap percentage of domestic demand.

Finally, to document the results for later reference, a date/time stamp is placed on the report along with identifying information on the source file.

Aluminum Metal (ST)
Surplus: 57588 NOTE: flashing character overrides theoretical value

FORECASTS	+1	+2	+3	+4	+5
NDomestic Supply	5.1	5.1	5.1	5.1	5.0
NDomestic Demand	12.8	12.8	12.8	12.8	12.8
Domestic Supply	94.7	94.8	94.9	95.0	95.1
Domestic Demand	144.7	144.8	145.0	145.2	145.4
Total Supply	99.8	99.9	100.0	100.1	100.1
Total Demand	157.5	157.6	157.8	158.0	158.2
Price	12.3	12.3	12.3	12.3	12.3
Y if Big Ticket	Y	Y	Y	N	N
- Base%	0.0500	0.0500	0.0500	0.0500	0.0500
- Cap %	0.1000	0.1000	0.1000	0.1000	0.1000
- Cap Ratio	5.0000	5.0000	5.0000	5.0000	5.0000
MARKET TOLERANCE	9.4	9.5	9.5	7.3	7.3
+Adjustment	0.0	0.0	0.0	0.0	0.0
=MAXIMUM ACTIVITY	9.4	9.5	9.5	7.3	7.3

FORECASTS	+6	+7	+8	+9	+10
NDomestic Supply	5.0	5.0	5.0	5.0	5.0
NDomestic Demand	12.8	12.8	12.8	12.8	12.8
Domestic Supply	95.2	95.3	95.4	95.5	95.6
Domestic Demand	145.6	145.7	145.9	146.1	146.3
Total Supply	100.2	100.3	100.4	100.5	100.6
Total Demand	158.4	158.5	158.7	158.9	159.1
Price	12.3	12.3	12.3	12.3	12.3
Y if Big Ticket	N	Y	N	N	Y
- Base%	0.0500	0.0500	0.0500	0.0500	0.0500
- Cap %	0.1000	0.1000	0.1000	0.1000	0.1000
- Cap Ratio	5.0000	5.0000	5.0000	5.0000	5.0000
MARKET TOLERANCE	7.3	9.5	7.3	7.3	9.6
+Adjustment	-3.0	0.0	0.0	0.0	0.0
=MAXIMUM ACTIVITY	4.3	9.5	7.3	7.3	9.6

Date: 930104 17:22 Source File: C:\AMPAT2\A.TOL 921222 18:29

Figure 3-12. Computing Market Tolerance Submodule

3.7 REVIEW IDA (INSTITUTE FOR DEFENSE ANALYSES) MODULE

This module automates the tedious manual process of reviewing the IDA "Top 20 Industry Demands Report" for accuracy. This report indirectly affects the AMP because the Joint Staff uses the report to set requirements for a stockpiled commodity. Errors are easily buried within the report and finding them complicates the already difficult task of building the AMP.

The report forecasts annual commodity demands during a four year period which sees the full economic and military mobilization of the United States because of a global conventional war of unknown duration. Annual demands are calculated down to each combination of commodity, tier, and industry sector. The three tiers describe the general application of the commodity (military, industrial, civilian) and the several hundred industry segments describe the specific use of the commodity, e.g., armor, cement, glass.

Reviewing the report is straightforward: find those commodities (and the affected years) whose industrial and civilian tiers each have too many demands (defined as a percentage by the user) in the defense intensive industry sectors. If a reason cannot be found to justify an imbalance, then the model which produced the report may have readily corrected logical flaws. However, to perform the review, one must first specify what the defense intensive sectors are and then must decide what constitutes an imbalance. Both may have to change in response to other issues which later arise, thus entailing another review of the report. Different submodules allow the user to swiftly identify military sectors, to detect imbalances, and to review a report.

3.7.1 HELP SUBMODULE

This submodule explains to a user how AMPAT-II reviews a report and the data it needs.

