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Appendix A

COMMON BLOCK AND VARIABLE DEFINITION

(NASA-CR-152279) DOCUMENTATION OF THE ANALYSES OF THE BENEFITS AND COSTS OF AERONAUTICAL RESEARCH AND TECHNOLOGY MODELS (ABC-ART). VOLUME 2: APPENDICES Final Report (SRI International Corp., Menlo Park, 6/3/66

N80-15866  
HC ACB/MF A01  
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## PREFACE

Under NASA sponsorship the Analysis of the Benefits and Costs of Aeronautical Research and Technology (ABC-ART) models have been developed for use in analyzing the economic feasibility of applying advanced aeronautical technology to future civil aircraft. The models were developed through in-house efforts at the Ames Research Center, with some contractor support. SRI International did not participate in the development of these models. The development work ended without the preparation of model documentation. SRI was contracted to document the ABC-ART models as they existed. This two volume report is the result of the SRI effort. The first volume contains the main body of the documentation while the second contains supporting appendices.

The assistance and cooperation of NASA in this study effort is gratefully acknowledged, particularly the contributions of Mr. Steven E. Belsley, who served as technical monitor, and Messrs. Louis J. Williams, Herbert Hoy, and Jeff V. Bowles, who provided valuable background information and technical assistance.

This research was conducted within the Transportation and Industrial Systems Center of SRI International, Dr. Robert Ratner, Director. Mr. James Gorham served as supervisor and Dr. John Bobick served as project leader and principal investigator. Other research team members included Mr. Ronald Braun and Ms. Rita Denny.

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## I INTRODUCTION

The Analysis of the Benefits and Costs of Aeronautical Research and Technology (ABC-ART) models have been developed by NASA for use in analyzing the economic feasibility of applying advanced aeronautical technology to future civil aircraft. The methodology is composed of three major modules: Fleet Accounting Module, Airframe Manufacturer Module, and Air Carrier Module.

The Fleet Accounting Module is used to estimate the number of new aircraft required as a function of time to meet demand. This estimate is based primarily upon the expected retirement age of existing aircraft and the expected change in revenue passenger miles demanded. Fuel consumption estimates are also generated by this module. The Airframe Manufacturer Module is used to analyze the feasibility of manufacturing the new aircraft demanded. The module includes logic for production scheduling and for estimating manufacturing costs. For a series of aircraft selling prices, cash flow analyses are performed and rates of return on investment are calculated. The Air Carrier Module provides a tool for analyzing the financial feasibility of an airline purchasing and operating the new aircraft. This module includes a methodology for computing direct and indirect operating costs, performing cash flow analyses, and estimating the internal rates of return on investment for a set of aircraft purchase prices.

Documentation for the Fleet Accounting, Airframe Manufacturing, and Air Carrier Modules is provided in Sections II, III, and IV, respectively. The documentation for each module begins with a description of the methodology, which includes an explanation of the mathematical model (including

equations and assumptions) embedded within the program. The implementation of the mathematical model into computer code is described in the program logic section of the documentation; this includes flowcharts of the logical construction and descriptions of the functions of the various program routines. Then, a description of the input to the module is provided in sufficient detail to enable a user to prepare an input data file. Finally, examples of the output of the module are provided, and the various entries in the output are described.

The sample output presented in the documentation of each module is extracted from a sample run of the ABC-ART models. This sample run is described in Section V of the report, including job setup, input data, and computer resource requirements. The sample problem was run at NASA Ames Research Center on a CDC 7600 computer system.

Additional programmer-oriented documentation is provided in Volume II of this report. This includes definition of common blocks and variables in Appendix A and listings of the program code, to which comments have been added, in Appendices C, D, and E. Also included in Appendix B is a detailed description of the ZETA plotter routines, which are used to plot results in the Fleet Accounting Module. This portion of the documentation is valuable for users interested in reading the program or modifying the code.

The documentation contained in the appendices is designed to meet the requirements\* for submitting the ABC-ART models to the NASA Computer Software Management and Information Center (COSMIC) operated under contract by

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\*"COSMIC Software Submittal Guidelines," Computer Software Management and Information Center, April 1976.

the Information Services Division of the University of Georgia's Computer Center. The specific COSMIC requirements are addressed in Appendix F. The appendices (Volume II) plus a copy of the program are available from COSMIC.

The scope of this research effort was limited to documenting the ABC-ART models as they exist. Code changes, program debugging, and justification of assumptions or relationships embodied in the models are outside the scope of the work. With the exception of the sample problem, which was supplied by NASA, SRI did not exercise the models. The documentation was prepared by reading the FORTRAN program code.

The ABC-ART models were originally developed for application within a specific study. As a result, assumptions have been made in the program code which constrain its flexibility. In addition, because of this limited past application, the computer program has not been subjected to a thorough series of debug test runs. Hence, program bugs can be expected to be present. In fact, in the course of reading the program code, several bugs were discovered and corrected. It is quite likely that other more subtle bugs still exist in the code. These generally can be found only by testing the program via a series of computer test runs.

Two steps need to be taken before the ABC-ART program can reasonably be expected to be useful in a variety of applications. First, the program code needs to be made more general and flexible. Parameters set in the code need to be made user inputs; and assumptions need to be relaxed. Most of the required reprogramming is in the Air Carrier Module, with some in the other two modules. Second, all modules need to be subjected to a thorough set of debugging runs.

## II FLEET ACCOUNTING MODULE

The function of the Fleet Accounting module is to project fleet composition and associated fuel consumption for each of the 31 years from 1975 through 2005. The fleet projections are based on the number of aircraft required to meet traffic passenger demand. Provisions are made in the model to account for modifications of aircraft in the fleet. New aircraft are assumed to be purchased as necessary to replace aircraft that have reached retirement age or to meet increased traffic demand. Descriptions of the mathematical modeling methodology, program logic, input, and output for the Fleet Accounting Module follow.

### A. Methodology

The aircraft fleet can be arbitrarily divided into as many as three markets. For example, aircraft might be categorized in markets by stage length of flights, i.e., short, medium, and long haul markets. For a given market, the user must specify, for each of the 31 years of analysis,

$GROWT_j$  = growth rate (in percent) of revenue passenger miles demanded in year  $j$  over those in the previous year

$LF_j$  = average load factor for flights serving the market in year  $j$

where  $j = 1$  to 31 with  $j = 1$  for 1975.

For a market, up to ten types of aircraft can be treated, including existing and new aircraft. These aircraft types may be generic types (e.g., four engine narrow-body aircraft) or specific aircraft types (e.g., Boeing 747-100). The parameters defining an aircraft type  $i$  include:

$YINTRO_i$  = year of introduction

$SEATS_i$  = average number of seats

$SFC_i$  = average fuel consumption (in pounds/seat mile)  
 $SPEED_i$  = average block speed (in miles/hour)  
 $UTILTZ_i$  = average utilization (in hours/year)  
 $LIFETIM_i$  = average aircraft lifetime (in years).

For aircraft types currently in the fleet, a history of buys and retirements is required. This history consists of the number of aircraft bought and retired in each year from 1960 through 1975. The methodology assumes that the fleet as of midyear represents the average fleet for the year for the purposes of computing fuel consumed, seat miles flown, etc. Therefore, the history of buys and retirements must be given on a midyear to midyear basis. For example, the aircraft bought in 1960 are those bought between 1 July 1959 and 30 June 1960.

The model provides the capability to account for one future modification of each aircraft currently in the fleet. The user specifies such a modification by identifying the type of aircraft to be modified and the year the modification is to begin. Then the new values of the parameters for the modified aircraft type are specified, i.e., the new values of number of seats, fuel consumption, block speed, utilization, and nominal retirement age. The model assumes that the modifications occur over a two-year period. Half the aircraft of the designated type are modified in the year specified. The remaining aircraft are modified in the following year.

In projecting the evolution of the fleet, the fleet accounting methodology keeps track of several major quantities. For each of the aircraft types (up to 10) defined for a given market, these quantities include:

- NOBUYS<sub>ik</sub> = number of aircraft of type i bought in year k \*
- NORETIR<sub>ik</sub> = number of aircraft of type i retired in year k \*
- POPUL<sub>ij</sub> = number of aircraft of type i in the fleet on 30 June of year j
- SEATMI<sub>ij</sub> = seat miles flown by each type i aircraft in year j.
- RPM<sub>ij</sub> = revenue passenger miles flown by each type i aircraft in year j
- FUELBRN<sub>ij</sub> = fuel consumed (in barrels) by each type i aircraft in year j
- MARKET<sub>j</sub> = total RPMs demanded in year j

where

k = 1 to 46 with k = 1 for 1 July 1959 to 30 June 1960 and  
j = 1 to 31 with j = 1 for 1975.

The number of aircraft of each type in the base year of 1975 (as of midyear) is computed from the input 16-year history of aircraft buys and retirements as follows:

$$POPUL_{ij} = \sum_{k=1}^{16} [NOBUYS_{ik} - NORETIR_{ik}] \quad (1)$$

with j = 1. The seat miles flown, revenue passenger miles flown, and fuel consumed in the base year by each aircraft of type i are computed as follows:

$$SEATMI_{ij} = (SPEED_i)(UTILIZ_i)(SEATS_i) \quad (2)$$

$$RPM_{ij} = (SEATMI_{ij})(LF_j) \quad (3)$$

$$FUELBRN_{ij} = (SFC_i/281.4)(SEATMI_{ij}) \quad (4)$$

with j = 1. The total number of RPMs demanded in the market under consideration in the base year is given by:

$$MARKET_1 = \sum_i [(RPM_{ij})(POPUL_{ij})] \quad (5)$$

\*The values for k = 1 to 16 are the input histories for existing aircraft types.



For each year of analysis beyond the base year, the first step in the methodology is to retire those aircraft scheduled to retire. The number of aircraft retired of a specific type in a given year is taken to be the number bought in a past year, which is determined by going back the number of years equal to the input retirement age. The next step is to update the characteristics of those aircraft scheduled for modification. Characteristics which are updated include the number of seats, speed, utilization, retirement age, and fuel consumption. Since it is assumed that modifications occur over a two year period, in the input year of modification, the average of the old and new values of aircraft characteristics are assumed to hold. In subsequent years, the new values hold.

Having retired and modified aircraft in the year of analysis, the next step is to determine if any new aircraft need be purchased to meet demand. The number of RPMs demanded,  $MARKET_j$ , for any year  $j$  (greater than 1) is computed as follows:

$$MARKET_j = (1.0 + GROWTH_j/100)(MARKET_{j-1}). \quad (6)$$

The number of RPMs supplied by the fleet without any new aircraft in year  $j$  is computed using Eqs. (2) and (3) to compute  $RPM_{ij}$  for each aircraft type  $i$  in the year  $j$ , and then summing over aircraft types. The difference between the RPMs demanded and those available is given by:

$$RPMDIFF = MARKET_j - \sum_i [(RPM_{ij})(POPUL_{ij})]. \quad (7)$$

If  $RPMDIFF$  is not positive, no new aircraft are purchased. In the case where  $RPMDIFF$  is negative, supply exceeds demand and the average load factor will be less than that expected for the year. If  $RPMDIFF$  is positive, more aircraft are needed to meet demand. The number of aircraft purchased

is given by

$$\text{NOBUYS}_{i,j} = \text{RPMDIFF}/\text{RPM}_{i,j} \quad (8)$$

where  $i'$  designates the aircraft type to be purchased in year  $j$ .

When defining aircraft types in the input data, existing aircraft types are defined first, then new\* aircraft types. The order of definition of aircraft types is important in determining which aircraft is purchased in a given year. The aircraft purchased in year  $j$  is the first aircraft type encountered that has been introduced in year  $j$  or earlier, where the aircraft types are considered in the reverse order (last to first) in which they were input.

The methodology records statistics on fleet population, buys, retirements, seat miles flown, RPMs flown, and fuel consumed. These are gathered on a yearly and cumulative basis for individual aircraft types and for markets. This information is provided in printed and plotted output.

In the remainder of this chapter, detailed descriptions of the program logic, input, and output for the Fleet Accounting Module are provided.

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\*New aircraft types are not necessarily aircraft types to be introduced at a later date. They may be current aircraft types.

B. Program Logic

Figure 1 illustrates the interrelationships among the routines which make up the Fleet Accounting Module program. BET acts as the main program for the Fleet Accounting Module and the Airframe Manufacturer Module. Subroutine INPLANT provides the interface between these two modules. Since it controls the flow of logic for the Airframe Manufacturer Module, it is considered part of this module and will be discussed in the next Section. Brief descriptions of each routine in the Fleet Accounting Module, together with flowcharts of the logic follow:

BET

Program BET serves as the main program for the Fleet Accounting Module. A flowchart of the BET logic is shown in Figure 2. The BET routine controls the flow of logic for the Fleet Accounting Module, considering the markets sequentially. It reads the data defining the market as well as the parameters defining the existing aircraft, new aircraft, and aircraft modifications. BET calls upon routines AMORTIZ, MODS, and BUYS for each year to determine aircraft retirements, modifications, and buys. BET controls the printing of various statistics regarding fleet composition and activity projections, including number of retirements, buys, seat miles flown, RPMs flown, and fuel consumed. These are printed for individual aircraft types and for markets on a yearly and cumulative basis. The BET program calls upon various routines to create plots of RPMs flown and fuel consumed on an individual aircraft type and market basis.

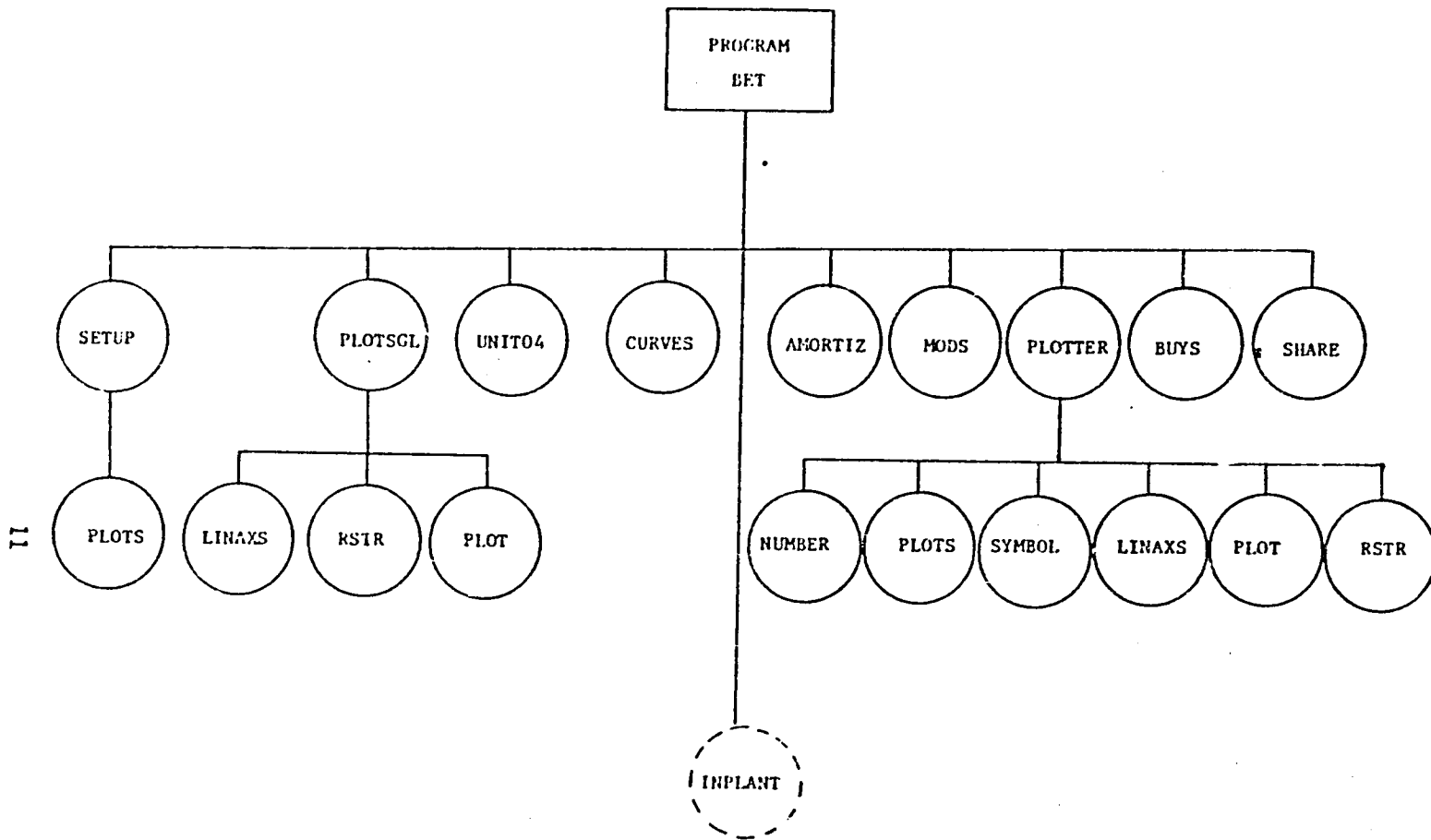


Figure 1 Program Structure of the Fleet Accounting Module

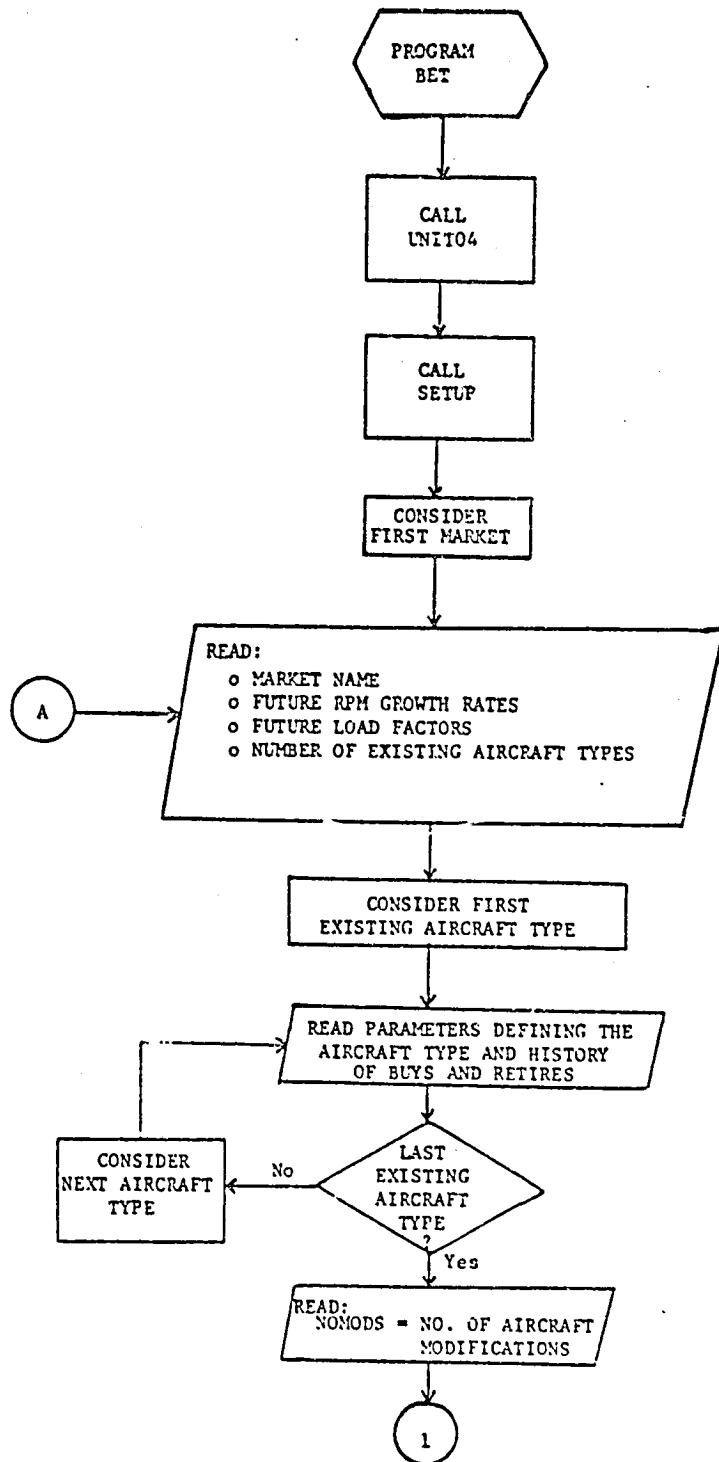


Figure 2 Flowchart of Program BET Logic

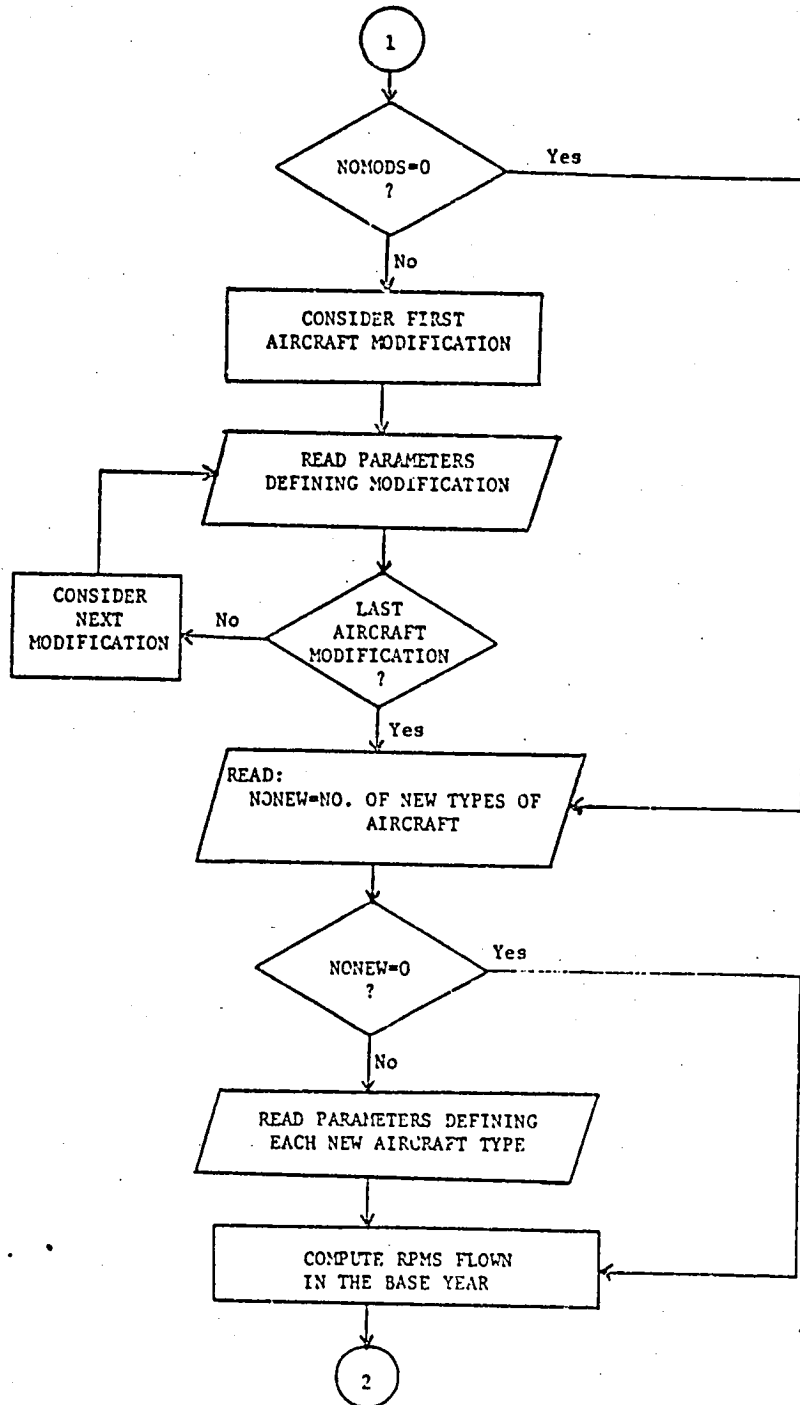


Figure 2 (Continued)

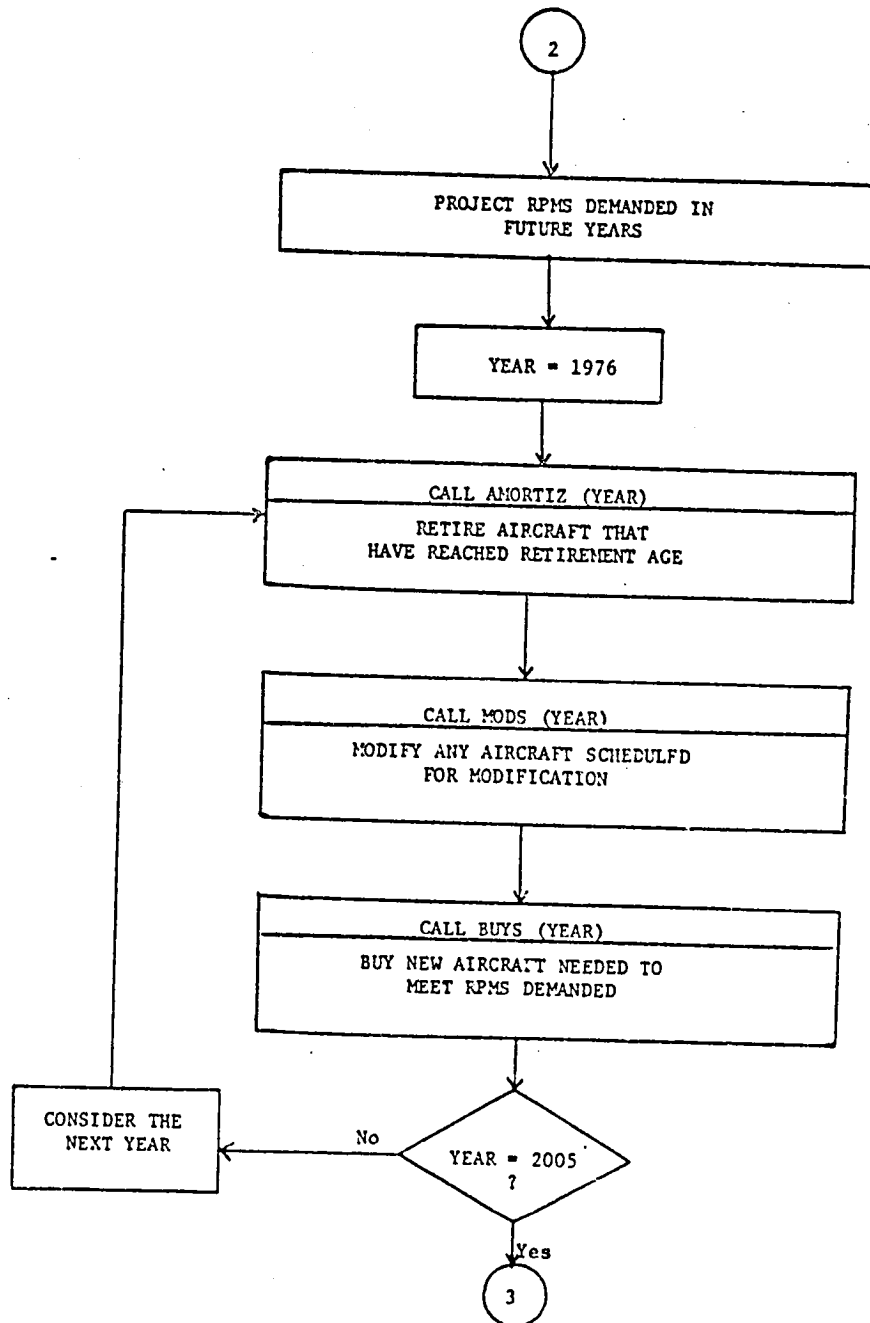


Figure 2 (Continued)

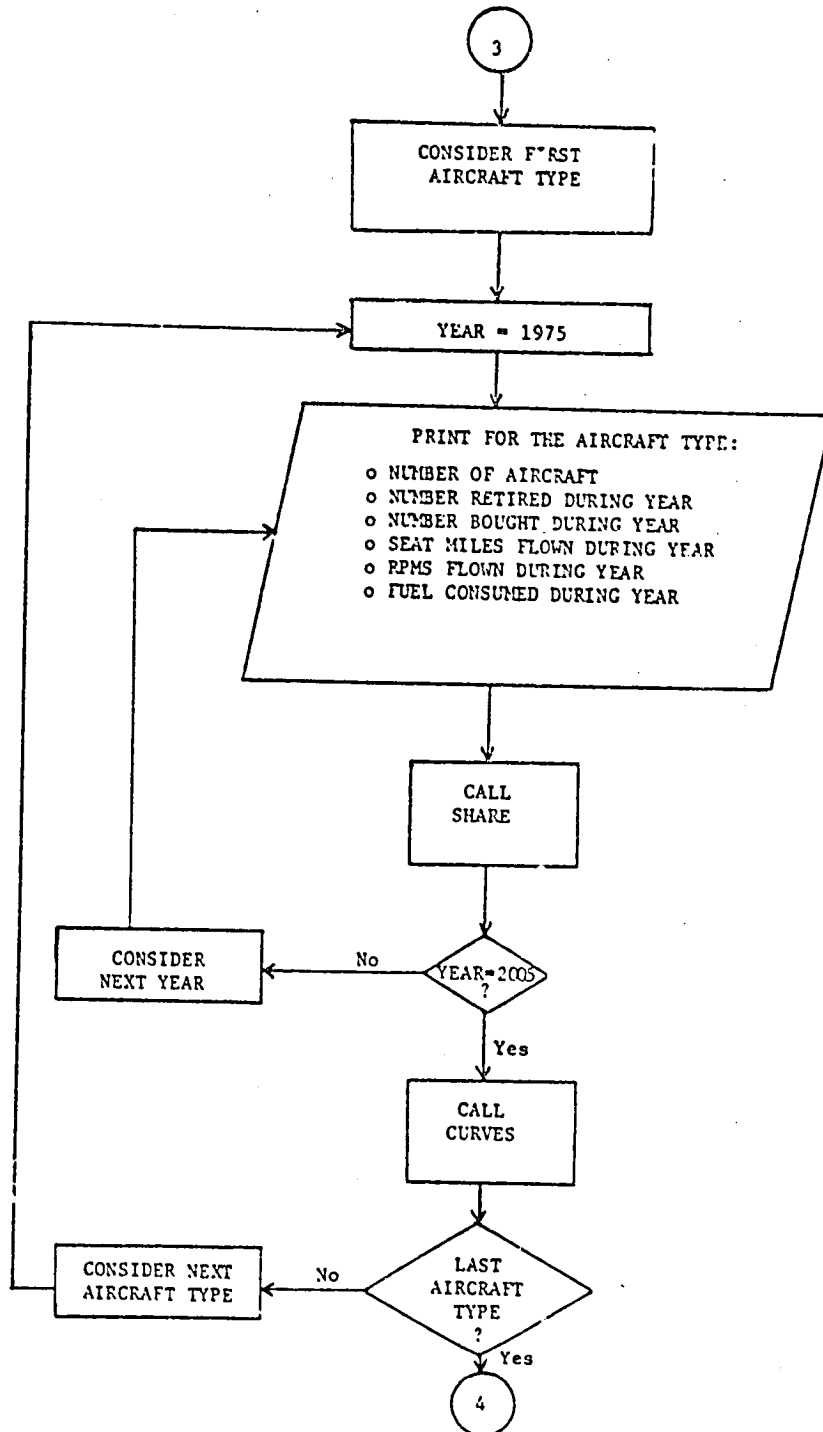


Figure 2 (Continued)



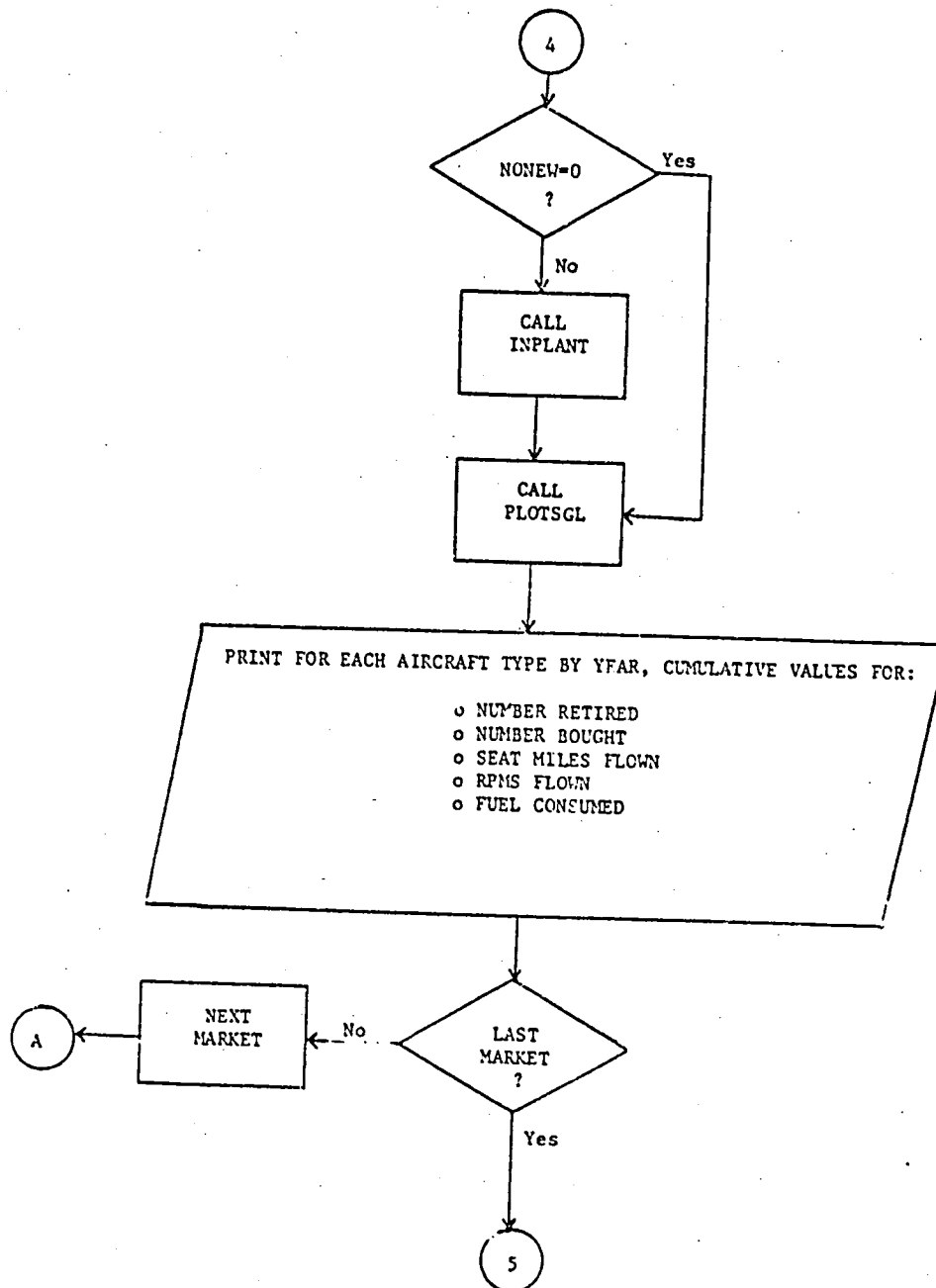


Figure 2 (Continued)

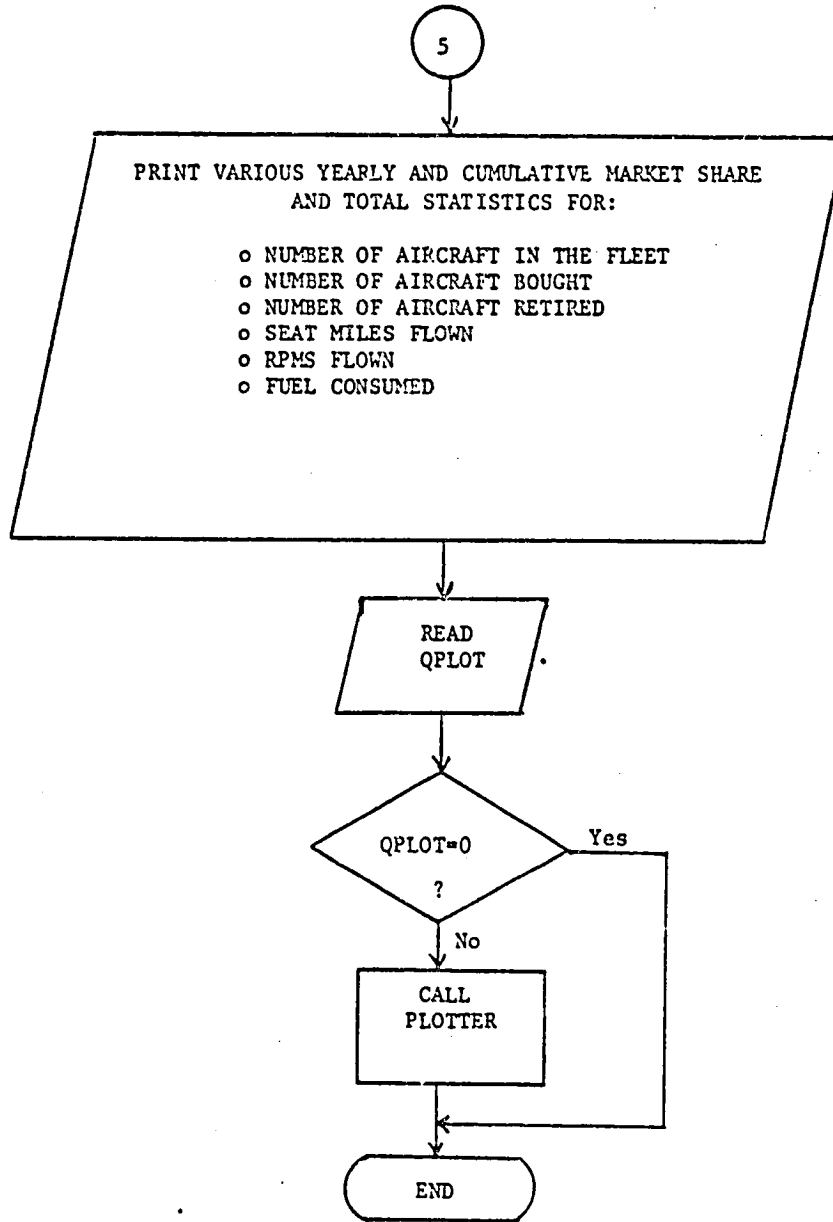


Figure 2 (Concluded)

### AMORTIZ

This subroutine is called upon in each year of the analysis to retire aircraft that have reached retirement age. AMORTIZ stores data on retirements for future use and updates the number of remaining aircraft in the fleet. A flowchart of subroutine AMORTIZ logic is shown in Figure 3.

### MODS

Subroutine MODS is called upon by BET in each year to update the characteristics of aircraft scheduled for modification. A modification is assumed to occur over a two-year period. In the year a modification begins, the aircraft characteristics are assumed to be the average of the old and new values. In the following (and subsequent years), the new values hold. A flowchart of the subroutine MODS logic is shown in Figure 4.

### BUYS

Subroutine BUYS is called upon by BET in each year for each market to determine the aircraft buys. A flowchart of this routine is shown in Figure 5. Aircraft are purchased if the difference between the RPMs demanded and the RPMs supplied by the remaining fleet in the market (after retirements and modifications) is positive. The aircraft type to be purchased is the first aircraft type encountered whose year of introduction has occurred, determined by examining the list of existing and new aircraft types in the market in the reverse order they were specified in the data input. The number of aircraft purchased is computed by dividing the additional RPMs needed to meet demand by the RPMs available per aircraft of the type to be purchased.

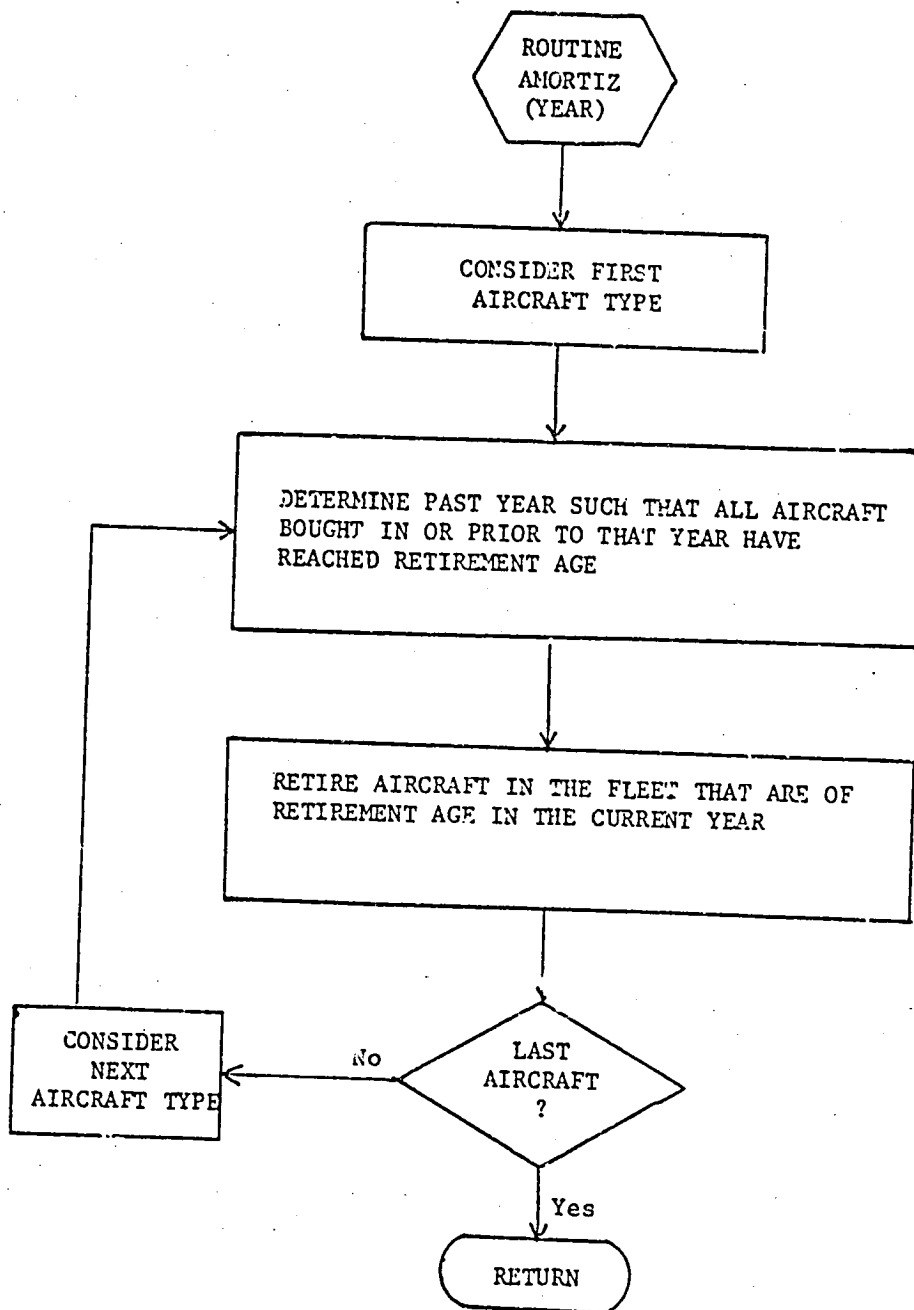


Figure 3 Flowchart of Subroutine AMORTIZ Logic

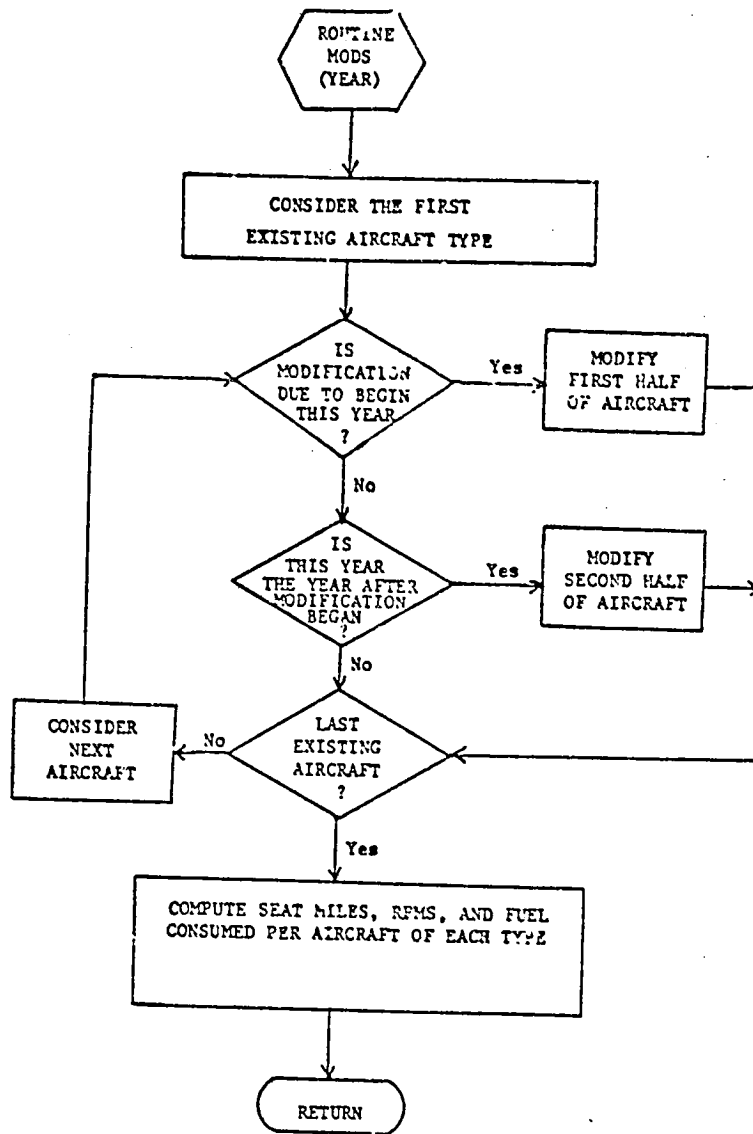


Figure 4 Flowchart of Subroutine MODS Logic

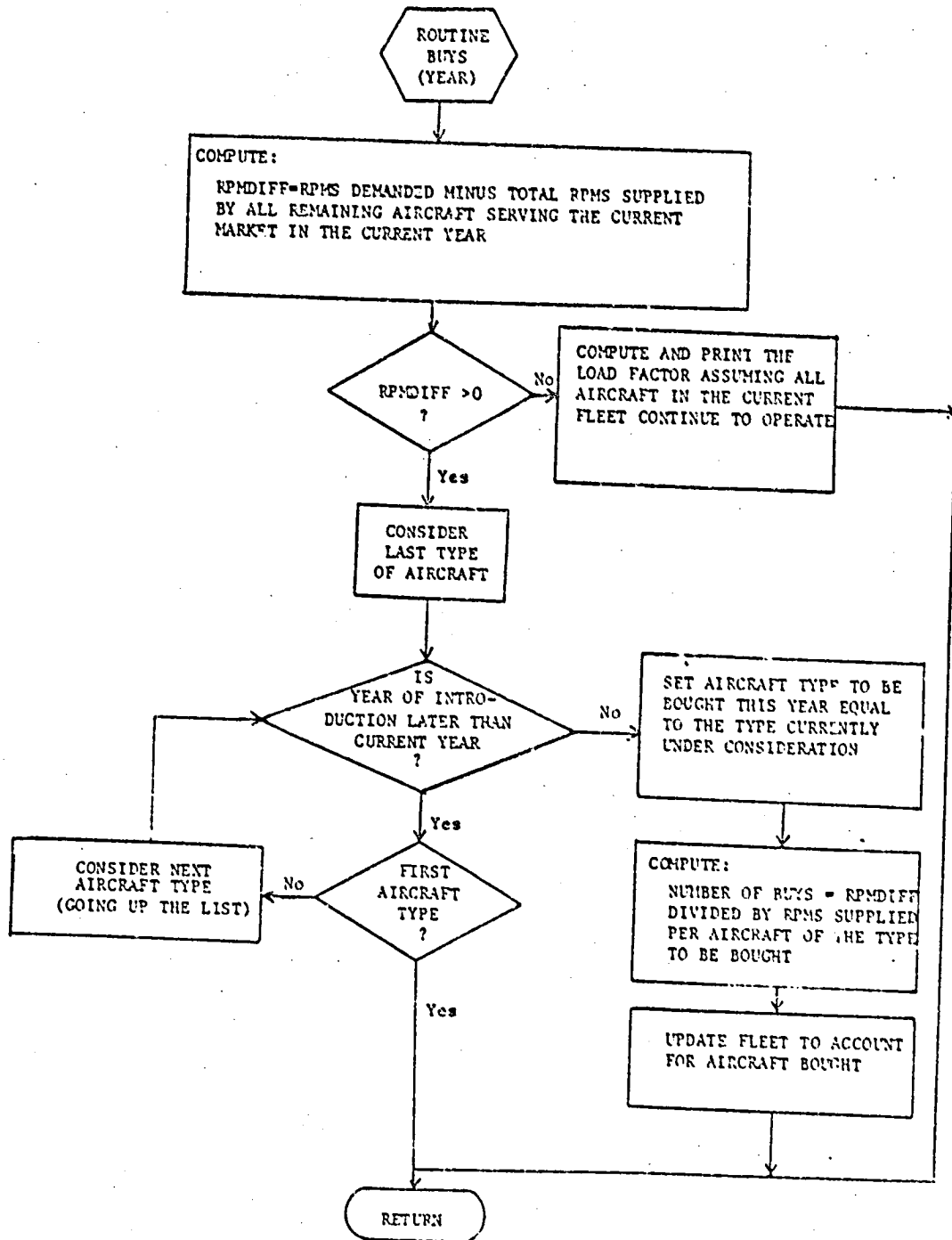


Figure 5 Flowchart of Subroutine BUYS Logic

#### SHARE

This subroutine is called upon by BET to maintain totals by market and year of such statistics as: number of aircraft, number of retirements, number of buys, seat miles, RPMs, and fuel consumed. A flowchart of subroutine SHARE logic is shown in Figure 6.

