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Appendix A

COMMON BLOCK AND VARIABLE DEFINITION

(NASA-CR-152279) DOCUMENTATION OF THE N80-15866
ANALYSES OF THE BENEFITS AND COSTS OF
AERONAUTICAL RESEARCH AND TECHNOLOGY MODELS HC A08/MF A01
(ABC-ART). VOLUME 2: APPENDICES Final Unclas
Report (SRI International Corp., Menlo Park, G3/66 44234

N80-15866#

CONTENTS

APPENDICES

A COMMON BLOCK AND VARIABLE DEFINITION A-1

B DESCRIPTION OF PLOTTER SOFTWARE ROUTINES B-1

C LISTING OF PROGRAM SOURCE CODE FOR THE FLEET ACCOUNTING MODULE C-1

D LISTING OF PROGRAM SOURCE CODE FOR THE AIRFRAME MANUFACTURER MODULE D-1

E LISTING OF PROGRAM SOURCE CODE FOR THE AIR CARRIER MODULE E-1

F COSMIC SOFTWARE SUBMITTAL INFORMATION F-1

TABLES

A.1 Common Block Definition and Usage A-2

A.2 Definition of Fleet Accounting Module Variables A-4

A.3 Definition of Airframe Manufacturer Module Variables A-10

A.4 Definition of Air Carrier Module Variables A-28

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.

CONTENTS

VOLUME I: Technical Report

PREFACE i

LIST OF ILLUSTRATIONS iv

LIST OF TABLES vi

I INTRODUCTION 1

II FLEET ACCOUNTING MODULE 5
- A. Methodology 5
- B. Program Logic 10
- C. Input 32
- D. Output 37

III AIRFRAME MANUFACTURER MODULE 53
- A. Methodology 53
- B. Program Logic 70
- C. Input 94
- D. Output 102

IV AIR CARRIER MODULE 119
- A. Methodology 119
- B. Program Logic 137
- C. Input 158
- D. Output 164

V SAMPLE PROBLEM 189
- A. Job Setup 189
- B. Input Data 191
- C. Computer Resources 191

VOLUME II:

APPENDICES

A COMMON BLOCK AND VARIABLE DEFINITION A-1

ILLUSTRATIONS

1 Program Structure of the Fleet Accounting Module 11
2 Flowchart of Program BET Logic 12
3 Flowchart of Subroutine AMORTIZ Logic 19
4 Flowchart of Subroutine MODS Logic 20
5 Flowchart of Subroutine BUYS Logic 21
6 Flowchart of Subroutine SHARE Logic 23
7 Flowchart of Subroutine UNIT04 Logic 24
8 Flowchart of Subroutine CURVES Logic 25
9 Flowchart of Subroutine SETUP Logic 26
10 Flowchart of Subroutine PLOTSGL Logic 28
11 Flowchart of Subroutine PLOTTER Logic 30
12 Sample Plotted Output of RPMs Flown versus Time for an Individual Aircraft Type 48
13 Sample Plotted Output of Fuel Consumed versus Time for an Individual Aircraft Type 49
14 Sample Plotted Output of RPMs Flown versus Time Accumulated over Aircraft Types 50
15 Sample Plotted Output of Fuel Consumed versus Time Accumulated over Aircraft Types 51
16 Program Structure of the Airframe Manufacturer Module 71
17 Flowchart of Subroutine INPLANT Logic 72
18 Flowchart of Subroutine PLANT Logic 75
19 Flowchart of Subroutine ACCOST Logic 77
20 Flowchart of Subroutine COSTPR Logic 80
21 Flowchart of Subroutine ACPRICE Logic 82
22 Flowchart of Subroutine CASHFLW Logic 83
23 Flowchart of Subroutine RDTE Logic 85
24 Flowchart of Subroutine REVENUE Logic 86
25 Flowchart of Subroutine COMCOS Logic 87
26 Flowchart of Subroutine INTROR Logic 89
27 Flowchart of Subroutine INRR Logic 91
28 Program Structure of the Air Carrier Module 138