3.7.2 INPUT DATA FROM INSTITUTE FOR DEFENSE ANALYSES REPORT SUBMODULE

AMPAT-II reviews a floppy disk copy of an IDA report that is comprised of three files (Appendix A). This submodule will convert each file to a format that it can process.

3.7.3 IDENTIFY DEFENSE INTENSIVE SECTORS SUBMODULE

The most difficult part of manually reviewing a report is keeping track of the defense intensive sectors and repeating the review when these change. In this submodule, AMPAT-II alphabetically lists all sectors in a menu from which the defense intensive sectors can be specified (Figure 3-13). Since the most recently identified defense intensive sectors will be highlighted, this submodule makes it easy to track what the current defense intensive sectors are. To alter a sector's membership in the defense intensive group, simply hit the return key on the sector to toggle membership on and off.

```
RETURN Toggles sector as defensive (black); F10 Update; ESC Quit
ALUMINUM CASTING
BLAST FURNACE, MILLS
CEMEMT
GLASS PRODUCTS
GLASS CONTAINERS
IRON FORGINGS
IRON FOUNDRIES
PRIM. ALUMINUM
PRIMARY COPPER
PRIMARY ZINC
STRUC CLAY PRODS
```

Figure 3-13. Selecting the Defense Intensive Industry Sectors

3.7.4 IDENTIFY DEFENSE INTENSIVE, NON-MILITARY TIER COMMODITIES SUBMODULE

After the defense intensive sectors have been identified, the user is ready to review IDA report for possible errors. This submodule will simply look for those commodities whose non-military tier demands have an unusually high percentage of defense intensive sectors as defined by the user. Although such an occurrence may be reasonably explained, experience has shown that this may well reveal a logical flaw in the report.

Since the defense intensive sectors have already been identified in the previous submodule, the user simply needs to provide the point at which an imbalance occurs. For example, an imbalance may occur in a commodity that has a non-military tier whose total demand in a given year consists of twenty percent or more of defense-intensive sector demands. AMPAT-II will ask the user to provide the point of imbalance (Figure 3-14).

```
At what percent of total annual tier demand does a commodity become
defense intensive (0.0-1.0)? .2
```

Figure 3-14. Establishing the Imbalance Point

After the imbalance point is specified, AMPAT-II searches the report for defense intensive imbalances in non-military tiers. All imbalances will be displayed together along with each one's commodity, year, tier, total demand, defense intensive demand, and the ratio between the two demands (Figure 3-15). With this information in-hand, the user can study the appropriate part of the report and judge if the imbalance is justified.

The following are defense intensive within a non-military tier, i.e., the ratio between a year's defense-intensive and total demands exceeds 0.2.

Ratio	Defense Intensive Total	TotalDemand	Tier Year	Commodity (Unit of Measure)
0.21	52511.0	255205.0	I 95	ALUMINUM CASTING (ST)
0.29	79856.0	271866.0	I 96	GLASS PRODUCTS (TONS)
0.23	60541.0	260046.0	C 96	PRIMARY ZINC (LONG DRY TONS)

Figure 3-15. Imbalances in the Top 20 Demands Report

3.8 DISPLAY COMMODITY INTERRELATIONSHIPS MODULE

Although the market tolerance module is the central one in AMPAT-II, the most difficult questions arise in the module that is described below. Indeed, the subject which it addresses is that which is most readily identified as belonging in the domain of an expert and most adaptable to modelling using artificial intelligence.

This module uses expert knowledge to reveal complex production dependencies among commodities that abound in the production processes of stockpiled commodities. Knowing such relationships would be useful when market conditions change for materials used in the production process of stockpiled materials. Armed with such knowledge, the analyst can better consider how these market changes may affect the price or a stockpiled commodity--a key factor used in forecasting market tolerance. AMPAT-II will allow this expert knowledge to be updated, modified, and enlarged by the user.

From the need to better estimate commodity prices arise the purposes of this module:

(1) Identify all possible production processes which culminate in the creation of a stockpiled commodity

(2) Identify all possible production processes which involve a material that appears in a production process of some stockpiled commodity

When this module is entered, a menu appears (Figure 3-16) from which the user may choose to: create or modify a production database; display production processes that either end in or arise from a given material; and add/modify narrative remarks attached to a material.