#### UNIT04

This subroutine is called by BET to reorganize the card input data file. A flowchart of subroutine UNIT04 logic is shown in Figure 7. Card input up to the first end-of-file is copied to a disk file on logical unit 4 while card input between the first and second end-of-file is copied to a disk file on logical unit 8. The data on units 4 and 8 are read by the Airframe Manufacturer Module program.

#### CURVES

This routine is called to store revenue passenger miles flown and fuel consumed by each aircraft type for use in plotting in subroutine PLOTTER. The data is stored to enable plotting RPMs flown and fuel burned as a function of time, accumulating over aircraft types. A flowchart of subroutine CURVES logic is shown in Figure 8.

#### SETUP

Subroutine SETUP is called by BET to initialize the plotting software on logical unit 11, where subroutine PLOTSGL produces plots of RPMs flown and fuel consumed for individual aircraft types. A flowchart of subroutine SETUP is shown in Figure 9.

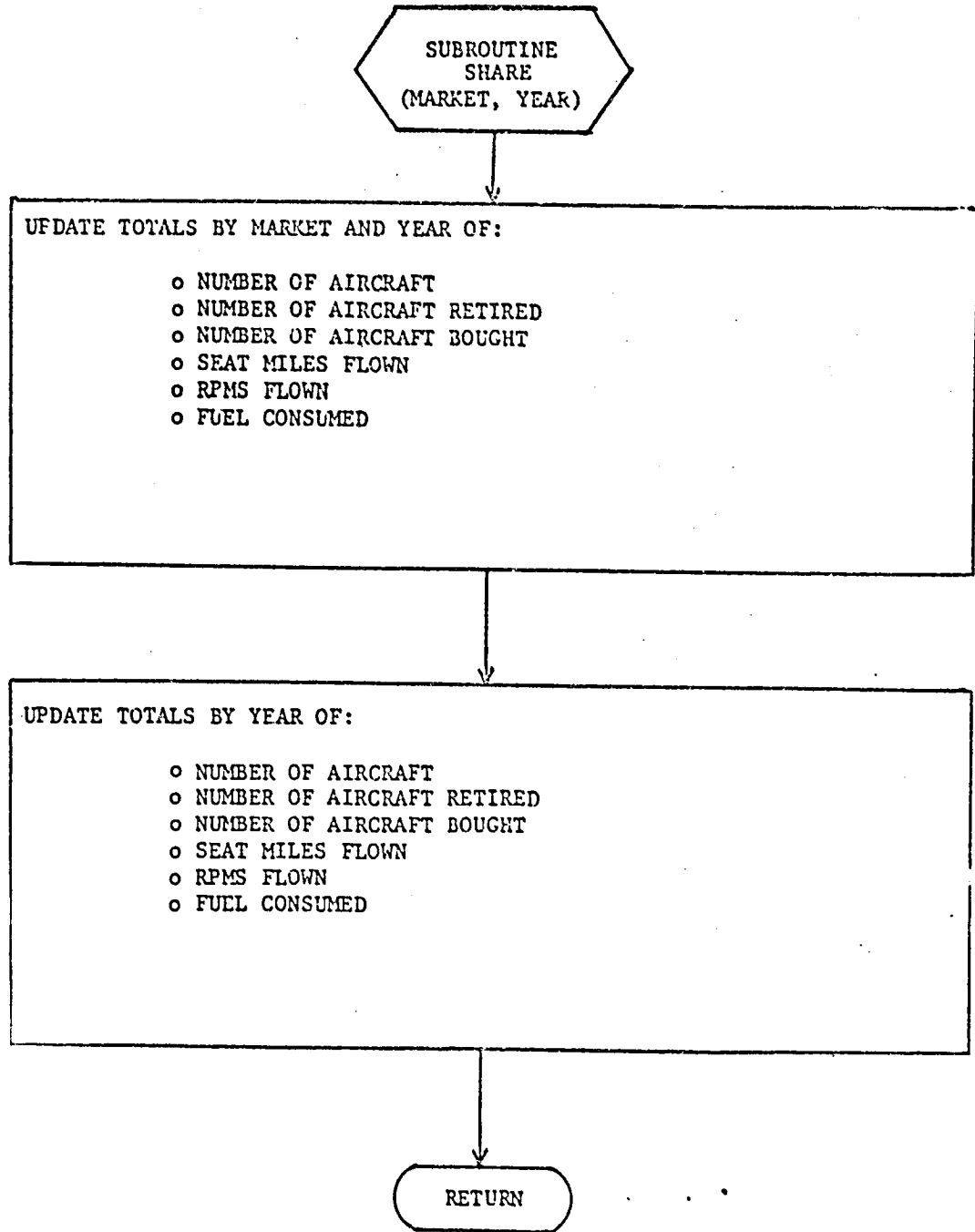


Figure 6 Flowchart of Subroutine SHARE Logic



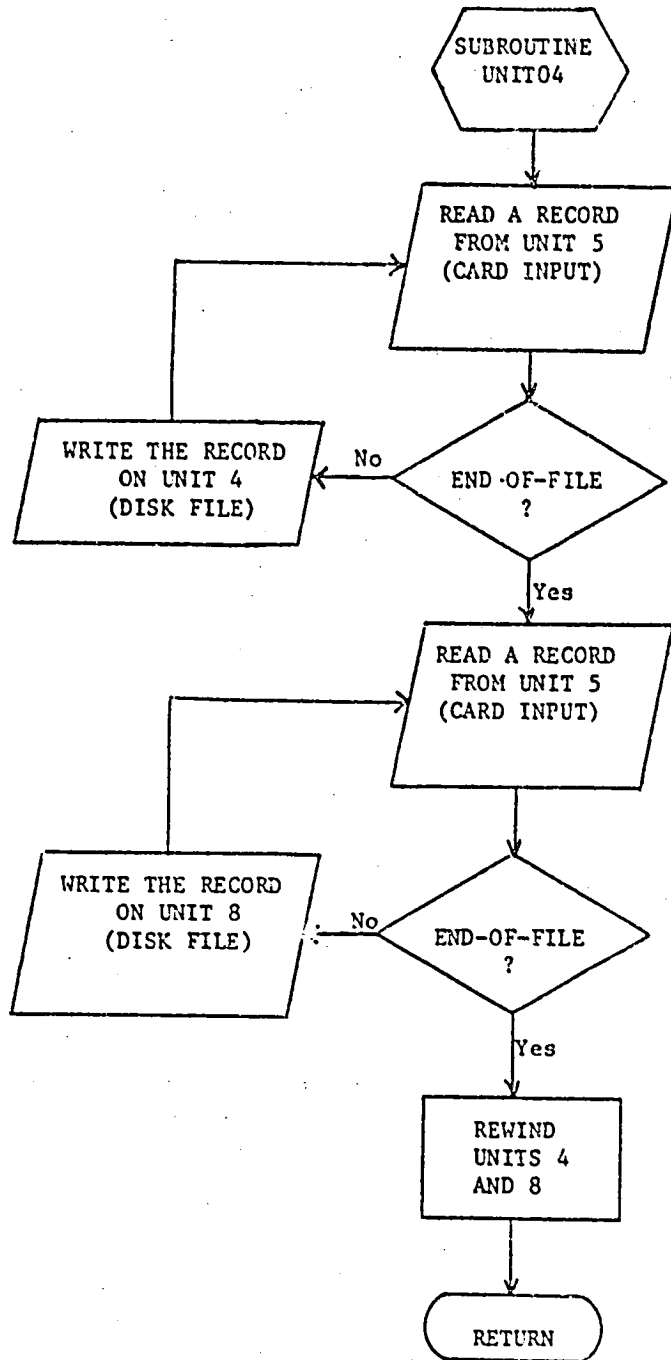


Figure 7 Flowchart of Subroutine UNIT04 Logic

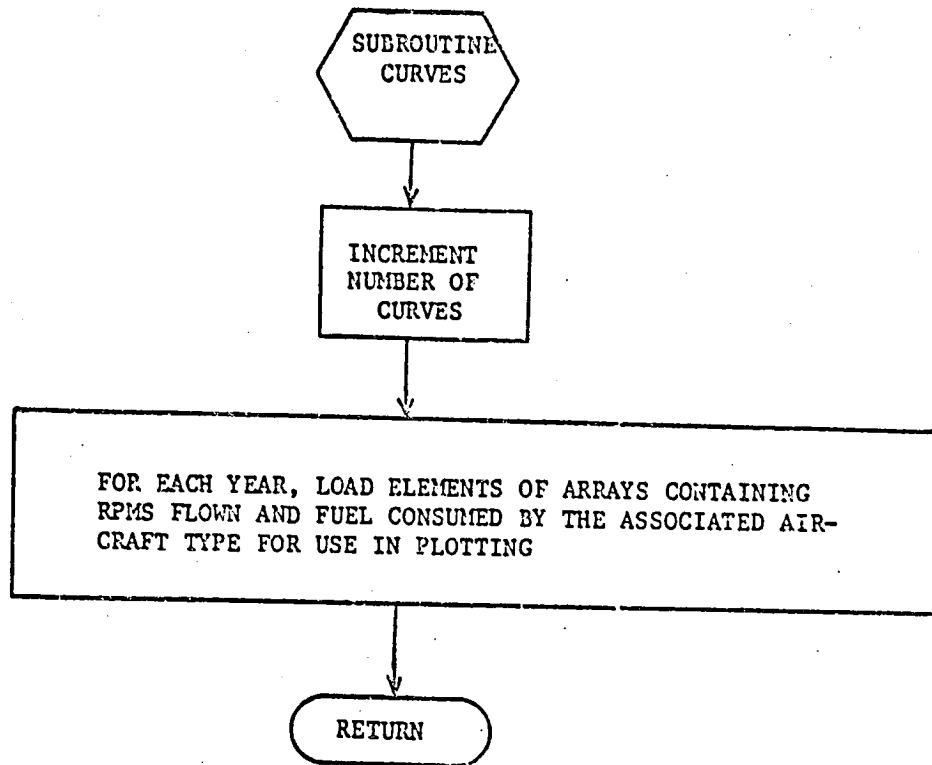


Figure 8 Flowchart of Subroutine CURVES Logic

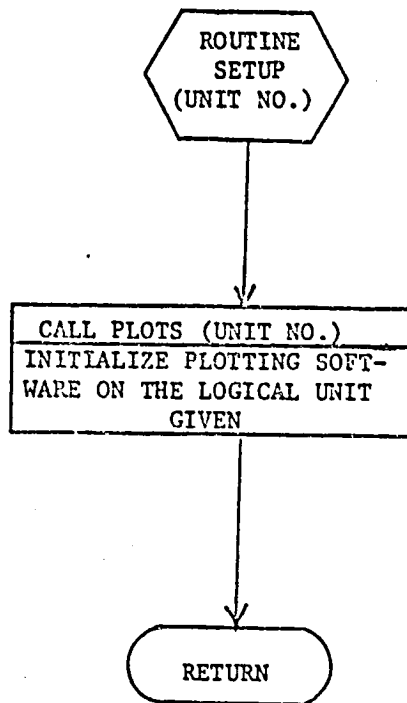


Figure 9 Flowchart of Subroutine SETUP Logic

### PLOTSGL

Subroutine PLOTSGL is called by BET to generate plots of RPMs flown (in billions of miles) and fuel consumed (in millions of barrels) versus time (in years) for individual aircraft types. Separate plots of each of these quantities is produced for each aircraft type for which the user has specified that such plots are desired. The plots are generated on an 8 by 6 inch set of coordinate axes with the scale of the axes calculated to cover the range of fuel consumed and RPMs flown in the market that the aircraft serves. The logic assumes that the fuel consumed in a market exceeds  $10^8$  barrels and that RPMs exceed  $10^{11}$  miles. A flowchart of the subroutine PLOTSGL logic is shown in Figure 10.

### PLOTTER

Subroutine PLOTTER generates two graphs, one for fuel consumption and one for RPMs flown. The yearly fuel consumption and RPMs flown versus time by each aircraft type in all markets are plotted. Each successive plot for an individual aircraft type is referenced to the accumulated fuel consumed or RPMs flown by all aircraft types already plotted. Curves are generated on an 8 by 6 inch set of coordinates. The scaling of the coordinates may be specified by the user or the default may be used. In all cases, the printed values along the axis are to three significant figures. For the default, RPMs are in billions of miles and fuel consumption is in millions of barrels. The scale is computed so that it covers the range of total RPMs flown and fuel consumed. The default logic assumes that the total RPMs exceed  $10^{11}$  miles and the fuel consumed exceeds  $10^8$  barrels. A flowchart of the subroutine PLOTTER logic is shown in Figure 11.

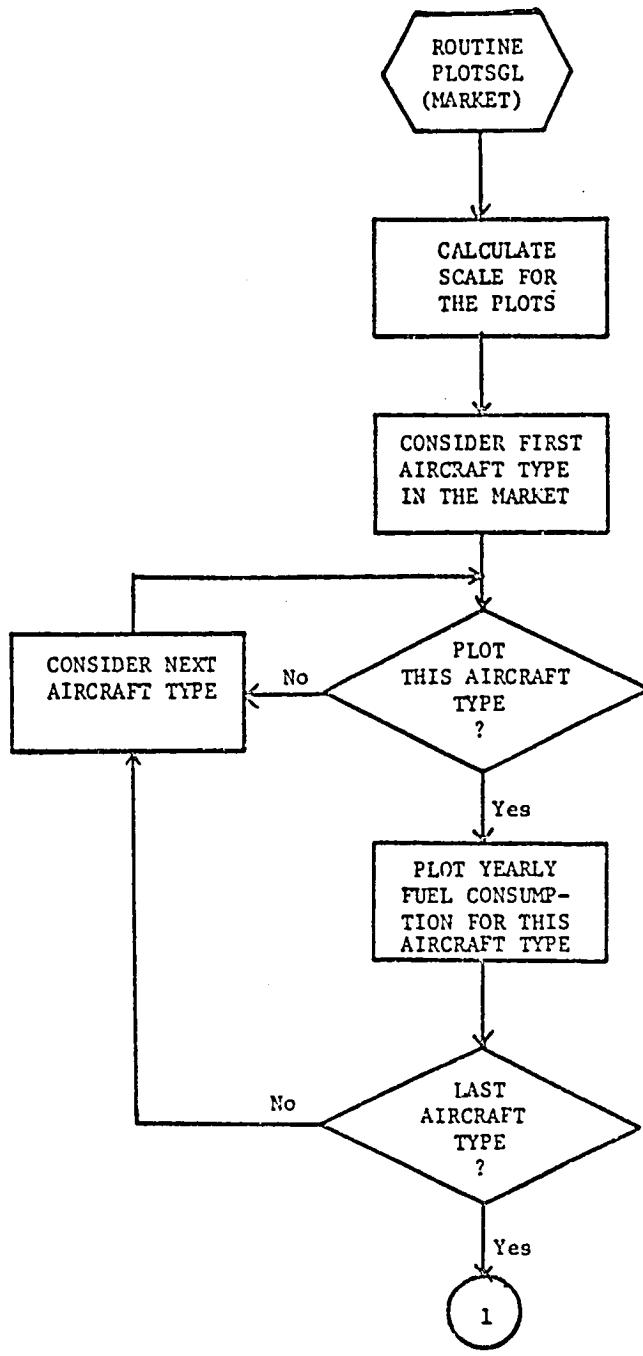


Figure 10 Flowchart of Subroutine PLOTSGL Logic

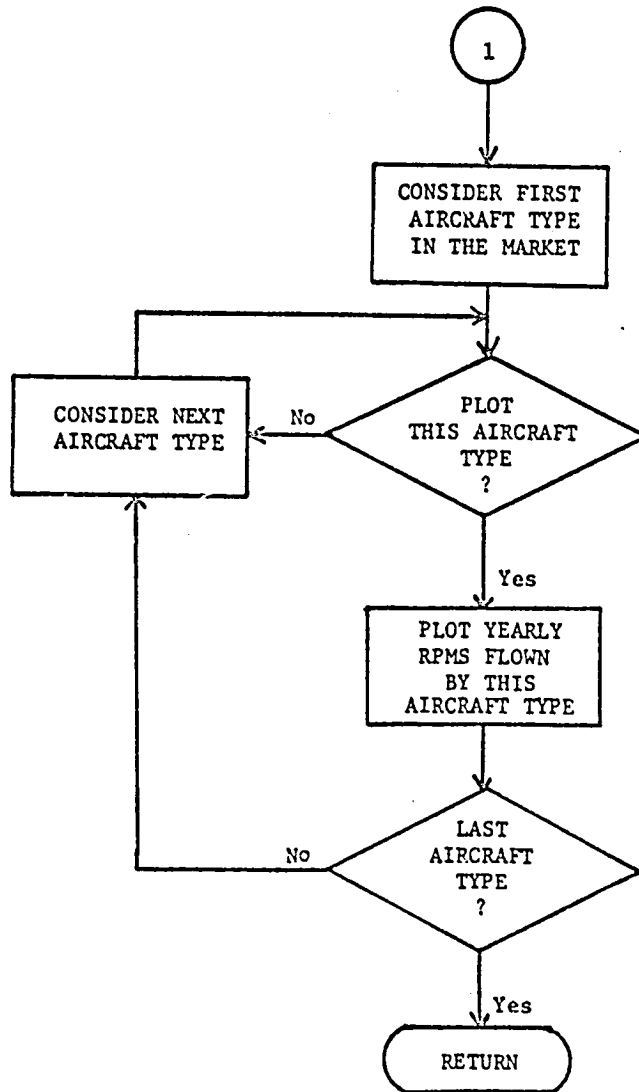


Figure 10 (Concluded)

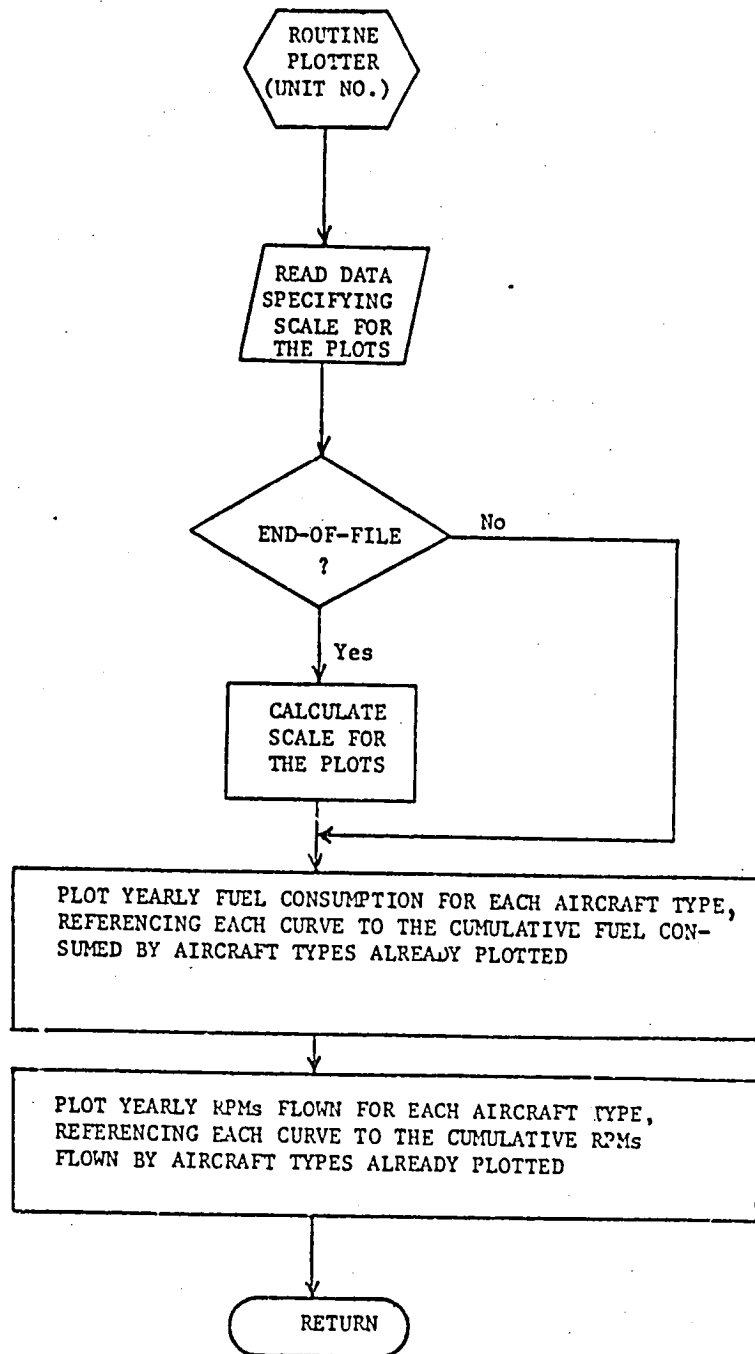


Figure 11 Flowchart of Subroutine PLOTTER Logic

The following are plotter software routines:

PLOTS

PLOTS initializes plotting routines; it must be called once for each logical unit on which plotter output is to be generated.

PLOT

PLOT is the fundamental plotter function. It causes the plotter pen to be moved from where it is to a specified location with pen either up or down.

LINAXS

LINAXS plots and labels a linear axis.

SYMBOL

SYMBOL causes a string of alphanumeric information to be plotted in a manner specified in the calling sequence.

NUMBER

NUMBER plots the EBCDIC representation of a floating point number.

RSTR

RSTR is called after each plot is finished. It clears the buffers, moves the pen to a new page, and reinitializes the necessary variables for a new plot.

Additional programmer-oriented documentation is provided in the appendices. In Appendix A, definitions of the common blocks and variables are provided. In Appendix B, descriptions of the plotter software routines and their arguments are provided. A listing of the code for all routines is provided in Appendix C. Comments have been added to this code to assist a user in reading the program.



C. Input

The input data to the Fleet Accounting Module is in card format and is read from logical unit 5. The input file is described in Table 1, where a description of each entry in this file is provided. All the cards are read by program BET except card 13, which is read by subroutine PLOTTER.

The information provided in Table 1 is of sufficient detail to enable a user to prepare input data for the Fleet Accounting Module. When preparing input, it may prove useful to refer to the listing of the input data for the sample problem in Section V.

Table 1 Card Input Data for the Fleet Accounting Module

<u>Card</u>	<u>Column</u>	<u>Parameter</u>	<u>Format</u> *	<u>Description</u>
1	1-20	MRKTYPE(I)	2A10	Alphanumeric name given to the Ith market, where I=1, 2, or 3. Cards 1 to 11 are repeated for each market to be analyzed.
2	1-10	GROWTH(1)	F10.0	Growth rate (in percent) of revenue passenger miles (RPMs) demanded in market I during the first year (1975). (This entry is not used in any computations, but is included for format consistency.)
2	11-20	GROWTH(2)	F10.0	Growth rate (in percent) of RPMs demanded in market I during the second year.
2 <sup>†</sup>	In increments of 10 columns	GROWTH(J)	F10.0	Growth rate (in percent) of RPMs demanded in market I during the Jth year, J=3 to 31.
3	1-10	LF(1)	F10.0	Load factor (decimal) for flights in market I during the first year.
3	11-20	LF(2)	F10.0	Load factor (decimal) for flights in market I during the second year.
3 <sup>†</sup>	In increments of 10 columns	LF(J)	F10.0	Load factor (decimal) for flights in market I during the Jth year, J=3 to 31.
4	1-5	NOEXPLS	15	Number (no more than 10) of existing types of aircraft serving market I.
5	1-10	TYPE(K)	A10	Alphanumeric name given the Kth existing aircraft type for market I, where K=1.
5	11-20	YRINTRO(K)	F10.0	Year type K aircraft began operating (e.g., 1971).
5	21-30	SEATS(K)	F10.0	Average number of seats available per flight by type K aircraft.
5	31-40	SFC(K)	F10.0	Average fuel consumption in pounds per seat-mile for type K aircraft.
5	41-50	SPEED(K)	F10.0	Average block-to-block speed in statute miles per hour for type K aircraft.
5	51-60	UTILIZ(K)	F10.0	Average utilization in hours per year for type K aircraft.

Table 1 (Continued)

<u>Card</u>	<u>Column</u>	<u>Parameter</u>	<u>Format</u> *	<u>Description</u>
5	61-70	LIFETIM(K)	F10.0	Nominal retirement age in years for type K aircraft.
5	71-80	PLOTS(K)	A10	Enter the word "PLOT" if plots of the revenue passenger miles and fuel consumption versus time for type K aircraft are desired, otherwise leave blank.
6	1-10	NOBUYS(K,1)	F10.0	Number of type K aircraft placed into service in year 1 (7/1/59 through 6/30/60).
6	11-20	NOBUYS(K,2)	F10.0	Number of aircraft of type K placed into service in year 2.
6 <sup>+</sup>	In increments of 10 columns	NOBUYS(K,L)	F10.0	Number of aircraft of type K placed into service in year L, L=3 to 16.
7	1-10	NORETIR(K,1)	F10.0	Number of aircraft of type K retired from service in year 1 (7/1/59 through 6/30/60).
7	11-20	NORETIR(K,2)	F10.0	Number of aircraft of type K retired from service in year 2.
7 <sup>+</sup>	In increments of 10 columns	NORETIR(K,L)	F10.0	Number of aircraft of type K retired from service in year L, L=3 to 16.
				Note: Repeat cards 5-7 for K=1 to NOEXPLS; i.e., repeat for each existing aircraft type in market I.
8	1-5	NOMODS	I5	Number (no more than 10) of modifications to existing types of aircraft.
				Note: Omit card 9 if NOMODS = 0.
9	1-10	MODATA(1)	A10	Alphanumeric name of a previously defined existing aircraft type which will undergo modification during the time period of concern.
9	11-20	MODATA(2)	F10.0	The year (from 1976 through 2005) during which the aircraft modification is to begin. The modification takes place over a two year period beginning in the year specified.

Table 1 (Continued)

<u>Card</u>	<u>Column</u>	<u>Parameter</u>	<u>Format</u> *	<u>Description</u>
9	21-30	MODATA(3)	F10.0	Average number of seats available on the modified aircraft.
9	31-40	MODATA(4)	F10.0	Average fuel consumption in pounds per statute seat-mile for the modified aircraft.
9	41-50	MODATA(5)	F10.0	Average block-to-block speed in statute miles per hour of the modified aircraft.
9	51-60	MODATA(6)	F10.0	Average utilization of the modified aircraft in hours per year.
9	61-70	MODATA(7)	F10.0	Nominal retirement age of the modified aircraft in years.
				Note: Repeat card 9 for each of the NOMODS modifications to existing aircraft types. Only one modification per aircraft type is allowed.
10	1-5	NONEW	I5	Number of new aircraft types that will be available to replace retiring aircraft in market I. (The sum of NOEXPL and NONEW must not exceed 10.)
				Note: Omit card 11 if NONEW = 0.
11				The contents of this card are the same as those for card 5, only the data pertains to new types of aircraft. Card 11 is repeated for each of the new aircraft types, i.e., for K=NOEXPLS + 1 to NOEXPLS + NONEW.
				Note: The data on cards 1-11 are repeated for each market; the maximum number of markets is three.
12				End-of-file card.
13	1-5	QPLOT	I5	Enter a one if plotted output is desired which shows RPMs flown and fuel consumed versus time for each aircraft type in a format for illustrating market share; enter a zero otherwise.
14	1-10	TOPFBRI	E10.4	Maximum value of fuel consumption (in barrels) on the fuel axis of the market share plot.

Table 1 (Concluded)

<u>Card</u>	<u>Column</u>	<u>Parameter</u>	<u>Format</u> <sup>*</sup>	<u>Description</u>
14	11-20	NOMFKSF	I10	Number of tick marks on the fuel axis of the fuel consumption market share plot.
14	21-30	TOPRPM	EJ.4	Maximum value of the RPMs flown (in miles) on the RPM axis of the market share plot.
14	31-40	NOMGKSR	I10	Number of tick marks on the RPM axis of the RPM market share plot.

Note: Card 14 is optional. If omitted, the fuel consumption will be shown in millions of barrels, and RPMs will be shown in billions of miles on the market share plots. There will be 40 tick marks on the axes. Card 13 must be inserted if the total fuel consumed does not exceed  $10^8$  barrels or the total RPMs flown does not exceed  $10^{11}$  miles.

\* All data should be placed as far to the right as possible within the columns allocated. Parameters with an "I" format must not contain a decimal point.

† Actually four cards are required.

‡ Actually two cards are required.

D. Output

The Fleet Accounting Module output consists of printed information and plotter output. The printed information includes statistics describing projected fleet composition and activity. These statistics include number of aircraft retired, number of aircraft bought, seat statute miles flown, revenue passenger statute miles (RPMs) flown, and fuel consumed for individual aircraft types and markets on an individual yearly and cumulative basis. The plotted output includes graphical presentation of RPMs flown and fuel consumed as a function of time by individual aircraft types and by markets.

To facilitate describing the printed output of the Fleet Accounting Module, excerpts from the printed output of the sample problem (see Section V) are presented. As shown in Table 2, the printed output for each market considered in the analysis begins with a printout of some of the input data. The data printed includes the RPM growth rates for each year of the analysis (1975-2005), the load factor for each year of the analysis, aircraft characteristics and buy and retirement histories for each existing aircraft in the market, aircraft modification data, and the characteristics of the new aircraft in the market. The computed values of the RPMs demanded in each year from 1975 through 2005 are then printed.

Following the initial page of printout for the market, a table of data like the one shown in Table 3 is printed for each new and existing aircraft type in the market. The statistics in the table include, for each year from 1975 through 2005, projections of the number of seat statute miles flown, barrels of fuel consumed, revenue passenger statute miles flown, number of aircraft (i.e., population), number of buys and number of

Table 2

SAMPLE PRINTOUT OF MARKET INPUT DATA AND PROJECTED RPM DEMAND

		MARKET = MEDIUM RANGE					
<b>GROWTH</b>							
5.0000	6.0000	5.0000	5.0000	6.0000	5.0000	6.0000	6.0000
5.0000	6.0000	6.0000	6.0000	6.0000	5.0000	6.0000	6.0000
6.0000	6.0000	6.0000	6.0000	6.0000	5.0000	6.0000	6.0000
5.0000	6.0000	6.0000	5.0000	6.0000	5.0000	6.0000	6.0000
<b>I.F.</b>							
.5500	.5500	.5500	.5500	.5500	.5500	.5500	.5500
.5500	.5500	.5500	.5500	.5500	.5500	.5500	.5500
.5500	.5500	.5500	.5500	.5500	.5500	.5500	.5500
.5500	.5500	.5500	.5500	.5500	.5500	.5500	.5500
<b>EXISTING FLEET</b>							
<b>3</b>							
4ENGRATE	1960.0000	134.0000	.2523	408.0000	2507.0000	16.0000	0.0000
3.0000	6.0000	5.0000	5.0000	6.0000	3.0000	6.0000	6.0000
3.0000	6.0000	6.0000	6.0000	6.0000	3.0000	6.0000	6.0000
0.0000	3.0000	3.0000	3.0000	6.0000	3.0000	6.0000	6.0000
0.0000	0.0000	0.0000	0.0000	6.0000	3.0000	6.0000	6.0000
<b>4ENGRATE</b>							
1961.0000	144.3000	.1957	504.0000	3102.0000	16.0000	17.0000	0.0000
7.0000	6.0000	5.0000	7.0000	7.0000	7.0000	7.0000	7.0000
24.2000	19.6000	23.5000	6.0000	6.0000	3.0000	6.0000	6.0000
1.0000	6.0000	3.0000	6.0000	6.0000	3.0000	6.0000	6.0000
7.0000	3.0000	3.0000	6.0000	6.0000	6.0000	6.0000	6.0000
<b>3ENGRATE</b>							
1963.0000	22.2000	.2140	338.0000	2679.0000	16.0000	77.0000	92.0000
3.0000	6.0000	6.0000	3.0000	3.0000	74.0000	77.0000	77.0000
110.1000	92.0000	52.4000	24.4000	13.3000	21.9000	55.0000	26.3000
0.0000	6.0000	7.0000	3.0000	6.0000	3.0000	6.0000	6.0000
3.0000	6.0000	0.0000	6.0000	6.0000	3.0000	6.0000	6.0000
<b>MODIFICATIONS</b>							
<b>0</b>							
<b>NEW AIRCRAFT TYPES</b>							
<b>2</b>							
M2ENGRATE	1987.0000	171.0000	.1140	339.0000	3079.0000	16.0000	0.0000
M1995AC	1995.0000	171.0000	.1140	339.0000	3079.0000	16.0000	0.0000
<b>MARKET</b>							
.6321424421673046375E+11	.634270986697500775E+11	.67556724920776636719E+11	.71714122299261660156E+11	.7561379598762578125000E+11	.79533995262578125000E+11	.834537451229913816359E+12	.873612862294267322266E+12
.7601779598762578125000E+11	.80173069883664592234E+12	.842737451229913816359E+12	.883612862294267322266E+12	.924537451229913816359E+12	.965437451229913816359E+12	.100637451229913816359E+12	.104737451229913816359E+12
.9597737451229913816359E+12	.1000637451229913816359E+12	.1043612862294267322266E+12	.10865437451229913816359E+12	.11294537451229913816359E+12	.11723612862294267322266E+12	.12152612862294267322266E+12	.1258173069883664592234E+12
.121152612862294267322266E+12	.125437451229913816359E+12	.12972612862294267322266E+12	.1340173069883664592234E+12	.13830612862294267322266E+12	.1425973069883664592234E+12	.1468883664592234E+12	.15117959883664592234E+12
.14296535673839662500E+12	.1472709883664592234E+12	.151562500775E+11	.15585400775E+11	.16014500775E+11	.16443600775E+11	.16872700775E+11	.17301800775E+11
.15211523856039355469E+12	.15640612862294267322266E+12	.1606973069883664592234E+12	.1649883664592234E+12	.16927959883664592234E+12	.1735709883664592234E+12	.177862500775E+11	.18215400775E+11
.1623853530739453125E+12	.16664537451229913816359E+12	.17093612862294267322266E+12	.17522709883664592234E+12	.17951800775E+11	.18380900775E+11	.18810000775E+11	.19239100775E+11
.16277953511420312500E+12	.1670709883664592234E+12	.171362500775E+11	.17565400775E+11	.17994500775E+11	.18423600775E+11	.18852700775E+11	.19281800775E+11

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Table 3  
 SAMPLE PRINTOUT OF YEARLY FLEET COMPOSITION AND ACTIVITY PROJECTIONS FOR AN INDIVIDUAL AIRCRAFT TYPE

AIRCRAFT TYPE = H2ENGWPF						
YEAR	SEAT-MILES (YEAR)	FUEL BURNED (YEAR)	RPMs (YEAR)	POPULATION AS OF MID-YEAR	# BUYS/YR (THRU MID-YEAR)	# RETIRED/YR (THRU MID-YEAR)
1975	J.	0.	J.	J.	0.	0.
1976	0.	0.	J.	J.	0.	0.
1977	J.	J.	0.	0.	J.	0.
1978	J.	0.	J.	0.	0.	J.
1979	J.	J.	J.	J.	0.	0.
1980	J.	J.	J.	J.	J.	0.
1981	0.	0.	0.	J.	J.	0.
1982	J.	0.	J.	J.	J.	J.
1983	J.	0.	0.	J.	J.	0.
1984	J.	J.	J.	J.	J.	0.
1985	J.	J.	J.	J.	J.	0.
1986	J.	J.	J.	J.	0.	0.
1987	.1549E+11	.0274E+07	.0518E+10	.0216E+02	.9215E+02	0.
1988	.3035E+11	.1230E+08	.1559E+11	.1610E+03	.7885E+02	0.
1989	.4796E+11	.1905E+08	.2599E+11	.2497E+03	.9864E+02	0.
1990	.6871E+11	.2734E+08	.3779E+11	.3645E+03	.1149E+03	0.
1991	.8775E+11	.3553E+08	.4424E+11	.4657E+03	.1009E+03	J.
1992	.1110E+12	.4495E+08	.6113E+11	.5497E+03	.1234E+03	J.
1993	.1354E+12	.5527E+08	.7504E+11	.7238E+03	.1391E+03	0.
1994	.1643E+12	.6656E+08	.9136E+11	.8716E+03	.1479E+03	0.
1995	.1643E+12	.6656E+08	.9136E+11	.8716E+03	J.	J.
1996	.1643E+12	.6656E+08	.9136E+11	.8716E+03	J.	0.
1997	.1643E+12	.6656E+08	.9136E+11	.8716E+03	J.	J.
1998	.1643E+12	.6656E+08	.9136E+11	.8716E+03	0.	0.
1999	.1643E+12	.6656E+08	.9136E+11	.8716E+03	0.	0.
2000	.1643E+12	.6656E+08	.9136E+11	.8716E+03	J.	0.
2001	.1643E+12	.6656E+08	.9136E+11	.8716E+03	J.	J.
2002	.1549E+12	.6656E+08	.9136E+11	.8716E+03	0.	0.
2003	.1549E+12	.6656E+08	.9136E+11	.8716E+03	J.	.8216E+02
2004	.1339E+12	.5425E+08	.7167E+11	.7104E+03	0.	.7895E+02
2005	.1172E+12	.4749E+08	.6440E+11	.6220E+03	J.	.8864E+02



retirements. The population, number of buys and number of retirements are shown as of midyear. The number of aircraft as of midyear is assumed to be the average number of aircraft operating during each year and is used in projecting the activity data (i.e., seat miles, fuel burned, etc.).

The next type of output provided by the Fleet Accounting Module is illustrated in Table 4. A table of this type is printed for each aircraft type in the market. It provides accumulated (through each year of the analysis) values for seat miles flown, fuel burned, revenue passenger miles flown, number of buys, and number of retirements.

The output discussed thus far is provided for each successive market analyzed. After the printout for the last market, a table like the one shown in Table 5 is printed for each market analyzed. This table provides results analogous to that provided in Table 4, except the results are totals for all aircraft types in a market. The next printed output is illustrated in Table 6. This table provides the totals over all markets analyzed for seat miles, fuel consumed (in barrels), RPMs, buys, and retirements.

The next type of output is illustrated in Table 7. This output is produced for each market analyzed, and includes the fractional share of seat miles, fuel burned, RPMs, and number of aircraft for the market relative to the totals over all markets.