ILLUSTRATIONS (Continued)

29 Flowchart of Program OPLIFE Logic 139
30 Flowchart of Subroutine INPUTS Logic 142
31 Flowchart of Subroutine DIRECT Logic 143
32 Flowchart of Subroutine INDIR Logic 145
33 Flowchart of Subroutine REPAY Logic 146
34 Flowchart of Subroutine DEPSUB Logic 148
35 Flowchart of Subroutine NETSUB Logic 149
36 Flowchart of Subroutine SUM Logic 150
37 Flowchart of Subroutine CFSUB Logic 152
38 Flowchart of Subroutine DCFSUB Logic 153
39 Flowchart of Subroutine TAX Logic 155
40 Flowchart of Subroutine OUTPUT Logic 157

TABLES

1 Card Input Data for the Fleet Accounting Module 33
2 Sample Printout of Market Input Data and Projected RPM Demand . 38
3 Sample Printout of Yearly Fleet Composition and Activity Projections for an Individual Aircraft Type 39
4 Sample Printout of Cumulative Fleet Composition and Activity Projections for an Individual Aircraft Type 41
5 Sample Printout of Cumulative Fleet Composition and Activity Projections for a Market 42
6 Sample Printout of Cumulative Fleet Composition and Activity Projections for All Markets 43
7 Sample Printout of the Fractional Market Share of Cumulative Fleet Composition and Activity Projections for a Market 44
8 Sample Printout of the Yearly Fleet Composition and Activity Projections for a Market 45
9 Sample Printout of the Total Yearly Fleet Composition and Activity Projections for All Markets 47
10 Card Input Data for the Airframe Manufacturer Module 96
11 Sample Printout of Aircraft Demand Information 103
12 Sample Printout of Production Scheduling Results 104
13 Sample Printout of Values of Variables in Namelists INPUT1 and INPUT2 105
14 Sample Printout of Program Variables 108
15 Sample Printout of Aircraft Manufacturing Cost Components by Production Level 110
16 Sample Printout of Cost Breakdown for Number of Vehicles Demanded 111
17 Sample Printout of Costs Versus Production Level 112
18 Sample Printout of Aircraft Price Estimation Results 113
19 Sample Printout of Internal Rate of Return Results. 115
20 Sample Printout of Individual Monthly Cost, Income, and Cash Flow Data 116
21 Sample Printout of Cumulative Monthly Cost, Income, and Cash Flow Data 118
22 Card Input Data for the Air Carrier Module 159

TABLES (Continued)

23 Sample Printout of Initial Investment Costs by Year 165

24 Sample Printout of Input Values for Namelist NSTAGE 165

25 Sample Printout of Input Table Heading and Values for Namelist NPLANE 166

26 Sample Printout of Direct Operating Costs per Aircraft Mile . 168

27 Sample Printout of Direct Operating Costs per Block Hour. . . 169

28 Sample Printout of Input Parameters for Indirect Operating Cost Calculations 170

29 Sample Printout of Indirect Operating Costs per Trip by Stage Length. 174

30 Sample Printout of Total Operating Costs by Year 175

31 Sample Printout of Depreciation and Earnings by Year. 177

32 Sample Printout of Total Initial Investment Costs by Year . . 178

33 Sample Printout of Double-Declining, Straight-line and Total Aircraft Depreciation by Year 179

34 Sample Printout of Cash Flow by Year without Operating Loss Carryovers or Capital Gains Tax. 180

35 Sample Printout of Capital Gains by Year 182

36 Sample Printout of the Cash Flow by Year with Tax Adjustments for Loss Carryovers and Capital Gains 183

37 Sample Printout of Trial Rates of Return on Investment and Associated Discounted Cash Flow Sum 184

38 Sample Printout of Summary Financial Analysis Statistics (Part 1). 185

39 Sample Printout of Summary Financial Analysis Statistics (Part 2). 186

40 Listing of Card Input Data for Sample Run of the Fleet Accounting and Airframe Manufacturer Modules. 192

41 Listing of Card Input Data for Sample Run of the Air Carrier Module 195

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 moduels. 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,