Modify Master Production Pairs
Display Paths Arising From Commodity
Modify "The" Master Production Pairs Remarks

Figure 3-16. Production Dependencies Main Menu

3.8.1 BUILD PRODUCTION PAIRS FILES SUBMODULE

This submodule allows the user to establish the simplest component of a production process: the fact that one material is a direct input into the production process of another, i.e., a "production pair." From these simple pairs will arise complex diagrams that the analyst will use to forecast market conditions for a given material. The user may choose to maintain separate production pairs files (e.g., minerals, metals) that can later be merged together.

Upon entering this submodule, the user chooses the production pairs file to modify or create. If an existing one is chosen, then it is pulled into a text editor in which the user modifies the file (Figure 3-17). An entry is easy to make: if commodity A is a direct input into the production process of commodity B, then both are typed into the file with a colon between them. When the user is finished, hitting F10 will resave the file with the new information.

```
ALUMINA : ALUMINUM
BAUXITE : ALUMINA
COMMODITY1 : COMMODITY2
COMMODITY1 : COMMODITY3
COMMODITY1 : COMMODITY4
COMMODITY2 : COMMODITY3
COMMODITY6 : COMMODITY4
COMMODITY3 : COMMODITY5
BERYL ORE : COMMODITY4
COMMODITY3 : COMMODITY6
COMMODITY3 : COMMODITY7

F10 Save and Return to MAIN     ESC Abort
```

Figure 3-17. Modify a Production Pairs File

The simplicity of this submodule hides the fact that it avoids the extensive and difficult knowledge engineering needed to codify the rules of the expert. Furthermore, the user may add new information as old production relationships die, whereas capturing the rules of the expert and codifying these would only be good while the underlying production relationships persist.

Lastly, it is much easier to identify a production pair and have software develop the complex inter-relationships than it is to painstakingly identify all the production rules.

3.8.2 DISPLAY SPECIFIC PRODUCTION DEPENDENCIES SUBMODULE

This submodule allows the user to merge multiple production pairs databases and build all the production paths that either extend from or end in a given material. The program it uses (DAVIE) was originally developed by the author in January 1988 to address concerns about the Air Force Personnel Data System.

When entering this submodule, the user has three options: review help text that describes the submodule; recall a production diagram that was built and saved in a previous session; and merge production pairs databases. If the second option is chosen, the user will then see another menu that describes each of the saved diagrams and from which one will be retrieved and displayed. However, if the user instead wants to merge production pairs databases, then the return key is hit on the directory box (Figure 3-18). All production pairs databases will be shown and the user will select those to merge.

Once the production pairs databases have been merged, the user specifies the commodity whose production processes are to be found. If the user wishes to identify all the processes that result in the production of the commodity, then the commodity's name is entered into the field labelled "Lead To." Otherwise, entering the name in the "Emit From" box will build all the processes that begin with the specified commodity as an input material. Instead of typing the commodity name, the user may display a list of all commodities found in the merged databases (the F3 option) and choose the commodity from a menu. The selection will then be entered into the box from which the list was originally called from, just as if it had been manually entered.