Table 8 illustrates the next type of output provided by the Fleet Accounting Module. This table is produced for each market analyzed. For each year of analysis, the seat miles flown, fuel consumed, revenue passenger miles flown, number of aircraft serving the market, and the number of aircraft bought and retired are shown. The final printed output is

Table 4  
 SAMPLE PRINTOUT OF CUMULATIVE FLEET COMPOSITION AND ACTIVITY PROJECTIONS FOR AN INDIVIDUAL AIRCRAFT TYPE

AIRCRAFT TYPE = N2FGWBPF

YEAR	ACCUMULATIVE SEAT-MILES	ACCUMULATIVE FUEL-BURNED	ACCUMULATIVE RPMs	ACCUMULATIVE # SHYS	ACCUMULATIVE # RETIRED
1975	0.	0.	0.	0.	0.
1976	0.	0.	0.	0.	0.
1977	0.	0.	0.	0.	0.
1978	0.	0.	0.	0.	0.
1979	0.	0.	0.	0.	0.
1980	0.	0.	0.	0.	0.
1981	0.	0.	0.	0.	0.
1982	0.	0.	0.	0.	0.
1983	0.	0.	0.	0.	0.
1984	0.	0.	0.	0.	0.
1985	0.	0.	0.	0.	0.
1986	0.	0.	0.	0.	0.
1987	0.	0.	0.	0.	0.
1988	.1549E+11	.4274E+17	.9518E+10	.8216E+02	0.
1989	.4584E+11	.1857E+08	.2521E+11	.1610E+03	0.
1990	.9289E+11	.3763E+08	.5109E+11	.2497E+03	0.
1991	.1616E+12	.6547E+08	.8988E+11	.3645E+03	0.
1992	.2493E+12	.1010E+09	.1371E+12	.4653E+03	0.
1993	.3503E+12	.1460E+09	.1981E+12	.5837E+03	0.
1994	.4957E+12	.2012E+09	.2732E+12	.7228E+03	0.
1995	.6610E+12	.2673E+09	.3636E+12	.8715E+03	0.
1996	.8253E+12	.3343E+09	.4539E+12	.9716E+03	0.
1997	.9396E+12	.4009E+09	.5443E+12	.8716E+03	0.
1998	.1154E+13	.4675E+09	.6346E+12	.8716E+03	0.
1999	.1318E+13	.5340E+09	.7250E+12	.8716E+03	0.
2000	.1492E+13	.6006E+09	.8154E+12	.8716E+03	0.
2001	.1647E+13	.6671E+09	.9057E+12	.8716E+03	0.
2002	.1811E+13	.7337E+09	.9951E+12	.8716E+03	0.
2003	.1975E+13	.8002E+09	.1086E+13	.8716E+03	0.
2004	.2124E+13	.8668E+09	.1169E+13	.8716E+03	0.
2005	.2249E+13	.9148E+09	.1242E+13	.8716E+03	.8216E+02
2006	.2375E+13	.9623E+09	.1306E+13	.8715E+03	.1610E+03
					.2497E+03

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Table 5

SAMPLE PRINTOUT OF CUMULATIVE FLEET COMPOSITION AND ACTIVITY PROJECTIONS FOR A MARKET

MARKET = MEDIUM RANGE

YEAR	ACCUMULATIVE SEAT-MILES (TO END OF YEAR)	ACCUMULATIVE FUEL-BURNED (TO END OF YEAR)	ACCUMULATIVE RPMs (TO END OF YEAR)	ACCUMULATIVE \$ GUYS (THRU MID-YEAR)	ACCUMULATIVE \$ RETIRED (THRU MID-YEAR)
1975	.1095E+12	.8220E+08	.6021E+11	.2630E+02	0.
1976	.2235E+12	.1694E+09	.1243E+12	.7941E+02	0.
1977	.3485E+12	.2618E+09	.1917E+12	.1425E+03	.0600E+01
1978	.4709E+12	.3597E+09	.2634E+12	.2160E+03	.1760E+02
1979	.6172E+12	.4635E+09	.3394E+12	.2969E+03	.3050E+02
1980	.7637E+12	.5738E+09	.4200E+12	.4249E+03	.8800E+02
1981	.9190E+12	.6908E+09	.5054E+12	.5814E+03	.1699E+03
1982	.1084E+13	.8150E+09	.5960E+12	.7467E+03	.2560E+03
1983	.1255E+13	.9470E+09	.6919E+12	.9433E+03	.3651E+03
1984	.1443E+13	.1087E+10	.7937E+12	.1174E+04	.4994E+03
1985	.1639E+13	.1236E+10	.9019E+12	.1394E+04	.6110E+03
1986	.1847E+13	.1394E+10	.1016E+13	.1566E+04	.6069E+03
1987	.2067E+13	.1556E+10	.1137E+13	.1649E+04	.7113E+03
1988	.2301E+13	.1723E+10	.1265E+13	.1727E+04	.7246E+03
1989	.2544E+13	.1894E+10	.1402E+13	.1816E+04	.7464E+03
1990	.2811E+13	.2069E+10	.1546E+13	.1930E+04	.8014E+03
1991	.3089E+13	.2250E+10	.1699E+13	.2031E+04	.8277E+03
1992	.3384E+13	.2435E+10	.1861E+13	.2155E+04	.8668E+03
1993	.3696E+13	.2624E+10	.2033E+13	.2290E+04	.9438E+03
1994	.4027E+13	.2817E+10	.2215E+13	.2438E+04	.1017E+04
1995	.4378E+13	.3013E+10	.2403E+13	.2598E+04	.1098E+04
1996	.4751E+13	.3216E+10	.2613E+13	.2792E+04	.1226E+04
1997	.5145E+13	.3419E+10	.2830E+13	.3013E+04	.1383E+04
1998	.5553E+13	.3625E+10	.3060E+13	.3247E+04	.1548E+04
1999	.6037E+13	.3832E+10	.3304E+13	.3509E+04	.1745E+04
2000	.6476E+13	.4039E+10	.3562E+13	.3801E+04	.1975E+04
2001	.6975E+13	.4247E+10	.3836E+13	.4039E+04	.2185E+04
2002	.7507E+13	.4463E+10	.4126E+13	.4367E+04	.2367E+04
2003	.8052E+13	.4691E+10	.4434E+13	.4617E+04	.2449E+04
2004	.8655E+13	.4930E+10	.4753E+13	.4874E+04	.2520E+04
2005	.9284E+13	.5185E+10	.5108E+13	.5152E+04	.2617E+04

Table 6

SAMPLE PRINTOUT OF CUMULATIVE FLEET COMPOSITION AND ACTIVITY PROJECTIONS FOR ALL MARKETS

ACCUMULATIVE TOTALS FOR ALL MARKETS

YEAR	ACCUMULATIVE SEAT-MILES (TO END OF YEAR)	ACCUMULATIVE FUEL-BURNED (TO END OF YEAR)	ACCUMULATIVE QPMS (TO END OF YEAR)	ACCUMULATIVE # BUYS (THRU MID-YEAR)	ACCUMULATIVE # RETIRED (THRU MID-YEAR)
1975	.1421E+12	.1472E+09	.7915E+11	.2630E+02	0.
1976	.2929E+12	.2210E+09	.1613E+12	.1041E+03	0.
1977	.5525E+12	.3415E+09	.2499E+12	.1932E+03	0.
1978	.6218E+12	.4682E+09	.3420E+12	.2945E+03	.6000E+01
1979	.9312E+12	.6047E+09	.4427E+12	.4047E+03	.1700E+02
1980	.9315E+12	.7484E+09	.5453E+12	.5639E+03	.3050E+02
1981	.1193E+13	.9010E+09	.6562E+12	.7833E+03	.8000E+02
1982	.1407E+13	.1063E+10	.7737E+12	.1065E+04	.1995E+03
1983	.1531E+13	.1235E+10	.9283E+12	.1435E+04	.3677E+03
1984	.1873E+13	.1417E+10	.1030E+13	.1858E+04	.6126E+03
1985	.2128E+13	.1611E+10	.1170E+13	.2123E+04	.9103E+03
1986	.2398E+13	.1815E+10	.1319E+13	.2346E+04	.1622E+04
1987	.2584E+13	.2029E+10	.1476E+13	.2475E+04	.1698E+04
1988	.2987E+13	.2249E+10	.1643E+13	.2633E+04	.1122E+04
1989	.3309E+13	.2477E+10	.1822E+13	.2745E+04	.2136E+04
1990	.3549E+13	.2712E+10	.2037E+13	.2915E+04	.3157E+04
1991	.4010E+13	.2956E+10	.2276E+13	.3075E+04	.4212E+04
1992	.4373E+13	.3208E+10	.2416E+13	.3235E+04	.5239E+04
1993	.4799E+13	.3469E+10	.2639E+13	.3513E+04	.6316E+04
1994	.5229E+13	.3738E+10	.2876E+13	.3759E+04	.7405E+04
1995	.5594E+13	.4016E+10	.3126E+13	.4022E+04	.8507E+04
1996	.6168E+13	.4302E+10	.3392E+13	.4328E+04	.9617E+04
1997	.6542E+13	.4595E+10	.3674E+13	.4695E+04	.1077E+04
1998	.722...+13	.4897E+10	.3973E+13	.5135E+04	.1196E+04
1999	.7798E+13	.5205E+10	.4289E+13	.5664E+04	.1278E+04
2000	.841...E+13	.5520E+10	.4525E+13	.6259E+04	.1364E+04
2001	.9055E+13	.5844E+10	.4990E+13	.6694E+04	.1458E+04
2002	.9700E+13	.6178E+10	.5357E+13	.7128E+04	.1558E+04
2003	.10347E+14	.6533E+10	.5757E+13	.7544E+04	.1667E+04
2004	.1124E+14	.6909E+10	.6180E+13	.7977E+04	.1786E+04
2005	.1225E+14	.7307E+10	.6629E+13	.8441E+04	.1915E+04

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Table 7

SAMPLE PRINTOUT OF THE FRACTIONAL MARKET SHARE OF CUMULATIVE FLEET COMPOSITION AND ACTIVITY PROJECTIONS FOR A MARKET

MARKET = MEDIUM RANGE

YEAR	FRACTIONAL SEAT-MILES	FRACTIONAL FUEL-BURNED	FRACTIONAL PPMs	FRACTIONAL POPULATION
1975	.7702E+00	.7665E+00	.7702E+00	.6683E+00
1976	.7702E+00	.7667E+00	.7702E+00	.6691E+00
1977	.7702E+00	.7666E+00	.7702E+00	.6701E+00
1978	.7702E+00	.7666E+00	.7702E+00	.6715E+00
1979	.7702E+00	.7667E+00	.7702E+00	.6730E+00
1980	.7702E+00	.7670E+00	.7702E+00	.6743E+00
1981	.7702E+00	.7672E+00	.7702E+00	.6754E+00
1982	.7702E+00	.7674E+00	.7702E+00	.6765E+00
1983	.7702E+00	.7678E+00	.7702E+00	.6781E+00
1984	.7702E+00	.7682E+00	.7702E+00	.6801E+00
1985	.7702E+00	.7685E+00	.7702E+00	.6815E+00
1986	.7702E+00	.7688E+00	.7702E+00	.6830E+00
1987	.7702E+00	.7626E+00	.7702E+00	.6777E+00
1988	.7702E+00	.7575E+00	.7702E+00	.6730E+00
1989	.7702E+00	.7519E+00	.7702E+00	.6682E+00
1990	.7702E+00	.7446E+00	.7702E+00	.6622E+00
1991	.7702E+00	.7393E+00	.7702E+00	.6576E+00
1992	.7702E+00	.7327E+00	.7702E+00	.6522E+00
1993	.7702E+00	.7258E+00	.7702E+00	.6468E+00
1994	.7702E+00	.7187E+00	.7702E+00	.6412E+00
1995	.7702E+00	.7115E+00	.7702E+00	.6357E+00
1996	.7702E+00	.7025E+00	.7702E+00	.6285E+00
1997	.7702E+00	.6924E+00	.7702E+00	.6215E+00
1998	.7702E+00	.6824E+00	.7702E+00	.6144E+00
1999	.7702E+00	.6712E+00	.7702E+00	.6066E+00
2000	.7702E+00	.6592E+00	.7702E+00	.5984E+00
2001	.7702E+00	.6481E+00	.7702E+00	.5913E+00
2002	.7702E+00	.6392E+00	.7702E+00	.5857E+00
2003	.7702E+00	.6302E+00	.7702E+00	.5807E+00
2004	.7702E+00	.6302E+00	.7702E+00	.5857E+00
2005	.7702E+00	.6392E+00	.7702E+00	.5857E+00

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Table 8  
 SAMPLE PRINTOUT OF THE YEARLY FLEET COMPOSITION AND ACTIVITY PROJECTIONS FOR A MARKET

YEAR	MARKET - MEDIUM RANGE					
	SEAT-MILES (YEAR)	FUEL BURNED (YEAR)	RPMS (YEAR)	POPULATION AS OF MID-YEAR	T TRUYS/YR (THRU MID-YEAR)	# RETIRED/YR (THRU MID-YEAR)
1975	.1095E+12	.322JE+08	.6021E+11	.8277E+03	.2630E+02	0.
1976	.1160E+12	.3719E+08	.6383E+11	.8068E+03	.5311E+02	0.
1977	.1230E+12	.4237E+08	.6766E+11	.9378E+03	.6295E+02	.6000E+01
1978	.1304E+12	.4793E+08	.7172E+11	.1000E+04	.7364E+02	.1100E+02
1979	.1382E+12	.5039E+09	.7602E+11	.1060E+04	.8588E+02	.1350E+02
1980	.1465E+12	.5110E+09	.8058E+11	.1138E+04	.1260E+03	.5750E+02
1981	.1553E+12	.5117E+09	.8542E+11	.1213E+04	.1564E+03	.8190E+02
1982	.1646E+12	.5242E+09	.9054E+11	.1292E+04	.1653E+03	.8610E+02
1983	.1745E+12	.5319E+09	.9597E+11	.1380E+04	.1968E+03	.1091E+03
1984	.1850E+12	.5402E+09	.1017E+12	.1476E+04	.2301E+03	.1343E+03
1985	.1951E+12	.5488E+09	.1078E+12	.1574E+04	.2104E+03	.1116E+03
1986	.2078E+12	.5581E+09	.1143E+12	.1680E+04	.1819E+03	.7590E+02
1987	.2203E+12	.5624E+09	.1212E+12	.1738E+04	.8216E+02	.2440E+02
1988	.2335E+12	.5668E+09	.1284E+12	.1804E+04	.7805E+02	.1320E+02
1989	.2475E+12	.5715E+09	.1361E+12	.1871E+04	.5864E+02	.2180E+02
1990	.2624E+12	.5751E+09	.1443E+12	.1938E+04	.1149E+03	.5500E+02
1991	.2781E+12	.5803E+09	.1532E+12	.2005E+04	.1009E+03	.2630E+02
1992	.2948E+12	.5847E+09	.1621E+12	.2075E+04	.1234E+03	.5311E+02
1993	.3125E+12	.5892E+09	.1719E+12	.2147E+04	.1351E+03	.6295E+02
1994	.3312E+12	.5935E+09	.1822E+12	.2222E+04	.1478E+03	.7364E+02
1995	.3511E+12	.5981E+09	.1931E+12	.2299E+04	.1585E+03	.8000E+02
1996	.3722E+12	.6009E+09	.2047E+12	.2367E+04	.1759E+03	.1280E+03
1997	.3945E+12	.6031E+09	.2170E+12	.2432E+04	.2211E+03	.1564E+03
1998	.4182E+12	.6054E+09	.2300E+12	.2500E+04	.2341E+03	.1653E+03
1999	.4433E+12	.6069E+09	.2439E+12	.2566E+04	.2623E+03	.1968E+03
2000	.4699E+12	.6076E+09	.2584E+12	.2628E+04	.2921E+03	.2301E+03
2001	.4981E+12	.6093E+09	.2739E+12	.2705E+04	.2876E+03	.2104E+03
2002	.5280E+12	.6139E+09	.2904E+12	.2781E+04	.2779E+03	.1819E+03
2003	.5594E+12	.6267E+09	.3078E+12	.2949E+04	.2502E+03	.8216E+02
2004	.5932E+12	.6403E+09	.3263E+12	.3147E+04	.2579E+03	.7885E+02
2005	.6288E+12	.6547E+09	.3458E+12	.3336E+04	.2779E+03	.8864E+02

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illustrated in Table 9. This table is analogous to Table 8, except it provides the totals over all markets analyzed.

Plotted output can also be provided by the Fleet Accounting Module, if the user desires. The plotted output is of two basic types. The first type provides separate plots of revenue passenger miles flown and fuel consumed in barrels versus time for individual aircraft types. These plots are illustrated in Figures 12 and 13. The results plotted are those provided in the printed output illustrated by Table 3.

The second type of plotted output is illustrated in Figures 14 and 15, where revenue passenger miles and fuel consumed in barrels, respectively, are plotted versus time in years for each aircraft in all markets. For each aircraft type, the curve of RPMs flown or fuel burned versus time is plotted relative to that for previous aircraft types plotted. This format for presenting results provides for illustration of the relative share of RPMs flown and fuel consumed by various types of aircraft in the markets analyzed.

Table 9  
 SAMPLE PRINTOUT OF THE TOTAL YEARLY FLEET COMPOSITION AND ACTIVITY PROJECTIONS FOR ALL MARKETS

TOTALS FOR ALL MARKETS						
YEAR	SEAT-MILES (YEAR)	FUEL BURNED (YEAR)	RPMS (YEAR)	POPULATION AS OF MID-YEAR	# RJS/YR (THRU MID-YEAR)	# RETIRED/YR (THRU MID-YEAR)
1975	.1421E+12	.1072E+09	.7316E+11	.1239E+04	.2630E+02	0.
1976	.1507E+12	.1137E+09	.8287E+11	.1316E+04	.7777E+02	0.
1977	.1597E+12	.1205E+09	.8784E+11	.1359E+04	.8909E+02	.6000E+01
1978	.1693E+12	.1277E+09	.9311E+11	.1490E+04	.1013E+03	.1100E+02
1979	.1795E+12	.1355E+09	.9872E+11	.1587E+04	.1102E+03	.1350E+02
1980	.1902E+12	.1438E+09	.1045E+12	.1688E+04	.1591E+03	.5750E+02
1981	.2016E+12	.1525E+09	.1119E+12	.1796E+04	.2194E+03	.1119E+03
1982	.2137E+12	.1618E+09	.1175E+12	.1910E+04	.2820E+03	.1678E+03
1983	.2265E+12	.1719E+09	.1246E+12	.2035E+04	.3697E+03	.2449E+03
1984	.2401E+12	.1825E+09	.1321E+12	.2176E+04	.4328E+03	.2977E+03
1985	.2555E+12	.1937E+09	.1400E+12	.2310E+04	.5222E+03	.1116E+03
1986	.2698E+12	.2056E+09	.1484E+12	.2460E+04	.2267E+03	.7590E+02
1987	.2860E+12	.2124E+09	.1573E+12	.2565E+04	.1290E+03	.2440E+02
1988	.3032E+12	.2202E+09	.1667E+12	.2685E+04	.1283E+03	.1330E+02
1989	.3214E+12	.2281E+09	.1757E+12	.2800E+04	.1412E+03	.2180E+02
1990	.3406E+12	.2351E+09	.1874E+12	.2915E+04	.1706E+03	.5500E+02
1991	.3611E+12	.2439E+09	.1986E+12	.3049E+04	.1399E+03	.2630E+02
1992	.3827E+12	.2522E+09	.2105E+12	.3182E+04	.2107E+03	.7777E+02
1993	.4057E+12	.2606E+09	.2231E+12	.3320E+04	.2277E+03	.8909E+02
1994	.4301E+12	.2693E+09	.2365E+12	.3465E+04	.2459E+03	.1013E+03
1995	.4559E+12	.2783E+09	.2507E+12	.3617E+04	.2525E+03	.1102E+03
1996	.4832E+12	.2860E+09	.2658E+12	.3764E+04	.3060E+03	.1591E+03
1997	.5122E+12	.2933E+09	.2817E+12	.3912E+04	.3679E+03	.2194E+03
1998	.5429E+12	.3010E+09	.2986E+12	.4070E+04	.4396E+03	.2820E+03
1999	.5756E+12	.3083E+09	.3165E+12	.4229E+04	.5293E+03	.3697E+03
2000	.6100E+12	.3150E+09	.3355E+12	.4391E+04	.5946E+03	.4328E+03
2001	.6466E+12	.3237E+09	.3557E+12	.4574E+04	.4351E+03	.2520E+03
2002	.6854E+12	.3346E+09	.3770E+12	.4782E+04	.4342E+03	.2260E+03
2003	.7269E+12	.3547E+09	.3976E+12	.5069E+04	.5159E+03	.1290E+03
2004	.7702E+12	.3760E+09	.4235E+12	.5374E+04	.4326E+03	.1265E+03
2005	.8164E+12	.3985E+09	.4490E+12	.5696E+04	.4636E+03	.1412E+03

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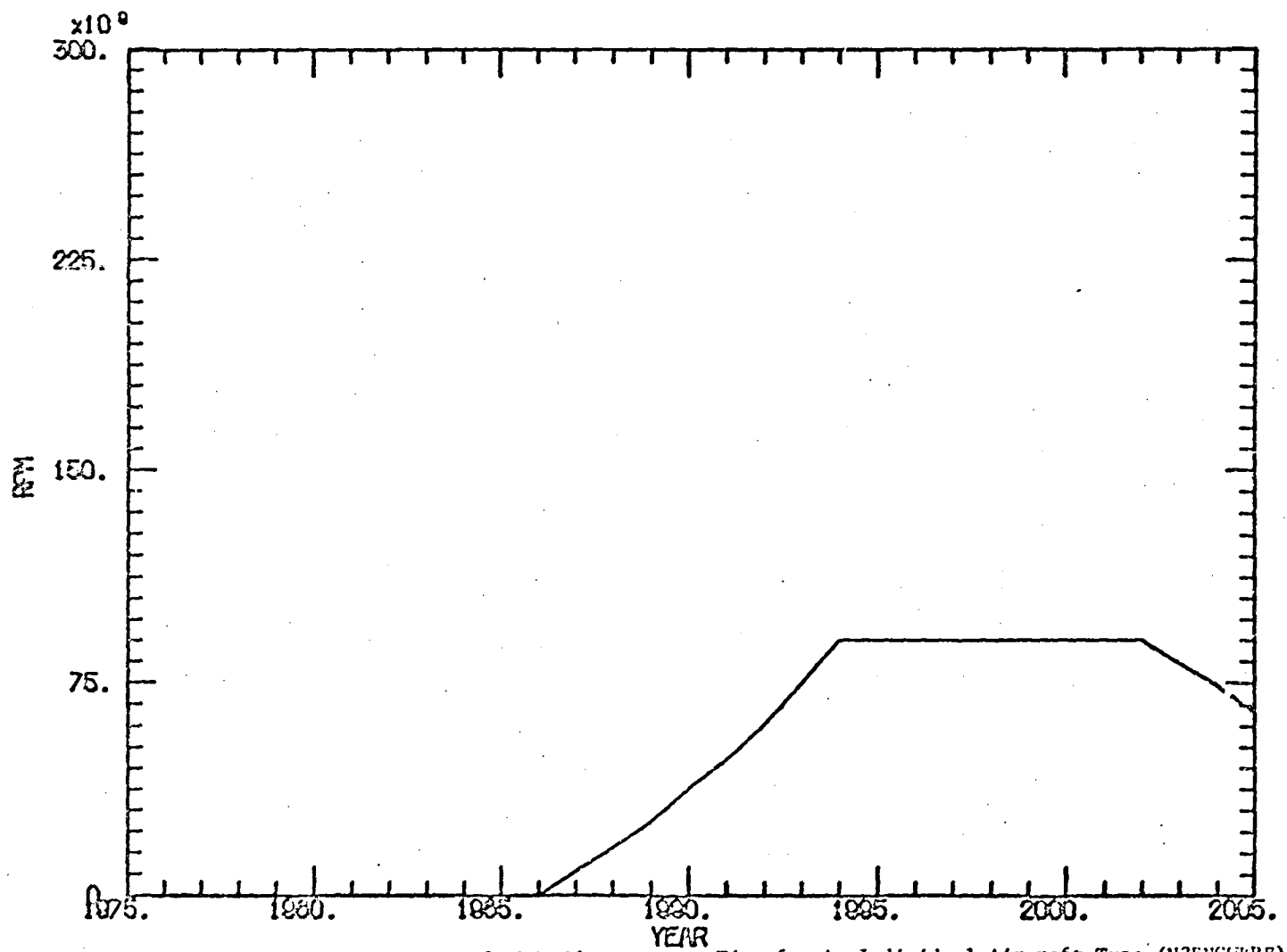


Figure 12 Sample Plotted Output of RPMs Flown versus Time for An Individual Aircraft Type (N2ENGWBPF)

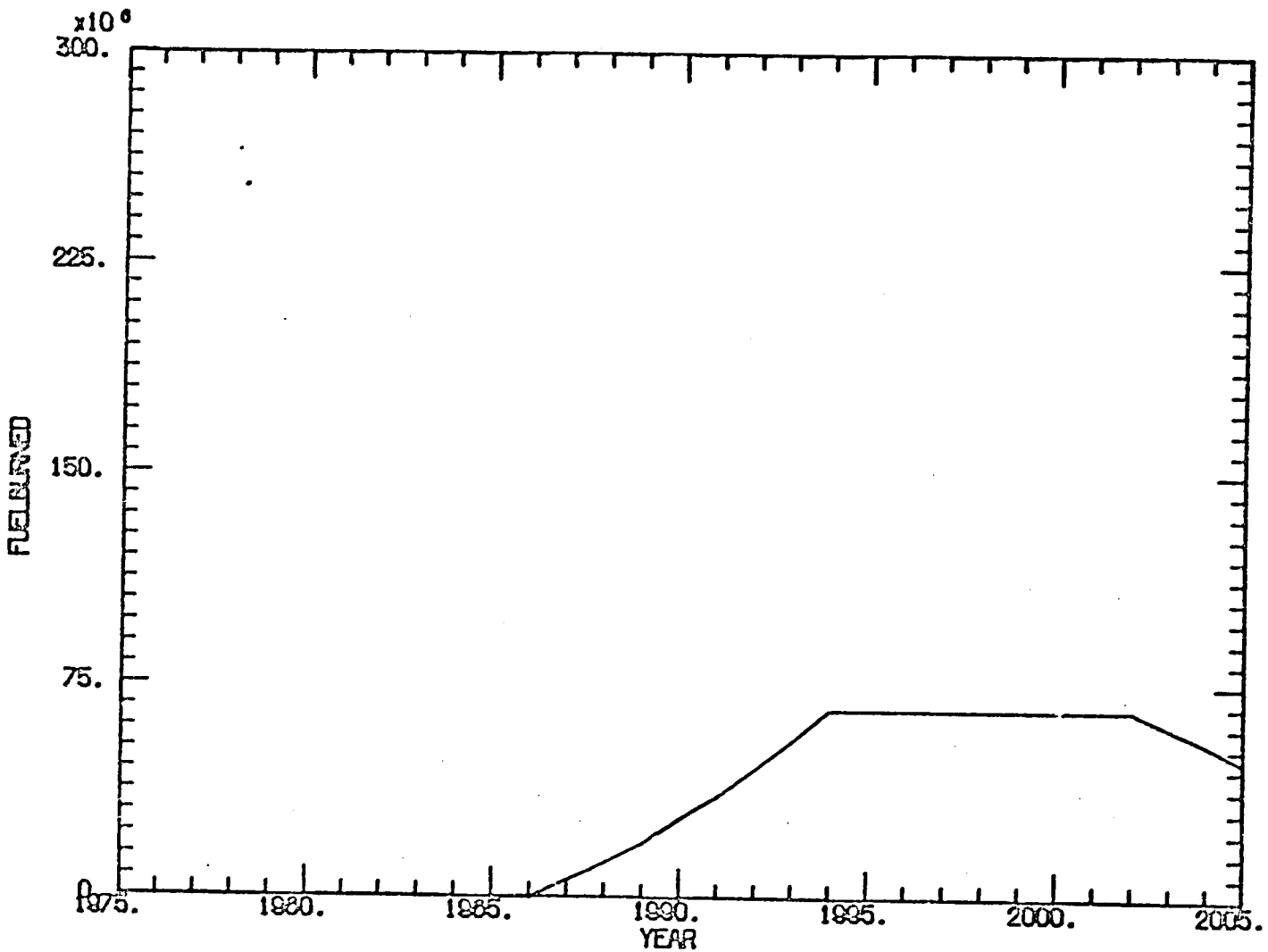


Figure 13 Sample Plotted Output of Fuel Consumed versus Time for an Individual Aircraft Type (H2ENGWEPF)

# FORECAST U.S. AIRLINE FLEET DISTRIBUTION

0.5%/yr RPM GROWTH

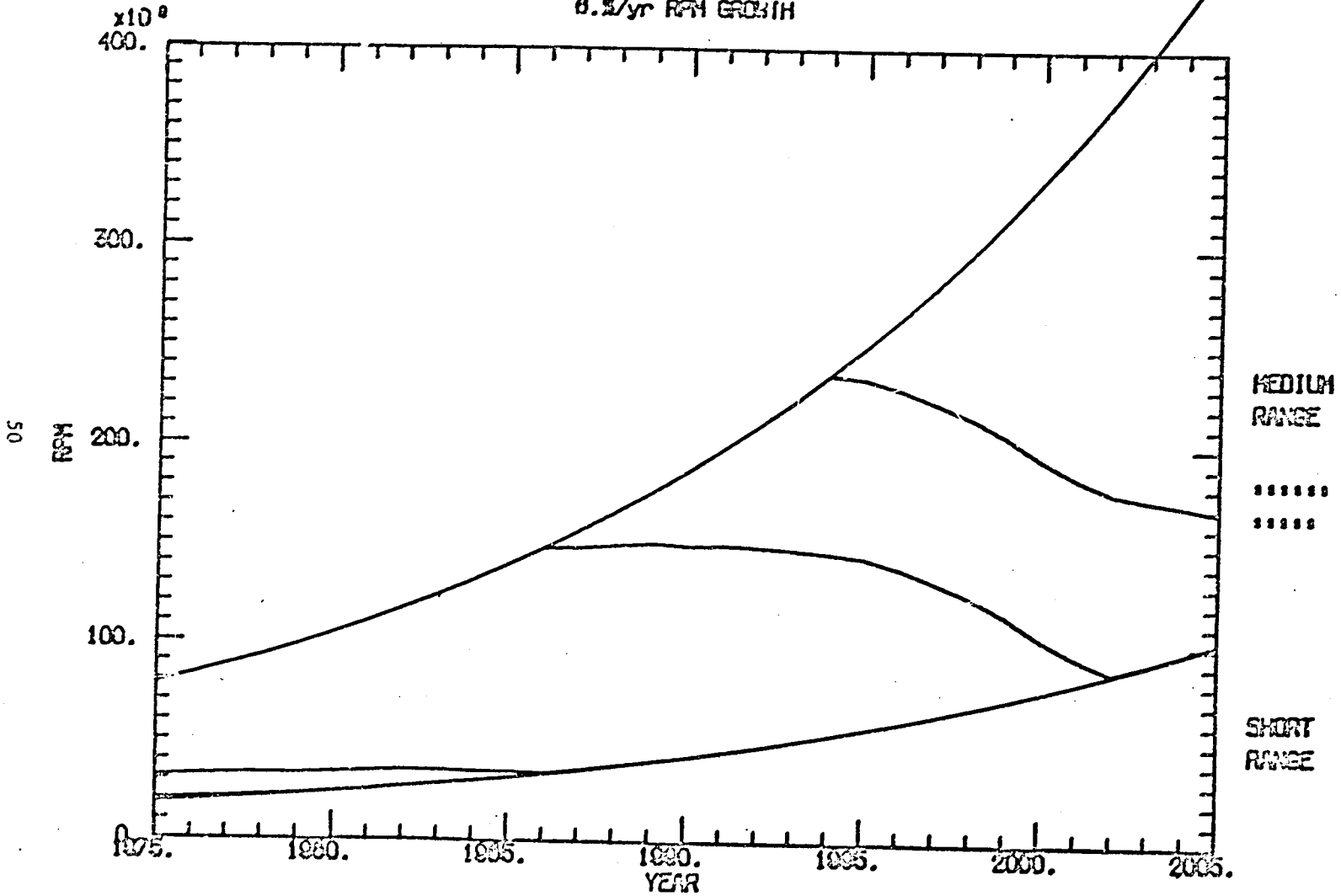


Figure 14 Sample Plotted Output of RPMs Flown Versus Time Accumulated over Aircraft Types

# FORECAST U.S. AIRLINE FUEL USAGE DISTRIBUTION

0.2%/yr RPM GROWTH

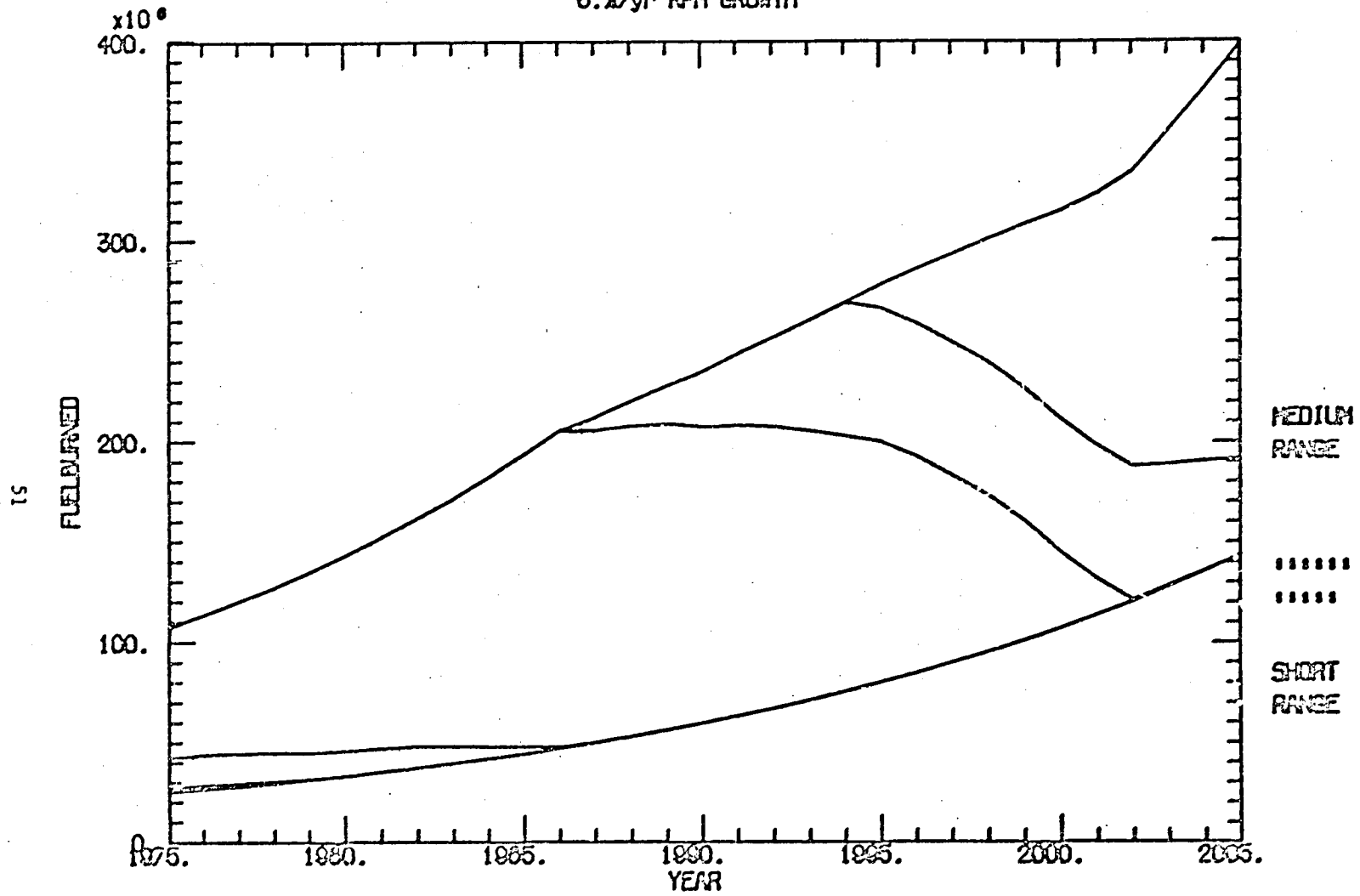


Figure 15 Sample Plotted Output of Fuel Consumed Versus Time Accumulated over Aircraft Types

### III AIRFRAME MANUFACTURER MODULE

The function of the Airframe Manufacturer Module is to estimate the aircraft manufacturing rates of return on investment. These estimates are based on the estimated numbers of aircraft required over time (as predicted by the Fleet Accounting Module) and assumed aircraft prices.

The major components included in this module are the following:

- PLANT - which generates production, order and delivery schedules from estimated fleet requirements.
- ACCOST - which estimates RDT&E costs and individual and total component manufacturing costs over the life of the production program.
- CASHFLW - which estimates the net cash flow that the manufacturer can expect to receive from manufacturing the new aircraft.

Using the net cash flow, the rates of return on investment for the aircraft manufacturer are estimated. Descriptions of the mathematical modeling methodology, program logic, input, and output for the Airframe Manufacturer Module follow.

#### A. Methodology

The Fleet Accounting Module determines the demand for new aircraft and the Airframe Manufacturer Module estimates the economic viability of producing new aircraft to meet that demand. Each new aircraft type is completely analyzed before analysis of subsequent types is initiated. Two basic constraints on the Airframe Manufacturer Module are that a new airframe must be produced for at least two years and airframe manufacturing must be continuous, that is, production cannot be zero in any intermediate year.

### Production Scheduling

The methodology begins with an analysis of the demand previously generated and develops optimized production, order, and delivery schedules to meet that demand. It is assumed that the manufacturer produces aircraft at constant integer rates per month and may change the production rate once during the entire production period. It is further assumed that the delivery schedule is identical to the production schedule and that the order schedule precedes the delivery schedule by 24 months.

Determination of the production schedule includes determining the two constant integer monthly production rates and the breakpoint in the production program when the production rate changes from the first to the second rate. To determine these parameters, all possible breakpoints (assumed to occur at the beginning of a year) in the demand period are tested. For a given breakpoint under consideration a constant integer monthly production rate is computed for each of the two production periods defined by the breakpoint. These production rates are determined by dividing the total aircraft demanded in each period by the months of production in the period. The month of demand for the last aircraft demanded in a year is assumed to be the last month of the year. The best production schedule is that which has the smallest maximum deviation between the demand and production months for the last aircraft demanded in any year. For the schedule chosen as the best, the start of production is then shifted by as much as 6 months earlier or later. This shift is chosen to minimize the algebraic sum of the deviations between the demand and production months for the last aircraft in each year of the production schedule.

### Cost Determination

Embedded within the Airframe Manufacturer Module is set of cost relationships for estimating research, development, test and evaluation (RDT&E) costs, aircraft manufacturing costs, and sustaining engineering costs over the life of the production program for a new aircraft. Parameters in the cost estimating relationships include various aircraft structural and operating characteristics, complexity factors, and costs. These parameters, which are inputs to the computer program, include:\*

- ADI = Avionics development cost.
- AFSPAO = Airframe spares factor in the production phase.
- AGEOI = Operational ground support equipment cost.
- AGEPI = Ground support equipment development cost.
- CFACS = Complexity factor for air conditioning system.
- CFAERO = Complexity factor for aerodynamic control system.
- CFANTC = Complexity factor for anti-icing system.
- CFAVON = Complexity factor for avionics system.
- CFBODY = Complexity factor for aircraft fuselage.
- CFELCD = Complexity factor for electrical distribution system.
- CFEMP = Complexity factor for empennage structure.
- CFENAC = Complexity factor for engine accessories.
- CFENG = Complexity factor for airbreathing engines.
- CFFUSY = Complexity factor for the fuel system.

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\* All weights are in pounds and costs in millions of dollars, unless otherwise specified.

CFHNDL = Complexity factor for the loading & handling system.  
CFHYCD = Complexity factor for the hydraulic system.  
CFINST = Complexity factor for the instrument system.  
CFLG = Complexity factor for alighting gear system.  
CFNAC = Complexity factor for engine nacelles.  
CFPACC = Complexity factor for passenger accommodations.  
CFPNDC = Complexity factor for pneumatic system.  
CFPOW = Complexity factor for auxiliary power system.  
CFTREV = Complexity factor for thrust reverser.  
CFWING = Complexity factor for wing structure.  
CONFIG = Complexity factor for airframe engineering.  
CTJI = Cost per aircraft engine.  
EN = Number of main engines.  
ENSPAO = Main engine spares factor in the production phase.  
ENSPAR = Main engine spares factor in the RDT&E phase.  
FACI = Production facilities cost.  
FEE = Manufacturer fee factor.  
FTOI = Flight test operation cost.  
FVSPAR = Flight test vehicle spares factor.  
GTSPAR = Ground test vehicle spares factor.  
IOPS = Indicator for operational program (1=commercial,  
0=other).  
LEARN = Airframe learning curve factor.  
LEARNA = Avionics learning curve factor.  
LEARNP = Engine learning curve factor.  
MACH = Maximum design flight mach number (decimal).



NCREW = Number in flight crew.  
NDATA = Number of production levels to be analyzed  
(from 1 to 5).  
NFV = Number of flight test vehicles to be produced.  
NGV = Number of ground test vehicles.  
NOCON = Number of concept formulation contractors.  
NOCON1 = Number of contract definition contractors.  
NOENG = Number of concept formulation engineers.  
NOENG1 = Number of contract definition engineers.  
NOYRS = Number of years for concept formulation.  
NOYRS1 = Number of years for contract definition.  
NV = Number of operational vehicles to be produced.  
PDTJI = Propulsion development cost.  
RATE = Maximum vehicle production rate, number per month  
RE = Engineering labor rate, dollars per hour.  
RT = Tooling labor rate, dollars per hour.  
SUBSYI = Subsystem development cost.  
T = Thrust per engine at sea level in pounds.  
TOOLC = Complexity factor for tooling.  
WACS = Air conditioning system weight.  
WAERO = Aerodynamic control system weight.  
WANTIC = Anti-icing system weight.  
WAVION = Avionics system weight.  
WBODY = Fuselage weight.  
WELCAD = Electric power conversion and distribution system  
weight.

WEMP = Empennage weight.  
WENACC = Engine accessories weight.  
WENGS = Engines total weight.  
WFUSYS = Fuel system weight.  
WFUTOT = Total fuel weight.  
WGROSS = Aircraft gross takeoff weight.  
WHANDL = Load and handling system weight.  
WHYCAD = Hydraulic power conversion and distribution system weight.  
WINST = Instrument system weight.  
WLG = Alighting gear system weight.  
WNACEL = Engine nacelles weight.  
WPACCO = Passenger accommodations weight.  
WPNCAD = Pneumatic power and distribution system weight.  
WPOWER = Auxiliary power system weight.  
WTREVS = Thrust reverser weight.  
WWING = Wing weight.  
WPAYL = Maximum payload weight.  
XAVD = Avionics development factor.  
XFASSY = Final assembly checkout cost factor.  
XNEW = Miscellaneous equipment development factor.

Using the input learning curve factors (LEARN, LEARNA, and LEARNP), the cost methodology accounts for the effects on production costs of the production quantity. Letting NVEH equal the total number of aircraft produced, the production learning curve factors are computed as follows:

AIRFRAME PRODUCTION LEARNING CURVE FACTOR (Z)

$$Z = NVEH ** ZETA$$

$$ZETA = 1.0 + (LOG (.01 * LEARN)/LOG(2.0))$$

AVIONICS PRODUCTION LEARNING CURVE FACTOR (ZA)

$$ZA = NVEH ** ZETAA$$

$$ZETAA = 1.0 + (LOG (.01 * LEARNA)/LOG (2.0)); \text{ if LEARNA} = 0, \\ ZETAA = ZETA$$

ENGINE PRODUCTION LEARNING CURVE FACTOR (ZP)

$$ZP = NVEH ** ZETAP$$

$$ZETAP = 1.0 + (LOG (.01 * LEARNP)/LOG (2.0))$$

Using these learning curve factors and the input values of the cost equation parameters, RDT&E, aircraft manufacturing, and sustaining production costs components (in millions of dollars) are computed using the following set of equations:

Airframe Manufacturer Cost Equations

RESEARCH, DEVELOPMENT, TEST AND EVALUATION COSTS

$$(RDTE = ADDE + SUBSYS + AD + PDTJ + DS)$$

- AIRFRAME DESIGN AND ENGINEERING DEVELOPMENT (ADDE = CF + CD + DDEL)

CONCEPT FORMULATION (CF)

$$CF = 35000. * NOENG * NOYRS * NOCON * 1.E - 06$$

CONTRACT DEFINITION (CD)

$$CD = 35000. * NOENG1 * NOYRS1 * NOCON1 * 1.E - .06$$

AIRFRAME ENGINEERING LABOR (DDEL)

$$DDEL = 207. * WA ** .931 * RE * 1.0E * CONFIG, \text{ for subsonic pro-} \\ \text{duction aircraft}$$

$$= RE * 3145. * WA ** 0.5825 * 1.0E -06 * CONFIG, \text{ for subsonic} \\ \text{prototype aircraft}$$

= RE \* 348. \* WA \*\* 0.931 \* 1.0E -06 \* CONFIG, for supersonic  
production aircraft

where

WA = WE - WENGS - WELCAD - WAVIOT - WACS - WPOWER

WE = WGROSS - WPAYL - WFUTOT

WAVIOT = WAVION + WINST

• SUBSYSTEMS DEVELOPMENT (SUBSYS)

SUBSYS = SUBSYI, if SUBSYI  $\neq$  0

= 0.35 \* (WACS + WINST \* .05 + WPOWER + WELCAD + WAERO +  
WHYCAD + WPNCAD + WENACC + WFUSYS + WPPROV) \* XNEW,  
if SUBSYI = 0

where

WPPROV = NCREW \* 500. - 500.