$GROWTH_j$ = 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:

$NOBUYS_{ik}$ = number of aircraft of type i bought in year k *

$NORETIR_{ik}$ = number of aircraft of type i retired in year k *

$POPUL_{ij}$ = number of aircraft of type i in the fleet on 30 June of year j

$SEATMI_{ij}$ = seat miles flown by each type i aircraft in year j.

RMS_{ij} = revenue passenger miles flown by each type i aircraft in year j

$FUELBRN_{ij}$ = fuel consumed (in barrels) by each type i aircraft in year j

$MARKET_{j}$ = 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:

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

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:

$$SEATMI_{ij} = (SPEED_{i})(UTILIZ_{i})(SEATS_{i}) \qquad (2)$$

$$RPM_{ij} = (SEATMI_{ij})(LF_{j}) \qquad (3)$$

$$FUELBRN_{ij} = (SFC_{i}/281.4)(SEATMI_{ij}) \qquad (4)$$

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

$$MARKET_{1} = \sum_{i} [(RPM_{ij})(POPUL_{ij})] . \qquad (5)$$

---

*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:

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

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:

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

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

$$NOBUYS_{i'j} = RPMDIFF/RPM_{i'j} \qquad (8)$$

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.

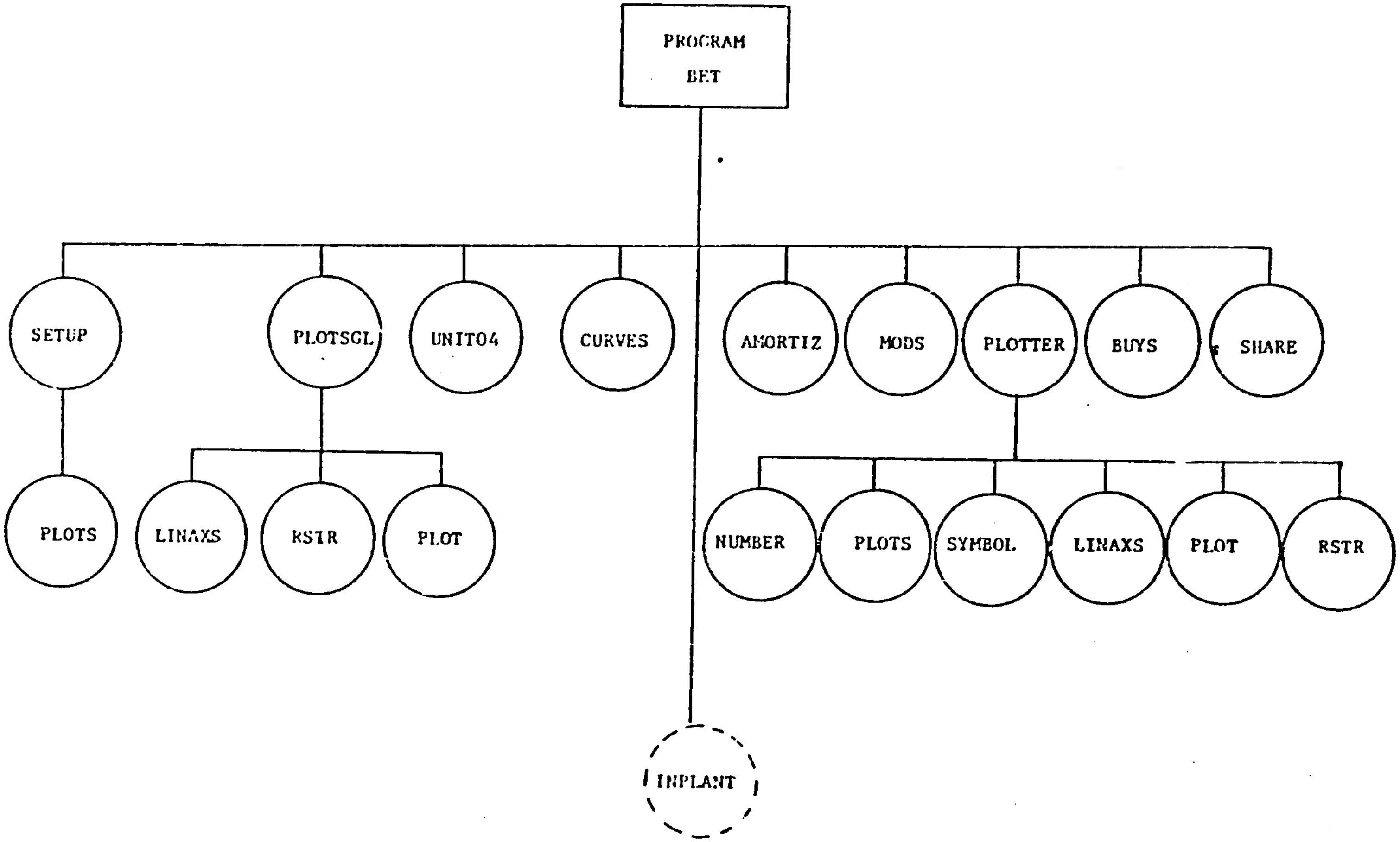


Figure 1 Program Structure of the Fleet Accounting Module

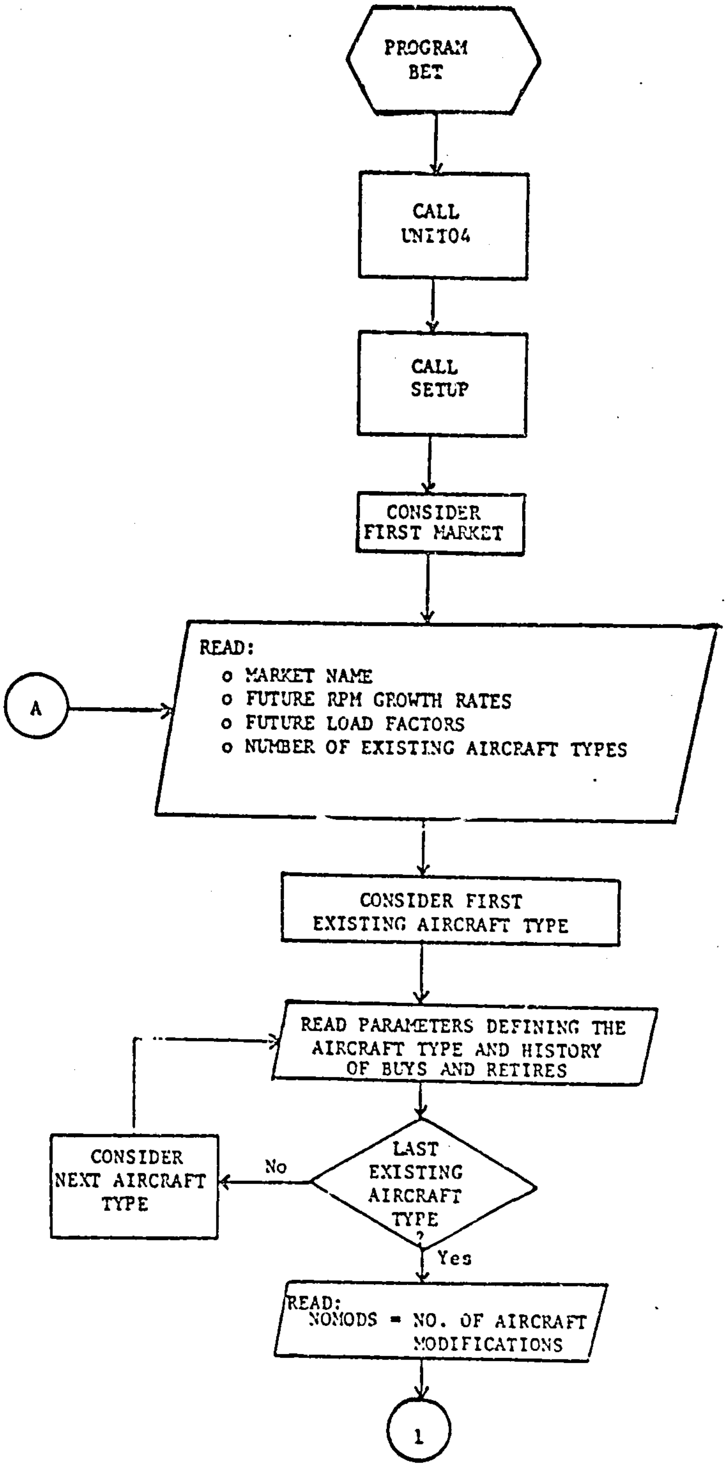
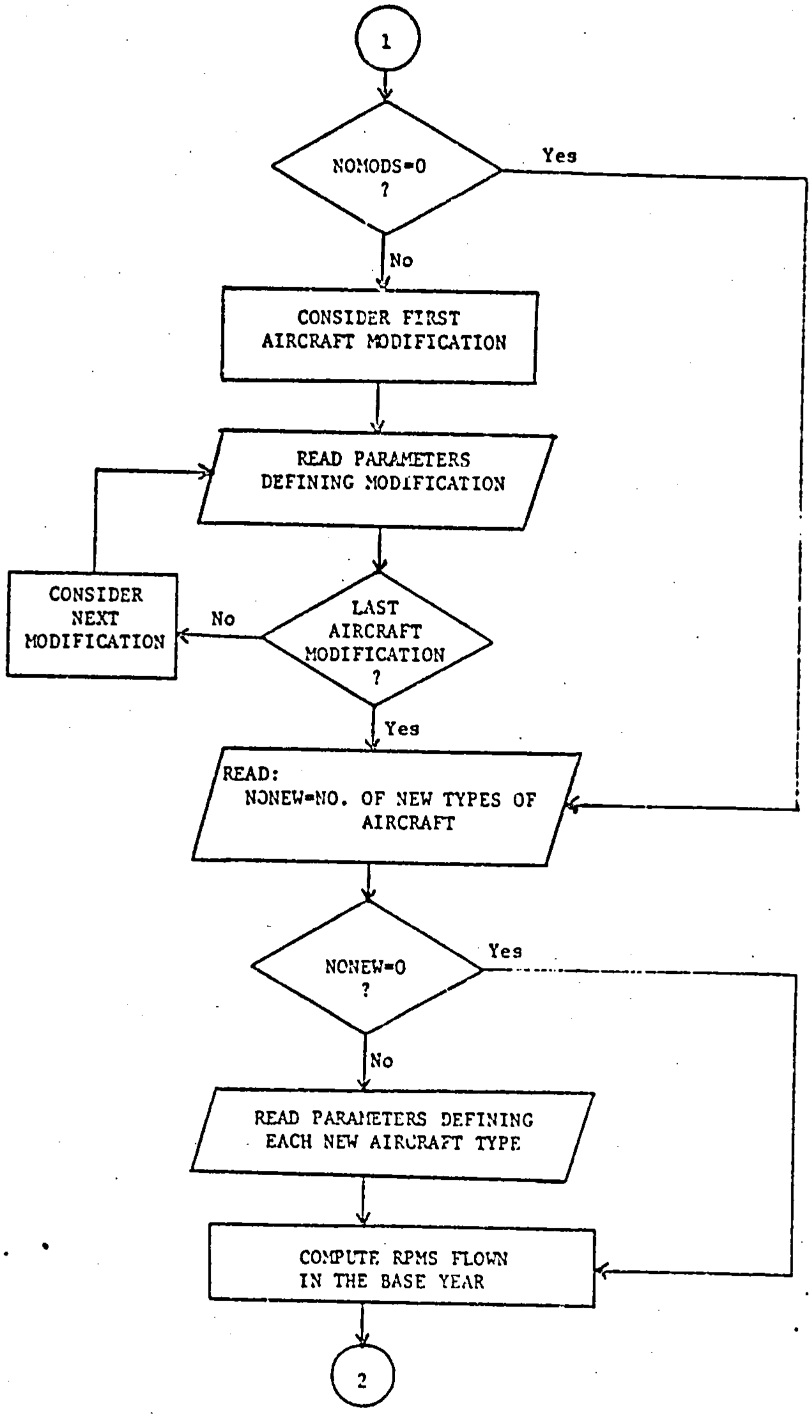