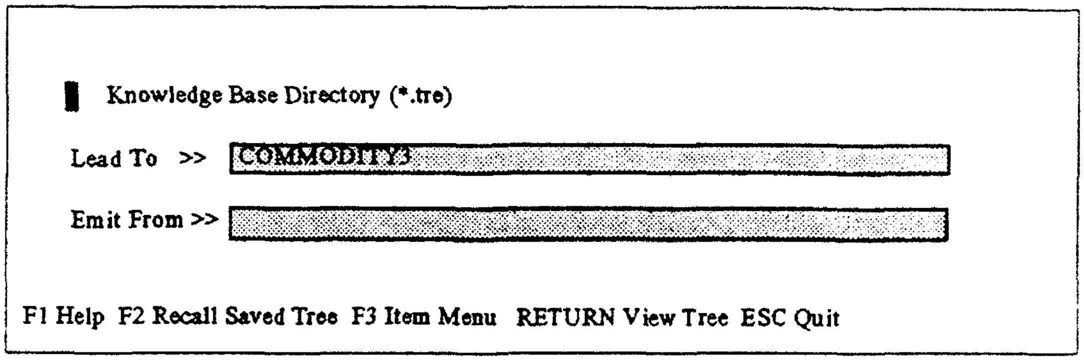

Figure 3-18. Display Production Dependencies Submodule

If the user chose to build the production process diagrams that resulted in the creation of COMMODITY 3, then the diagram shown in Figure 3-19 would appear. This is simply only one part of the entire diagram which is too large to fit on a screen. Reading from the bottom level upwards, the user can trace all the production paths that result in the creation of COMMODITY 3. A single, unbroken sequence of materials comprises one production process. The user may save this computed diagram by hitting the F2 key and writing a one-line narrative that will be shown when the tree is later considered for retrieval. Also, when the return key is hit within a commodity's box, any established remarks on that commodity will appear. The rest of the iagram can be seen by using the arrow keys.

In general, a full production diagram will not fit on a screen. So to get a bird's-eye view of all production processes, the user hits F3 (Figure 3-20). The resulting diagram displays the same information as the full diagram except that the identities of the smaller boxes are not shown.