• AVIONICS DEVELOPMENT (AD)

AD = ADI, if ADI  $\neq$  0.1

= (5.3 \* (WAVION \* 0.75) \*\* .439 + 2.19 \* (0.25 + WAVION) \*\*  
.439 + 0.55 \* (0.50 \* WINST) \*\* .439) \* XAVD, otherwise

• PROPULSION DEVELOPMENT (PDTJ)

PDTJ = PDTJI, if PDTJI  $\neq$  0.1

= 29.5 \* (T/1000.) \*\* .55 \* MACH \*\* .62 [(NVHF) \* EN \*  
(1. + ENSPAR + ENSPAO)] \*\* 0.1, otherwise

where

NVHF = NV + NFV

• DEVELOPMENT SUPPORT (DS = GRV + GTS + FTS + TST + FTO + AGEV + TDP)

GROUND TEST VEHICLES (GTV)

GTV = AMFG (for first unit) \* NG

GROUND TEST SPARES (GTS)

$$GTS = GRV * GTSPAR$$

FLIGHT TEST SPARES (FTS)

$$FTS = FV * FVSPAR$$

TOOLING AND SPECIAL TEST EQUIPMENT (TST)

$$TST = RT * .0267 * WA ** .99 VMAX ** 1.21 * RATE ** .4 * NFV **$$

.14 \* TOOLC \* 1.E - 06, for production aircraft

$$= RT * 6.19 * WA ** 1.062 * TOOLC * 1.0E - 06, \text{ for prototype}$$

aircraft or if IPROP = 0

where

$$VMAX = 660.0 * MACH$$

RATE = maximum monthly aircraft production rate

FLIGHT TEST OPERATIONS (FTO)

$$FTO = FTOI, \text{ if } FTOI \neq .1$$

$$= .90 * NFV ** 1.1 * VMAX ** .9 * 1.E - 6 * WCROSS ** .8,$$

otherwise

GROUND SUPPORT EQUIPMENT (AGEP)

$$AGEP = AGEPI, \text{ if } AGEPI = 0.1$$

$$= .15 * FV + .05 * ADDE, \text{ otherwise}$$

TECHNICAL DATA (TDP)

$$TDP = .02 * FV$$

where

$$\text{FLIGHT TEST VEHICLES } ((FV = CAFFC + CAVFV + CPFV) * (1.0 + XFASSY))$$

FLT. TEST AIRFRAME (CAFFV)

$$CAFFV = AMFG (\text{for 1st unit}) * NFV ** ZETA$$

FLT. TEST VEH. AVIONICS (CAVAV)

$$\text{CAVAV} = \text{CAVION (for 1st unit)} * \text{NFV} ** \text{ZETA}$$

FLT. TEST PROPULSION SYSTEM (CPFV)

$$\text{CPFV} = \text{PROPU (for 1st unit)} * \text{NFV} ** \text{ZETA}$$

- RDT&E FEE (RDFEE)

$$\text{RDFEE} = \text{RDTE} * \text{FEE}$$

AIRCRAFT MANUFACTURING COSTS (OV = AMFG + CAVION + PCPU + CFASSY)

- AIRFRAME STRUCTURE (AMFG = CWING + CEMP + CBODY + CLG + CNACEL + CAERO  
+ CHYCAD + CELCAD + CPNCAD + CACS + CANTIC  
+ CPOWER + CPACCO + CHANDL)

WING (CWING)

$$\text{CWING} = .036 * \text{WWING} ** .451 * \text{Z} * \text{CFWING}$$

EMPENNAGE (CEMP)

$$\text{CEMP} = .01023 * \text{WEMP} ** .451 * \text{Z} * \text{CFEMP}$$

BODY (CBODY)

$$\text{CBODY} = .0561 * \text{WBODY} ** .451 * \text{Z} * \text{CFBODY}$$

LANDING GEAR (CLG)

$$\text{CLG} = .01043 * \text{WLG} ** .541 * \text{Z} * \text{CFLG}$$

NACELLES GROUP (CNACEL)

$$\text{CNACEL} = .0561 * \text{WNACEL} ** .451 * \text{Z} * \text{CFNAC}$$

AERODYNAMIC CONTROLS (CAERO)

$$\text{CAERO} = .004 * \text{WAERO} * \text{Z} * \text{CFAERO}$$

HYDRAULICS (CHYCAD)

$$\text{CHYCAD} = .00197 * \text{WHYCAD} ** 0.766 * \text{Z} * \text{CFHYCD}$$

ELECTRICAL SYSTEMS (CELCAD)

$$\text{CELCAD} = .00197 * \text{WELCAD} ** 0.766 * \text{Z} * \text{CFELCD}$$

PNEUMATIC (CPNCAD)

CPNCAD = .0002 \* WPNCAD \* Z \* CFPNCD

AIR CONDITIONING SYSTEM (CACS)

CACS = .00643 \* WACS \*\* 0.5065 \* Z \* CFACS

ANTI-ICING (CANTIC)

CANTIC = .00023 \* WANTIC \* Z \* CFANTIC

AUXILIARY POWER SOURCE (CPOWER)

CPOWER = .000243 \* WPOWER \* Z \* CFPW

PASSENGER ACCOMMODATIONS (CPACCO)

CPACCO = .000115 \* WPACCO \* Z \* CFPACC

LOADING AND HANDLING (CHANDL)

CHANDL = (WHANDL/WBODY) \* CBODY \* CFHNDL

• AVIONICS SYSTEM (CAVION = CINST + CAVONT)

INSTRUMENTATION (CINST = CINSTE + CINSTI)

EQUIPMENT (CINSTE)

CINSTE = .00193 \* (WINST/2.0) \* ZA \* CFINST

INSTALLATION (CINSTI)

CINSTI = .000154 \* (WINST/2.0) \* ZA \* CFINST

AVIONICS (CAVONT = CAVONE + CAVONI)

EQUIPMENT (CAVONE)

CAVONE = .00193 \* (WAVION/2.0) \* ZA \* CFAVON

INSTALLATION (CAVONI)

CAVONI = .00154 \* (WAVION/2.0) \* ZA \* CFAVON

• PROPULSION SYSTEM (PROPU = (CENGS + CTREVS + CFUSYS + CENACC

ENGINES (CENGS)

CENGS = CTJ \* EN

where

CTJ = CTJI, if CTJI ≠ 1

= .00277 \* T \*\* 0.60 \* ZP \* CFENG, otherwise

THRUST REVERSER (CTREVS)

CTREVS = .0028 \* WTREVS \*\* 0.766 \* ZP \* CFTREV

FUEL SYSTEM (CFUSYS)

CFUSYS = .0000619 \* WFUSYS \* ZP \* CFFUSY

ENGINE ACCESSORIES (CENACC)

CENACC = .0003 \* WENACC \* ZP \* CFENAC

- FINAL ASSEMBLY AND CHECKOUT (CFASSY)

CFASSY = XFASSY \* (AMFG + CAVION + PROPU)

- MANUFACTURING FEE (MFEE)

MFEE = OV \* FEE

SUSTAINING PRODUCTION COSTS (SC = OS + FAC + SE + ST + AGE0 + TDO + MEQ + OT + IT + TRI)

- OPERATIONAL SPARES (OS = OSA + OSP), if IOPS = 1, OS = 0

PRODUCTION AIRFRAME SPARES (OSA)

OSA + AFSPAO \* (AMFG + CAVION)

PRODUCTION ENGINE SPARES (OSP)

OSP = PROPU (for 1st unit) ((NVHF \* (1.0 + ENSPAO)) \*\*

ZETAP - NVHF \* ZETAP)

- FACILITIES (FAC)

FAC = FACI

- SUSTAINING ENGINEERING (SE)

SE = .10 \* OV, if IOPS = 1

= ADDE \* (NVHF \*\* 2.0 - 1.0), if IOPS ≠ 1



- SUSTAINING TOOLING (ST)
  - ST = TST \* NVHF \*\* .14 - 1.)
- OPERATIONAL GROUND SUPPORT EQUIPMENT (AGEO)
  - AGEO = AGEOI, if AGEOI ≠ 0.50
  - AGEO = .15 \* OV, otherwise
- PRODUCTION AIRCRAFT TECHNICAL DATA (TDO)
  - TDO = .02 \* OV
- MISCELLANEOUS EQUIPMENT (MEQ); if IOPS = 1, MEQ = 0
  - MEQ = 500. \* NPL \* 4. \* 1.0E - 06
  - NPL = NCREW \* NVHF \* 2.0
- OPERATIONAL TRAINING EQUIPMENT (OT); if IOPS = 1, OT = 0
  - OT = 1.442 E - 01 \* OV \* NVHF \*\* (-0.4525)
- INITIAL FLIGHT CREW TRAINING (IT); if IOPS = 1, IT = 0
  - IT = .05 \* NPL
- INITIAL TRANSPORTATION ( TRI)
  - TRI = .005 \* (OV + OS + MEQ + OT + AGEO)
- SUSTAINING COST FEE (SFEE)
  - SFEE = SC \* FEE

#### Aircraft Price Determination

A methodology for estimating aircraft selling price is embedded within the Airframe Manufacture Module. Subroutine ACPRICE, which contains the logic for this methodology, is called upon to estimate aircraft selling price and print results. However, at the present time the computed selling price estimate is not used in subsequent analysis of cash flows. Instead, a base selling price estimate is read from the input stream along with a

price increment. This input base price and thirteen successive upward increments of the base price are used in subsequent calculations.

The aircraft price estimating relationships depend upon several input parameters. These include:

- API = Average annual increase in the national price cost index (decimal).
- EN = Number of main engines.
- HP = Engine design shaft horsepower (for non-jets).
- IAIRPL = An indicator for aircraft type (1 for conventional jet transports, 2 for small jet transports, 3 for wide-body jet transports, 4 for turboprop transports, 5 for general aviation types, 6 for supersonic transports).
- IENGS = An indicator for engine type (1 for turbojet and turbofan, 2 for turboprop, 3 for reciprocating, 4 for air-breathing).
- PN = Total passenger capacity.
- T = Thrust per engine, pounds (for jets).
- WE = Aircraft empty weight, pounds.
- WENGs = Engines total weight, pounds.
- YEAR = Year of introduction into service.

Using the values for these parameters, the following equations comprise the price estimation methodology, where all computed prices are in millions of dollars and  $C = 10^{-6}$ :

#### Aircraft Pricing Equations

- ESTIMATED AIRFRAME DEVELOPMENT COST (EDEVc)  
$$EDEVc = 128.9 ** (0.1097 * (YEAR - 1940.)) * WE * C$$
- ESTIMATED AIRPLANE UNIT PRODUCTION COST (EUPROC)  
$$EUPROC = 7.8 ** (0.068 * (YEAR - 1940.)) * WE * C$$

- ESTIMATED MARKETPLACE PRICE (EPRICE)
  - CONVENTIONAL JET TRANSPORTS (IAIRPL = 1):
  - EPRICE =  $0.04867 * PN (1.0 + API) ** (YEAR - 1975.)$
  - SMALL JET TRANSPORTS (IAIRPL = 2):
  - EPRICE =  $0.5 + 0.0305 * PN * (1.0 + API) ** (YEAR - 1975.)$
  - WIDE-BODY JET TRANSPORTS (IAIRPL = 3):
  - EPRICE =  $1.0 + 0.05935 * PN * (1.0 + API) ** (YEAR - 1975.)$
- ESTIMATED AIRPLANE PRICE BY SEAT COST (ESEPRI)
  - FOR ALL AIRCRAFT AND ENGINE TYPES:
  - ESEPRI (1) =  $3100.0 * PN ** (0.0641 * (YEAR - 1930.)) * C$
  - FOR ALL AIRCRAFT AND ENGINE TYPES EXCEPT IAIRPL = 3 or IENGS = 1:
  - ESEPRI (2) =  $4000.0 * PN ** (0.0652 * (YEAR - 1930.)) * C$
  - FOR IAIRPL = 3 AND IENGS ≠ 1:
  - ESEPRI (3) =  $20500. * PN ** (0.0350 * (YEAR - 1950.)) * C$
- ESTIMATED ENGINE PRICE (EENGPR)
  - TURBOJET AND TURBOFAN (IENGS = 1):
  - EENGPR =  $111.114 * EN * T ** 0.962 * (1.0 + API) ** (YEAR - 1975.) * C$
  - TURBOPROP (IENGS = 2):
  - EENGPR =  $173.075 * EN * HP ** 0.9283 * (1.0 + API) ** (YEAR - 1975.) * C$
  - RECIPROCATING (IENGS = 3):
  - EENGPR =  $4.693 * EN * HP ** 1.3917 * (1.0 + API) ** (YEAR - 1975.) * C$
- AIRFRAME WEIGHT (WAIRFR)
  - WAIRFR = WE - WENGS

• ESTIMATED AIRFRAME PRICE (EAIQFP)

CONVENTIONAL JET TRANSPORTS (IAIRPL = 1):

EAIQFP = 1663.07 \* WAIRFR \*\* 0.7300 \* (1.0 + API) \*\* (YEAR - 1975.) \* C

SMALL JET TRANSPORTS (IAIRPL = 2):

EAIQFP = 400.40 \* WAIRFR \*\* 0.8936 \* (1.0 + API) \*\* (YEAR - 1975.) \* C

WIDE-BODY JET TRANSPORTS (IAIRPL = 3):

EAIQFP = 3603.35 \* WAIRFR \*\* 0.69823 \* (1.0 + API) \*\* (YEAR - 1975.) \* C

TURBOPROP TRANSPORTS (IAIRPL = 4):

EAIQFP = 1878.04 \* WAIRFR \*\* 0.65989 \* (1.0 + API) \*\* (YEAR - 1975.) \* C

GENERAL AVIATION TYPES (IAIRPL = 5):

EAIQFP = .003408 \* WAIRFR \*\* 2.1938 \* (1.0 + API) \*\* (YEAR - 1975.) \* C

SUPERSONIC TRANSPORTS (IAIRPL = 6):

EAIQFP = 176690. \* WAIRFR \*\* 0.4506 \* (1.0 + API) \*\* (YEAR - 1975.) \* C

• ESTIMATED AIRPLANE PRICE (EAIRPR)

EAIRPR = EAIQFP + EENGPR

Cash Flow Determination

A determination of estimated manufacturer cash flow over the period of production is made by the following procedure. Research, development, test and evaluation costs are spread over the period of production by component. Airframe design and engineering costs, subsystems development costs, and avionics development costs are distributed uniformly over the 42 month period ending with the month production starts. Propulsion development costs are distributed evenly over the 52 month period ending with the month production starts. Development support costs are distributed evenly over the 42 month period ending the twelfth month after start of production.

Aircraft production costs are uniformly spread over the production month and the eleven preceding months for each unit to be produced. Revenue (income) based on the estimated aircraft selling price is distributed as 5 percent on order, 70 percent on delivery, and 25 percent evenly spread over the months between order and delivery for each unit produced. Finally, revenue minus the sum of the cost factors is calculated both for each month individually and cumulatively by month.

#### Internal Rate of Return on Investment

The final calculation step in the methodology of the Airframe Manufacturer Module is to employ an iterative technique to calculate the internal rate of return for each estimated cash flow generated. The internal rate of return (or marginal efficiency of investment) is that rate of interest or return which would render the discounted present value of its expected future marginal yields (income) exactly equal to the investment cost of the project.

Since both the investment costs and the income are spread over time, the internal rate of return sought is that which reduces the summed present value of the cash flow stream over time to zero. The cash flow stream sum can be represented as:

$$\text{SUM} = \left(\frac{1}{1+R}\right) \text{CF}_1 + \left(\frac{1}{1+R}\right)^2 \text{CF}_2 + \dots + \left(\frac{1}{1+R}\right)^n \text{CF}_n \quad (9)$$

where  $R$  = internal rate of return

$\text{CF}_1$  = net cash flow in year 1.

The iterative procedure estimates values for R, calculates the SUM described above using the cash flow figures previously generated, performs tests to determine if SUM is getting closer to zero, then successively chooses new values for R in attempting to obtain a value for SUM closer to zero.

The methodology described above produces output lists and tables that summarize the calculations being performed. Outputs include time history of demand for each aircraft type, breakpoints of production periods and startup times, component and cumulative cost tables, tables of costs versus aircraft quantity, estimated price data, iteration results (every tenth cycle) from rate of return calculations and final rate of return value, and tables showing cost, income and cash flow by year and month within year (both for individual months and for cumulative monthly figures).

In the remainder of this chapter, detailed descriptions of the program logic, input, and output for the Airframe Manufacturer Module are provided.

#### B. Program Logic

Figure 16 illustrates the interrelationships among the routines which make up the Airframe Manufacturer Module program. Subroutine INPLANT acts as the interface between the main program BET and the rest of the subroutines comprising the Airframe Manufacturer Module. INPLANT then acts as a driver for the rest of the subroutines in the module. Brief descriptions of each subroutine in the Airframe Manufacturer Module, together with flowcharts of the program logic follow:

##### INPLANT

Subroutine INPLANT serves as the driver for the Airframe Manufacturer Module. A flowchart of the program logic for INPLANT is shown in Figure 17.

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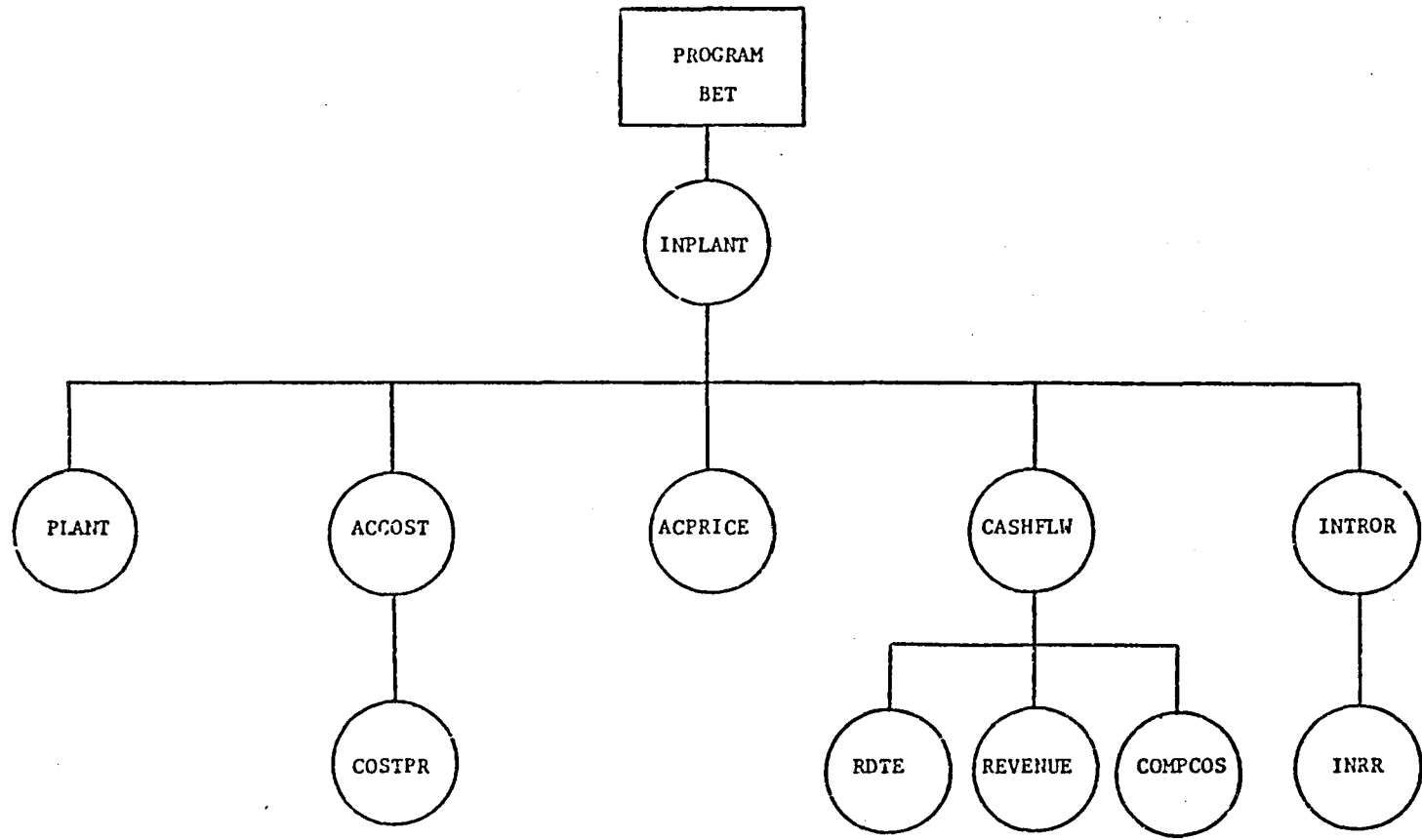


Figure 16 Program Structure of the Airframe Manufacturer Module

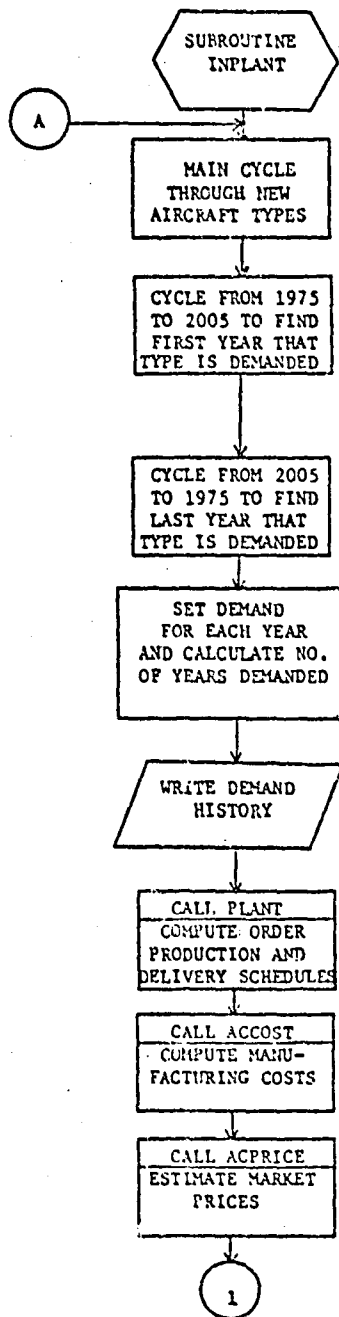


Figure 17 Flowchart of Subroutine INPLANT Logic



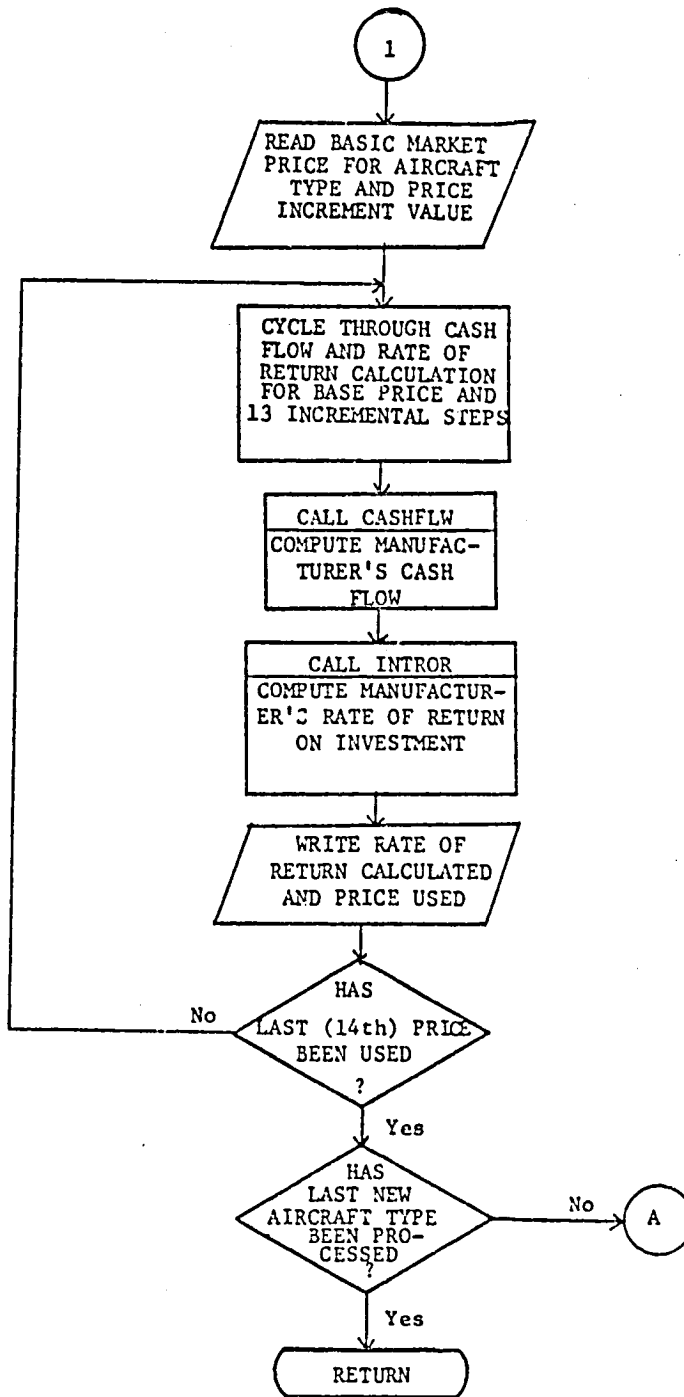


Figure 17 (Concluded)

Each time the main program BET calls INPLANT, the demand for each type of new aircraft is analyzed. The beginning and end dates of demand for each type are determined. INPLANT then calls subroutines PLANT, ACCOST, and ACPRICE to compute order, production and delivery schedules; compute manufacturing costs; and estimate market prices. Then, INPLANT calls subroutines CASHFLW and INTROR to compute the manufacturer's cash flow and rate of return on investment for the base estimated market price and 13 additional incremental price figures. INPLANT prints the demand history by year and the calculated values of price and rate of return for each new aircraft type.

#### PLANT

Subroutine PLANT determines a production schedule that best meets demand for a new aircraft type, as determined by BET. A flowchart of the program logic for PLANT is provided in Figure 18. The algorithm assumes that the manufacturer must produce aircraft at constant integer monthly rates and may change rates once during the production program. To find the breakpoint in the production program, i.e., the time the manufacturer changes production rates, each possible breakpoint in the demand period is examined. The possible breakpoints are assumed to occur at the beginning of a year. A breakpoint divides the production program into two periods. The production rate during a period is computed by dividing the number of aircraft demanded during the period by the number of months in the period.

For each possible breakpoint, the largest year-end deviation between total aircraft produced and total aircraft demanded is computed. The breakpoint with the smallest such deviation is taken as the best. The

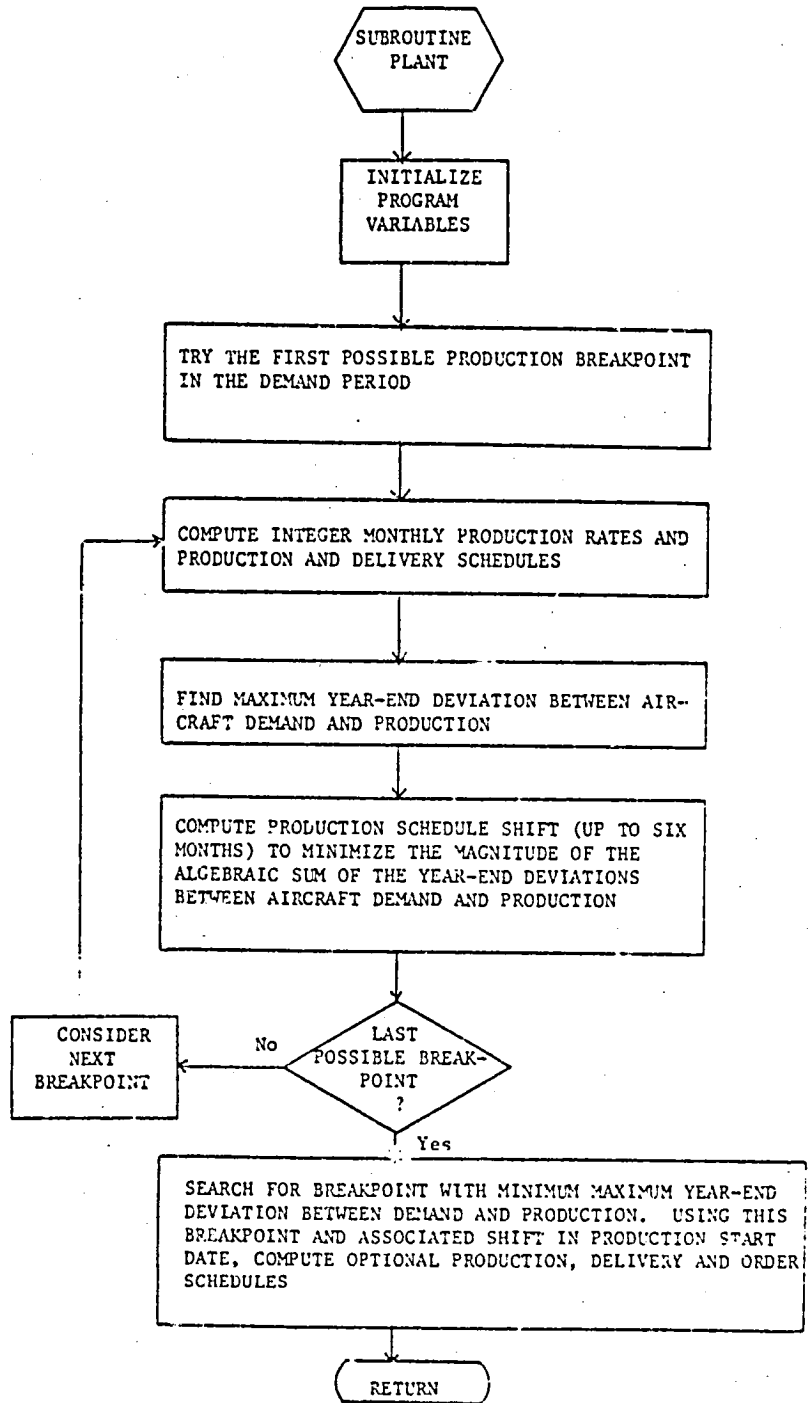


Figure 18 Flowchart of Subroutine PLANT Logic

final production schedule is determined by shifting the start of production by as much as six months. The shift is computed to minimize the magnitude of the algebraic sum of the year-end deviations between cumulative aircraft demand and production. This shifted production program is used to generate a production schedule, that is, a month of production for each aircraft demanded. In addition, an order and delivery schedule are generated. The month of delivery for an aircraft is assumed to coincide with the month of production, the month of order is assumed to precede production by 24 months.

The printed output of this subroutine include the demands and production rates for each possible breakpoint and the start of production for the best schedule.

#### ACCOST

Subroutine ACCOST consists of a set of equations that estimate RDT&E and manufacturing costs for each specific aircraft type. The program basically encodes the set of cost equations previously described in this chapter. The manufacturing costs are adjusted to take into consideration cost reductions associated with increased learning or familiarity with the production of a particular aircraft type. The cost formulae are based on aircraft characteristics (primarily system weights) and correlations with historical cost data.

A flowchart of the subroutine ACCOST logic is shown in Figure 19. The input data is read via NAMELIST statements. Many of the input parameters are initialized to a default value before the data is read. Thus, if such parameters are not specified in the input data, the default values will hold.

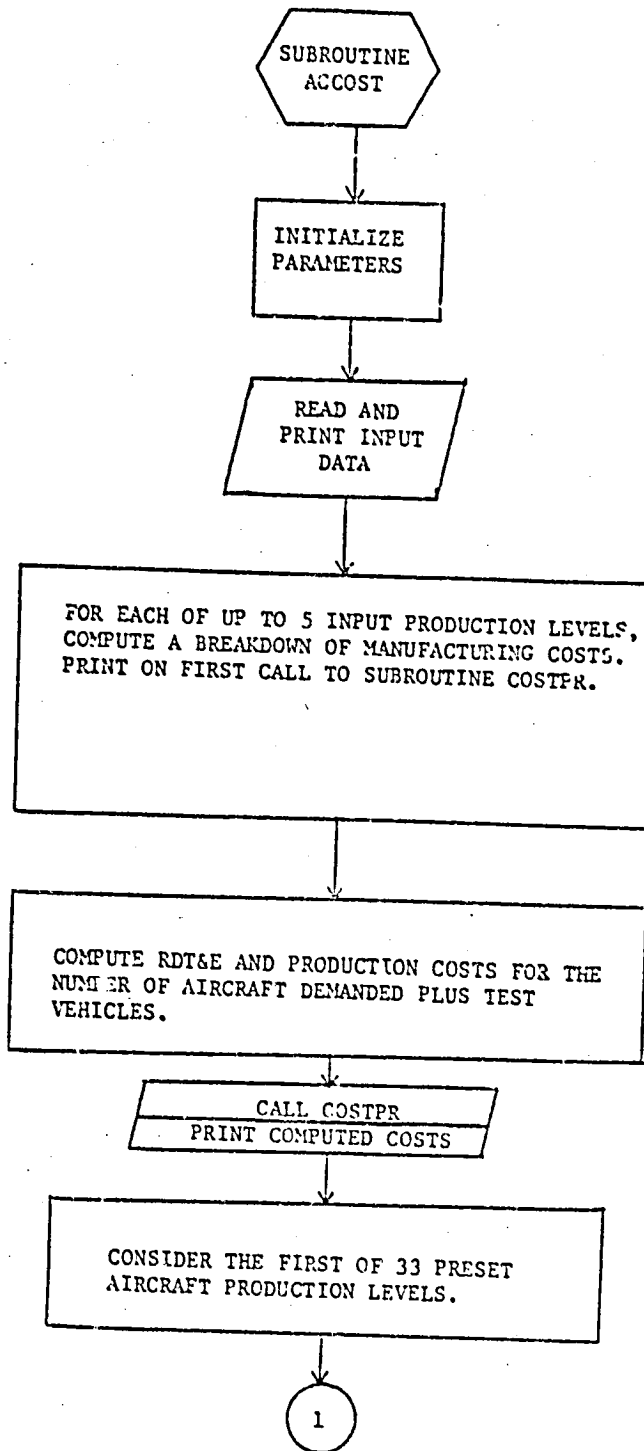


Figure 19 Flowchart of Subroutine ACCOST Logic

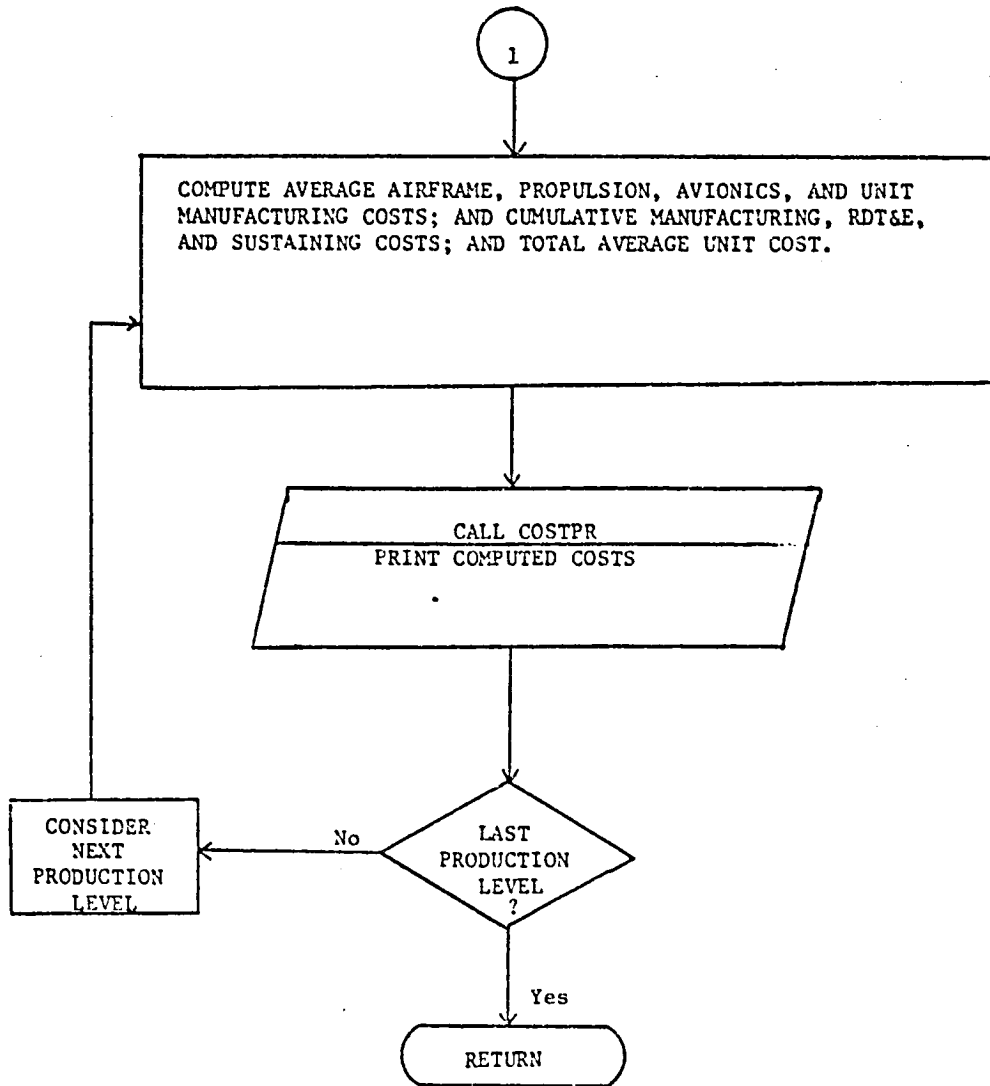


Figure 19 (Concluded)

The ACCOST program next computes and prints a breakdown of manufacturing costs for up to five user-specified production levels. This cost analysis provides information on the effect of the learning curve of production costs on a component by component basis.

The ACCOST program next does a cost analysis for the number of aircraft demanded plus the number of test vehicles as specified by the user. A breakdown of RDT&E and production cost for this case are computed and printed.

The ACCOST program next analyzes costs associated with an array of 33 potential production levels. These levels, which are set in the ACCOST code are: 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 200, 300, 400, 500, 600, 700, 800, 900, 1,000, 1,200, 1,400, 1,600, 1,800, and 2,000. For each of these production levels, average unit manufacturing costs are computed for the airframe, propulsion, and avionics systems. In addition, RDT&E and sustaining costs are computed; and total average unit cost is computed.

Subroutine COSTPR is called upon by ACCOST to print the computed costs for the various cases.

#### COSTPR

Subroutine COSTPR is called by ACCOST to print each set of computed cost figures. The flow of the program logic for COSTPR is shown in Figure 20. The first time COSTPR is called during the execution of ACCOST, a title describing the aircraft type being analyzed is read and printed. Then, the breakdown of component manufacturing costs for the five input levels of production are printed as well as the cost results for the number of aircraft demanded.

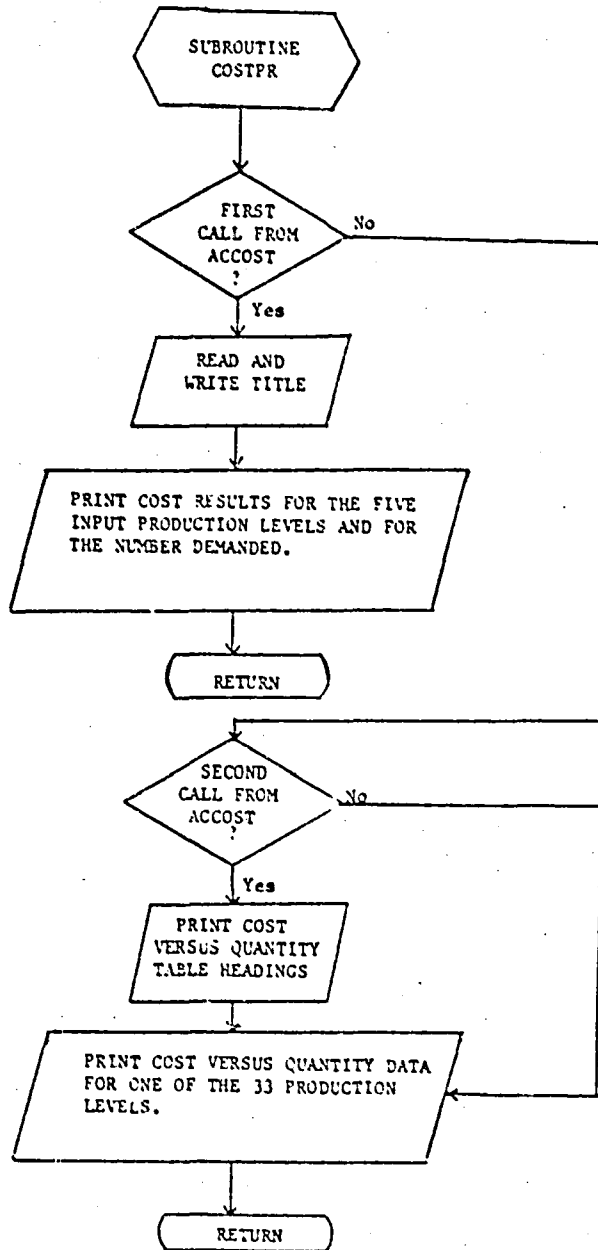


Figure 20 Flowchart of Subroutine COSTPR Logic



On the second call to COSTPR, the table for printing the cost versus quantity results is set up, and the results for the first of the 33 preset production levels is printed. Each subsequent call to COSTPR prints the cost data for one of the remaining 33 production levels.

#### ACPRICE

A flowchart for subroutine ACPRICE is shown in Figure 21. This routine incorporates the aircraft price determination equations described in Section II.B. The computed aircraft price is based upon the user input values of the following parameters: average national price/cost index, airplane type, aircraft empty weight, total passenger capacity, type of engines, number of main engines, engine design shaft horsepower, thrust per engine, total weight of engines, and year of introduction into service.

As previously mentioned, the aircraft price computed by ACPRICE is not used in the subsequent cash flow analysis. It is overridden by input of an aircraft price in subroutine INPLANT.

#### CASHFLW

Subroutine CASHFLW is called by INPLANT to estimate the net monthly cash flow that the manufacturer can expect to receive from manufacturing aircraft. A flowchart of the program logic for CASHFLW is shown in Figure 22. Each time CASHFLW is called by the driver program INPLANT, costs and revenues are spread over the months of production, and the difference between them calculated. CASHFLW calls three subroutines to spread the cost and revenue data: RDTE (RDT&E cost factors), COMPCOS (production cost factors) and REVENUE (revenue).

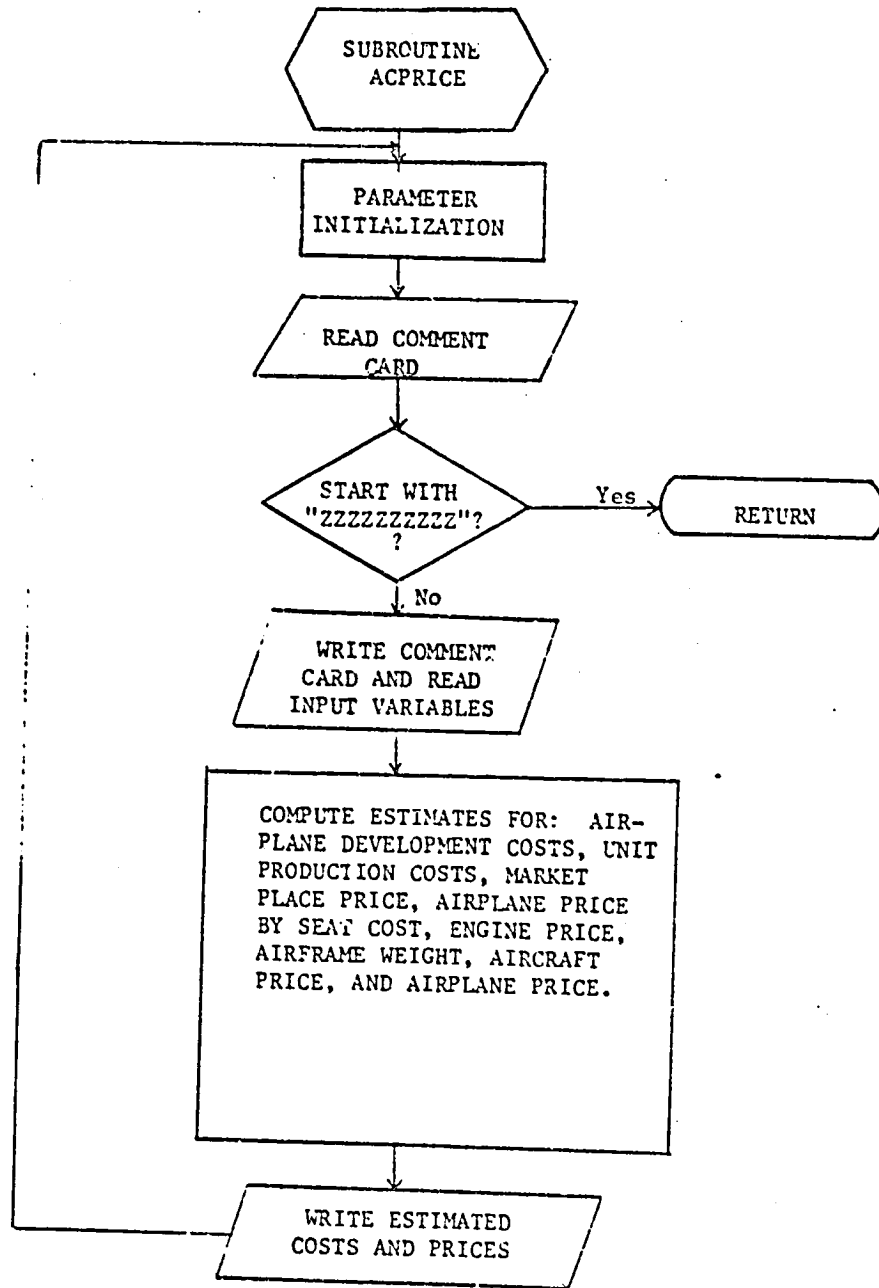


Figure 21 Flowchart of Subroutine ACPRICE Logic

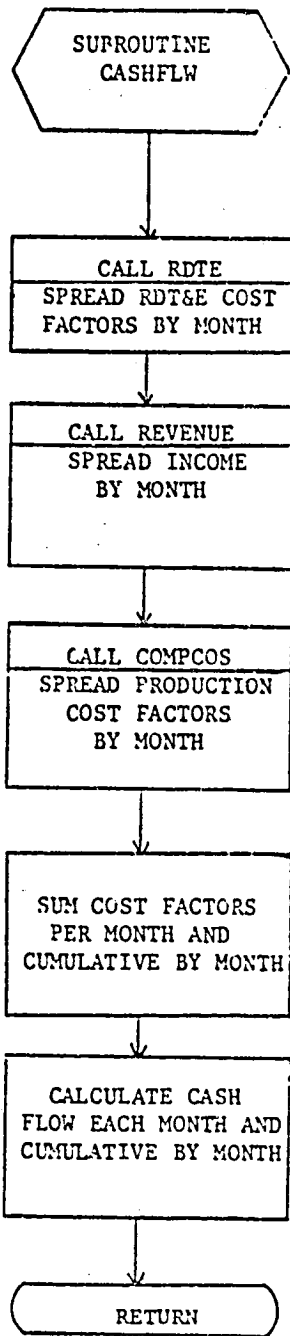


Figure 22 Flowchart of Subroutine CASHFLW Logic

### RDTE

A flowchart of subroutine RDTE logic is shown in Figure 23. This routine is called CASHFLW to distribute five RDT&E cost components over designated time periods. Airframe design and engineering costs, subsystem development costs, and avionics development costs are distributed uniformly over the 42 month period ending with the month production starts. Propulsion development costs are distributed evenly over the 52 month period ending with the month production starts. Development support costs are distributed evenly over the 42 month period ending the twelfth month after start of production.