Figure 2 Flowchart of Program BET Logic



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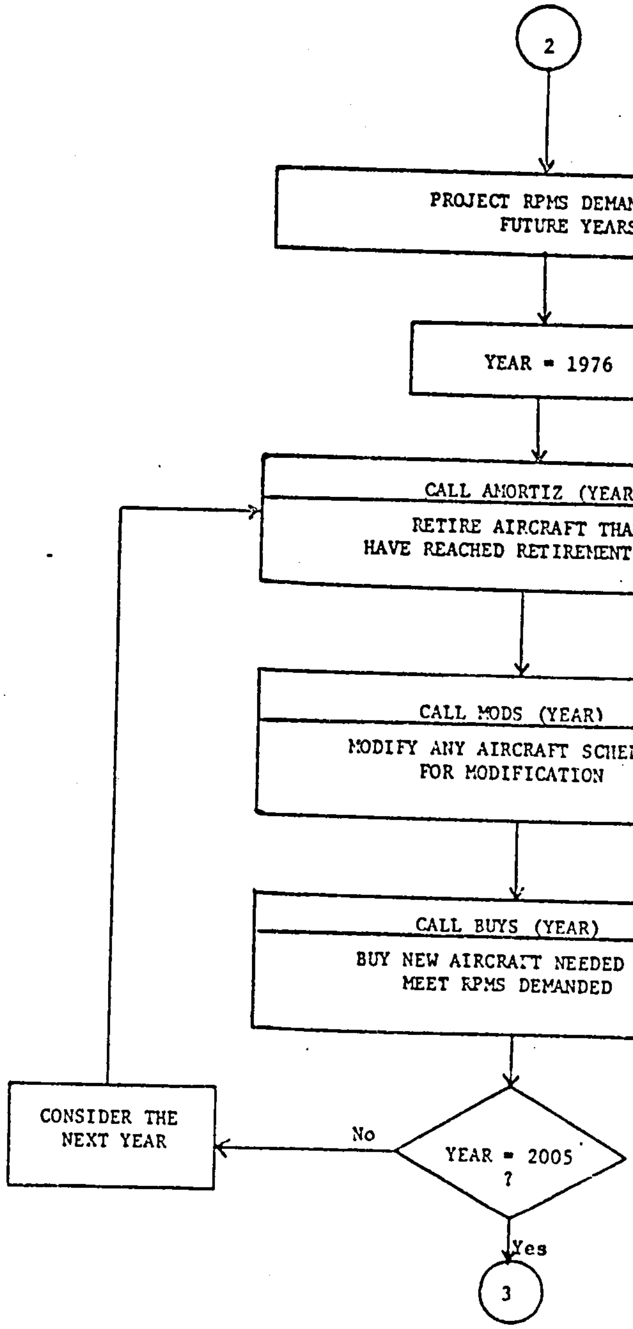