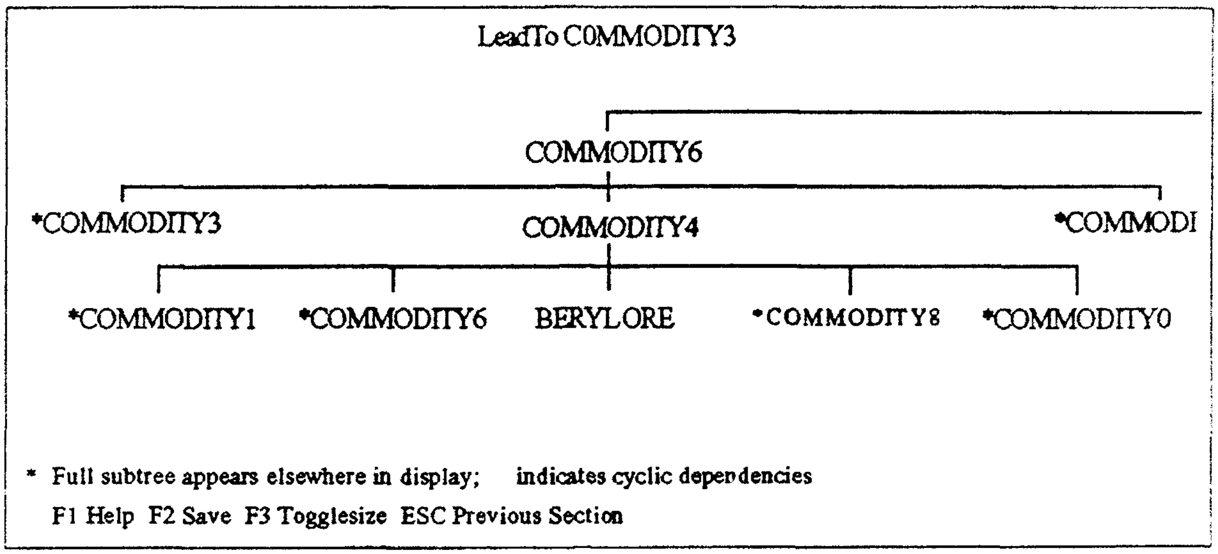

Figure 3-19. Production Processes that Create COMMODITY 3

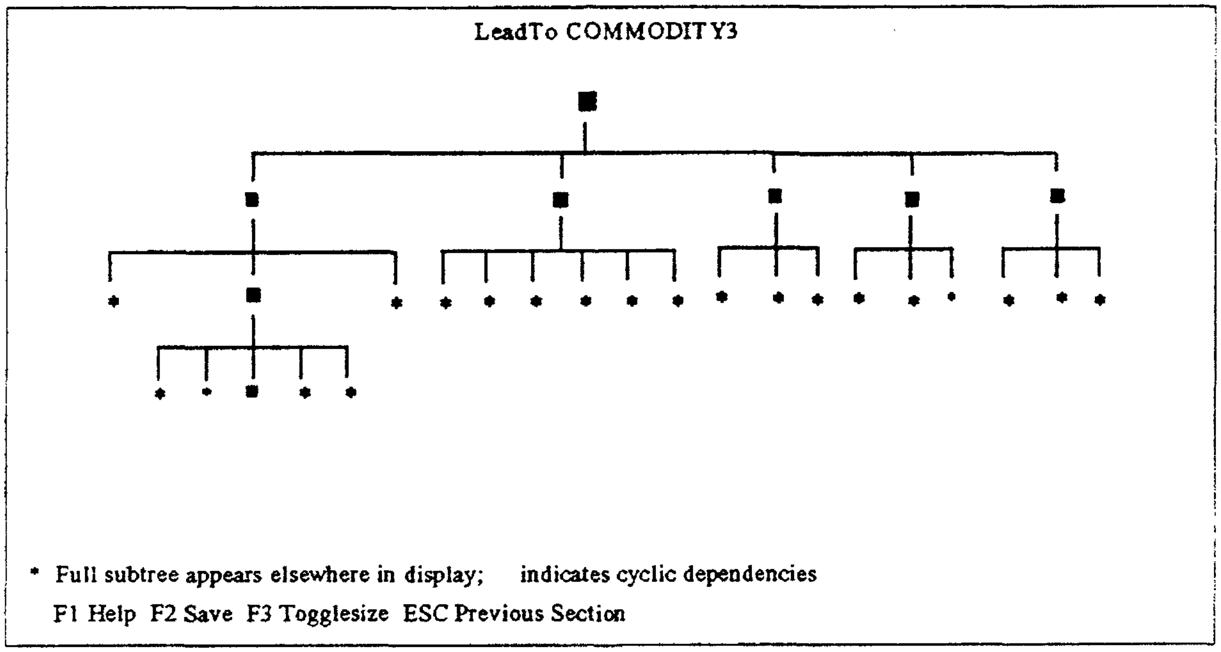

Figure 3-20. Bird's-Eye View of Production Processes

Production diagrams that arise from a given commodity are created in the same manner as above except that the commodity is specified in the "Emit From" box. Figures 3-21 and 3-22 show the full and condensed such diagrams for COMMODITY 3. Note that even the condensed diagram may not fit on one screen.