### REVENUE

Subroutine REVENUE is called by CASHFLW to compute revenue (income) flows over time (individually and cumulatively by month) for aircraft to be produced. A flowchart of the program logic for REVENUE is shown in Figure 24. Revenue is generated by payments of 5 percent of market price on order, 70 percent on delivery, and 25 percent evenly spread in months between order and delivery.

### COMPOS

The logical flow of subroutine COMPOS is shown in Figure 25. This routine is called by CASHFLW to allocate aircraft manufacturing costs and sustaining production costs over time for all aircraft produced. Each of the cost components are allocated uniformly over a twelve month period ending on the month of production for the unit. Seven of the sustaining production cost components are taken to be equal for each unit produced, i.e., the cost per unit is computed by dividing total component cost by the number of

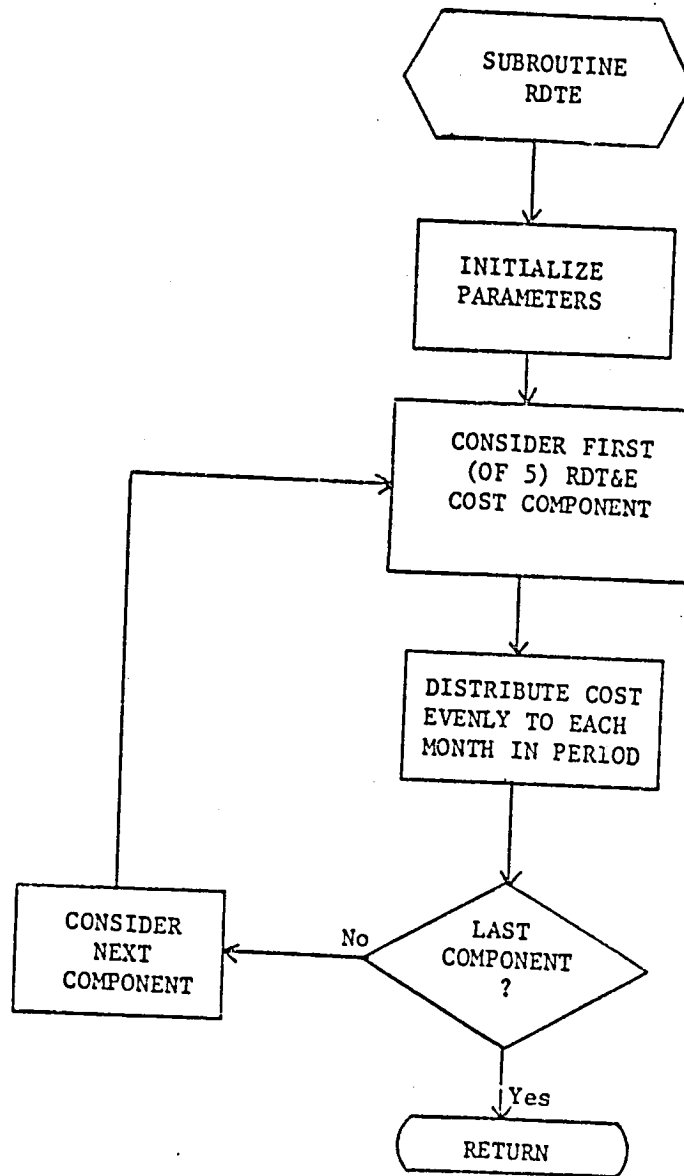


Figure 23 Flowchart of Subroutine RDTE Logic

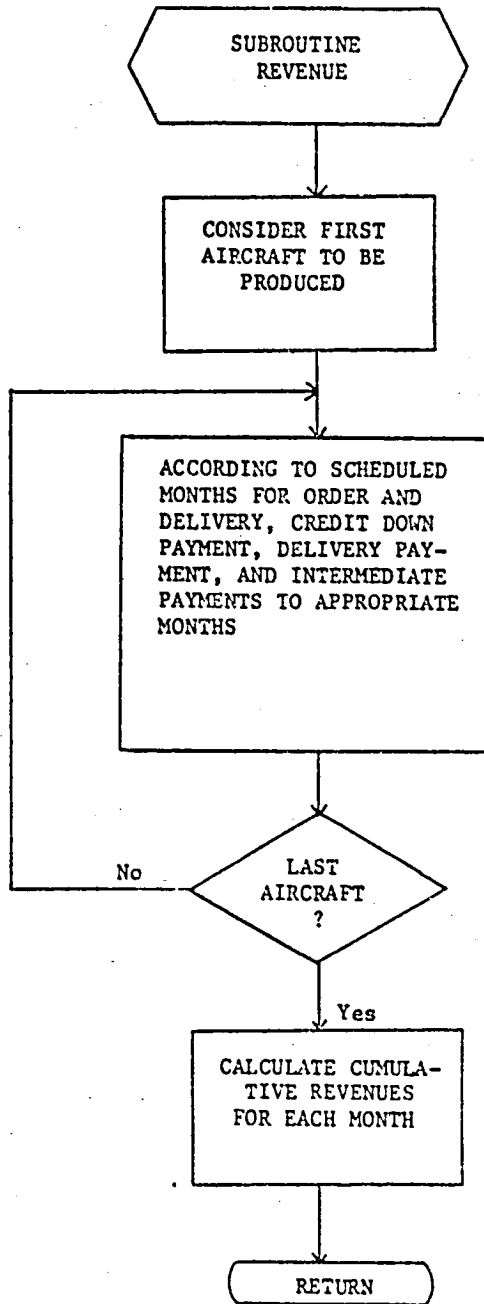


Figure 24 Flowchart of Subroutine REVENUE Logic

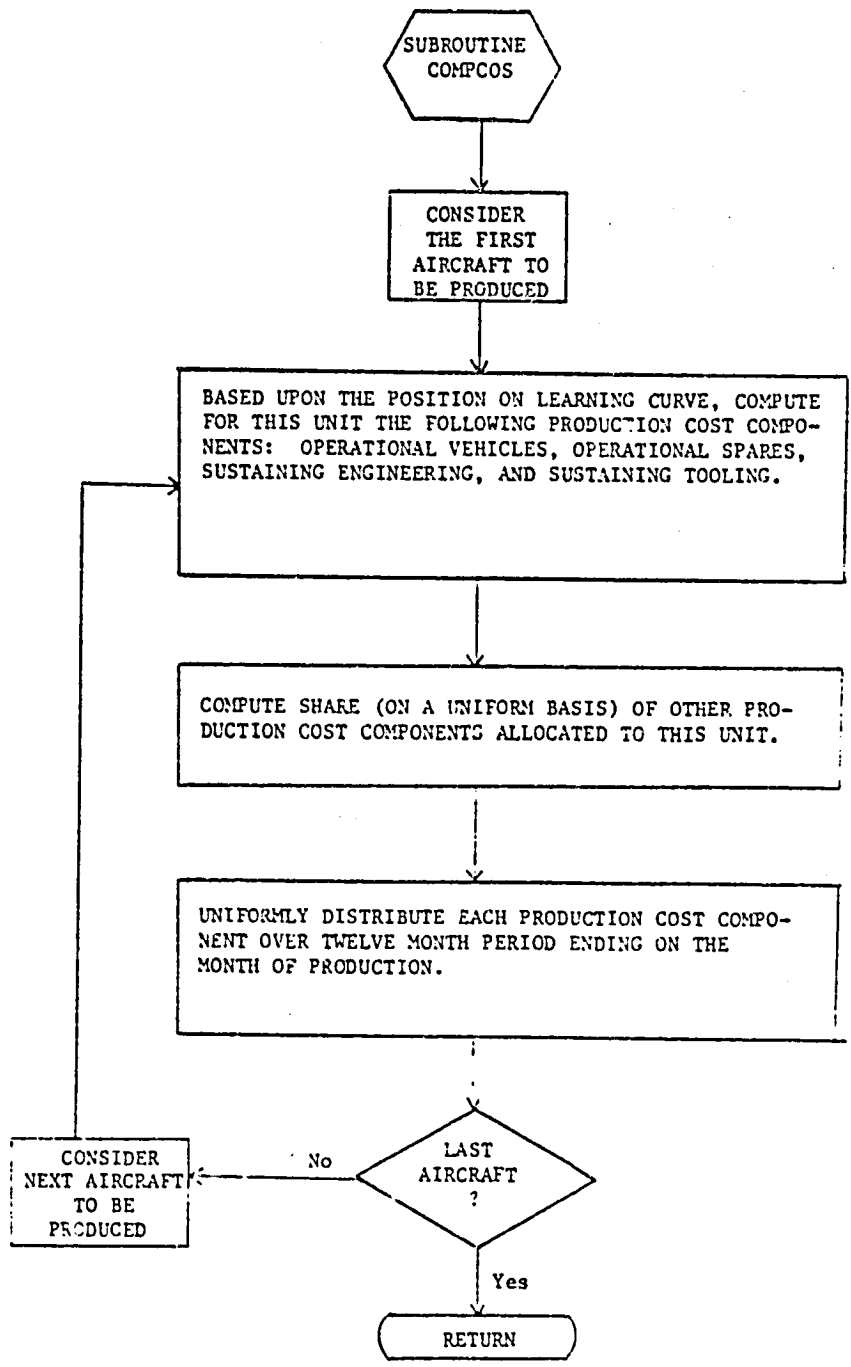


Figure 25 Flowchart of Subroutine COMCOS Logic

units produced. These costs are facilities, operational ground support equipment, production aircraft technical data, miscellaneous equipment, operational training equipment, initial flight crew training, and initial transportation. The remaining three sustaining production cost components (i.e., operational spares, sustaining engineering, and sustaining tooling), as well as aircraft manufacturing costs, are computed on a unit to unit basis depending on the current position on the learning curve.

#### INTROR

Subroutine INTROR is called by INPLANT to compute and print the internal rate of return; and to print tables of cost components (RDT&E and production), income, and cash flow for each month within the years 1975 - 2005. If the user specifies that these tables are to be printed, individual monthly figures and accumulated figures by month are printed. The subroutine INRR is called to calculate the internal return on investment based on the income and cost figures. A flowchart of the program logic for INTROR is shown in Figure 26.

#### INRR

Subroutine INRR is called by INTROR to compute and print the internal rate of return corresponding to the cash flow generated by subroutine CASHFLW. A flowchart of the program logic for INRR is shown in Figure 27.

The iterative procedure utilizes a current experimental rate of return (R) and its two iterative predecessors (RR and RRR). Also utilized is the sum of the discounted cash flow (SUM) which is biased by -0.009 to obtain K and its two iterative predecessor biased sums (KK and KKK) for test purposes. The procedure is initialized by selecting a small initial value for R (+1.E-32 or -1.E-32, depending on whether the final sum of the cash



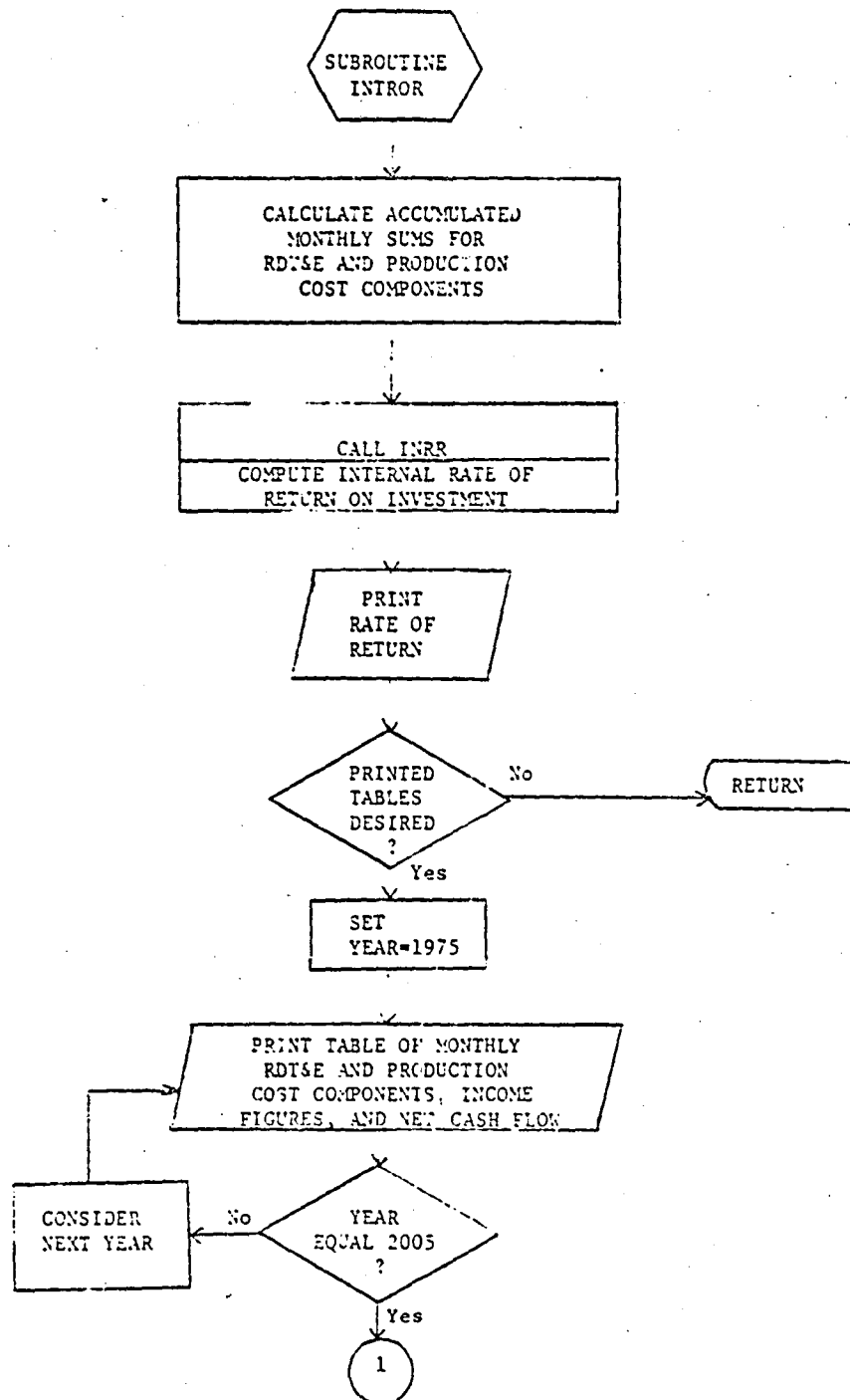


Figure 26 Flowchart of Subroutine INTROR Logic

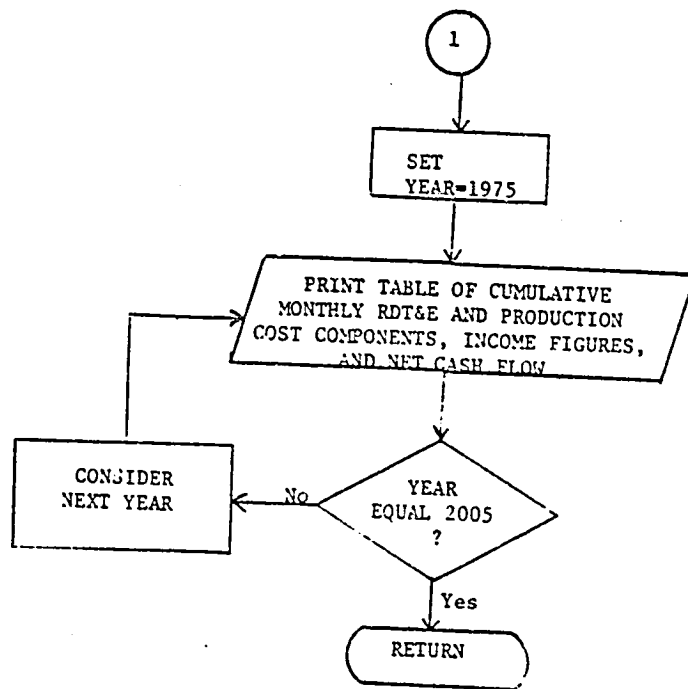


Figure 26 (Concluded)

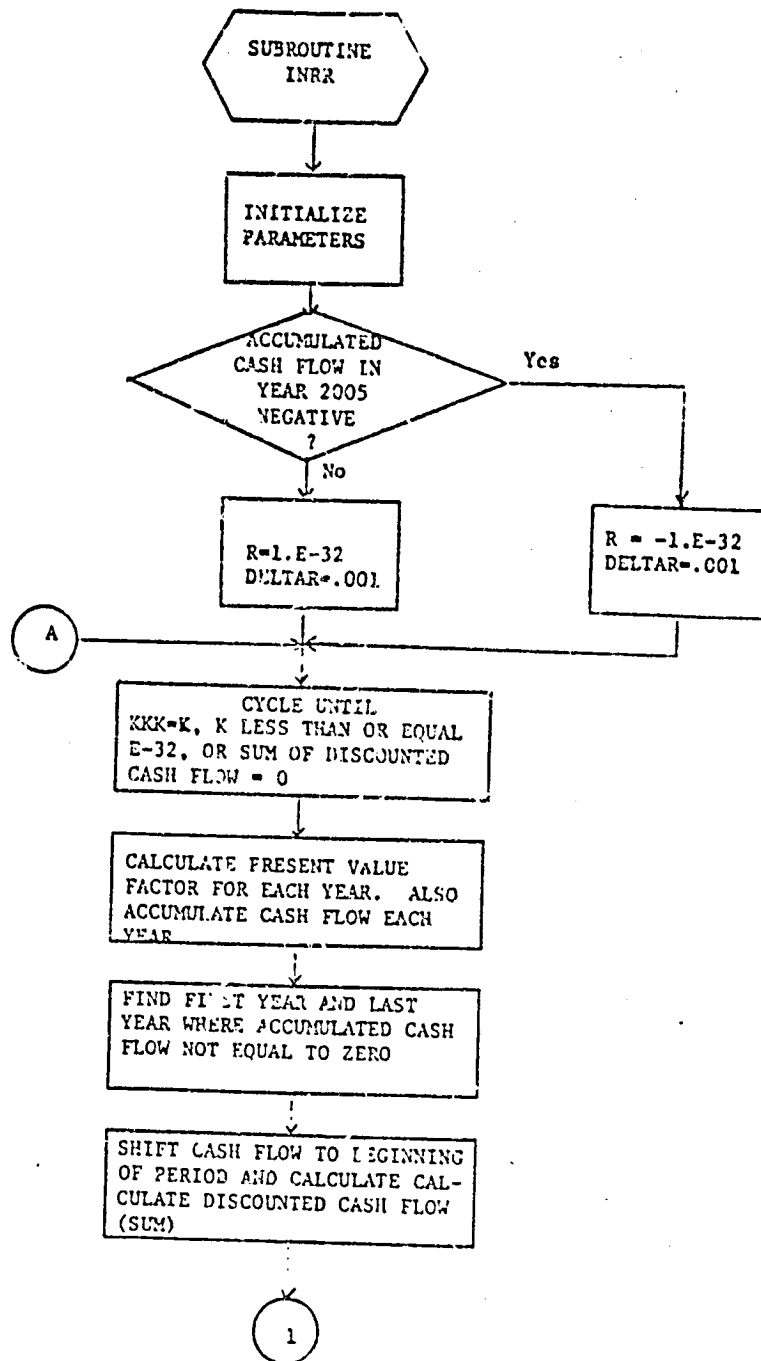


Figure 27 Flowchart of Subroutine INRR Logic

c-2

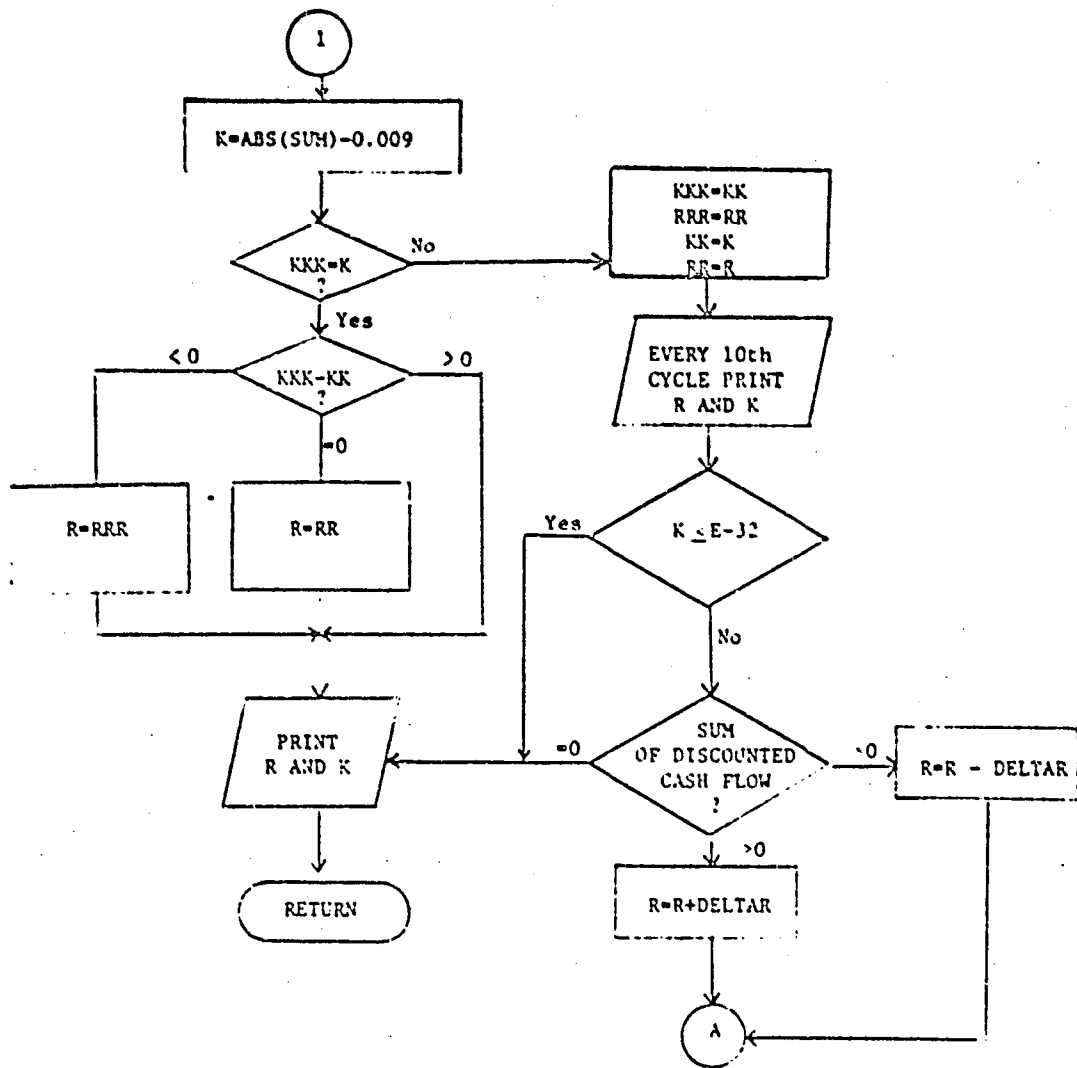


Figure 27 (Concluded)

flow is positive or negative respectively). An incremental change value for rate of return used during iteration is DELTAR (=0.001).

The iterative portion of the procedure uses the current value of R and generates the sum of the discounted present value of the cash flow under examination (SUM). The biased sum ( $K=ABS(SUM)-0.009$ ) is also calculated. If  $KKK=K$ , the iteration procedure is completed and a final test is made to select the appropriate value for R (if KK is greater than KKK, R is set equal to RRR; and if  $KK=KKK$ , R is set equal to RR). If KKK is not equal to K, the iteration procedure continues by storing the past two values of R and K (into RR and RRR, and KK and KKK, respectively). If the current value of K is less than or equal to  $1E-32$ , or if  $SUM=0$ , the procedure also terminates. Otherwise the value for R is increased or decreased by DELTAR (=0.001) depending on whether the discounted cash flow sum (SUM) is positive or negative, respectively. The iteration procedure then continues as described previously until one of the three termination conditions is met. At termination, both the values of the internal rate of return (R) and the biased sum of the discounted present value of the cash flow (K) are printed.

Additional programmer-oriented documentation is provided in the appendices. In Appendix A, definitions of the common blocks and variables are provided. A listing of the FORTRAN code for the routines is provided in Appendix D.

### C. Input

The input data to the Airframe Manufacturer Module is in card format and is read from logical units 4 and 8. The input files are originally read from input (unit 5) by Subroutine UNIT04 as called by BET. They are the first two data files in the input data. Subroutine UNIT04 writes the input file to units 4 and 8 from which they are read by the Airframe Manufacturer Module.

The input file is described in Table 10, where a description of each entry in this file is provided. Cards 1, 2, and 5 are input using the FORTRAN Namelist\* mode, which allows the input of constant values for all or only some of the variables specified by the named list. Variables and their values can appear in the input stream in any order in the form "NAME = VALUE," where NAME can be a variable name, an array name, or an array element name, and where VALUE can be a single constant or a list of constants when NAME is an array name or an array element name. Only columns 2 through 80 of the input cards may be used (column 1 must be blank). The input list begins with "\$NAMELIST" followed by at least one blank character, followed by the desired list of input variables (NAME = VALUE,), and terminated by a "\$". This format allows the selective changing of some (or all) of the input parameters, without specifying values for all the input variables as is the case with fixed format inputs.

Cards 1, 2, and 5 contain input for namelists INPUT1, INPUT2, and IN, respectively. Table 10 contains the default values for the various parameters

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\*The FORTRAN Namelist mode is a nonstandard FORTRAN feature available at most computer installations. However, exact input details may vary among installations, so appropriate reference manuals should be consulted.

which are assumed when the user does not specify a parameter value. These default values have been initialized in the program using data statements.

Cards 1 and 2 are read in by subroutine ACCOST, while card 3 is read by subroutine COSTPR. Cards 4, 5, and 6 are read by subroutine ACPRICE. The data on these six cards reside on logical unit 4. Card 8 is read by subroutine INPLANT and resides on logical unit 8.

Table 10

## CARD INPUT DATA FOR THE AIRFRAME MANUFACTURER MODULE

<u>Card</u>	<u>Default Value</u>	<u>Parameter</u>	<u>Format</u>	<u>Description</u> *
1 <sup>†</sup>	4.0	EN	Real	Number of main engines.
1	0.80	MACH	Real	Maximum design flight mach number (decimal).
1	1.0	PN	Real	Not used.
1	None	T	Real	Thrust per engine at sea level in pounds.
1	0.0	WACS	Real	Air conditioning system weight.
1	0.0	WAERO	Real	Aerodynamic control system weight.
1	0.0	WANTIC	Real	Anti-icing system weight.
1	0.0	WAVION	Real	Avionics system weight.
1	0.0	WBODY	Real	Fuselage weight.
1	0.0	WELCAD	Real	Electric power conversion and distribution system weight.
1	0.0	WENF	Real	Empennage weight.
1	0.0	WENACC	Real	Engine accessories weight.
1	0.0	WENGS	Real	Engines total weight.
1	0.0	WFUSYS	Real	Fuel system weight.
1	0.0	WFUTOT	Real	Total fuel weight.
1	0.0	WGROSS	Real	Aircraft gross takeoff weight.
1	0.0	WHANDL	Real	Load and handling system weight.
1	0.0	WHYCAD	Real	Hydraulic power conversion and distribution system weight.
1	0.0	WINST	Real	Instrument system weight.
1	0.0	WLG	Real	Alighting gear system weight.
1	0.0	WLGCON	Real	Alighting gear controls weight.
1	0.0	WLGSTR	Real	Alighting gear structure weight.
1	0.0	WLGTRS	Real	Weight of tires.
1	0.0	WLGWHL	Real	Wheels and brake weight.
1	0.0	WNACEL	Real	Engine nacelles weight.
1	0.0	WPACCO	Real	Passenger accommodations weight.
1	0.0	WPNCAD	Real	Pneumatic power and distribution system weight.



Table 10 (Continued)

<u>Card</u>	<u>Default Value</u>	<u>Parameter</u>	<u>Format</u>	<u>Description</u>
1	0.0	WPOWER	Real	Auxiliary power system weight.
1	0.0	WTREVS	Real	Thrust reverser weight.
1	0.0	WWING	Real	Wing weight.
1	0.0	WPAYL	Real	Maximum payload weight.
1	0	IWLG	Integer	Indicator for landing gear component breakdown.  (If set $\geq 1$ , then WLG is computed as the sum of WLGSTR, WLGCON, WLGWHL, and WLGTRS.)
2 <sup>5</sup>	0.10	ADI	Real	Avionics development cost (omit if this cost to be computed).
2	0.10	AGEOI	Real	Operational ground support equipment cost (omit if this cost to be computed).
2	0.10	AGEPI	Real	Ground support equipment development cost (omit if this cost to be computed).
2	1.0	CFACS	Real	Complexity factor for air conditioning system.
2	1.0	CFAERO	Real	Complexity factor for aerodynamic control system.
2	1.0	CFANTC	Real	Complexity factor for anti-icing system.
2	1.0	CFAVON	Real	Complexity factor for avionics system.
2	1.0	CFBODY	Real	Complexity factor for aircraft fuselage.
2	1.0	CFELCD	Real	Complexity factor for electrical distribution system.
2	1.0	CFEMP	Real	Complexity factor for empennage structure.
2	1.0	CFENAC	Real	Complexity factor for engine accessories.
2	1.0	CFENG	Real	Complexity factor for airbreathing engines.
2	1.0	CFFUSY	Real	Complexity factor for the fuel system.
2	1.0	CFIRNDL	Real	Complexity factor for the loadings and handling system.

Table 10 (Continued)

<u>Card</u>	<u>Default Value</u>	<u>Parameter</u>	<u>Format</u>	<u>Description</u>
2	1.0	CFHYCD	Real	Complexity factor for the hydraulic system.
2	1.0	CFINST	Real	Complexity factor for the instrument system.
2	1.0	CFLG	Real	Complexity factor for alighting gear system.
2	1.0	CFNAC	Real	Complexity factor for engine nacelles.
2	1.0	CFPACC	Real	Complexity factor for passenger accommodations.
2	1.0	CFPNCD	Real	Complexity factor for pneumatic system.
2	1.0	CFPOW	Real	Complexity factor for auxiliary power system.
2	1.0	CFTREV	Real	Complexity factor for thrust reverser.
2	1.0	CFWING	Real	Complexity factor for wing structure.
2	1.0	CONFIG	Real	Complexity factor for airframe engineering.
2	1.0	CTJI	Real	Cost per aircraft engines (omit if cost to be computed).
2	0.13	AFSPA0	Real	Airframe spares factor for production phase.
2	0.4	ENSPA0	Real	Main engine spares factor for production phase.
2	0.4	ENSPAR	Real	Main engine spares factor for RDT&E phase.
2	0.0	FACI	Real	Production facilities cost.
2	0.10	FEE	Real	Manufacturer fee factor.
2	0.10	FIOI	Real	Flight test operation cost (omit if cost to be computed).
2	0.20	FVSPAR	Real	Flight test vehicle spares factor.
2	0.10	GTSPAR	Real	Ground test vehicle spares factor.
2	6	ICONFG	Integer	Indicator for aircraft type (6=subsonic, 7=prototype, 8=supersonic).
2	1	ADATA	Integer	Not used.
2	2	IPOWER	Integer	Not used.

Table 10 (Continued)

<u>Card</u>	<u>Default Value</u>	<u>Parameter</u>	<u>Format</u>	<u>Description</u>
2	1	IPROD	Integer	Indicator (1=production, 0=prototype tooling).
2	0	IOPS	Integer	Indicator for operational program (1=commercial, 0=other).
2	80.0	LEARN	Real	Airframe learning curve factor.
2	80.0	LEARNA	Real	Avionics learning curve factor.
2	90.0	LEARNP	Real	Engine learning curve factor.
2	1	NCREW	Integer	Number in flight crew.
2	5	NDATA	Integer	Number of production levels to be analyzed (from 1 to 5).
2	1.0	NFV	Integer	Number flight test vehicles to be produced.
2	1.0	NG	Integer	Number ground test vehicles.
2	0.0	NOCON	Integer	Number of concept formulation contractors.
2	0.0	NOCON1	Integer	Number of contract definition contractors.
2	150.0	NOENG	Integer	Number of concept formulation engineers.
2	500.0	NOENGL	Integer	Number of contract definition engineers.
2	0.75	NOYRS	Integer	Number of years for concept formulation.
2	1.0	NOYRS1	Integer	Number of years for contract definition.
2	1.0	NV	Integer	Number operational vehicles demanded (as determined by BET) minus the number of flight test vehicles.
2	1.0	NVEH(I)	Integer	Production levels to be analyzed, I=1 to 5 (the input value for NVEH(1) must equal 1).
2	0.10	PDTJI	Real	Propulsion development cost (omit if cost to be computed).
2	--	RATE	Real	The value of this variable always defaults to the maximum monthly aircraft production rate determined by PLANT.
2	17.0	RE	Real	Engineering labor rate in dollars per hour.

Table 10 (Continued)

<u>Card</u>	<u>Default Value</u>	<u>Parameter</u>	<u>Format</u>	<u>Description</u>
2	15.0	RT	Real	Tooling labor rate in dollars per hour.
2	0.0	SUBSYI	Real	Subsystems development cost (omit if this cost to be computed).
2	1.0	TOOC	Real	Complexity factor for tooling.
2	0.0	XAVD	Real	Avionics development factor.
2	0.05	XFASSY	Real	Final assembly checkout cost factor.
2	0.20	XNEW	Real	Miscellaneous equipment development factor.
3	None	TITLE(8)	8A10	Title to be printed on manufacturing cost table.
4	None	COMENT(8)	8A10	Title to be printed on price estimation results table.
5**	0.06	API	Real	Average annual increase in national price/cost index.
5	None	EN	Real	Number of main engines.
5	None	FEE	Real	Not used.
5	None	IAIRPL	Integer	Indicator for airplane type, 1=conventional jet transports, 2=small jet transports, 3=wide body jet transports, 4=turboprop transports, 5=general aviation, 6=supersonic transport.
5	None	IENG5	Integer	Indicator for engine type, 1=turbojet and turbofan, 2=turboprop, 3=reciprocating, 4=airbreathing.
5	None	NVHF	Integer	Not used.
5	None	PN	Real	Total passenger capacity.
5	None	T	Real	Thrust per engine (omit if IENG ≠ 1).
5	None	WE	Real	Aircraft empty weight.
5	None	WENG5	Real	Engines total weight.
5	None	YEAR	Real	Year of introduction into service.
5	None	HP	Real	Engine design shaft horsepower (omit if IENG = 1).

Table 10 (Concluded)

<u>Card</u>	<u>Default Value</u>	<u>Parameter</u>	<u>Format</u>	<u>Description</u>
6	None	COMENT(8)	8A10	Special comment card. Enter ZZZZZZZZZZ if aircraft price estimation process is not to be repeated. Otherwise, repeat card 5 and 6 entering data to be used during next price estimation in subroutine ACPRIE for the current aircraft type.  Note: Cards 1 through 6 must be repeated for each new aircraft type, in the same order as defined in BET.
7	--			End-of-file mark.
8	None	PO	F20.0	Initial aircraft price in millions of dollars.
8	None	DELTAP	F20.0	Increment for aircraft price in millions of dollars.  Note: Card 8 must be repeated for each new aircraft type, in the same order as defined in BET.
9	--			End-of-file mark.  Note: The card input to the Fleet Accounting Module follows card 9.

\* All weights are in pounds and costs in millions of dollars, unless otherwise specified.

+ Card 1 contains input data for Namelist INPUT1. More than one card may actually be required.

5 Card 2 contains input data for Namelist INPUT2. More than one card may actually be required.

\*\* Card 5 contains input data for Namelist IN. More than one card may actually be required.

D. Output

Excerpts from the output of the sample problem (see Section V) are provided in Tables 11 through 21. These tables illustrate the types of output for the Airframe Manufacturer Module, which includes statistics on demand, production scheduling, production costs, rates of return on investment, aircraft price estimations, and individual and cumulative monthly cost, income, and cash flow data.

The output for each new aircraft type begins with a printout of the number of aircraft demanded in each of the 30 years beginning with the year the aircraft was first demanded. Then, the length of the demand period in years is printed, that is, the number of years from the first to the last year of nonzero demand. This output, which is illustrated in Table 11, is computed and printed by subroutine INPLANT.

Next, results of computations to determine the production schedule are printed by subroutine PLANT. This printout is illustrated in Table 12. For each possible yearly breakpoint of the demand period into two periods, the number of aircraft demanded and the computed monthly production rates for each of the two periods are printed. The final entries in Table 12 are the production rates determined to be best and the month computed as the best to start production (month 1 = January 1975).

The next information which is printed provides the user with the values of the parameters used in the cost computations. This information, illustrated in Tables 13 and 14, is printed by subroutine ACCOST. Table 13 contains the values of the variables in namelists INPUT1 and INPUT2. Table 14 also provides a printout of the values of many of these same variables. It also prints the value of TOVERW (aircraft thrust over weight ratio) and

Table 11

SAMPLE PRINTOUT OF AIRCRAFT DEMAND INFORMATION

0.21640402774222+ 2	0.78951008655451+02	0.38635757790141E+02	0.11417953131700E+03	0.13077581195797E+03
0.123380174425415+03	0.13514961042455E+03	0.14779342002705E+03		
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
0.	0.	0.	0.	0.
PERIOD =	6	0.	0.	0.

Table 12

SAMPLE PRINTOUT OF PRODUCTION SCHEDULING RESULTS

TOTAL DEMAND FOR FIRST PERIOD =	32		
TOTAL DEMAND FOR SECOND PERIOD =	790		
TOTAL DEMAND FOR THIS AIRCRAFT =	872		
PRODUCTION RATE FOR 1ST & 2ND PERIOD RESPECTIVELY IS =		7,	10
TOTAL DEMAND FOR FIRST PERIOD =	161		
TOTAL DEMAND FOR SECOND PERIOD =	711		
TOTAL DEMAND FOR THIS AIRCRAFT =	872		
PRODUCTION RATE FOR 1ST & 2ND PERIOD RESPECTIVELY IS =		7,	10
TOTAL DEMAND FOR FIRST PERIOD =	250		
TOTAL DEMAND FOR SECOND PERIOD =	622		
TOTAL DEMAND FOR THIS AIRCRAFT =	872		
PRODUCTION RATE FOR 1ST & 2ND PERIOD RESPECTIVELY IS =		7,	11
TOTAL DEMAND FOR FIRST PERIOD =	365		
TOTAL DEMAND FOR SECOND PERIOD =	507		
TOTAL DEMAND FOR THIS AIRCRAFT =	872		
PRODUCTION RATE FOR 1ST & 2ND PERIOD RESPECTIVELY IS =		8,	11
TOTAL DEMAND FOR FIRST PERIOD =	465		
TOTAL DEMAND FOR SECOND PERIOD =	406		
TOTAL DEMAND FOR THIS AIRCRAFT =	872		
PRODUCTION RATE FOR 1ST & 2ND PERIOD RESPECTIVELY IS =		8,	11
TOTAL DEMAND FOR FIRST PERIOD =	589		
TOTAL DEMAND FOR SECOND PERIOD =	283		
TOTAL DEMAND FOR THIS AIRCRAFT =	872		
PRODUCTION RATE FOR 1ST & 2ND PERIOD RESPECTIVELY IS =		8,	12
TOTAL DEMAND FOR FIRST PERIOD =	724		
TOTAL DEMAND FOR SECOND PERIOD =	148		
TOTAL DEMAND FOR THIS AIRCRAFT =	872		
PRODUCTION RATE FOR 1ST & 2ND PERIOD RESPECTIVELY IS =		9,	12
TOTAL DEMAND FOR FIRST PERIOD =	589		
TOTAL DEMAND FOR SECOND PERIOD =	283		
TOTAL DEMAND FOR THIS AIRCRAFT =	872		
PRODUCTION RATE FOR 1ST & 2ND PERIOD RESPECTIVELY IS =		8,	12
TIME FOR START-UP OF PRODUCTION = 157			

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Table 13  
 SAMPLE PRINTOUT OF VALUES OF VARIABLES IN NAMELISTS INPUT1 AND INPUT2

SENPITI	
EN	.2E+01,
NACH	.4E+00,
PN	.1E+01,
T	.45E+05,
WACS	.395E+04,
WAERO	.389E+04,
WANTIC	.5E+03,
WAVION	.212E+04,
WRODY	.3632E+05,
WELCAN	.252E+04,
WEM	.416E+04,
WENACC	.126E+04,
WENGS	.2611E+05,
WFUSYS	.54E+03,
WFUTOT	.4863E+05,
WGRSS	.2691E+06,
WHANDL	.1E+03,
WHYCAD	.377E+04,
WINST	.67E+03,
WLG	.1557E+05,
WLGCON	0.0,
WLGSTP	0.0,
WLGTR	0.0,
WLGWML	0.0,
WNACEL	.1129E+05,
WPAOCH	.1937E+05,
WPNCHD	0.0,
WPOWER	.206E+04,
WYDEUS	.506E+04,
WVING	.4073E+05,
WPAYL	.4573E+05,
WVCG	0,
WEND	

Table 13 (Continued)

UNITZ	
ADI	.1E+00
AGEDT	.1E+00
AGEPT	.1E+00
CFACS	.27E+01
CFAERN	.05E+00
CFANTC	.1E+02
CFAYON	.2E+01
CFRODY	.7E+00
CFELCO	.8E+00
CFENP	.19E+01
CFENAC	.4E+00
CFENG	.1E+01
CFRUSY	.1E+00
CFHNDL	.1E+02
CFNYCH	.55E+00
CFINST	.7E+00
CFLG	.7E+00
CFNAC	.1E+02
CFPACC	.11E+01
CFPACD	.1E+01
CFPOW	.32E+01
CFTRV	.1E+01
CFVING	.9E+00
CONFIC	.1E+01
CTJI	.1E+01
ENSPAD	.13E+00
ENSPAD	.4E+00
ENSPAR	.4E+00
FACT	0.0
FEE	0.0
FTOI	.1E+00

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Table 13 (Concluded)

FVSPAR	=	.7E+00,
GTSPAR	=	.1E+00,
ICONFR	=	6,
IDATA	=	1,
IPOWER	=	2,
IIRON	=	1,
IOPS	=	0,
LEARN	=	.8105E+02,
LEARNA	=	.9185E+02,
LEARNP	=	.8818E+02,
NCREW	=	.3E+01,
NOATA	=	5,
NFV	=	.9E+01,
NG	=	.1E+01,
NOCON	=	0.0,
NOCON1	=	0.0,
NOENG	=	.15E+03,
NOENGI	=	.5E+03,
NOYRS	=	.75E+00,
NOYRS1	=	.1E+01,
NV	=	.907E+03,
NVEM	=	.1E+01, .5E+01, .1E+03, .3E+03, .5E+03,
POTJT	=	.1E+00,
RATE	=	.12E+02,
RE	=	.17E+02,
RY	=	.15E+02,
SUASVT	=	0.0,
YDLC	=	.1E+01,
YAVD	=	0.0,
YFASV	=	.5E+01,
YNEW	=	.2E+00,
YEND		

Table 14  
 SAMPLE PRINTOUT OF PROGRAM VARIABLES

MVE4 =	1.0	5.0	100.0	300.0	600.0						
MOATA =	5	ICONFG = 6	IDATA = 1	IPOWER = 2	IPROG = 1						
ADI =	.100	AG =	1.000	CONFIG =	1.000	LEARN =	81.856	NOCOM =	0.300	NOCOM1 =	0.000
FACI =	0.000	NV =	867.000	ENSPAD =	.400	LEARN# =	88.186	NDEMG =	150.000	NOENGI =	300.000
FEE =	0.000	RE =	17.000	ENSPAR =	.400	LEARN#A =	91.850	NOYRS =	.750	NYRPS1 =	1.000
FACH =	.800	RT =	15.000	FTOI =	.100	NFY =	5.000	XNEW =	.200	YAYD =	6.000
RATE =	12.000			IODLG =	1.000	CFAC1 =	2.700	XFASSY =	.000		
AREPI =	.100	FVSPAR =	.200	POTJ =	0.000	SUBSYS =	0.000	INPS =	0	PH =	1.000
AGEPI =	.100	GTSPAR =	.200	POTJI =	.100	SUBSYI =	0.000	HCREW =	3.000		
CFAEPO =	.650	CFANTC =	1.000	CFAYON =	1.000	CFANDY =	.700	CFELCO =	.000		
CFEMG =	1.000	CFEMP =	1.900	CFEMAC =	.400	CFMYCO =	.550	CFEUSY =	.100		
CFINST =	.700	CFLG =	.700	CFEMAC =	1.000	CFMCO =	1.000	CFPOW =	3.200		
CFMMDL =	1.000	CFTRV =	1.000	CFWING =	.900	CFPACC =	3.100	CFACS =	2.000		
TQYER# =	.33545E+04	EM =	.20000E+01								
Z =	49000.0	MACH =	.800	NV =	867.000	NFY =	5.000	EM =	2.000		
ENSPAR =	.400	ENSPAD =	.400	AFSPAD =	.100						
POTJ =	.45632E+03										

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the propulsion development cost (PDTJ) for the number of new aircraft demanded (NV + NVF).