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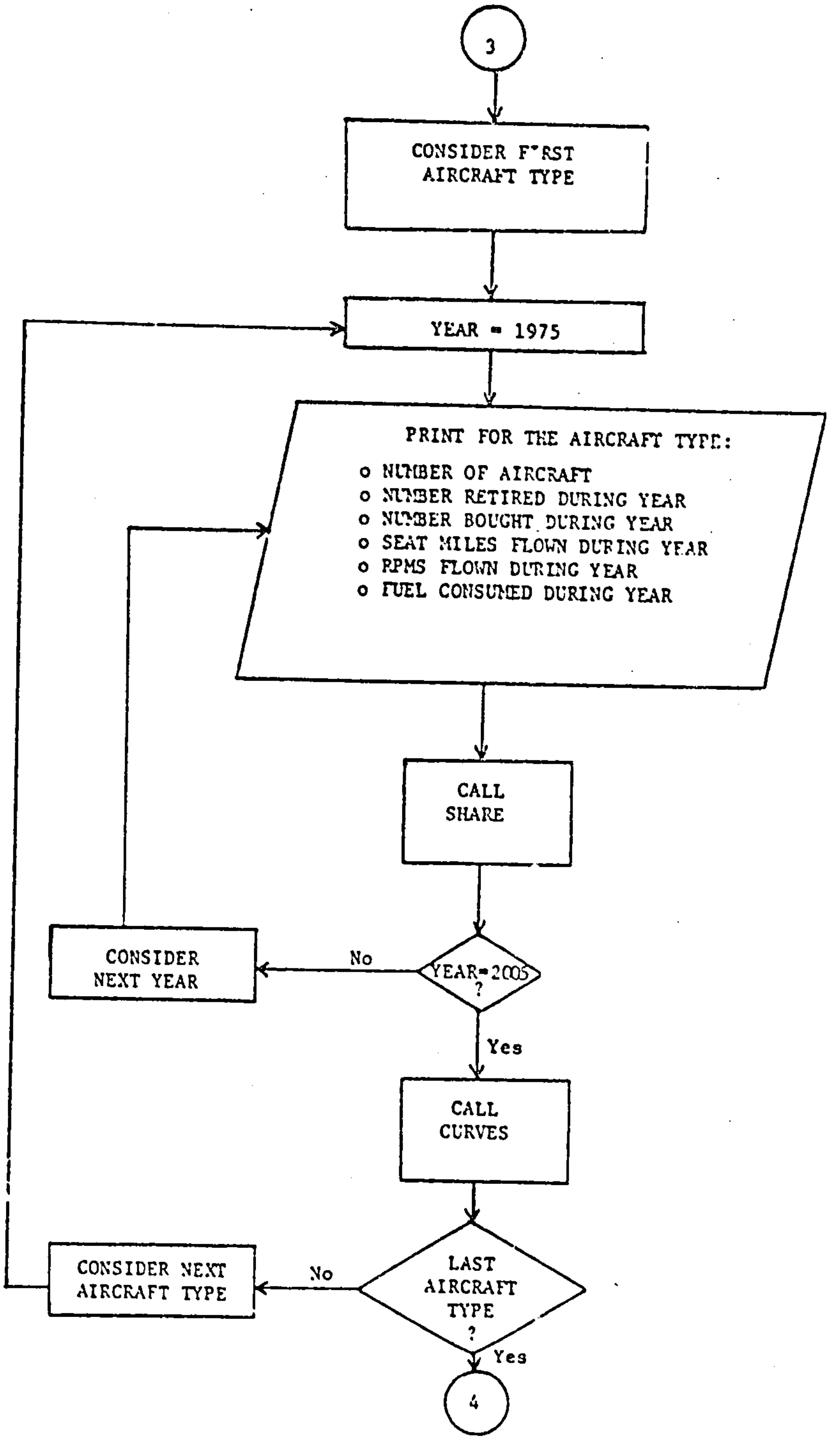