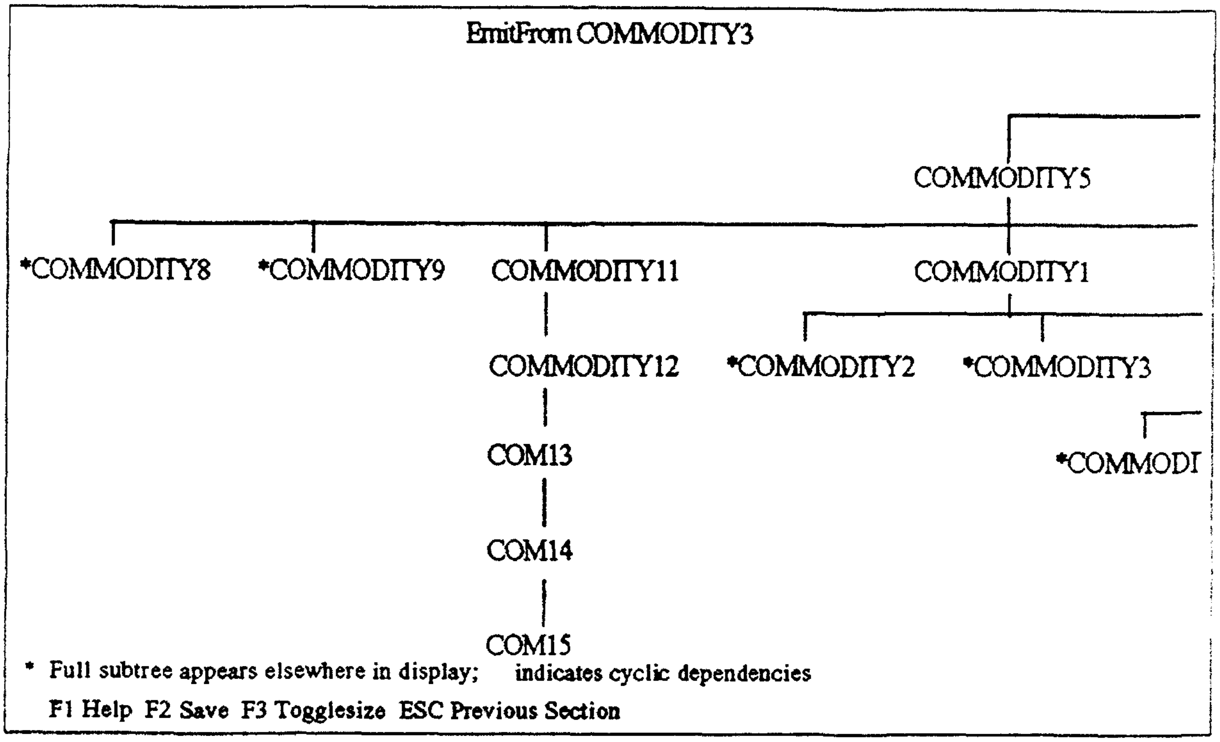

Figure 3-21. Production Processes That Arise From COMMODITY 3

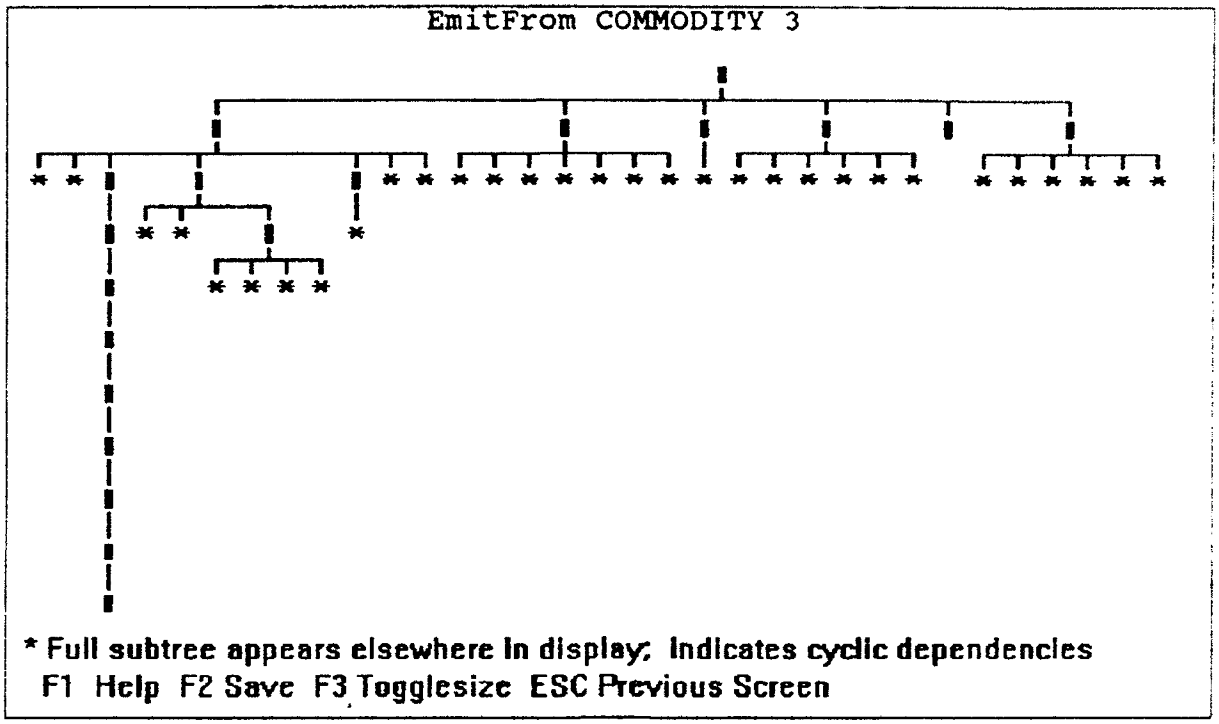

Figure 3-22. Bird's-Eye View of Production Processes Arising From COMMODITY 3

3.8.3 ATTACH REMARKS TO A PRODUCTION ITEM SUBMODULE

This submodule allows the user to establish remarks on any commodity that appears in a production database. Such remarks are important because they shed important information concerning the significance of a material in a production process. When this submodule is entered, a menu appears from which the user may choose the commodity whose remarks are to be created or changed. The user will then be moved into a text editor where the remarks are entered.

3.9 <u>BACKUP AMPAT-II FILES MODULE</u>

This module simply copies each file used in AMPAT-II into the BACKUP subdirectory located on the current path from which AMPAT-II is run. Backing up files will allow a user to recover from a session which accidently modifies a file or a power outage that occurs while a database is being updated.

3.10 OVERVIEW MODULE

This module simply provides point of contact information regarding AMPAT-II, its programming environment, and a short word about AMPAT-I.

3.11 INTERFACE WITH AMPAT-I

Upon completion of an AMPAT-II run, all the information necessary to compute an optimal AMP is available for AMPAT-I. Due to the large size and memory requirements of these models, the data are passed through common files that are written by AMPAT-II and read by AMPAT-I.

SECTION 4
CONCLUSIONS

This study reaches the following conclusions:

(1) That the process of planning for and computing an Annual Materials Plan can be represented in a model that uses classical operations research and artificial intelligence concepts and tools.

(2) Such a model permits the swift analysis of an economic-political scenario for which an AMP is to be computed.

(3) The expert rules which govern much of the planning phases of building an AMP may be effectively represented without extensive traditional knowledge engineering.