Tables 15 through 17 illustrate results of the airframe manufacturer cost analyses performed in subroutine ACCOST. The tables are printed in subroutine COSTPR. The costs presented in these tables are computed by using the airframe manufacturer cost equations given in Section III.A (Cost Determination).

Table 15 contains computed aircraft manufacturing cost components for each of the production levels (up to five) input by the user (input variable NVEH(I)). These costs do not include the manufacturer's fee. Table 16 provides a breakdown of research, development, test, and evaluation costs; aircraft manufacturing costs; and sustaining production costs for the number of vehicles demanded (NV + NVF). In addition, a breakdown of first unit aircraft manufacturing costs are provided.

Table 17 provides cost versus quantity data. At the top of this table, several program variables are printed. Then, costs are printed for various levels of production. The first column shows that number of vehicles corresponding to the data in that row. The second, third, and fourth columns show average unit manufacturing costs for the airframe, propulsion, and avionics systems, respectively. The fifth column, unit cost, is the sum of the previous three columns plus final assembly and checkout costs and manufacturer's fee. Cumulative manufacturing costs are shown in column six, while total (including fee) RDT&E costs and sustaining costs are shown in columns seven and eight, respectively. The final column shows the average total cost per unit (the sum of the previous three columns divided by the number of aircraft).

Table 15

## SAMPLE PRINTOUT OF AIRCRAFT MANUFACTURING COST COMPONENTS BY PRODUCTION LEVEL

REDUCED ENERGY PROP-FAN (767-762)

NUMBER OF VEHICLES	BREAKDOWN OF CUMULATIVE MANUFACTURING COST, MILLIONS OF DOLLARS				
	1.	5.	100.	300.	600.
WING	3.8870	12.2074	102.7366	224.3900	367.3101
EMPELLAGE	1.1293	3.5466	29.9476	65.1892	106.7132
BODY STRUCTURE	4.4739	14.4505	110.2484	259.2594	422.7690
LANDING GEAR	1.3534	4.2503	35.7706	79.1229	127.8872
WING, PODS, PYLONS, SUPPORTS	3.7734	11.8504	99.7324	217.8109	356.5696
PROPULSION SYSTEM	( 5.9827) (	22.3368) (	259.3843) (	637.4977) (	1124.2909)
ENGINES	3.4311	12.8103	148.7593	365.6107	644.7911
THRUST REVERSER	2.4662	9.2377	106.9238	262.7902	463.4568
FUEL SYSTEM	.0050	.6148	.1719	.4221	.7445
ENGINE ACCESSORIES	.3814	.3039	3.5295	9.6746	15.2985
AERODYNAMIC CONTROLS (SURFACE CONTROLS)	1.6114	3.1764	26.7320	58.3934	95.5739
HYDRAULIC	.5947	1.8677	15.7186	34.3310	56.1983
ELECTRICAL POWER CONVERSION AND DISTRIBUTION	.6354	1.9954	16.7934	36.6773	60.4407
PNEUMATIC	0.0063	0.0066	0.0060	0.0077	0.0060
AIR CONDITIONING	.9932	3.1192	26.2511	57.3334	93.8547
ANTI-ICING	.1150	.3612	3.0395	6.6344	16.8671
AUXILIARY POWER SOURCE	1.6019	5.0307	42.3352	92.4643	151.3700
PASSENGER ACCOMMODATIONS	6.9354	21.6968	182.5147	393.6195	652.5377
INSTRUMENTATION	( .4897) (	1.5344) (	12.9165) (	29.2193) (	46.1803)
EQUIPMENT	.4526	1.4214	11.9521	26.1757	42.7678
INSTALLATION	.0361	.1134	.9645	2.0436	3.4126
AVIONICS	( 2.2090) (	6.9376) (	58.3965) (	127.5193) (	208.7469)
EQUIPMENT	2.0458	6.4249	54.0719	119.0940	193.3213
INSTALLATION	.1632	.5127	4.3145	9.4253	15.4256
LOAD AND HANDLING	.4123	.6387	.3256	.7111	1.1640
FINAL ASSEMBLY AND CHECKOUT	1.7583	5.6995	92.5369	114.1077	194.1037
VEHICLE TOTAL	36.9249	119.6498	1092.2724	2439.2519	4676.1772

Table 16  
 SAMPLE PRINTOUT OF COST BREAKDOWN FOR NUMBER OF VEHICLES DEMANDED

		COST (MILLIONS OF DOLLARS)	
<b>RESEARCH, DEVELOPMENT, TEST, AND EVALUATION</b>			
AIRFRAME DESIGN AND ENGINEERING DEVELOPMENT			1279.84
CONCEPT FORMULATION		0.00	223.73
CONTRACT DEFINITION		0.00	
AIRFRAME ENGINEERING		223.73	
SUBSYSTEMS DEVELOPMENT			129.12
AVIONICS DEVELOPMENT			0.00
PROPULSION DEVELOPMENT			466.32
DEVELOPMENT SUPPORT			452.68
GROUND TEST VEHICLES ( 1.0)		26.49	
GROUND TEST SPARES		2.65	
FLIGHT TEST SPARES		23.94	
TOOLING AND SPECIAL TEST EQUIPMENT		342.15	
FLIGHT TEST OPERATIONS		32.92	
GROUND SUPPORT EQUIPMENT		29.14	
TECHNICAL DATA		2.39	
FEE			0.00
<b>(MANUFACTURING--FIRST UNIT)</b>			
AIRFRAME		( 26.49)	36.92
AVIONICS PROCUREMENT		( 2.70)	
PROPULSION PROCUREMENT		( 5.98)	
FINAL ASSEMBLY AND CHECKOUT		( 1.75)	
<b>AIRCRAFT PRODUCTION,</b>			
OPERATIONAL VEHICLES ( 872.0)			8774.91
SPARES			3280.59
FACILITIES			951.79
SUSTAINING ENGINEERING			0.00
SUSTAINING TOOLING			642.80
GROUND SUPPORT EQUIPMENT			540.71
TECHNICAL DATA			807.09
MISCELLANEOUS EQUIPMENT			107.61
TRAINING EQUIPMENT			10.46
INITIAL TRAINING			36.24
INITIAL TRANSPORTATION			251.60
FEE			35.93
			0.00
<b>TOTAL COST</b>			
<b>TOTAL NUMBER OF FLIGHT VEHICLES PRODUCED</b>			10953.75
<b>AVERAGE UNIT AIRPLANE COST</b>			872.00
			11.93

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Table 17  
 SAMPLE PRINTOUT OF COSTS VERSUS PRODUCTION LEVEL

AIRPLANE COST VERSUS QUANTITY

AMPR WEIGHT (LBS)		144310.		MACH NO.		.80		TAKE-OFF GROSS WT. (LBS)		269100.	
NO. AIRCRAFT		067.		PRODUCTION RATE AC/MO		12.00		TEST AC		5.	
				PROGRAM TYPE		PRODUCTION		PERCENT PROFIT		0.0	
QUANTITY	AVERAGE MANUFACTURING COSTS			UNIT COST	CUMULATIVE	R O T A E COSTS	SUSTAINING COSTS	AVERAGE COST			
	AIRFRAME	PROPULSION	AVIONICS								
1	26.4862	5.9827	2.6977	35.92							
2	21.6789	5.2735	2.2081	32.82	36.92	1049.46	17.87	1104.26			
3	19.2822	4.9013	1.9640	27.45	61.24	1066.57	35.61	611.66			
4	17.7442	4.5520	1.8073	25.41	82.35	1078.97	147.55	435.63			
5	16.6362	4.4674	1.6945	23.94	101.65	1094.69	187.00	343.56			
6	15.7825	4.3220	1.6075	22.80	119.69	1090.83	221.49	285.40			
7	15.0750	4.2027	1.5375	21.88	136.79	1095.95	250.59	247.22			
8	14.5236	4.1021	1.4793	21.11	153.14	1100.36	276.47	218.57			
9	14.0377	4.0154	1.4298	20.46	168.89	1104.22	299.02	195.63			
10	13.6168	3.9393	1.3869	19.89	184.11	1107.68	321.44	179.25			
20	11.1453	3.4737	1.1352	16.54	193.90	1110.91	341.41	165.11			
30	9.9131	3.2273	1.0097	14.86	230.84	1132.22	492.84	97.79			
40	9.1224	3.0631	.9292	13.77	445.75	1145.45	601.89	73.10			
50	8.5528	2.9415	.8711	12.98	550.82	1155.16	691.37	59.93			
60	8.1139	2.8458	.8284	12.38	649.19	1162.50	769.17	51.63			
70	7.7604	2.7673	.7904	11.88	742.53	1169.34	839.07	45.82			
80	7.4667	2.7010	.7605	11.47	831.89	1174.89	903.22	41.57			
90	7.2169	2.6439	.7351	11.13	917.97	1179.76	962.94	38.26			
100	7.0005	2.5938	.7130	10.82	1001.31	1184.11	1019.13	35.61			
200	5.7299	2.2873	.5836	7.63	1082.27	1190.06	1072.43	33.43			
300	5.0964	2.1250	.5191	8.13	1805.15	1215.00	1512.46	22.67			
400	4.6849	2.0169	.4777	7.54	2438.26	1231.65	1866.69	17.46			
500	4.3971	1.9360	.4479	7.12	3017.49	1243.88	2178.62	16.10			
600	4.1714	1.8738	.4249	6.79	3560.44	1253.62	2464.10	14.56			
700	3.9997	1.8221	.4064	6.53	4176.13	1261.73	2731.01	13.45			
800	3.8397	1.7785	.3910	6.31	4570.37	1268.71	2983.94	12.60			
900	3.7103	1.7409	.3779	6.12	5046.88	1274.84	3225.83	11.93			
1000	3.5990	1.7079	.3666	5.96	5504.45	1280.32	3458.71	11.30			
1200	3.4143	1.6523	.3478	5.69	5957.17	1285.28	3684.04	10.93			
1400	3.2656	1.6067	.3326	5.47	6422.15	1293.97	4116.19	9.62			
1600	3.1420	1.5684	.3233	5.28	7651.25	1301.45	4528.51	9.62			
1800	3.0308	1.5351	.3093	5.13	8450.87	1308.63	4925.04	9.14			
2000	2.9458	1.5060	.3000	4.99	9225.61	1313.90	5319.59	8.96			
					9975.92	1319.21	5681.18	8.49			

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Printed results of the aircraft price estimation process appear next in the output. These results are illustrated in Table 18. They are computed and printed by subroutine ACPRICE. The methodology described in Section III.A (Aircraft Price Determination) are used to compute these results.

The next printed information is illustrated in Table 19. This table contains the following:

- The first line (printed by subroutine COMPCOS) contains 11 cost components (in millions), including the first unit manufacturing cost plus sustaining costs OS, FAC, SE, ST, AGEO, TDO, MEQ, OT, IT, and TRI for NV + NFV vehicles.
- The next 21 lines are the trial rates of return and residuals (one line for every 10th cycle) from the estimation of interval rate of return by subroutine INRR, the last line indicating the final value estimated.
- The next line is the restatement by subroutine INTROR of the rate of return determined by the iteration process of subroutine INRR.
- Finally, the last line is output by subroutine INPLANT and shows the determined rate of return and the aircraft price (millions of dollars) for which this rate of return was computed.

Fourteen tables such as that illustrated in Table 19 are printed. The first for the input value of base aircraft price (PO). The others are for aircraft prices determined by incrementing the price upward by the input price increment (DELTA P).

Table 18  
SAMPLE PRINTOUT OF AIRCRAFT PRICE ESTIMATION RESULTS

ESTIMATED AIRPLANE DEVELOPMENT COST, MILLIONS	2372.5557
ESTIMATED AIRPLANE UNIT PRODUCTION COST, MILLIONS	27.5434
ESTIMATED AIRPLANE MARKET PLACE PRICE	19.1750
ESTIMATED AIRPLANE PRICE BY SEAT COST, MILLIONS, (ESAPRI(1))	13.0379
ESTIMATED ENGINES TOTAL PRICE	3.0000
ESTIMATED AIRFRAME PRICE	25.9882
AIRFRAME WEIGHT	145570.0000
ESTIMATED AIRPLANE PRICE	25.9882

Table 19  
 SAMPLE PRINTOUT OF INTERNAL RATE OF RETURN RESULTS

Rate	Value
.3692E+02	4122.9252510
.9518E+03	4334.4032739
.6429E+J3	4557.3094323
.5407E+C3	4795.8649175
.8071E+03	5051.3944698
.1076E+03	5325.3483609
.1046E+02	5610.2116433
.3624E+02	5935.0202430
.2616E+03	6274.3712457
.3593E+02	6639.4384762
	7032.4887953
	7455.9869431
	7912.6392197
	8405.3424083
	8937.2963988
	9527.9202282
	10132.5052743
	10804.2013654
	11522.0077144
	12314.7467657
	13163.0198773
	14079.5354674
	15058.9998731
	16135.9570582
	17284.5556079
	18518.2393180
	19839.2625216
	21249.0967792
	22742.5503967
	24316.5928047
	25958.7473681
	27649.8967747
	29360.3037796
	31045.5584458
	32841.0676870
	34054.5566477
	35155.8521650
	35762.9401343
	35622.9989547
	34385.7632592
	31568.5982796
	26505.9665889
	18281.4031161
	5632.2691395
	729.8042870

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Next, 31 tables similar to those illustrated in Table 20 are printed, one for each year from 1975 through 2005. For each month of the year, this table shows, in millions of dollars, five RDT&E cost components (ADEE, SUBSYS, AD, PDTJ, DS), manufacturer's income (i.e., revenue), aircraft manufacturing cost (OV), ten sustaining production cost components (OS, FAC, SE, ST, AGEO, TDO, MEQ, OT, IT, TRI), and cash flow for the demand schedule and number of vehicles demanded.

Finally, 31 tables similar to that illustrated in Table 21 are printed. These tables are identical to the previously described tables except they provide cumulative data instead of individual monthly data. After the last of these tables, the rate of return on investment for the last aircraft price and the last aircraft price are printed. The tables illustrated in Tables 20 and 21 are printed by subroutine INTROR.

The output described above is printed successively for each new aircraft type.

Table 20  
 SAMPLE PRINTOUT OF INDIVIDUAL MONTHLY COST, INCOME, AND CASH FLOW DATA

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
AIRFHOE1992	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SUSSYSD1992	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
AVOATCS1992	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PROPULS1992	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
DEVELOP1992	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
INCOME 1992	1.607E+02	1.500E+02	1.574E+02	1.73E+02	1.542E+02	1.651E+02	1.666E+02	1.668E+02	1.677E+02	1.686E+02	1.694E+02	1.703E+02
MANUF 1992	4.410E+01	4.389E+01	4.368E+01	4.38E+01	4.329E+01	4.339E+01	4.290E+01	4.272E+01	4.254E+01	4.235E+01	4.217E+01	4.202E+01
SPARES 1992	7.906E+00	7.872E+00	7.838E+00	7.805E+00	7.773E+00	7.741E+00	7.710E+00	7.680E+00	7.651E+00	7.622E+00	7.593E+00	7.566E+00
FACILITY1992	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SUSENGR1992	2.840E+00	2.797E+00	2.756E+00	2.717E+00	2.678E+00	2.641E+00	2.605E+00	2.570E+00	2.536E+00	2.503E+00	2.471E+00	2.440E+00
SUSTODL1992	2.115E+00	2.081E+00	2.049E+00	2.017E+00	1.986E+00	1.956E+00	1.920E+00	1.900E+00	1.873E+00	1.847E+00	1.821E+00	1.797E+00
GSEQUIP1992	7.404E+00	7.404E+00	7.404E+00	7.404E+00	7.404E+00	7.404E+00	7.404E+00	7.404E+00	7.404E+00	7.404E+00	7.404E+00	7.404E+00
TECHDAT1992	9.873E-01	9.873E-01	9.873E-01	9.873E-01	9.873E-01	9.873E-01	9.873E-01	9.873E-01	9.873E-01	9.873E-01	9.873E-01	9.873E-01
MISCQUI1992	9.600E-02	9.600E-02	9.600E-02	9.600E-02	9.600E-02	9.600E-02	9.600E-02	9.600E-02	9.600E-02	9.600E-02	9.600E-02	9.600E-02
TRAINED1992	3.325E-01	3.325E-01	3.325E-01	3.325E-01	3.325E-01	3.325E-01	3.325E-01	3.325E-01	3.325E-01	3.325E-01	3.325E-01	3.325E-01
TYILTRAI1992	2.400E+00	2.400E+00	2.400E+00	2.400E+00	2.400E+00	2.400E+00	2.400E+00	2.400E+00	2.400E+00	2.400E+00	2.400E+00	2.400E+00
TYILTRAI1992	3.296E-01	3.296E-01	3.296E-01	3.296E-01	3.296E-01	3.296E-01	3.296E-01	3.296E-01	3.296E-01	3.296E-01	3.296E-01	3.296E-01
CASHFLOW1992	9.149E+01	9.181E+01	8.912E+01	9.578E+01	9.694E+01	9.810E+01	9.926E+01	1.004E+02	1.015E+02	1.027E+02	1.038E+02	1.049E+02

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Table 21

SAMPLE PRINTOUT OF CUMULATIVE MONTHLY COST, INCOME, AND CASH FLOW DATA

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
AIRFMD1992	2.237E+02	2.237E+02	2.237E+02	2.237E+02	2.237E+02	2.237E+02	2.237E+02	2.237E+02	2.237E+02	2.237E+02	2.237E+02	2.237E+02
SURVYSO1992	1.291E+02	1.291E+02	1.291E+02	1.291E+02	1.291E+02	1.291E+02	1.291E+02	1.291E+02	1.291E+02	1.291E+02	1.291E+02	1.291E+02
AVONICS1992	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
PRNPULS1992	4.663E+02	4.663E+02	4.663E+02	4.663E+02	4.663E+02	4.663E+02	4.663E+02	4.663E+02	4.663E+02	4.663E+02	4.663E+02	4.663E+02
DEVELOP1992	4.597E+02	4.597E+02	4.597E+02	4.597E+02	4.597E+02	4.597E+02	4.597E+02	4.597E+02	4.597E+02	4.597E+02	4.597E+02	4.597E+02
INCOME 1992	8.352E+03	8.512E+03	8.669E+03	8.832E+03	8.997E+03	9.162E+03	9.328E+03	9.494E+03	9.662E+03	9.831E+03	1.000E+04	1.017E+04
MANUF 1992	3.171E+03	3.215E+03	3.259E+03	3.303E+03	3.346E+03	3.389E+03	3.432E+03	3.475E+03	3.517E+03	3.559E+03	3.602E+03	3.644E+03
SPARES 1992	5.521E+02	5.600E+02	5.678E+02	5.756E+02	5.834E+02	5.911E+02	5.989E+02	6.065E+02	6.142E+02	6.221E+02	6.294E+02	6.370E+02
FACILITY1992	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.	0.
SUSSEMS1992	5.277E+02	5.305E+02	5.332E+02	5.359E+02	5.386E+02	5.413E+02	5.439E+02	5.464E+02	5.490E+02	5.515E+02	5.539E+02	5.564E+02
SUSTOOL1992	4.568E+02	4.599E+02	4.629E+02	4.659E+02	4.689E+02	4.719E+02	4.748E+02	4.776E+02	4.804E+02	4.832E+02	4.860E+02	4.888E+02
STEADY1992	3.961E+02	4.035E+02	4.109E+02	4.184E+02	4.258E+02	4.332E+02	4.406E+02	4.480E+02	4.554E+02	4.628E+02	4.702E+02	4.776E+02
TECHDAT1992	5.282E+01	5.381E+01	5.479E+01	5.578E+01	5.677E+01	5.775E+01	5.874E+01	5.973E+01	6.072E+01	6.170E+01	6.269E+01	6.368E+01
MISCEQUI1992	5.136E+00	5.232E+00	5.328E+00	5.424E+00	5.520E+00	5.616E+00	5.712E+00	5.808E+00	5.904E+00	6.000E+00	6.096E+00	6.192E+00
TRAINED1992	1.779E+01	1.812E+01	1.845E+01	1.879E+01	1.912E+01	1.945E+01	1.978E+01	2.012E+01	2.045E+01	2.078E+01	2.111E+01	2.145E+01
LITILTRM1992	1.204E+02	1.300E+02	1.332E+02	1.356E+02	1.380E+02	1.404E+02	1.428E+02	1.452E+02	1.476E+02	1.500E+02	1.524E+02	1.548E+02
LITILTR41992	1.764E+01	1.797E+01	1.830E+01	1.862E+01	1.895E+01	1.928E+01	1.961E+01	1.994E+01	2.027E+01	2.060E+01	2.093E+01	2.126E+01
CASHFLOW1992	1.747E+03	1.839E+03	1.928E+03	2.024E+03	2.121E+03	2.219E+03	2.318E+03	2.419E+03	2.520E+03	2.623E+03	2.727E+03	2.832E+03

#### IV AIR CARRIER MODULE

The Air Carrier Module provides a tool for analyzing the financial feasibility of an airline purchasing and operating an aircraft. The module provides a methodology for computing the air carrier costs and revenues over the economic life of the aircraft, performing a cash flow analysis, and computing an internal rate of return on investment. The Air Carrier Module includes models for estimating direct and indirect operating expenses and techniques for accounting for initial investment, purchase loan repayments, depreciation, and tax expenses. The salvage value of the aircraft at the end of its economic life is treated as a capital gain.

The program for the Air Carrier Module contains bits and pieces of code that would suggest that the module was intended to be quite general and flexible. However, these generalizations are not fully implemented. Hence, the program that is actually workable is quite limited. In describing the Air Carrier Module, only the workable program code is treated. Extraneous unworkable code is not documented, but remains in the program code.

Descriptions of the mathematical modeling methodology, program logic, input, and output of the Air Carrier Module follow. In addition, a listing of the program code for this module is provided in Appendix D.

##### A. Methodology

The methodology, as currently implemented, provides for analysis of the costs and revenues an airline will experience in purchasing and operating one aircraft. Based on a set of parameters, which are assigned values via input or preset within the program code, the methodology computer

calculates direct, indirect, and total operating costs; repayment schedule for the financed portion of the aircraft purchase price; depreciation schedules; net earnings before interest and taxes; interest and tax payments; cash flow; discount factors and discounted cash flow; net present value; tax adjustments (due to loss carryovers); adjusted tax payments and cash flows; and finally internal rate of return on investment based on the discounted cash flow.

The Air Carrier Module performs a financial analysis for a series of aircraft prices. The aircraft price is initially set at \$5,000,000. After the analysis based on the initial price has been performed and results printed, the aircraft price is increased by \$2,500,000 and the analysis is repeated, with the final aircraft price analyzed being \$30,000,000.

In developing the methodology, several assumptions have been "hard-wired" into the code. Specifically, the initial investment cost (portion of aircraft price not financed) is set equal to 40 percent of the price, and the financed cost is set equal to 60 percent of the price. The annual inflation rate is set equal to zero, and the annual revenue is set at \$7,500,000. Values are also set for economic life (15 years), residual value fraction (0.15), and interest rate (10%). The program code does not, in general, allow the user to modify these assumptions simply.

The methodology for performing the financial analysis includes models for estimating direct and indirect operating expenses. Descriptions of these models follow:

#### Direct Cost Calculations

The direct cost model is a modified version of the 1967 ATA (Air Transport Association) formulae for estimating direct operating costs of



turbine-powered transport airplanes.\* This model limits direct operating costs to flying costs (flight crew, fuel and oil, and insurance costs) and direct flight equipment maintenance costs (labor, material, and maintenance burden).

The methodology for calculating direct operating costs is based upon parameters which describe aircraft physical and operational characteristics. These parameters which are inputs to the cost model are:

- ADCC = Costs of added flight crew (over 2), dollars.
- AMT = Air maneuver time, hours.
- CLS = Climb speed, mph.
- COFL = Cost of fuel, dollars per pound.
- COIL = Cost of oil, dollars per gallon.
- CRS = Cruise speed, mph.
- D1 = Distance at maximum payload point on range-payload diagrams, miles.
- D2 = Distance at maximum payload point on range-payload diagrams, miles.
- DESS = Descent speed, mph.
- F1 = Fuel at maximum payload point on range-payload diagrams, pounds.
- F2 = Fuel at maximum fuel point on range-payload diagrams, pounds.
- FCK = Basic flight crew cost factor (for a crew of 2), dollars.
- GMT = Ground maneuver time, hours.
- H = Cruise altitude, feet.

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\*"Standard Method of Estimating Comparative Direct Operating Costs of Turbine Powered Transport Airplanes," Air Transportation Association of America, December 1967.

NRCREW = Number in crew.  
 NRENGN = Number of engines.  
 NRSEAT = Number of seats.  
 NSL = Number of flight stage lengths (up to 12).  
 RCH = Rate of climb at cruise altitude, feet per minute.  
 RCSL = Rate of climb at sea level, feet per minute.  
 RL = Maintenance labor rate, dollars per hour.  
 SL(I) = Distance for the Ith stage length (I = 1 to NSL), miles.  
 T = Time factor in engine labor cost calculations.  
 U = Annual utilization per aircraft in block hours.  
 VA = Airframe cost, dollars.  
 VE = Unit engine cost, dollars.  
 WEM = Aircraft empty weight, pounds.  
 WEN = Unit engine weight pounds.  
 WGR = Gross vehicle weight, pounds,

Using these input parameters, various operational characteristics and direct operating costs are computed for each of the flight stage lengths. The operational characteristics include speed, time, and fuel consumption, which are computed using the following equations:

CLIMB TIME (hours)

$$CLT = 2 * H / ((RCSL + RCH) * 60.0)$$

DESCENT TIME (hours)

$$DEST = CLT$$

CRUISE TIME (hours)

$$\begin{aligned} \text{CRT(I)} &= ((\text{SL(I)} + 0.015 * \text{SL(I)}) - (\text{CLS} * \text{CLT} + \text{DESS} * \text{DEST}))/\text{CRS}, \\ &\quad \text{if } \text{SL(I)} \leq 1400 \\ &= ((\text{SL(I)} + 0.02 * \text{SL(I)} + 20.0) - (\text{CLS} * \text{CLT} + \text{DESS} * \text{DEST}))/ \\ &\quad \text{CRS, if } \text{SL(I)} > 1400 \end{aligned}$$

BLOCK TIME (hours)

$$\text{BT(I)} = \text{GMT} + \text{CLT} + \text{DEST} + \text{CRT(I)} + \text{AMT}$$

BLOCK SPEED (mph)

$$\text{BS(I)} = \text{SL(I)}/\text{BT(I)}$$

BLOCK FUEL (pounds)

$$\begin{aligned} \text{BF(I)} &= \text{WGR} * 0.01 + ((\text{F1} - \text{F2})/(\text{D2} - \text{D1})) * \text{SL(I)} + 0.03 * ((\text{F1} - \text{F2})/ \\ &\quad (\text{D2} - \text{D1})) * \text{CRS} \end{aligned}$$

FLIGHT TIME (hours)

$$\text{FLTT(I)} = \text{BT(I)} - \text{GMT}$$

The equations for computing flight crew, fuel and oil, and hull insurance costs are:

FLIGHT CREW COSTS (\$/mile)

$$\text{CFC(I)} = (\text{WGR} * 5.0E - 5 + \text{FCK})/\text{BS(I)}$$

where  $\text{FCK} = \text{FCK} + \text{ADDC} * (\text{NRCREW} - 2.0)$ , if  $\text{NRCREW} > 2$

FUEL AND OIL COSTS (\$/mile)

$$\text{CFO(I)} = 1.02 * (\text{COFL} * \text{BF(I)} + \text{NRENGN} * 0.135 * \text{COIL} * \text{BT(I)})/\text{SL(I)}$$

HULL INSURANCE COSTS (\$/mile)

$$\text{CI(I)} = .001 * \text{VT}/(\text{U} * \text{BS(I)})$$

where  $\text{VT} = \text{VA} + \text{VE} * \text{NRENGN}$

TOTAL FLIGHT OPERATIONS COSTS (\$/mile)

$$\text{CFOP(I)} = \text{CFC(I)} + \text{CFO(I)} + \text{CI(I)}$$

Direct maintenance costs are computed for the airframe and engines using the following cost equations:

AIRFRAME MAINTENANCE LABOR COSTS (\$/mile)

$$\text{CLA(I)} = \text{RL} * (\text{FHAL} * \text{FLTT(I)} + \text{FCAL}) / \text{SL(I)}$$

$$\text{where WA} = \text{WEM} - \text{WEN} * \text{NRENGN}$$

$$\text{FCAL} = (\text{WA} * (5.0\text{E} - 5) + 6.0 - 630.0 / (120.0 + \text{WA} * 1.0\text{E} - 3))$$

$$\text{FHAL} = 0.59 * \text{FCAL}$$

AIRFRAME MAINTENANCE MATERIAL COSTS (\$/mile)

$$\text{CMA(I)} = (\text{FHAM} * \text{FLTT(I)} + \text{FCAM}) / \text{SL(I)}$$

$$\text{where FCAM} = \text{VA} * 6.24\text{E} - 6 * 0.5$$

$$\text{FHAM} = \text{VA} * 3.08\text{E} - 6 * 0.5$$

ENGINE MAINTENANCE LABOR COSTS (\$/mile)

$$\text{CLE(I)} = \text{RL} * (\text{FHEL} * \text{FLTT(I)} + \text{FCEL}) / \text{SL(I)}$$

$$\text{where FCEL} = (0.3 + \text{T} * 3.0\text{E} - 5) * \text{NRENGN} * 0.5$$

$$\text{FHEL} = (0.6 + \text{T} * 2.7\text{E} - 5) * \text{NRENGN} * 0.5$$

ENGINE MAINTENANCE MATERIAL COSTS (\$/mile)

$$\text{CME(I)} = (\text{FHEM} * \text{FLTT(I)} + \text{FCEM}) / \text{SL(I)}$$

$$\text{where FCEM} = \text{VE} * \text{NRENGN} * 2.0\text{E} - 5$$

$$\text{CHEM} = \text{VE} * \text{NRENGN} * 2.5\text{E} - 5$$

MAINTENANCE BURDEN (\$/mile)

$$\text{CMB(I)} = 1.8 * (\text{CLA(I)} + \text{CLE(I)})$$

TOTAL DIRECT MAINTENANCE COSTS (\$/mile)

$$\text{CM(I)} = \text{CLA(I)} + \text{CMA(I)} + \text{CLE(I)} + \text{CME(I)} + \text{CMB(I)}$$

Finally, several additional direct operating costs ratios are computed.

These include:

DEPRECIATION OF FLIGHT EQUIPMENT (\$/mile)

$$CD(I) = 0$$

TOTAL COST PER AIRCRAFT MILE (dollars)

$$CAM(I) = CFOP(I) + CM(I) + CD(I)$$

COST PER FLIGHT HOUR (dollars)

$$CFH(I) = CAM(I) * BS(I) * BT(I)/FLTT(I)$$

COST PER BLOCK HOUR (dollars)

$$CBH(I) = CAM(I) * BS(I)$$

COST PER AVAILABLE SEAT MILE (dollars)

$$CASM(I) = CAM(I)/NRSEAT$$

COST PER CRUISE MILE FOR THE AIRCRAFT (dollars)

$$CACM = (CAM(2) * SL(2) - CAM(1) * SL(1))/(SL(2) - SL(1))$$

COST PER TAKEOFF FOR THE AIRCRAFT (dollars)

$$CTO = (CAM(1) - CACM) * SL(1)$$

COST PER CRUISE MILE PER SEAT (dollars)

$$CSCM = CACM/NRSEAT$$

COST PER TAKEOFF PER SEAT (dollars)

$$CSTO = CTO/NRSEAT$$

COST PER AIRCRAFT TRIP (dollars)

$$CPAT = CSTO + CACM * SL(I)$$

COST PER SEAT TRIP (dollars)

$$CPST = CSTO + CSCM * SL(I)$$

The direct operating costs (flight and maintenance) are also computed on a dollar per block hour basis. This is accomplished simply by multiplying the dollar per mile cost figures by the block speed (BS(I)).

The annual direct cost for an aircraft for use in the subsequent financial analysis is taken to be the direct cost per block hour for the first stage length, i.e., CBH(I), times the annual aircraft utilization, U, which is input by the user.

#### Indirect Cost Calculations

Within the OPLIFE model is embedded a methodology for estimating the indirect operating costs for the following indirect operating expenses:

- Stewardess
- Passenger food
- Other passengers in-flight expenses
- Aircraft servicing
- Traffic servicing
- Reservations and sales
- Advertising and publicity
- Maintenance for ground, property, and equipment
- Depreciation and amortization of ground, property, and equipment
- Depreciation of maintenance equipment
- General and administrative expense.

The methodology is based on a set of parameters which are inputs to computer program. These parameters include:

- AI1 = Flight operations expense (less rentals) in dollars per block hour.
- AI2 = Maintenance expense for flight equipment in dollars per block hour.
- AI4 = Flight operations expense for rentals in dollars per block hour.
- AI5 = Dollar cost per stewardess per block hour.
- AI6 = Food expense in dollars per passenger per block hour.
- AI7 = Cost of other passenger in-flight expenses in dollars per passenger per mile.
- AI8 = Aircraft line servicing expense per departure.
- AI9 = Aircraft control servicing expense in dollars per block hour.
- AI10 = Landing fee per departure in dollars.
- AI11 = Passenger traffic servicing expense in dollars per passenger.
- AI12 = Baggage traffic servicing expense in dollars per ton.
- AI12A = Cargo traffic servicing expense in dollars per ton.
- AI13 = Reservation and sales expense per passenger in dollars.
- AI14 = Reservation and sales expense per passenger-mile in dollars.
- AI15 = Reservation and sales expense for property in dollars per ton-mile.
- AI16 = Advertising and publicity expense per passenger-mile in dollars.
- AI17 = Advertising and publicity expense for property in dollars per ton-mile.
- AI18 = Maintenance expense for ground property and equipment per departure in dollars.
- AI19 = Expense for depreciation of general ground property, and equipment and amortization per departure in dollars.
- AI20 = Maintenance equipment depreciation factor.





- RTP = Tons of property (cargo) carried per flight.  
 U = Annual aircraft utilization in block hours.

Using these parameters, several flight speed and time characteristics are computed for each of the flight stage lengths. The equations used are as follows:

CLIMB TIME (hours)

$$CLT = 2 * H / ((RCSL + RCH) * 60.0)$$

DESCENT TIME (hours)

$$DEST = CLT$$

CRUISE TIME (hours)

$$CRT(I) = ((SL(I) + 0.015 * SL(I)) - (CLS * CLT + DESS * DEST)) / CRS, \\ \text{if } SL(I) \leq 1400$$

$$= ((SL(I) + 0.02 * SL(I) + 20.0) - (CLS * CLT + DESS * DEST)) / CRS, \text{ if } SL(I) > 1400$$

$$\text{where } SL(I) = DIS(I)$$

BLOCK TIME (hours)

$$TB(I) = GMT + CLT + DEST + CRT(I) + AMT$$

BLOCK SPEED (mph)

$$SB(I) = SL(I) / TB(I)$$

FLIGHT TIME (hour)

$$FLTT(I) = TB(I) - GMT$$

Using these computed flight characteristics and the input parameter values, the various indirect operating cost components in dollars per trip are computed for each stage length as follows:

FLIGHT OPERATIONS (LESS RENTALS) EXPENSE

$$CI(I) = A11 * TB(I)$$

MAINTENANCE EXPENSE FOR FLIGHT EQUIPMENT

$$C2(I) = AI2 * TB(I)$$

RENTALS OF FLIGHT EQUIPMENT

$$C4(I) = AI4 * TB(I)$$

STEWARDESS EXPENSE

$$C8(I) = AI5 * (FSTEW + CSTEW) + TB(I)$$

FOOD EXPENSE

$$C11(I) = AI6 * (FS * FLF(I) * FOODR + CS + CLF(I)) * TB(I)$$

OTHER PASSENGER IN-FLIGHT EXPENSES

$$C14(I) = AI7 * (FS * FLF(I) + CS * CLF(I)) * DIS(I) * CF(I)$$

AIRCRAFT LINE SERVICING EXPENSE

$$C15(I) = AI8 * DPT(I)$$

AIRCRAFT CONTROL SERVICING EXPENSE

$$C16(I) = AI9 * TB(I)$$

AIRCRAFT LANDING FEES

$$C17(I) = AI10 * DPT(I)$$

TOTAL AIRCRAFT SERVICING EXPENSE

$$TAS(I) = C15(I) + C16(I) + C17(I)$$

TRAFFIC SERVICING EXPENSE FOR PASSENGERS AND BAGGAGE

$$C22(I) = (AI11 + AI12 * LA / 2000) * (FS * FLF(I) + CS * CLF(I))$$

TRAFFIC SERVICING EXPENSE FOR CARGO

$$C23(I) = AI12A * (RTM + RTP)$$

TOTAL TRAFFIC SERVICING EXPENSE

$$TTS(I) = C22(I) + C23(I)$$

RESERVATION AND SALES EXPENSE FOR PASSENGERS

$$C26(I) = (AI13 + AI14 * DYS(I) * CF(I)) * (FS * FLF(I) + CS * CLF(I))$$

RESERVATION AND SALES EXPENSE FOR PROPERTY

$$C27(I) = RTP * AI15 * DLS(I) * CF(I)$$

TOTAL RESERVATION AND SALES EXPENSE

$$TRS(I) = C26(I) + C27(I)$$

ADVERTISING AND PUBLICITY EXPENSE FOR PASSENGERS

$$C30(I) = AI16 * (FS * FLF(I) + CS + CLF(I)) * DIS(I) * CF(I)$$

ADVERTISING AND PUBLICITY EXPENSE FOR PROPERTY

$$C31(I) = R1P * AI17 * DIS(I) * CF(I)$$

TOTAL ADVERTISING AND PUBLICITY EXPENSE

$$TAP(I) = C30(I) + C31(I)$$

MAINTENANCE EXPENSE FOR GROUND PROPERTY AND EQUIPMENT

$$C32(I) = AI18 * DPT(I)$$

DEPRECIATION OF GENERAL GROUND PROPERTY AND EQUIPMENT AND AMORTIZATION

$$C33(I) = AI19 * DPT(I)$$

DEPRECIATION OF MAINTENANCE EQUIPMENT

$$C34(I) = AI20 * ((C2(I) + C32(I)))$$

GENERAL AND ADMINISTRATIVE EXPENSE

$$C35(I) = AI21 * (C1(I) + C2(I) + C4(I) + C8(I) + C11(I) + C14(I) + C15(I) + C16(I) + C17(I) + C22(I) + C23(I) + C26(I) + C27(I) + C30(I) + C31(I) + C32(I))$$

TOTAL INDIRECT EXPENSE

$$C36(I) = C8(I) + C11(I) + C14(I) + C15(I) + C16(I) + C17(I) + C22(I) + C23(I) + C26(I) + C27(I) + C30(I) + C31(I) + C32(I) + C33(I) + C34(I) + C35(I)$$

In addition, several indirect cost ratios are computed. These include:

INDIRECT COST PER AIRCRAFT MILE

$$\text{CAM}(I) = \text{C36}(I)/\text{SL}(I)$$

INDIRECT COST PER FLIGHT HOUR

$$\text{CFH}(I) = \text{C36}(I)/\text{FLTT}(I)$$

INDIRECT COST PER BLOCK HOUR

$$\text{CBH}(I) = \text{C36}(I)/\text{TB}(I)$$

INDIRECT COST PER AVAILABLE SEAT MILE

$$\text{CASM}(I) = \text{CAM}(I)/\text{NRSEAT}$$

INDIRECT COST PER CRUISE MILE

$$\text{CACM} = (\text{CAM}(2) * \text{SL}(2) - \text{CAM}(1) * \text{SL}(1))/(\text{SL}(2) - \text{SL}(1))$$

INDIRECT COST PER TAKEOFF

$$\text{CTO} = (\text{CAM}(1) - \text{CACM}) * \text{SL}(1)$$

INDIRECT COST PER AIRCRAFT TRIP = CTO plus CACM per mile

INDIRECT COST PER CRUISE MILE PER SEAT

$$\text{CSCM} = \text{CACM}/\text{NRSEAT}$$

INDIRECT COST PER TAKEOFF PER SEAT

$$\text{CSTO} = \text{CTO}/\text{NRSEAT}$$

INDIRECT COST PER SEAT TRIP = CSTO plus CSCM per mile

For the purposes of the subsequent financial analysis, the annual indirect cost for an aircraft is taken to be the indirect cost per block hour for the first stage length, i.e.,  $\text{CBH}(1)$ , times the input value of the annual aircraft utilization,  $U$ .

The sum of the annual direct and indirect operating costs for a single aircraft for flights in the first stage length is assumed to be the total annual operating cost in the subsequent financial analysis. The operating

costs in each of the years during the lifetime (set at 15 years) of the aircraft are identical since inflation is set at zero. The financial analysis includes computation of the purchase load repayment schedule, depreciation, earnings and taxes, cashflow, tax adjustments (due to loss carryovers and capital gains) and internal rate of return on investment. These computations, which are performed for each of the eleven aircraft prices analyzed (\$5,000,000 through \$30,000,000 in increments of \$2,500,000), are described below:

#### Loan Repayment Schedule

It is assumed within the model that the airline borrows 60% of the aircraft price at 10% annual interest rate. This loan is repaid by equal annual cash payments over the economic life of the aircraft (15 years). The amount of cash payment (M) is computed using the following standard formula:

$$M = P \frac{i(1+i)^N}{(1+i)^N - 1} \quad (10)$$

where

P = amount of loan

i = annual interest rate

N = total number of annual payments.

In addition, the amount of interest paid in each year is computed by applying the interest rate to the outstanding principal. The amount of principal payment in a year is the difference between M and the interest.

#### Depreciation

The aircraft is depreciated using the double declining balance method to the midpoint of the economic life and the straight-line method

for the remaining period. Aircraft are depreciated over a 15-year life to a 15% residual (salvage) value, and the sale at this residual value is reflected in the net cash flow.

#### Earnings and Taxes

Earnings before interest and taxes are calculated by subtracting both operating costs and depreciation from the annual revenue. Earnings before tax is calculated by subtracting interest payments from the earnings before interest and taxes. Income tax payments are calculated by applying a corporate income tax rate (set to 48 percent) to the earnings before tax. Finally, net earnings are obtained by subtracting the income taxes paid from the earnings before tax.

#### Cash Flow

The net cash flow for each year under study is calculated by subtracting total cash outflows from total cash inflows. Cash inflows consist of annual revenue plus salvage value from the sale of the aircraft at the end of its economic life. Cash outflows consist of the initial capital investment, principal payments, interest costs, operating costs and income taxes.

#### Tax Adjustments

The tax adjustments are intended to account for corporate practices in the treatment of operating losses and capital gains and losses. Positive values of revenue can be offset by losses being carried back up to 3 years or forward up to 5 years. However, the algorithm used is not general. Carry-back of losses is not properly implemented. Carry-forward of losses works properly only when all losses occur in the early years of the aircraft life with gains in later years. Once a gain is realized in a given year, any loss in a subsequent year may not be handled properly.

Capital gains tax is computed on the residual value of the aircraft at a rate of 22 percent if the value is less than \$25,000, or at 30 percent if the value is \$25,000 or more. However, this treatment is inconsistent with the earlier calculations of depreciation which are performed only to the residual value of the aircraft, not to zero.

After the tax adjustments are made, adjusted earnings, taxes and net cash flow are computed for use in estimating rates of return.

#### Internal Rate of Return on Investment

The final step in the methodology of the Air Carrier Module is to employ an iterative technique to calculate the internal rate of return for each net cash flow generated. The internal rate of return (or marginal efficiency of investment) is that rate of interest or return which would render the discounted present value of its expected future marginal yields (income) exactly equal to the investment cost of the project.

Since both the investment costs and the income are spread over time, the internal rate of return sought is that which reduces the summed present value of the cash flow stream over time to zero. The cash flow stream sum can be represented as:

$$\text{SUM} = \left(\frac{1}{1+R}\right)CF_1 + \left(\frac{1}{1+R}\right)^2 CF_2 + \dots + \left(\frac{1}{1+R}\right)^N CF_n \quad (11)$$

where R = internal rate of return

$CF_i$  = net cash flow in year i.

The iterative procedure estimates values for R, calculates the SUM described above using the cash flow figures previously generated, performs tests

to determine if SUM is approaching zero, then successively chooses new values for R in attempting to obtain a value for SUM closer to zero.

The procedure is initialized by selecting a small initial value for R (+0.01 or -0.01, depending on whether the final sum of the input cash flow is positive or negative, respectively). The incremental value for R used during iteration is 0.001. The iteration procedure continues until the discounted cash flow sum is near (or equal to) zero. At every tenth cycle of the iteration procedure and for the final values, the internal rate of return value and the sum of the discounted cash flow are printed.

The program code for the Air Carrier Module provides output lists and tables that summarize the calculations being performed. Outputs include initial investment costs, listings of input parameters, summary tables of direct and indirect operating costs, total operating costs, depreciation and net earnings values, cash flow, capital gains values, rate of return on investment and associated discounted cash flow sums during iterations and final values, and final summary tables by year showing annual revenue, initial investment, principal payments, operating cost, depreciation, earnings before interest and taxes, interest, earnings before tax, income tax, net earnings, net cash flow, discount factors (with associated rate of return), discounted cash flow, and net present value.

In the remainder of this chapter, detailed descriptions of the program logic, input, and output for the Air Carrier Module are provided.



B. Program Logic

Figure 28 illustrates the interrelationships among the routines which make up the Air Carrier Module program. Program OPLIFE is an independent main program that controls the rest of the subroutines comprising the Air Carrier Module in a series of calls to produce aircraft operating cost and financial performance data for varying aircraft initial prices. Brief descriptions of each subroutine in the Air Carrier Module, together with flowcharts of the program logic, follow.

OPLIFE

The OPLIFE program serves as the controlling driver for the other subroutines in the Air Carrier Module. A flowchart of the program logic for OPLIFE is shown in Figure 29. OPLIFE sets a basic aircraft price of \$5,000,000, then calls subroutine INPUT which initializes program parameters, calls subroutine DIRECT to compute and print direct operation costs, and calls subroutine INDIR to compute and print indirect operating costs. The operating costs for each year of the economic life of the aircraft are set equal to the sum of the computed annual direct and indirect costs for one aircraft. For each year in the 15 year life of the aircraft, subroutines are called by OPLIFE to calculate a repayment schedule for the financed portion of aircraft cost (REPAY), a depreciation schedule (DEPSUB), and earnings and tax data (NETSUB). OPLIFE then calls subroutines to calculate individual and cumulative sums by year for computed income, cost and tax data (SUM), cash flow (CFSUB), tax adjustments for operating losses and capital gains (TAX), cash flow with tax considerations (CFSUB), and internal rates of return on investment. OUTPUT is then called to print results.

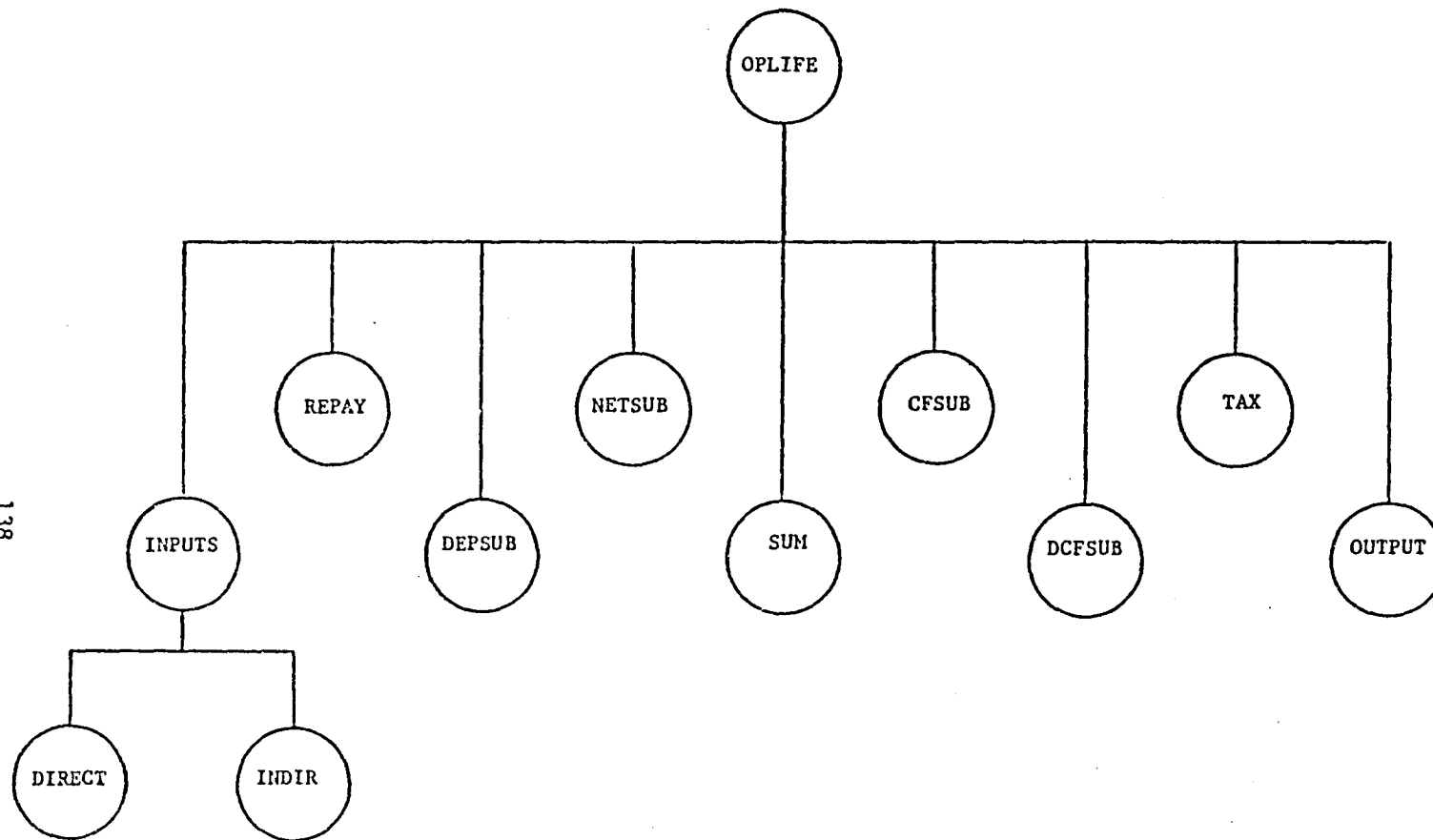


Figure 28 Program Structure of the Air Carrier Module

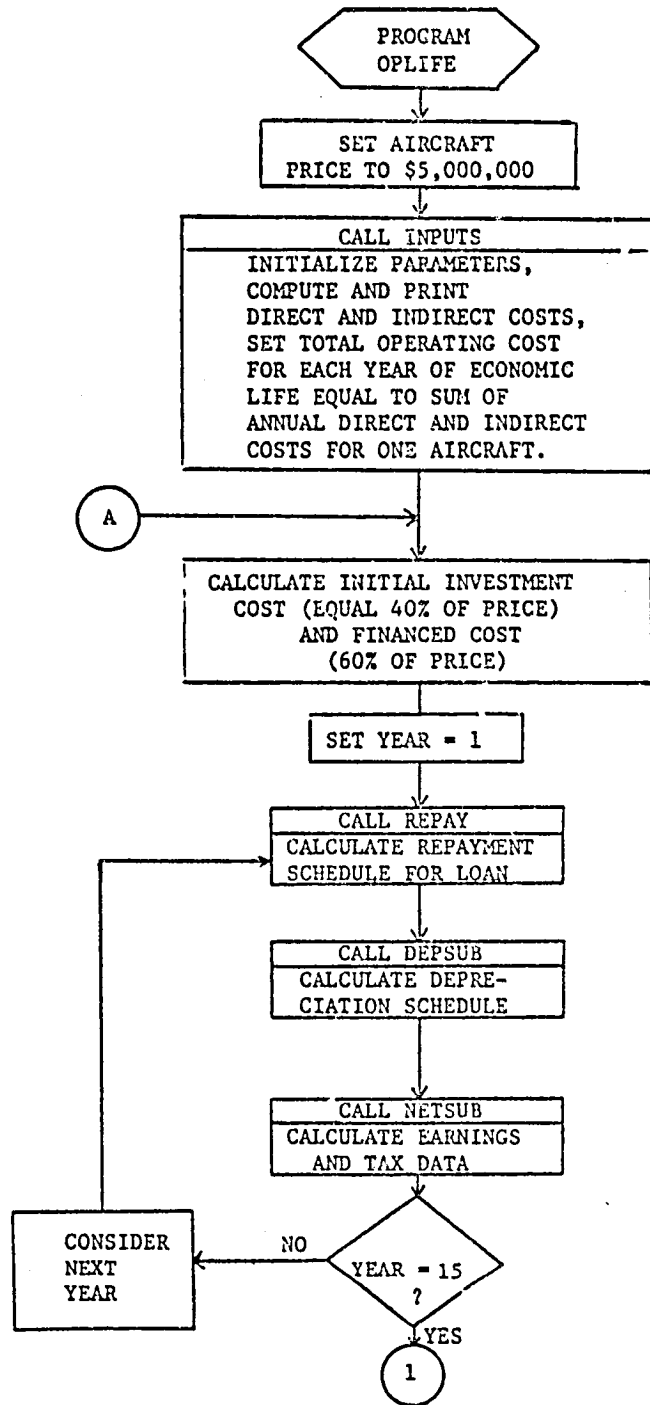


Figure 29 Flowchart of Program OPLIFE Logic

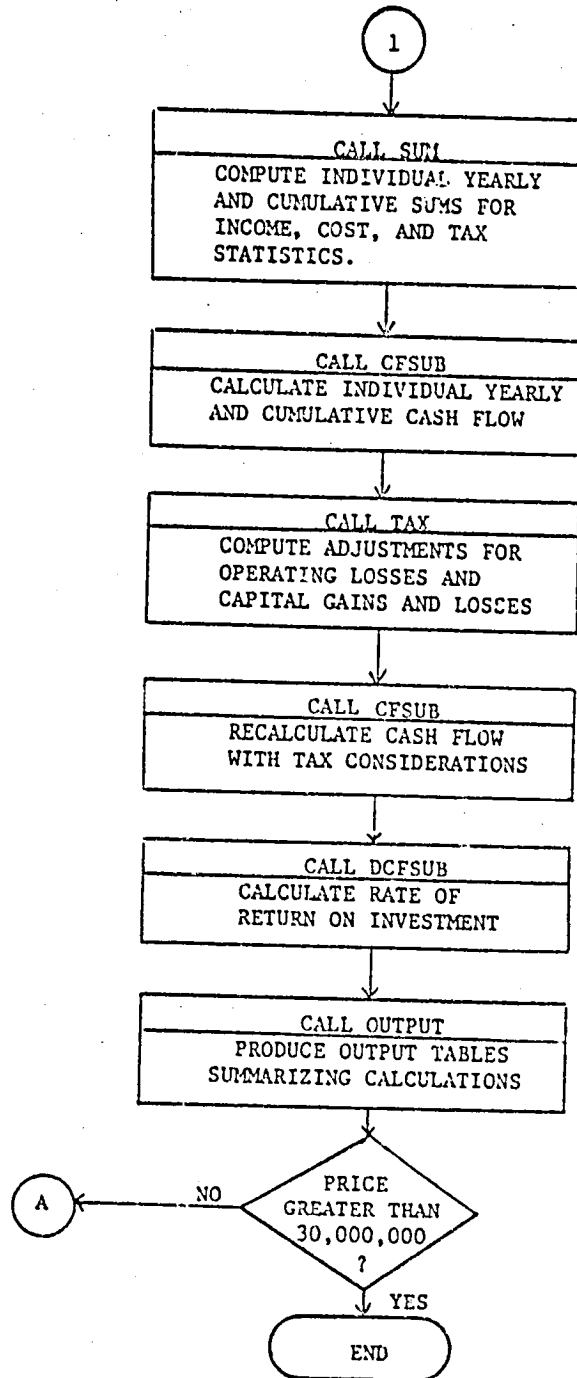


Figure 29 (Concluded)

The above analysis is repeated for 11 aircraft prices. The aircraft prices range from \$5,000,000 to \$30,000,000 in increments of \$2,500,000.

#### INPUTS

A flowchart of the program logic for subroutine input is shown in Figure 30. This subroutine sets various program parameters, then computes and prints initial investment by year. The initial investment is assumed to be 40% of the aircraft price, paid upon purchase. Hence, the initial investment will always be incurred in year 1, with zero investment in years 2 through 15 of the economic life.

Next, subroutines DIRECT and INDIRECT are called to compute direct and indirect operating costs, respectively. The operating cost for each of the 15 years of life is then set equal to the sum of the computed annual direct and indirect operating cost for a single aircraft for flights in the first stage length. This cost is then printed for each year.

#### DIRECT

Embedded in subroutine DIRECT are the direct cost equations described in Section IV.A (Direct Cost Calculations). A flowchart of the logic is provided in Figure 31. The first step in the program is to read and print the direct cost equation parameters. Direct costs for a single aircraft are then computed and printed on a per mile basis for each of the up to 12 input stage lengths. Direct costs are then computed and printed on a per block hour basis.

Based on the input aircraft utilization in block hours per year, the annual direct cost of operating an aircraft for flights in the first stage

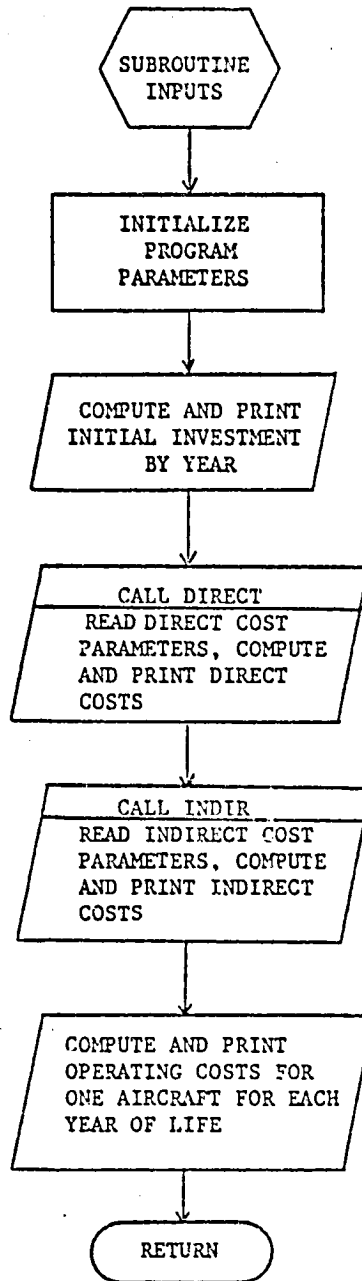


Figure 30 Flowchart of Subroutine INPUTS Logic

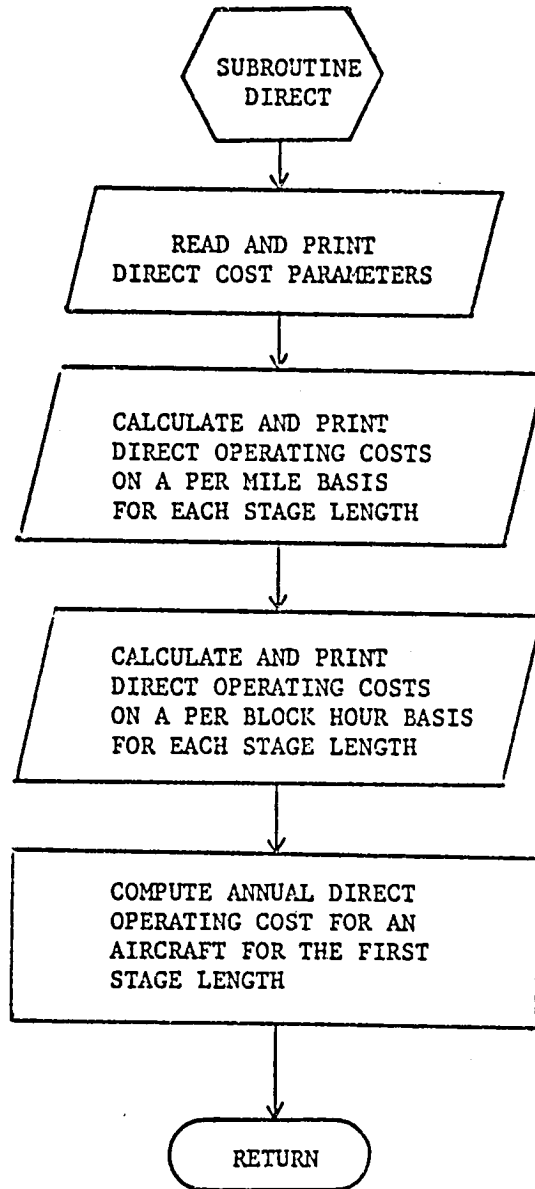


Figure 31 Flowchart of Subroutine DIRECT Logic

length is computed. This is the direct cost figure used for subsequent financial analysis.

#### INDIR

Within subroutine INDIR is encoded the indirect cost equations described in Section IV.A (Indirect Cost Calculation:). As indicated in the flowchart of subroutine INDIR logic provided in Figure 32, the first step in the logic is to read and print the indirect cost parameters. Next, the indirect costs are computed on a per trip basis for each of the up to 17 stage lengths. These costs are later printed. The annual cost of operating an aircraft or flights in the first stage length category is computed by multiplying the indirect cost per block hour by the input annual hours of utilization. This is the indirect cost used in the subsequent financial analysis.

#### REPAY

The logical flow for subroutine REPAY is shown in Figure 33. This subroutine computes the aircraft purchase loan repayment schedule. The constant annual loan payment due in each year of the economic life of the aircraft is computed using the formula described in Section IV.A (Loan Repayment Schedule). The interest and principal portions for each payment are then computed.

#### DEPSUB

Subroutine DEPSUB calculates depreciation, book value, and salvage value over the economic life of the aircraft. Depreciation is calculated using the double-declining balance method (DEPR) to the midpoint of the



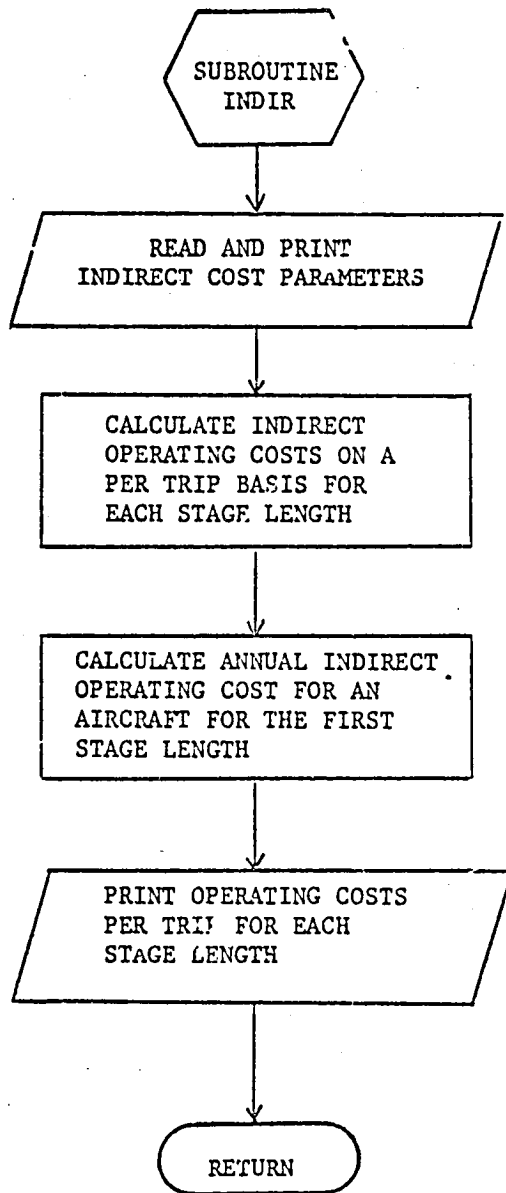


Figure 32 Flowchart of Subroutine INDIR Logic

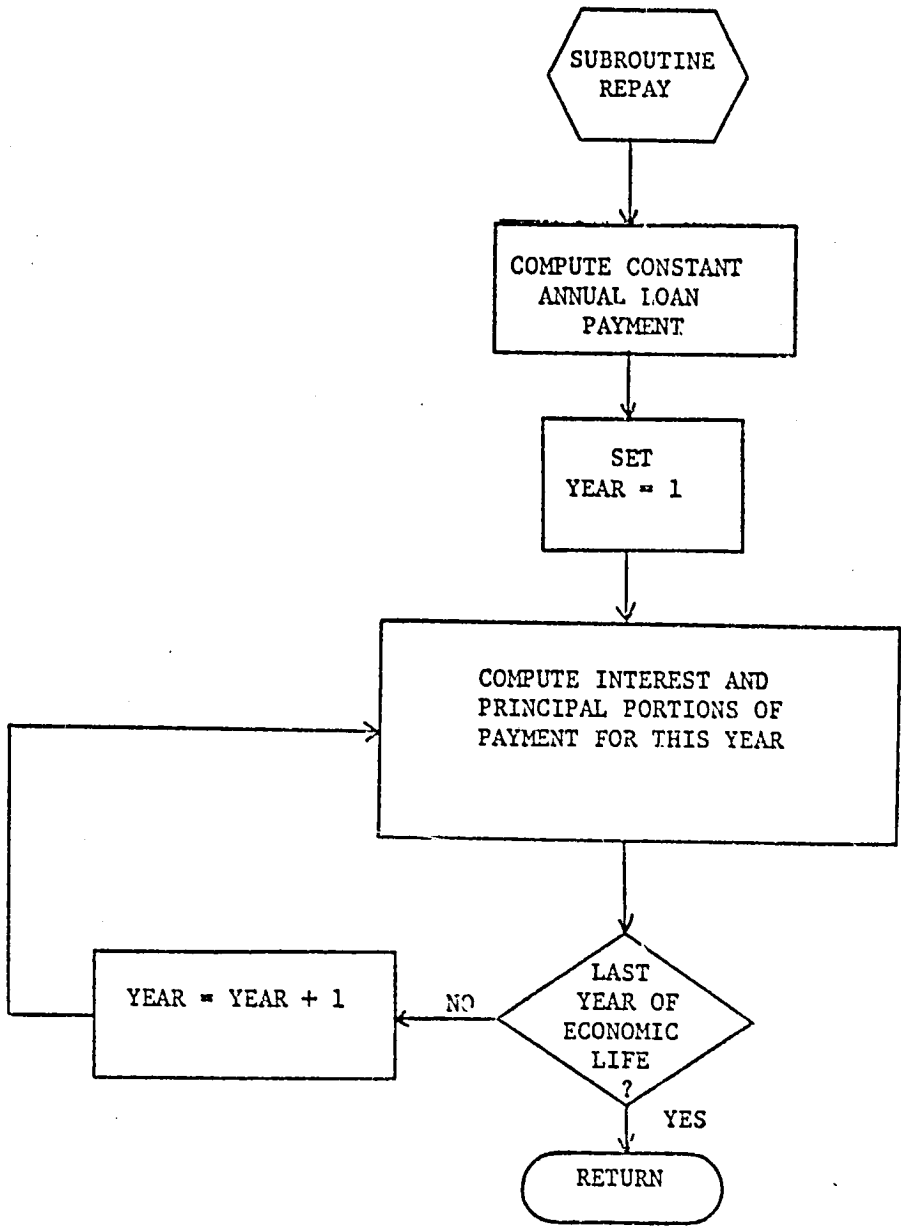


Figure 33 Flowchart of Subroutine REPAY Logic

economic life (in this case for 7 of 15 years), and the straight-line method for the remaining period (in this case 8 years). The aircraft is depreciated to a residual value (in this case 15 percent) at the end of the economic life. A flowchart of the program logic for DEPSUB is shown in Figure 34.

#### NETSUB

Subroutine NETSUB calculates earnings before interest and taxes, earnings before taxes, income tax, and net earnings. Earnings before interest and taxes is calculated by subtracting both operating costs and depreciation from annual revenue. Earnings before taxes is calculated by subtracting interest payments from earnings before interest and taxes. Income tax is calculated by multiplying earnings before taxes by the corporate tax rate (in this case 48 percent). Finally, net earnings are obtained by subtracting the income taxes paid from the earnings before taxes. A flowchart of the program logic for NETSUB is shown in Figure 35.

#### SUM

Subroutine SUM calculates individual yearly and cumulative sums over all years for annual revenue, initial investment principal payments, operating cost, total depreciation (equal to the sum of double-declining and straight-line depreciation), earnings before interest and taxes, earnings before taxes, interest payments, income taxes, and net earnings. Also computed are yearly values for salvage, double-declining depreciation and straight-line depreciation. A flowchart of the program logic for SUM is shown in Figure 36.

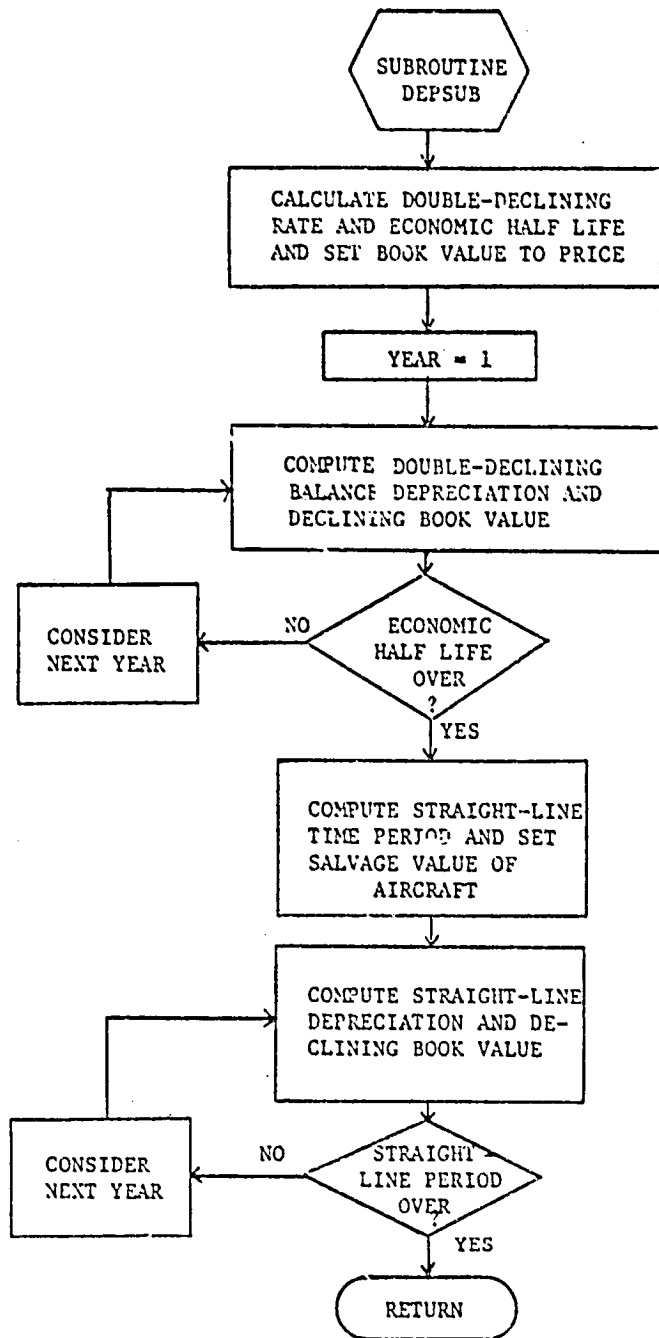


Figure 34 Flowchart of Subroutine DEPSUB Logic

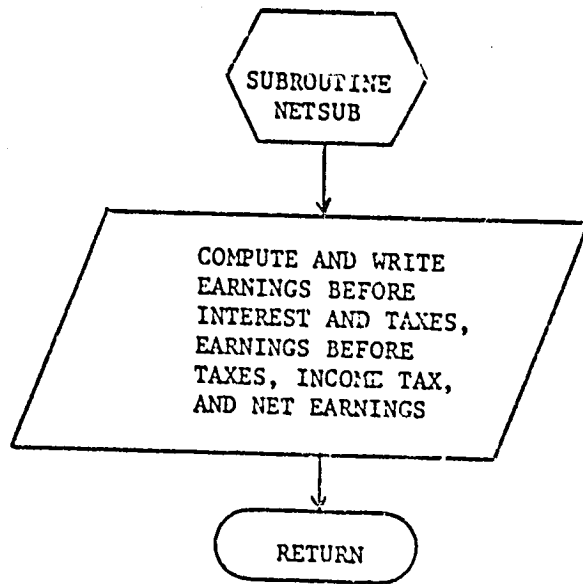


Figure 35 Flowchart of Subroutine NETSUB Logic

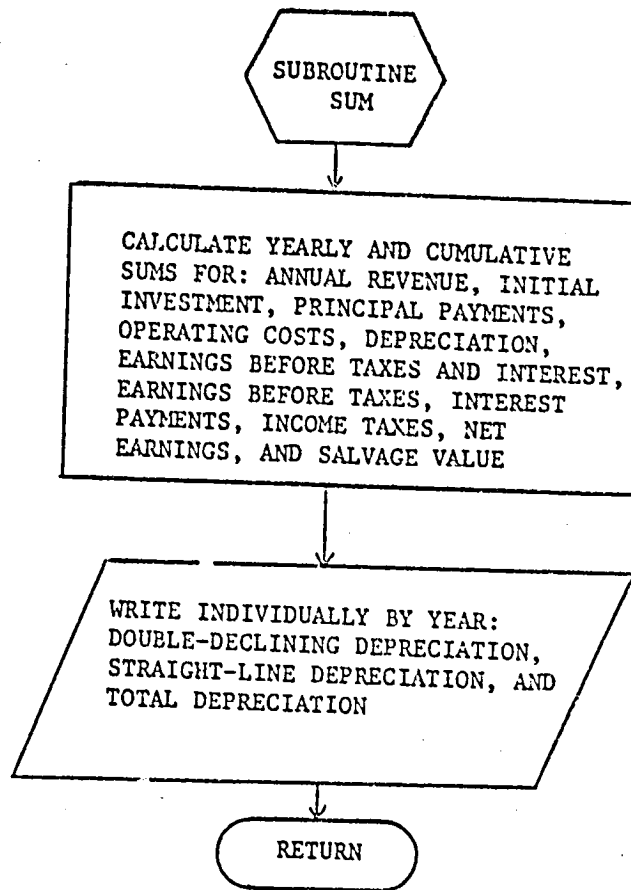


Figure 36 Flowchart of Subroutine SUM Logic

### CFSUB

Subroutine CFSUB calculates the net cash flow for each year under study. Net cash flow is obtained by subtracting the sum of initial capital investment, principal payments, interest payments, operating costs, and income taxes from cash inflow, i.e., the sum of annual revenue and salvage. A flowchart of the program logic for CFSUB is shown in Figure 37.

### DCFSUB

Subroutine DCFSUB computes and prints the interval rate of return on investment (R) for each cash flow generated by subroutine CFSUB. An iterative procedure is employed as described in Section IV.A (Internal Rate of Return on Investment). The iterative procedure utilizes a current trial rate of return (R) and its two iterative predecessors (RR and RRR). The sum of the discounted cash flow (SUM) is biased by -9000 to obtain a biased cash flow sum (K) and its two iterative predecessors (KK and KKK) for test purposes. The procedure is initialized by selecting a small initial value for R (+ 0.01 or -0.01 depending on the corresponding sign of the cash flow sum). Using the estimate for R, a cash flow SUM is generated and biased to obtain K. Successive tests are performed to determine if the value for SUM is near or equal to zero. Then the value for R is incremented by 0.001 and the process is repeated until the test conditions are met. A flowchart of the program logic for DCFSUB is shown in Figure 38.

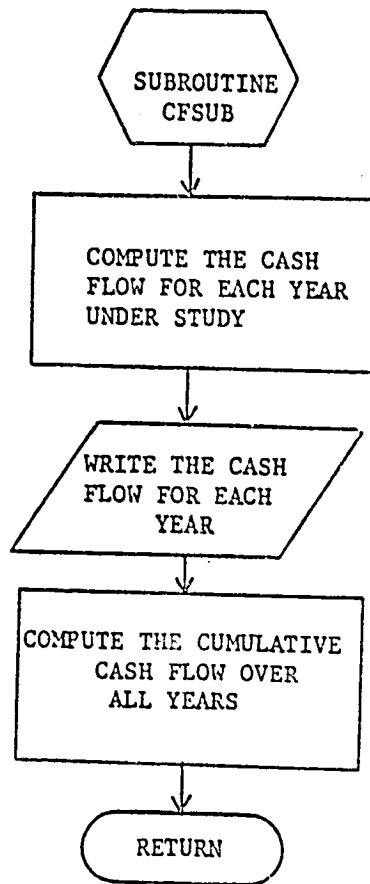


Figure 37 Flowchart of Subroutine CFSUB Logic



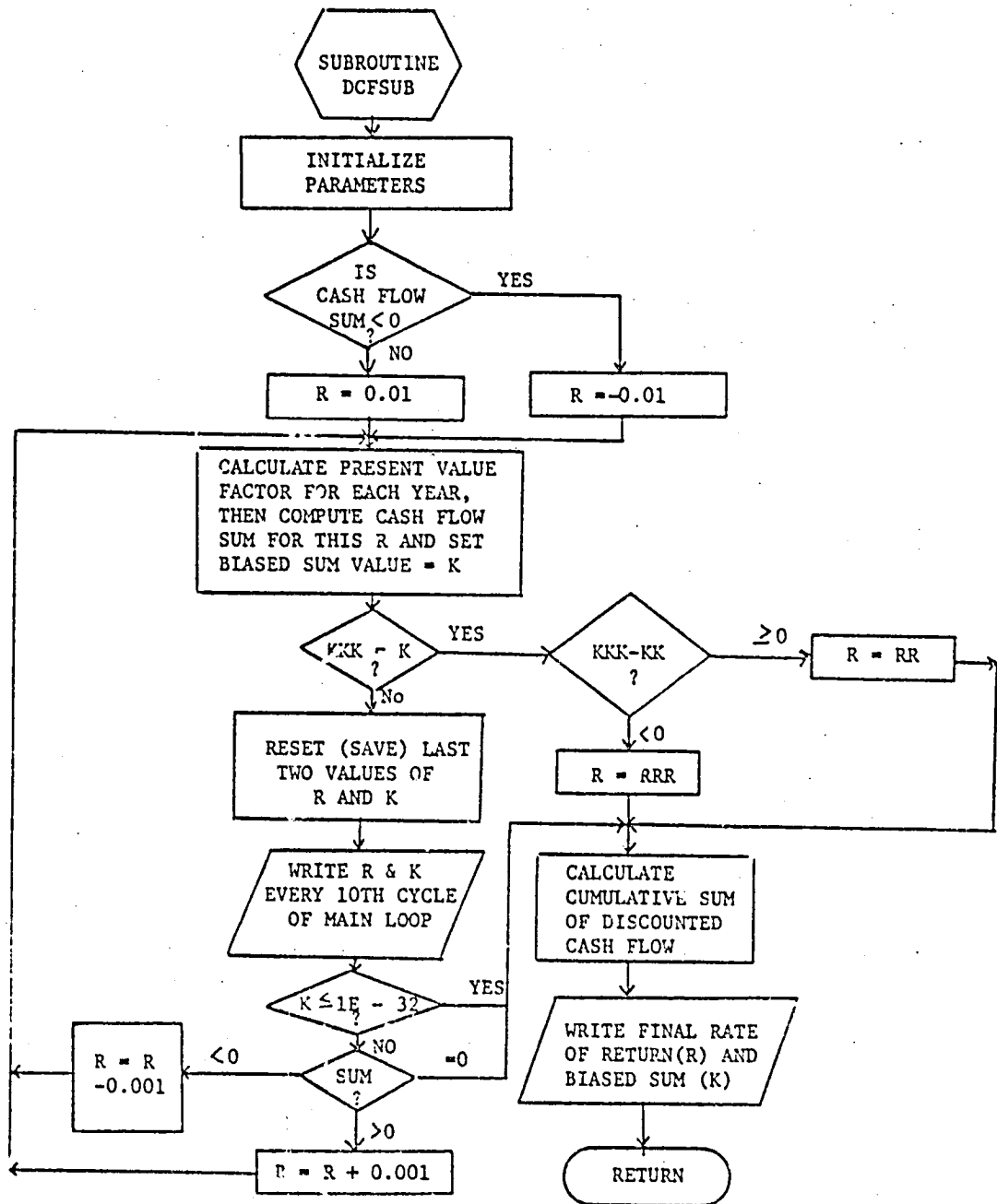


Figure 38 Flowchart of Subroutine DCFSUB Logic

## TAX

Subroutine TAX provides logic for tax adjustments due to carry-forward of operating losses and computing capital gains tax on the residual value of aircraft. Limitations and shortcomings of the methodology are discussed in Section IV.A (Tax Adjustments). Some code for providing for carry-back of losses exists but is never executed because of the structure of the program; it is, therefore, not included in the logical flowchart of subroutine TAX provided in Figure 39.

Subroutine TAX operates by considering each successive year beginning with the first. If there is a loss, it is carried forward against future operating profits for up to five years. The carry-forward process stops in the first year that a positive income (after adjustment for past losses) occurs.

After the carry-forward process is completed, earnings before taxes, net earnings, and income taxes are recalculated. Then, cumulative total depreciation is computed.

Next, long term capital gains with capital gains tax are computed based on the residual value of the aircraft. The capital gains tax rate used is 22 percent if the capital gain in any year is less than \$25,000, or 30 percent if the gain is \$25,000 or greater. New values for net earnings and income tax are calculated, including capital gains and capital gains taxes. Cumulative sums are also produced for earnings before taxes, net earnings, and income taxes.

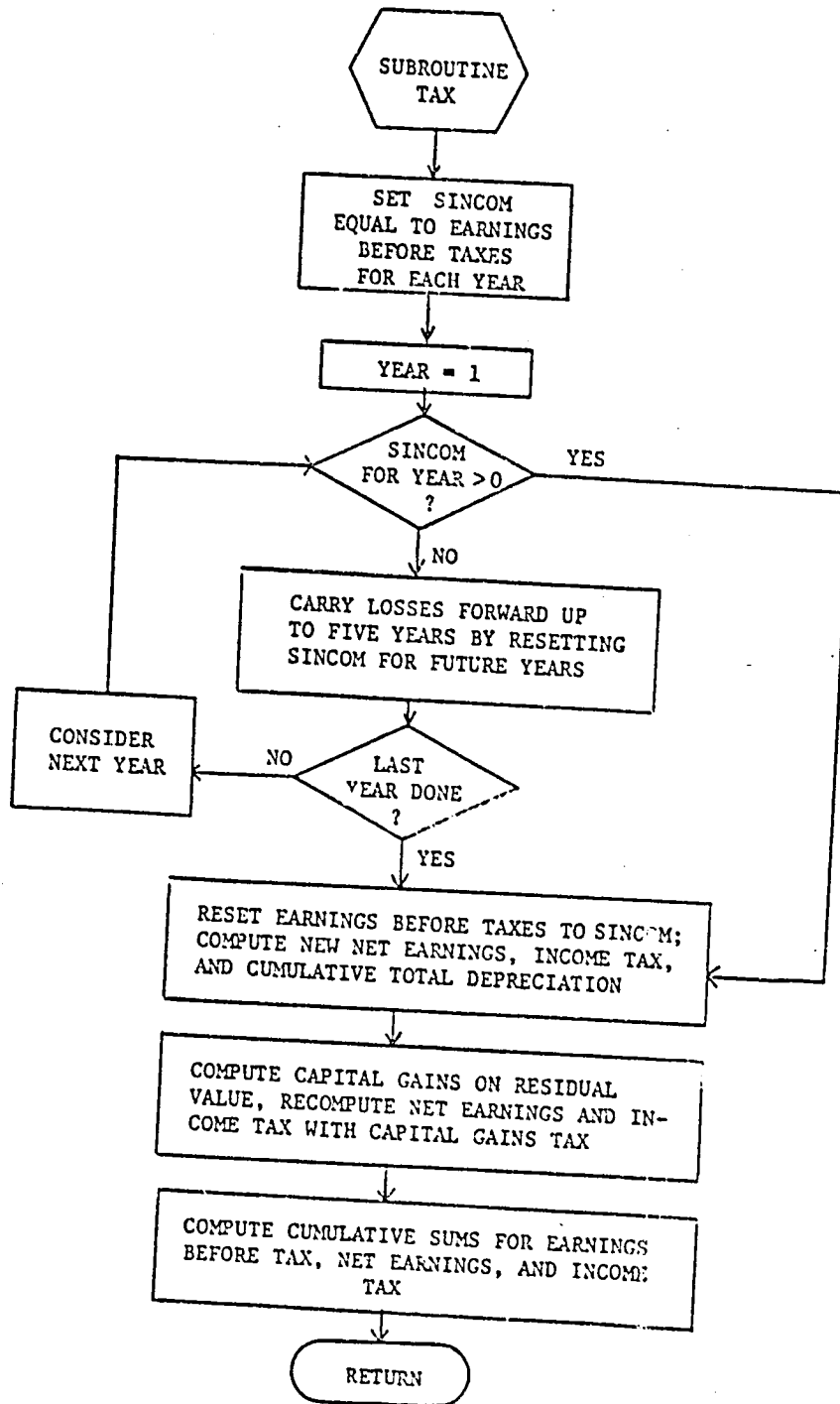


Figure 39 Flowchart of Subroutine TAX Logic

## OUTPUT

Subroutine OUTPUT is called to produce summary tables of the major parameters calculated by the Air Carrier Module. One basic table is produced which is printed on two pages because of the number of columns of values to be output. The values printed summarize information about each year of operation, with a cumulative total appearing as the last line for all appropriate columns. The printout includes values for annual revenue, initial investment, principal payments, operating costs, cumulative depreciation, earnings before interest and taxes, interest, earnings before tax, income tax, net earnings, cash flow, discount factors for associated rate of return (R), discounted cash flow, and net present value (or cumulative discounted cash flow). A flowchart of the program logic for OUTPUT is shown in Figure 40.

Additional programmer-oriented documentation is provided in the appendices. In Appendix A, definitions of the common blocks and variables are provided. A listing of the FORTRAN code for the routines is provided in Appendix E.

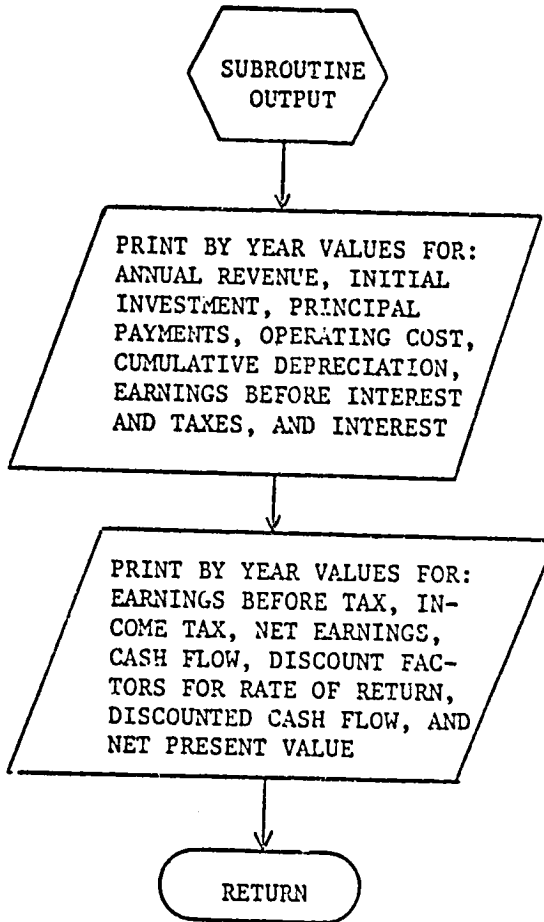


Figure 40 Flowchart of Subroutine OUTPUT Logic

### C. Input

The input data to the Air Carrier Module is in card format and is read from logical unit 5. The input file is described in Table 22 where a description of each entry in this file is provided. Cards 1 through 4 are read by subroutine DIRECT and cards 5 through 16 are read by subroutine INDIRECT. The variable values read in by a routine are those used in calculations within that routine. Thus, the variables on cards 1 through 4 are those used in computing direct operating costs, while those on cards 5 through 16 are used in computing indirect operating costs.