SECTION 5
RECOMMENDATIONS

This study recommends that AMPAT-II be:

(1) Used in the planning process that precedes the building of an AMP.

(2) Used in conjunction with AMPAT-I and the Defense National Stockpile Center should aggressively monitor both models for shortcomings and oversights so that they may be corrected and the scope of the tools extended.

APPENDIX A

FORMAT OF INSTITUTE FOR DEFENSE ANALYSES DATA

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FORMAT OF INSTITUTE FOR DEFENSE ANALYSES DATA

The following files from the Institute for Defense Analyses (IDA) are used by AMPAT-II to review the Top 20 Industry Demands Report that is created by IDA. The files must be in ASCII format with the specified names assigned to them and copied to the subdirectory from which AMPAT-II operates.

SECTOR.IDA: Translates between sector code and its clear text.

01-03	SectorID (e.g., 179)
04-35	SectorName (e.g., Radio/TV Comm Eq)

COMMOD.IDA: Translates between IDA commodity code and its clear text.

01-30	Commodity Code (e.g., MNGNS@ORE@CHEM&METAL)
31-70	Commodity Clear Text (e.g., Manganese Ore, Chemical & Metal)
71-90	Unit of Measure (e.g., SDT)

DEMAND.IDA: Top 20 Industry Demands

01-30	Commodity Code (e.g., CADMIUM)
31-31	Tier (M Military; I Investment; C Civilian; T Total) (e.g., M)
32-33	Year (e.g., 94, 95, 96, XX=Total)
34-36	SectorID (e.g., 197)
37-45	Demand (e.g., 522)

APPENDIX B

COMPUTATION OF MARKET TOLERANCE AND MAXIMUM MARKET ACTIVITY

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COMPUTATION OF MARKET TOLERANCE AND MAXIMUM MARKET ACTIVITY

B-1.1 OVERVIEW

This appendix gives the formula used to compute a stockpiled commodity's "market tolerance": the most number of commodity units that can be sold in a given year without disrupting the commodity's international market and without raising the ire of political interests. When adjusted due to anticipated events affecting the commodity, this tolerance becomes "maximum market activity."