Cards 2 and 5 are comment cards to be used as titles for output listings. Any combination of characters may appear on these card types except those duplicating computer-control cards for the installation running the program. All other cards use the FORTRAN Namelist mode for the input of constant values for all or only some of the variables referring to the named list. The associated namelist is shown for each of these cards in Table 22. Variables and their values can appear in the input stream in any order in the form "NAME = VALUE", where NAME can be a variable name, an array name, or an array element name; and where VALUE can be a single constant or a list of constants when NAME is an array name or an array element name. Only columns 2 through 80 of the input cards may be used (column 1 must be blank). The input list begins with "\$NAMELIST" followed by at least one blank character, followed by the desired list of input variables (NAME = VALUE); and terminated by a "\$". This format allows the selective changing of some (or all) of the input parameters without specifying values for all the input variables as is the case with fixed format inputs.

Table 22

## CARD INPUT DATA FOR THE AIR CARRIER MODULE

<u>Card</u> *	<u>Parameter</u>	<u>Format</u>	<u>Description</u>
1 (Namelist NSTAGE)	U	Integer	Annual aircraft utilization in block hours.
	RL	Real	Maintenance labor rate in dollars per hour.
	NSL	Integer	Number of flight stage lengths (up to 12).
	SL(I)	Real	Length of stage length I in miles, I = 1 to NSL.
	FCK	Real	Basic flight crew cost factor (for a crew of 2) in dollars.
	ADDC	Real	Costs of added flight crew (over 2) in dollars.
	COFL	Real	Cost of fuel in dollars per pound.
	COIL	Real	Cost of oil in dollars per gallon.
2	XNAME(20)	20A4	Comment card containing heading for direct operating cost output table.
3 (Namelist NPLANE)	H	Real	Cruise altitude in feet.
	RCCL	Real	Rate of climb at sea level in feet per minute.
	RCH	Real	Rate of climb at cruise altitude in feet per minute.
	CLS	Real	Climb speed in miles per hour.
	CRS	Real	Cruise speed in miles per hour.
	DESS	Real	Descent speed in miles per hour.
	GMT	Real	Ground maneuver time in hours.
	AMT	Real	Air maneuver time in hours.
	WGR	Real	Gross vehicle weight in pounds.
	F1	Real	Fuel at maximum payload point on range-payload diagrams in pounds.
	D1	Real	Distance at maximum payload point on range-payload diagrams in miles.

\* All cards except 2 and 5 contain inputs for a namelist. The namelist associated with each card is indicated. More than one physical card may be used for any namelist input.

Table 22 (Continued)

<u>Card</u>	<u>Parameter</u>	<u>Format</u>	<u>Description</u>
3 (Namelist NPLANE)	F2	Real	Fuel at maximum fuel point on range-payload diagrams in pounds.
	D2	Real	Distance at maximum payload point on range-payload diagrams in miles.
	VA	Real	Airframe cost in dollars.
	VE	Real	Unit engine cost in dollars.
	WEH	Real	Aircraft empty weight in pounds.
	WEN	Real	Unit engine weight in pounds.
	T	Real	Time factor in engine labor cost calculation.
	NRCREW	Integer	Number in crew.
	NRENGN	Integer	Number of engines.
	NRSEAT	Integer	Number of seats.
	MPLANE	Integer	Aircraft number for this set of input data. (Since the number of aircraft is set equal to one in the program, MPLANE must equal 1.)
4 (Namelist NSTAGE)	NUSTAG	Integer	SET equal to zero, if previously read NSTAGE namelist is to hold. SET equal to 1 if a new NSTAGE namelist is to be entered to override previously read values.
	--	--	If NUSTAG ≠ 0, namelist NSTAGE is entered here. The format for this card is identical to that of card 1.
5	XNAME(20)	20A4	Comment card containing heading for indirect operating cost output table.



Table 22 (Continued)

<u>Card</u>	<u>Parameter</u>	<u>Format</u>	<u>Description</u>
6 (Namelist NPLANE)			Same as for card 3, except only variables H, KCSL, RCH, CLS, CRS, DESS, GMT, AMT, and NKSEAT may be entered. GMT and AMT are set to 0.16 regardless of input values.
7 (Namelist STAGE)	NSL	Integer	Number of flight stage lengths (up to 17).
	FLF(I)	Real	First class load factor (decimal) for stage length I, I = 1 to NSL.
	CLF(I)	Real	Coach load factor (decimal) for stage length I, I = 1 to NSL.
	DIS(I)	Real	Passenger trip length in miles for stage length I, I = 1 to NSL.
	CF(I)	Real	Passenger trip circuitry factor for stage length I, I = 1 to NSL.
	DPT(I)	Real	Departure per passenger trip (flight basis) for stage length I, I = 1 to NSL.
	U	Real	Annual aircraft utilization rate in block hours.
8 (Namelist STEW)	AI5	Real	Dollar cost per stewardess per block hour.
	FSTEW	Real	Average number of stewardesses in first class.
	CSTEW	Real	Average number of stewardesses in coach.
9 (Namelist FOOD)	AI6	Real	Food expense in dollars per passenger per block hour.
	FS	Real	Number of first class seats.
	CS	Real	Number of coach seats.
	FOOD2	Real	First class food expense factor.
10 (Namelist PAXFLT)	AI7	Real	Cost of other passenger in-flight expenses in dollars per passenger per mile.

Table 22 (Continued)

<u>Card</u>	<u>Parameter</u>	<u>Format</u>	<u>Description</u>
11 (Name list ACSERV)	A18	Real	Aircraft line servicing expense in dollars per departure.
	A19	Real	Aircraft control servicing expense in dollars per block hour.
	A110	Real	Landing fee per departure in dollars.
12 (Name list TRAPP)	A111	Real	Passenger traffic servicing expense in dollars per passenger.
	A112	Real	Baggage traffic servicing expense in dollars per ton.
	A112A	Real	Cargo traffic servicing expense in dollars per ton.
	BAG	Real	Baggage per passenger in pounds.
	KTM	Real	Tons of mail carried per flight.
	KTP	Real	Tons of property (cargo) carried per flight.
13 (Name list RES)	A113	Real	Reservation and sales expense per passenger in dollars.
	A114	Real	Reservation and sales expense per passenger-mile in dollars.
	A115	Real	Reservation and sales expense for property in dollars per ton-mile.
	EXP	Real	Fraction of KIP that is express cargo. (The value input does not affect costs.)
14 (Name list ADV)	A116	Real	Advertising and publicity expense per passenger-mile in dollars.
	A117	Real	Advertising and publicity expense for property in dollars per ton-mile.
15 (Name list MAINT)	A118	Real	Maintenance expense for ground property and equipment per departure in dollars.
	A119	Real	Expense for depreciation of general ground property and equipment and amortization in dollars per departure.

Table 22 (Concluded)

<u>Card</u>	<u>Parameter</u>	<u>Format</u>	<u>Description</u>
15 (Namelist MAIN)	AI20	Real	Maintenance equipment depreciation factor.
	AI2	Real	Maintenance expense for flight equipment in dollars per block hour.
16 (Namelist GENADM)	AI21	Real	General and administrative expense factor.
	AI1	Real	Flight operations expense (less rentals) in dollars per block hour.
	AI4	Real	Flight operations expense for rentals in dollars per block hour.

The information provided in Table 22 is of sufficient detail to enable a user to prepare input data for the Air Carrier Module. However, it is important to remember that a number of major program variables are not input parameters but are "hard-wired" into the program modules themselves. Changing these parameters requires modifying the program code. When preparing input, it may be useful to refer to the listing of the input data for the sample problem in Section V.

D. Output

The Air Carrier Module output consists of printout showing the values of input parameters, computed direct and indirect operating costs, and various statistics computed in the financial analysis (including depreciation, earnings, taxes, cash flows, and rate of return on investment). A detailed description of the form and content of this printed output is provided here. To facilitate this description, excerpts from the output of the sample problem (see Section V) are presented in Tables 23 through 39.

The printout begins with a display of the initial investment cost (INTINV) in dollars for the aircraft in each of the 15 years of economic life for the initial trial aircraft price of \$5,000,000. This output is illustrated in Table 23. It is printed by subroutine INPUTS. Since the initial investment cost, i.e., the portion of the aircraft purchase price not borrowed, is assumed to be incurred in the first year, all entries in Table 23 are zero except for the first, which will be equal to 40% of the purchase price.

The information illustrated in Tables 24 and 25 are printed next by subroutine DIRECT. Table 24 provides a printout of the input values for

Table 23  
 SAMPLE PRINTOUT OF INITIAL INVESTMENT COSTS BY YEAR

INTINV=	.2000E+C7	0.	0.	0.	0.	0.	0.	0.	0.	0.
INTINV=	G.	U.	0.	0.	0.	0.	0.	0.	0.	0.

Table 24  
 SAMPLE PRINTOUT OF INPUT VALUES FOR NAMELIST NSTAGE

```

$NSTAGE
U      = .3079E+04,
RL     = .8E+01,
NSL   = 4,
SL     = .575E+03, .115E+04, .1726E+04, .27E+04, 3.0, 3.0, 0.3, 0.3, 0.0, 0.0, 0.0, 0.0,
FCX   = .2E+03,
ADDC  = .7E+02,
COFL  = .4779E-01,
COIL  = .2778E+01,
$END
  
```

Table 25  
SAMPLE PRINTOUT OF INPUT TABLE HEADING AND VALUES FOR NAMELIST NPLANE

\*PROP FAN \*

```

      NPLANE
      N      = .3E+05,
      RCSL   = .376E+04,
      RCH    = .175E+04,
      CLS    = .4E+03,
      CRS    = .542E+03,
      DESS   = .3E+03,
      GHT    = .16E+00,
      AMT    = .16E+00,
      WGR    = .2691E+06,
      F1     = .112E+05,
      D1     = .575E+03,
      F2     = .198E+05,
      D2     = .1115E+05,
      VA     = .197E+08,
      VE     = .1765E+07,
      WEM    = .1845E+06,
      WEN    = .1483E+05,
      T      = .374E+05,
      VRCREW = 2,
      NRENGN = 2,
      NRSEAT = 171,
      MPLANE = 1,
      NUSTAG = 0,
      $END
```

namelist NSTAGE (see card 1 in Table 22). Table 25 provides a printout of the input table heading (card 2 in Table 22), followed by a printout of the input values for namelist NPLANE (card 3 in Table 22). Another table like that illustrated in Table 24 may follow if input parameter NUSTAG is non-zero.

Subroutine DIRECT next prints the direct operating costs illustrated in Tables 26 and 27. These costs are calculated using the equations provided in Section IV.A (Direct Cost Calculations). Table 26 provides computed direct operating costs in dollars per aircraft mile for each of the input flight stage lengths. Table 27 provides direct operating costs in dollars per block hour for each stage length.

Next, the input parameters for the indirect cost calculations are printed by subroutine INDIR. This printout is illustrated in Table 28. It contains a printout of the input table heading as well as the values of namelists NPLANE, NSTAGE, STEWS, FOOD, PAXFLT, ACSERV, TRAFF, RES, ADV, MAINT, and GENADM (see cards 5 through 16 in Table 22). As illustrated in Table 29, subroutine INDIR next prints computed indirect operating costs on a dollar per trip basis for each of the input flight stage lengths. These costs are computed using the indirect cost equations described in Section IV.A (Indirect Cost Calculations).

The next printed output is provided by subroutine INPUTS and is illustrated in Table 30. This table provides the total operating costs for an aircraft in each of the 15 years analyzed. This cost is taken to be the sum of the computed annual direct and indirect operating costs for a single aircraft operating in flights with the first stage length. The total operating costs in each year will be equal since inflation is set

Table 26

SAMPLE PRINTOUT OF DIRECT OPERATING COSTS PER AIRCRAFT MILE

\$ PER AIRCRAFT MILE  
\*PROP FAN \*

CRUISE ALTITUDE (FEET)	30000.			
STAGE LENGTH (MILES)	575.	1150.	1726.	2700.
BLOCK SPEED (MPH)	377.	442.	452.	485.
BLOCK TIME (HOURS)	1.525	2.602	3.734	5.567
FLIGHT TIME (HOURS)	1.365	2.442	3.574	5.407
CRUISE TIME (HOURS)	.842	1.919	3.051	4.834
BLOCK FUEL (POUNDS)	11200.	19800.	28300.	34300.

D.O.C. FACTORS (INPUT) - ANN UTILIZATION(HR) = 3279. LABJR RATE(\$/HR) = 8.00

DIRECT OPERATING COSTS

FLYING OPERATIONS COSTS

FLIGHT CREW	.566	.433	.462	.440
FUEL AND OIL	.952	.841	.815	.621
HULL INSURANCE	.020	.017	.015	.016
TOTAL FLIGHT OPS	1.538	1.341	1.293	1.076

DIRECT MAINTENANCE COSTS

LABOR AIRFRAME	.288	.194	.155	.142
MATERIAL AIRFRAME	.179	.118	.098	.084
LABOR ENGINES	.050	.037	.033	.030
MATERIAL ENGINES	.332	.249	.224	.203
MAINT. BURDEN	.608	.417	.357	.310
TOTAL MAINTENANCE	1.458	1.015	.877	.768

TOTAL DIRECT OPERATING COST

\$/AIRCRAFT MILE	2.995	2.356	2.170	1.845
\$/FLIGHT HOUR	1261.5	1109.6	1348.1	921.3
\$/BLOCK HOUR	1129.1	1041.4	1003.2	894.8
\$/AVAIL. SEAT MILE	.018	.014	.013	.011

COST PER AIRCRAFT TRIP = \$ 734.91 PLUS \$ 1.72/MILE

COST PER SEAT TRIP = \$ 4.30 PLUS \$ .0100/MILE



Table 27

SAMPLE PRINTOUT OF DIRECT OPERATING COSTS PER BLOCK HOUR

\$ PER BLOCK HOUR  
\*PROP FAN \*

CRUISE ALTITUDE (FEET)	30000.			
STAGE LENGTH (MILES)	575.	1150.	1726.	2700.
BLOCK SPEED (MPH)	377.	442.	452.	485.
BLOCK TIME (HOURS)	1.525	2.602	3.734	5.557
FLIGHT TIME (HOURS)	1.365	2.442	3.574	5.407
CRUISE TIME (HOURS)	.842	1.919	3.051	4.884
BLOCK FUEL (POUNDS)	11200.	19800.	23300.	34300.

D.O.C. FACTORS (INPUT) - ANN UTILIZATION(%) = 3079. LABOR RATE (\$/HR) = 8.00

DIRECT OPERATING COSTS

FLYING OPERATIONS COSTS				
FLIGHT CREW	213.455	213.455	213.455	213.455
FUEL AND OIL	358.678	371.672	376.770	301.121
HULL INSURANCE	7.545	7.545	7.545	7.545
TOTAL FLIGHT OPS	579.677	592.672	597.769	522.121

DIRECT MAINTENANCE COSTS				
LABOR AIRFRAME	108.424	85.920	76.260	58.944
MATERIAL AIRFRAME	67.450	52.093	45.500	40.507
LABOR ENGINES	18.985	16.458	15.373	14.052
MATERIAL ENGINES	125.277	109.955	103.377	98.196
MAINT. BURDEN	229.336	184.282	164.940	150.293
TOTAL MAINTENANCE	549.472	448.708	405.450	372.093

Table 28

SAMPLE PRINTOUT OF INPUT PARAMETERS FOR INDIRECT OPERATING COST CALCULATIONS

\*PROP FAN \*

\$NPLANE

H = .3E+05,  
 RCSL = .376E+04,  
 RCH = .175E+04,  
 CLS = .4E+03,  
 CRS = .542E+03,  
 DESS = .3E+03,  
 GMT = .16E+00,  
 AMT = .16E+00,  
 NRSEAT = 171,  
 SEND

\$NSTAGE

NSL = 3,  
 FLF = .37E+00, .35E+00, .4E+00, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,  
 CLF = .64E+00, .6E+00, .67E+00, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,  
 DIS = .575E+03, .115E+04, .1726E+04, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,  
 CF = .101E+01, .101E+01, .101E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,  
 DPT = .11E+01, .1E+01, .12E+01, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,  
 U = .3079E+04,  
 SEND

Table 28 (Continued)

\$STEWS

AI5 = .2219E+02,

FSTEW = .12E+01,

CSTEW = .18E+01,

\$END

\$FOOD

AI6 = .94995E+00,

FS = .12E+02,

CS = .159E+03,

FOODR = .236E+01,

\$END

\$PAXFLT

AI7 = .107E-02,

\$END

\$ACSERV

AI8 = .688E+02,

AI9 = .1978E+02,

AI10 = .3436E+02,

\$END

Table 28 (Continued)

\$TRAFF

AI11    "   .201E+01,  
AI12    "   .9906E+02,  
AI12A   "   .9906E+02,  
BAG      "   .3E+02,  
RTM      "   .2E+00,  
RTP      "   .4E+00,  
\$END

\$RES

AI13    "   .121E+01,  
AI14    "   .474E-02,  
AI15    "   .625E-02,  
EXP      "   .14E+00,  
\$END

\$ADV

AI16    "   .142E-02,  
AI17    "   .525E-02,  
\$END

Table 28 (Concluded)

\$MAINT

AI18 = .2432E+02,  
AI19 = .2097E+02,  
AI20 = .1729E-01,  
AI2 = .15525E+03,

\$END

\$GENADH

AI21 = .5407E-01,  
AI1 = .38279E+03,  
AI2 = .15525E+03,  
AI4 = .2418E+02,

\$E'D

Table 29

SAMPLE PRINTOUT OF INDIRECT OPERATION COSTS PER TRIP BY STAGE LENGTH

\*PROP FAN \*

PASSENGER TRIP DISTANCE (MILES)	575.	1150.	1726.
BLOCK SPEED (MPH)	377.	442.	462.
BLOCK TIME (HOURS)	1.623	2.622	3.734
FLIGHT TIME (HOURS)	1.355	2.442	3.574
DEP/PAX TRIP (FLIGHT BASIS)	1.100	1.000	1.200
PASSENGER TRIP CIRCUITRY FACTOR	1.013	1.013	1.010
COACH LOAD FACTOR	.640	.600	.670
FIRST CLASS LOAD FACTOR	.370	.350	.400
FLYING OPERATIONS(LESS RENTALS) EXP	C1 583.901	995.098	1429.213
MAINTENANCE EXPENSE FLY EQUIPMENT	C2 235.815	403.988	579.553
RENTALS FLT EQUIP	C4 36.884	52.921	90.280
PASSENGER IN FLY EXPENSE			
STEWES	C8 101.545	173.227	248.551
FOOD	C11 152.537	250.325	418.019
OTHER	C14 59.993	123.733	207.653
AIRCRAFT SERVICING EXP			
LINE SERVICE	C15 75.580	53.800	82.560
CONTROL	C16 30.172	51.471	73.852
LANDING FEES	C17 37.796	34.360	41.232
TOTAL AIRCRAFT SERVICING	TAS 143.548	154.531	197.644
TRAFFIC SERVICING EXP			
PAX ^ BAGGAGE	C22 371.265	343.192	389.199
CARGO	C23 59.435	59.436	59.435
TOTAL TRAFFIC SERVICING	TTS 430.701	407.628	448.635
RESERVATION ^ SALES			
PAX	C25 420.845	553.865	1054.635
PROPERTY	C27 1.452	2.904	4.353
TOTAL RESERVATION ^ SALES	TRS 422.295	571.769	1058.993
ADVERTISING ^ PUBLICITY			
PAX	C30 87.579	154.273	275.590
PROPERTY	C31 1.220	2.439	3.661
TOTAL ADVERTISING ^ PUBLICITY	TAP 93.799	165.712	279.250
MAINTENANCE EXP- GRD PROP ^ EQUIP	C32 25.752	24.320	29.134
DEPR-GENERAL GRD PROP ^ EQUIP ^ AMORT	C33 23.057	20.970	25.154
DEPR-MAINTENANCE EQUIP	C34 4.557	7.405	10.527
GENERAL ^ ADM EXPENSE	C35 124.359	135.292	259.652
TOTAL INDIRECT OPERATING EXPENSE	C35 1574.355	177.053	193.281
INDIRECT COST PER AIRCRAFT MILE	2.773	1.910	1.850
INDIRECT COST PER FLIGHT HOUR	1158.	900.	894.
INDIRECT COST PER BLOCK HOUR	1045.217	914.315	855.255
INDIRECT COST PER AV. SEAT MILES	.015	.011	.011

COST PER AIRCRAFT TRIP = \$ 991.55 PLUS \$ 1.05/MILE

COST PER SEAT TRIP = \$ 5.80 PLUS \$ .0061/MILE

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Table 30  
SAMPLE PRINTOUT OF TOTAL OPERATING COSTS BY YEAR

OPCOST(\$)									
6694873.	6694873.	6694873.	6694873.	5594873.	6694873.	6694873.	6694873.	6694873.	6694873.
6694873.	6694873.	5594873.	5594873.	5594873.					

to zero in the program.

Program OPLIFE then prints a repeat of Table 23, which provides initial investment costs by year for the first aircraft price (\$5,000,000).

The remainder of the printout provides information computed during the financial analysis performed for each of the 11 aircraft prices (\$5,000,000 to \$30,000,000 in increments of \$2,500,000). The information illustrated in Tables 31 through 39 are printed for each aircraft price. The tables provided here are for the first aircraft price, i.e., \$5,000,000. All the printed information is in dollars, unless otherwise noted.

Table 31 is printed by subroutine NETSUB. This table presents the computed values for double-declining depreciation (DEPR), straight-line depreciation (STDEP), earnings before interest and taxes (EBIAT), and earnings before taxes (EBT) for each of the 15 years. Next, a table like that illustrated in Table 23 is printed by subroutine SUM for the aircraft price under consideration. Table 32 is then printed by subroutine SUM. This table provides the total initial investment costs (SINTIN) by year for the aircraft price under consideration. Because the number of aircraft analyzed is preset in the program at one, the total initial investment cost is always equal to the initial investment cost (INTINV) for one aircraft, which was previously printed.

Subroutine SUM then prints the depreciation statistics illustrated in Table 33. In this table, the double-declining aircraft depreciation (DEPR) by year is printed, followed by the straight-line depreciation (STDEP) by year, and the total depreciation (DEPREC) by year.

The next printed output is produced by subroutine CFSUB and is illustrated in Table 34. This table provides the net cash flow in each year.



Table 31

SAMPLE PRINTOUT OF DEPRECIATION AND EARNINGS BY YEAR

DEPR	.5567E+06
STDEP	0.
EBIAT	.2385E+06
EBT	-.6154E+05
DEPR	.5024E+06
STDEP	0.
EBIAT	.3027E+06
EBT	.1212E+05
DEPR	.4455E+06
STDEP	0.
EBIAT	.3596E+06
EBT	.7945E+05
DEPR	.3950E+06
STDEP	0.
EBIAT	.4101E+06
EBT	.1414E+06
DEPR	.3502E+06
STDEP	0.
EBIAT	.4549E+06
EBT	.1987E+06
DEPR	.3105E+06
STDEP	0.
EBIAT	.4946E+06
EBT	.2522E+06
DEPR	.2754E+06
STDEP	0.
EBIAT	.5298E+06
EBT	.3026E+06
DEPR	C.
STDEP	.1755E+06
EBIAT	.6296E+06
EBT	.4192E+06
DEPR	C.
STDEP	.1755E+06
EBIAT	.6296E+06
EBT	.4376E+06
DEPR	0.
STDEP	.1755E+06
EBIAT	.6296E+06
EBT	.4578E+06
DEPR	0.
STDEP	.1755E+06
EBIAT	.6296E+06
EBT	.4801E+06
DEPR	C.
STDEP	.1755E+06
EBIAT	.6296E+06
EBT	.5046E+06
DEPR	0.
STDEP	.1755E+06
EBIAT	.6296E+06
EBT	.5315E+06
DEPR	C.
STDEP	.1755E+06
EBIAT	.6296E+06
EBT	.5611E+06
DEPR	C.
STDEP	.1755E+06
EBIAT	.6296E+06
EBT	.5937E+06





Table 34  
 SAMPLE PRINTOUT OF CASH FLOW BY YEAR WITHOUT OPERATING LOSS  
 CARRYOVERS OR CAPITAL GAINS TAX

CASH FLOW*	-.1560E+07	.4049E+06	.3725E+05	.3428E+05	.3153E+06	.2896E+06	.2654E+06	.2095E+06	.2007E+06	.1910E+06
CASH FLOW*	.1803E+06	.1685E+06	.1556E+06	.1414E+06	.8757E+06					

The net cash flow in any year is computed as cash inflow (revenue plus salvage value of retired aircraft) minus cash outflow (initial investment cost plus payment on purchase loan plus total operating cost plus income taxes). In this case, taxes are computed at a straight 48% of earnings before taxes, without operating loss carryovers or tax on capital gains. Earnings before taxes in this case is taken as revenue minus operating cost minus depreciation minus loan interest.

Subroutine TAX provides the next printed output, which is illustrated in Table 35. This table provides the capital gains (CG) after capital gains tax by year. Since the aircraft is assumed to be retired in year 15, the only nonzero capital gain will occur in year 15. After tax adjustments are computed for carryovers of operating losses and capital gains tax (see Section IV.A - Tax Adjustments), subroutine CFSUB prints the cash flow for each year including these tax adjustments. This printout is illustrated in Table 36. The cash flow with tax adjustments is used in the remainder of the financial analysis.

Next in the printed output, subroutine DCFSUB provides information on the iterative calculations used to determine internal rate of return on investment. This printout is illustrated in Table 37. After every tenth iteration, the trial rate of return is printed along with the associated discounted cash flow sum. The last line in Table 37 contains the final values to which the iterative procedure converges.

Subroutine OUTPUT next prints summary statistics computed in the financial analysis for the current aircraft price. This printout is illustrated in Tables 38 and 39. The information printed for each year includes annual revenue, initial investment, principal payments on the



Table 36  
 SAMPLE PRINTOUT OF THE CASH FLOW BY YEAR WITH TAX ADJUSTMENT FOR LOSS  
 CARRYOVERS AND CAPITAL GAINS

CASH FLOW=	-.1589E+07	.4107E+06	.3963E+06	.3284E+06	.2331E+06	.1120E+06	.2654E+06	.2095E+06	.2007E+06	.1910E+06
CASH FLOW=	.1803E+06	.1685E+06	.1556E+06	.1414E+06	.4507E+06					

Table 37

SAMPLE PRINTOUT OF TRIAL RATES OF RETURN ON INVESTMENT AND ASSOCIATED  
DISCOUNTED CASH FLOW SUM

.0190000	1590540.4742752
.0290000	1386319.4164780
.0390000	1202453.6305562
.0490000	1036495.9877356
.0590000	806328.6796901
.0690000	750115.1137735
.0790000	626259.3143743
.0890000	513371.5913789
.0990000	410239.4516678
.1090000	315802.9055015
.1190000	229133.4634741
.1290000	149416.2423242
.1390000	75934.6815063
.1490000	8057.4816714
.1510000	-4895.6622882



Table 38  
 SAMPLE PRINTOUT OF SUMMARY FINANCIAL ANALYSIS STATISTICS (PART 1)

YEAR	ANNUAL REVENUE (\$)	INVESTMENT INITIAL (\$)	PRINCIPAL PAY (\$)	OPERATING COST (\$)	DEPRECIATION (\$)	EARNING BEFORE INTEREST AND TAX (\$)	INTEREST (\$)
1	7500000.00	2000000.00	94421.33	5594873.45	566656.67	238459.88	300000.00
2	7500000.00	0.00	103353.45	5694873.45	1069111.11	302682.10	290557.87
3	7500000.00	0.00	114249.81	6694873.45	1514611.85	359625.81	280171.52
4	7500000.00	0.00	125574.79	6694873.45	1909622.51	410115.89	258746.54
5	7500000.00	0.00	138242.27	6694673.45	2259855.29	454883.77	256179.06
6	7500000.00	0.00	152066.50	6694873.45	2570413.89	494577.95	242354.83
7	7500000.00	0.00	167273.15	6694873.45	2845756.98	529773.46	227148.18
8	7500000.00	0.00	184000.46	6694873.45	3021295.11	629597.42	210420.87
9	7500000.00	0.00	202400.51	6694873.45	3196825.24	629597.42	192020.02
10	7500000.00	0.00	222640.56	6694873.45	3372354.36	629597.42	171780.77
11	7500000.00	0.00	244304.51	6694873.45	3547883.49	629597.42	149516.72
12	7500000.00	0.00	269395.38	6694873.45	3723412.62	629597.42	125026.25
13	7500000.00	0.00	298334.58	6694873.45	3898941.75	629597.42	98086.75
14	7500000.00	0.00	329959.04	6694873.45	4074470.87	629597.42	68453.29
15	7500000.00	0.00	353564.85	6694873.45	4250000.00	629597.42	35856.48
TOTALS	112500000.00	2000000.00	3000000.00	100423101.78	4250000.00	7826875.22	2916319.96

Table 39  
 SAMPLE PRINTOUT OF SUMMARY FINANCIAL ANALYSIS STATISTICS (PART 2)

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YEAR	EARNINGS BEFORE TAX (\$)	INCOME TAX (\$)	NET EARNINGS (\$)	NET CASH FLOW (\$)	DISCOUNT FACTOR ROI = .151	DISCOUNTED CASH FLOW (\$)	NPV (\$)
1	-61540.12	0.00	-61540.12	-1589294.78	1.0000	-1589294.78	-1589294.78
2	0.	0.00	0.00	410709.22	.8688	356824.69	-1232470.09
3	.30E+05	14418.43	15619.97	396286.78	.7548	299129.29	-933340.80
4	.17E+06	82275.72	89132.03	328429.49	.6558	215385.36	-717455.44
5	.37E+06	177653.98	192458.48	233051.24	.5678	132785.34	-565170.11
6	.62E+06	298721.08	323614.50	111984.14	.4950	55434.47	-529735.64
7	.30E+06	145260.13	157365.14	255445.09	.4301	114162.31	-415573.33
8	.42E+06	201204.74	217971.81	209500.47	.3737	78281.25	-337292.08
9	.44E+06	210036.77	227539.33	200668.45	.3246	65144.31	-272147.77
10	.46E+06	219751.99	238064.65	190953.23	.2820	53657.86	-218289.91
11	.48E+06	230438.74	247641.97	180266.48	.2450	44173.49	-174116.41
12	.50E+06	242194.16	262377.01	158511.06	.2129	35875.66	-138240.76
13	.53E+06	255125.12	275285.55	155580.09	.1850	28777.31	-109463.45
14	.56E+06	259349.18	291794.95	141355.03	.1607	22716.17	-86747.28
15	.59E+06	509995.65	833745.29	650709.57	.1396	90851.52	4104.34
TOTALS	.54E+07	2856425.70	.33E+07	2054152.56		4104.34	

purchase loan, operating cost, depreciation, earnings before interest and taxes (excluding capital gains), interest payment on the purchase loan, earnings before income taxes (excluding capital gains), income taxes (including capital gains tax), net earnings (including capital gains taxes), net cash flow, discount factor for the computed rate of return, discounted cash flow and cumulative sum of discounted cash flow (NPV). In addition, the totals for many of these quantities are provided.

The remainder of printed output of the Air Carrier Modules consists of a repeat of Tables 31 through 39 for each of the other 10 aircraft prices.

## V SAMPLE PROBLEM

The sample outputs which were presented for illustration purposes in Sections II, III, and IV were generated from a sample run of the ABC-ART models. In this Section, the job setup, input data, and computer resources for the sample problem are described. This description should prove valuable in preparing job control language for a run and preparing an input file. The sample problem can also be run as a check on proper program installation.

### A. Job Setup

The sample problem was run at the NASA Ames Research Center using the CDC 7600 in batch mode using the SCOPE 2.1.3 operating system. The ABC-ART models are exercised in two distinct job steps. The Fleet Accounting Module and Airframe Manufacturer Modules are run in the first job step. The Air Carrier Module is then run in the second job step.

Assuming that the FORTRAN source code for the Fleet Accounting and Airframe Manufacturer Modules (as shown in Appendices C and D) reside in a direct-access disk file named FILE1, that the object code for the ZETA plotter resides on a direct-access disk file named ULPLOT, and that the input data is on a card file (using 029 ASCII punch), the job setup on the CDC 7600 to compile, load, and execute the Fleet Accounting and Airframe Manufacturer Modules is as follows:

```
Job card  
Account card  
ATTACH, FILE1.  
FTN, I=FILE1, R=3, OPT=2.  
ATTACH, PLOTPGK, ULPLOT, ID=MSXELT.  
LIBRARY, PLTPGK.
```

LDSET, PRESET=ZERO  
LGO.  
DISPOSE, TAPE9, \*PR.  
DISPOSE, TAPE11, \*PR.  
7/8/9 card  
Card input data  
6/7/8/9 card

The 7/8/9 card consists of a 7/8/9 punch in column one; the 6/7/8/9 card consists of a 6/7/8/9 punch in column 1.

The card input data is assumed to be read from logical unit 5 and the printer output is provided on logical unit 6. Logical units 9 and 11 provide temporary disk storage for output generated by the Fleet Accounting Module that is to be plotted. Logical units 9 and 11 are used by subroutines PLOTTER and PLOTSGL, respectively, in plotting results.

Assuming that the FORTRAN source code for the Air Carrier Module (as shown in Appendix E) resides on a direct-access disk file named FILE2 and that the input data is on a card file (using 029 ASCII punch), the job setup on the CDC 7600 to compile, load, and execute the Air Carrier Module is as follows:

Job card  
Account card  
ATTACH, FILE2.  
FTN, I=FILE2, LCM=1, OPT=1, R=3.  
LGO, PL=7777.  
7/8/9 card  
Card input data  
6/7/8/9 card

The card input data is assumed to be read from logical unit 5 and the printed output is provided on logical unit 6.

B. Input Data

The card input data for the Fleet Accounting and Airframe Manufacturer Modules are prepared in accordance with the specifications provided in Sections II.C and III.C, respectively. As indicated previously, the input data for the Airframe Manufacturer Module precedes that for the Fleet Accounting Module in the input stream. Table 40 provides a listing of the card input data file for the sample run of these modules. Note that several end-of-file cards (which consist of a 7/8/9 punch in column one) are embedded in the data file.

The card input data for the Air Carrier Module is prepared using the format described in Section IV.C. Table 41 provides a listing of the card input data for the sample run of the Air Carrier Module.

C. Computer Resources

Hardware requirements to utilize the ABC-ART software include a card reader, printer, disk storage, and a ZETA plotter. The software is currently programmed for use on the CDC 7600 computer system. The program makes use of both small core memory and large core memory on the CDC 7600 system.

The job step to run the Fleet Accounting and Airframe Manufacturer Modules requires 132K octal words of small core memory and no large core memory. The sample problem took 5 CPU seconds to compile and 17 CPU seconds to execute. The Air Carrier Module requires 154K octal words of small core memory and 144K octal words of large core memory to run. The sample problem took 3 CPU seconds to compile and 1 CPU second to execute.

Table 40  
 LISTING OF CARD INPUT DATA FOR SAMPLE RUN OF THE FLEET ACCOUNTING AND  
 AIRFRAME MANUFACTURER MODULES

```

$INPUT1
EN=2.0, WACLM=0.8,
T=4500.0,
WACS=2450.0, WAERO=3890.0, WRBODY=36320.0,
WELCAN=2520.0, WEMPE=8140.0, WENACC=1280.0, WENGS=20110.0,
WFUSY=64.0, WFUTUT=48630.0, WGRASS=269100.0, WNYCAD=3770.0,
WINST=47.0, WLG=15570.0, WACEL=11290.0, WACCU=19370.0, WPOWER=2060.0,
WING=43730.0, WPAYL=45730.0,
WHANDI=100.0, WANTIC=500.0, WAVION=2120.0, WTREVS=6990.0,
SEND
$INPUT2
ADI=0.1, AGEPI=0.1, AGEPI=0.1, CFACS=2.7, CFAERO=0.65, CFDOUY=0.70,
CFFLCD=0.80, CFEMP=1.9, CFENAC=0.40,
CFHYC=0.55, CFINSI=0.70, CFLG=0.70, CFPACC=3.10, CFPWE=3.2,
CFWING=0.9, CONFIG=1.0, CTJI=1.0, ENSPAD=0.4, ENSPAR=0.0,
FACI=0.0, FEE=0.00, FTOI=0.10, FVSPAR=0.2, GTSPAR=0.10, ICUNFG=6,
IDATA=1, IPWER=2, IPROD=1,
IOPS=0, WCRLE=3, NCMIA=5, WCV=5.0, NG=1,
NOENGL=5000.0, NOYRS=0.75, NOYRS1=1.0,
NV=87.0, WVT=1.0, 5.0, 100.0, 300.0, 600.0,
PUTJI=0.10, RATE=11.0, RE=17.0, RT=15.0, TOOLC=1.0,
AFASSY=0.00, XNF=0.20,
LEARN=0.00, LEARN=1.85, LEARN=81.85,
CFFUSY=0.10,
SEND
REDUCED ENERGY PROP-FAN (167-762)
$IN
YEAR = 1985.0, VE = 165570.0, FEE = 0.00, NVHF = 872.0, IAIRPL=3,
APY = 0.06, IENGS = 2, PH = 171.0, EN = 2.0, T = 42420.0,
WENGS = 20000.0,
SEND
ZZZZZZZZZZ
$INPUT1
EN=2.0, WACLM=0.8,
T=4500.0,
WACS=2450.0, WAERO=3890.0, WRBODY=36320.0,
WELCAN=2520.0, WEMPE=8140.0, WENACC=1280.0, WENGS=20110.0,
WFUSY=64.0, WFUTUT=48630.0, WGRASS=269100.0, WNYCAD=3770.0,
WINST=47.0, WLG=15570.0, WACEL=11290.0, WACCU=19370.0, WPOWER=2060.0,
WING=43730.0, WPAYL=45730.0,
WHANDI=100.0, WANTIC=500.0, WAVION=2120.0, WTREVS=6990.0,
SEND
  
```

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Table 40 (Continued)

```

SINPUT2
AUI=0.1, AUCO=0.1, AGEPI=0.1, CFACS=2.7, CFAERO=0.65, CFBODY=0.70,
CFELCD=0.80, CFEMP=1.9, CFEMAC=0.40,
CFHYCD=0.55, CFINSI=0.70, CFLB=0.70, CFPACC=3.10, CFPow=3.2,
CFPIG=0.9, CONFIG=1.0, CTJI=1.0, ENSPAC=0.4, ENSPAR=0.40,
FACI=0.0, FEEMP=0.0, FTDI=0.10, FVSPAR=0.2, GTSPAR=0.10, ICUNFG=6,
IDATA=1, IFUNF=2, IPHOU=1,
IOPS=0, NCHOP=3, NDATA=5, NFV=5.0, NG=1,
NUENGL=500.0, NOYRS=0.75, NOYHS1=1.0,
NV=867.0, NVHF=1.0, 5.0, 100.0, 300.0, 600.0,
PUTJI=0.1, WATE=11.0, RE=17.0, RT=15.0, TOOLC=1.0,
XFASSY=1.00, XNF=0.20,
LEARN=55.10, LEARNH=1.85, LEARNB=1.85,
CFFUSV=0.10,
SEND
REDUCED ENERGY PROP-FAN (767-767)

```

```

SIN
YEAR = 1985.0, WE = 165570.0, FEE = 0.00, NVHF = 872.0, IAIRPL=3,

```

```

APT = 0.04, IENOS = 2, PN = 171.0, EN = 2.0, T = 42*20.0,
#ENOS = 2000.0,

```

```

SEND
ZZZZZZZZZZ
END OF FILE

```

```

7. 1.
7. 1.

```

```

END OF FILE

```

SHUNT	RANGE						
6.0	0.0	6.0	6.0	6.0	6.0	6.0	6.0
6.0	7.0	6.0	6.0	6.0	6.0	6.0	6.0
6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
6.0	7.0	6.0	6.0	6.0	6.0	6.0	6.0
.55	.55	.55	.55	.55	.55	.55	.55
.55	.55	.55	.55	.55	.55	.55	.55
.55	.55	.55	.55	.55	.55	.55	.55
.55	.55	.55	.55	.55	.55	.55	.55



Table 40 (Concluded)

1	2ENGNBTF	1464.	89.7	.2157	311.	2649.	16.	
	0.	0.	0.	0.	0.	30.0	81.7	135.8
	163.4	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
0								
0								
	MEDIUM	Range						
	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
	6.0	4.0	6.0	6.0	6.0	6.0	6.0	6.0
	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
	.55	.55	.55	.55	.55	.55	.55	.55
	.55	.55	.55	.55	.55	.55	.55	.55
	.55	.55	.55	.55	.55	.55	.55	.55
	.55	.55	.55	.55	.55	.55	.55	.55
3	4ENGNBTJ	1900.	134.0	.2523	408.	2509.0	16.	
	0.	0.0	6.0	6.0	0.0	0.0	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	4ENGNBTF	1901.	144.3	.1959	404.	3102.	16.	
	0.	0.	5.0	7.5	7.5	7.5	8.4	17.
	24.2	19.0	23.5	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
	3ENGNBTF	1403.	112.2	.2140	358.	3079.	16.	
	0.	0.	0.	0.	50.	74.4	77.7	92.1
	110.1	92.	52.4	24.4	13.3	21.8	55.0	26.3
	0.	0.	0.	0.	0.	0.	0.	0.
	0.	0.	0.	0.	0.	0.	0.	0.
0								
2	NZENGWHPF	1401.	171.	.114	358.	3079.	16.	NZENGWHPF
	N1995AC	1495.	171.	.114	358.	3079.	16.	
	END OF FILE							
1	END OF FILE							

Table 41  
LISTING OF CARD INPUT DATA FOR SAMPLE RUN OF THE AIR CARRIER MODULE

```

$NSTAGE
U=3079., NL=0., NSL=0.
SL=575., L1=0., L2=1726., L3=2700., L4=0., L5=0., L6=0., L7=0., L8=0., L9=0., L10=0., L11=0., L12=0.
FCK=200., ANDC=71., CFL=0+79., CIL=2.778.
SEND
  *PKOP 0.0 *
$NPLANE
M=3000., MSL=376., HCL=1750., CLS=400., CRS=5*2., DESS=300., GMT=.16.
AMT=.16., M=26910., F1=11200., D1=575., F2=19800., D2=11150.
VA=1470000., VF=1765000., *EN=10*500., *EN=10*300., T=37400., MCREW=0.
NHENGR=2., NSEAT=171., NPLANE=1., NSTAG=0.
SEND
  *PHID 0.0 *
$NPLANE
M=3000., MSL=376., HCL=1750., CLS=400., CRS=5*2., DESS=300., GMT=.16.
AMT=.16., NSEAT=171.
SEND
$NSTAGE
NSI=3.
FLF=.37., J1=.40., J2=.00., J3=.00., J4=.00., J5=.00., J6=.00., J7=.00., J8=.00., J9=.00., J10=.00.
CLF=.64., J1=.67., J2=.00., J3=.00., J4=.00., J5=.00., J6=.00., J7=.00., J8=.00., J9=.00., J10=.00.
DIS=575., L1=0., L2=1726., L3=0., L4=0., L5=0., L6=0., L7=0., L8=0., L9=0., L10=0., L11=0., L12=0.
CF=1.01., J1=.01., J2=.00., J3=.00., J4=.00., J5=.00., J6=.00., J7=.00., J8=.00., J9=.00., J10=.00.
DPT=1.11., J1=.17., J2=.00., J3=.00., J4=.00., J5=.00., J6=.00., J7=.00., J8=.00., J9=.00., J10=.00.
U=3079.
SEND
$STEPS
AIS=22.1., I=TLW=1.2., COSTEN=1.8.
SEND
$FOOD
A10=.94970., F=12., CS=159., FOODW=2.36.
SEND
$PAXFLT
A17=.00107.
SEND
$ACSENV
A18=66.H., A19=19.7H., A110=34.36.
SEND
$THUFF
A111=2.01., A112=99.06., A113=09.06., BAG=30., NIMS=2., MTF=.4.
SEND
$RES
A114=1.21., A115=.0474., A116=.00625., EXP=.14.
SEND
$ADV
A110=.00142., A117=.00525.
SEND
$MATH
A118=24.12., A119=2.97., A120=.01724., A121=155.25.
SEND
$GENADM
A121=.05407., A11=302.79., A12=155.25., A14=24.16.
SEND
END OF FILE

```

END

DATE

FILMED

MAR 14 1980



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Delete your name from this slip when returning material to the library.		
NAME	DATE	MS
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