The formula below is the algebraic expression of how the expert (at the Defense National Stockpile Center, Mr. Richard Corder) determines a commodity's market tolerance. It is important to note that this formula was not rigorously derived through algebraic arguments. Rather, the formula was developed over many years and offers a practical approach to computing disposal activity which has proven politically and economically acceptable.

B-1.2 DEFINITIONS

The following variables pertain to the commodity under consideration:

(1) AdjustmentToTolerance(i): the user-specified amount by which the commodity's market tolerance is adjusted in year i to yield the maximum activity.

(2) BaseRate(i): the minimum percentage of domestic demand at which the commodity will be sold in year i

(3) BigTicketFlag: a yes/no flag; when "yes", the surplus has one of the highest dollar values among all other commodities with a surplus

(4) CapRate(i): the highest percentage of domestic demand at which the commodity will be sold in year i

(5) CapRatio(i): in year i, the minimum ratio between domestic demand and domestic supply at which the commodity is sold at CapRate(i). In other words, the Cap Ratio allows adjustment of the disposal rate of the commodity, which is always constrained to be between the Base and Cap percentage of domestic demand.

(6) DomesticDemand(i): the domestic demand for the commodity in year i

(7) DomesticSupply(i): the domestic supply for the commodity in year i

(8) LifeSpanFlag: a yes/no flag; when "yes", sales should be accelerated because the market for the commodity may turn sour in the next few years

(9) MARKET TOLERANCE(i): the ideal maximum number of units which can be sold on the commodity's international market in year i

(10) MAXIMUM ACTIVITY(i): the market tolerance in the commodity for year i adjusted for anticipated events that will affect the commodity

B-1.3 NOTATION

(1) {Statement?} is a boolean variable that evaluates to 1 if Statement? is true, 0 if false

(2) min(X,Y) is the smaller of the numbers X and Y

B-1.4 FORMULAS

(1) MAXIMUM ACTIVITY(i) = MARKET TOLERANCE(i) + AdjustmentToTolerance(i)

(2) MARKET TOLERANCE(i) = [BaseRate(i) + ExtraRate(i)] * DomesticDemand(i)

(3) ExtraRate(i) = {BigTicket = 'Y' or LifeSpanFlag = 'Y' } * {DomesticDemand(i) > DomesticSupply(i)} * Rate(i)

(4) Rate(i) = RateOfIncrease(i) * [min(CapRatio(i),SupplyDemandRatio(i)) - 1]

(5) RateOfIncrease(i) = [CapRate(i) - BaseRate(i)] / [CapRatio(i) - 1]

(6) SupplyDemandRatio(i) = DomesticDemand(i) / DomesticSupply(i)

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13. ABSTRACT *(Maximum 200 words)*

AMPAT-II is a personal computer based analysis tool developed for use by the Defense National Stockpile Center (DNSC) to model decision processes that precede computing an Annual Materials Plan (AMP). Per public law, the President submits the AMP to Congress and in it proposes inventory changes to the Defense National Stockpile. AMPAT-II computes how much can be sold of a commodity on international markets and passes its results to AMPAT-I (project DLA-93-P10218) which uses mathematical programming to compute a 10-year AMP.

To determine these market limits, AMPAT-II uses a rule that evolved over many years and has proven to be politically and economically acceptable. This rule, authored by a newly-retired DNSC expert, needs many preliminary computations and decisions to be made, the most difficult of which is determining production relationships among materials. AMPAT-II addresses this matter by constructing complex production rules from simple production relationships entered by the user. AMPAT-II was created using the artificial intelligence language PDC-PROLOG and the procedural language TURBO C++.

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