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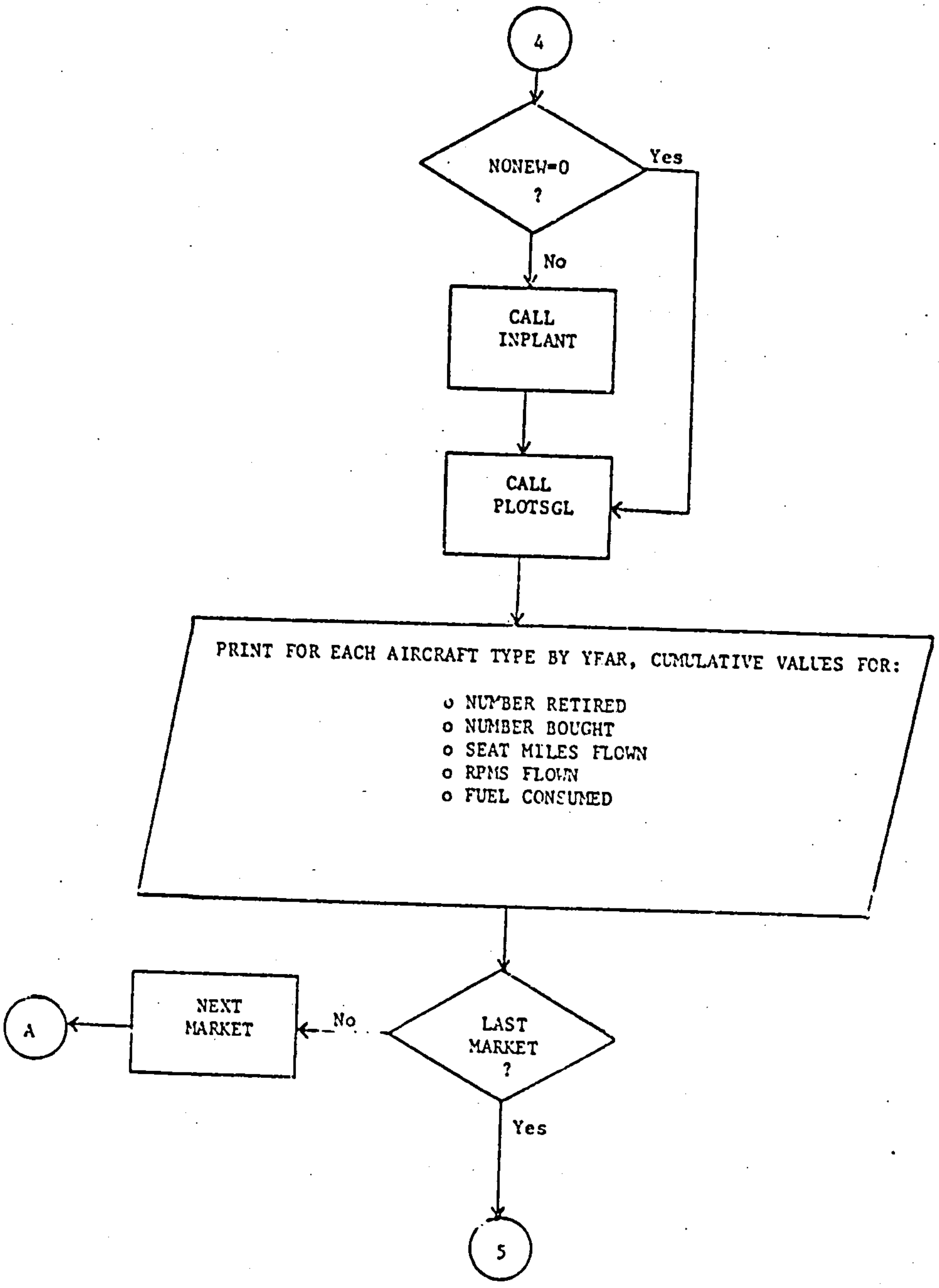

Figure 2 (Continued)

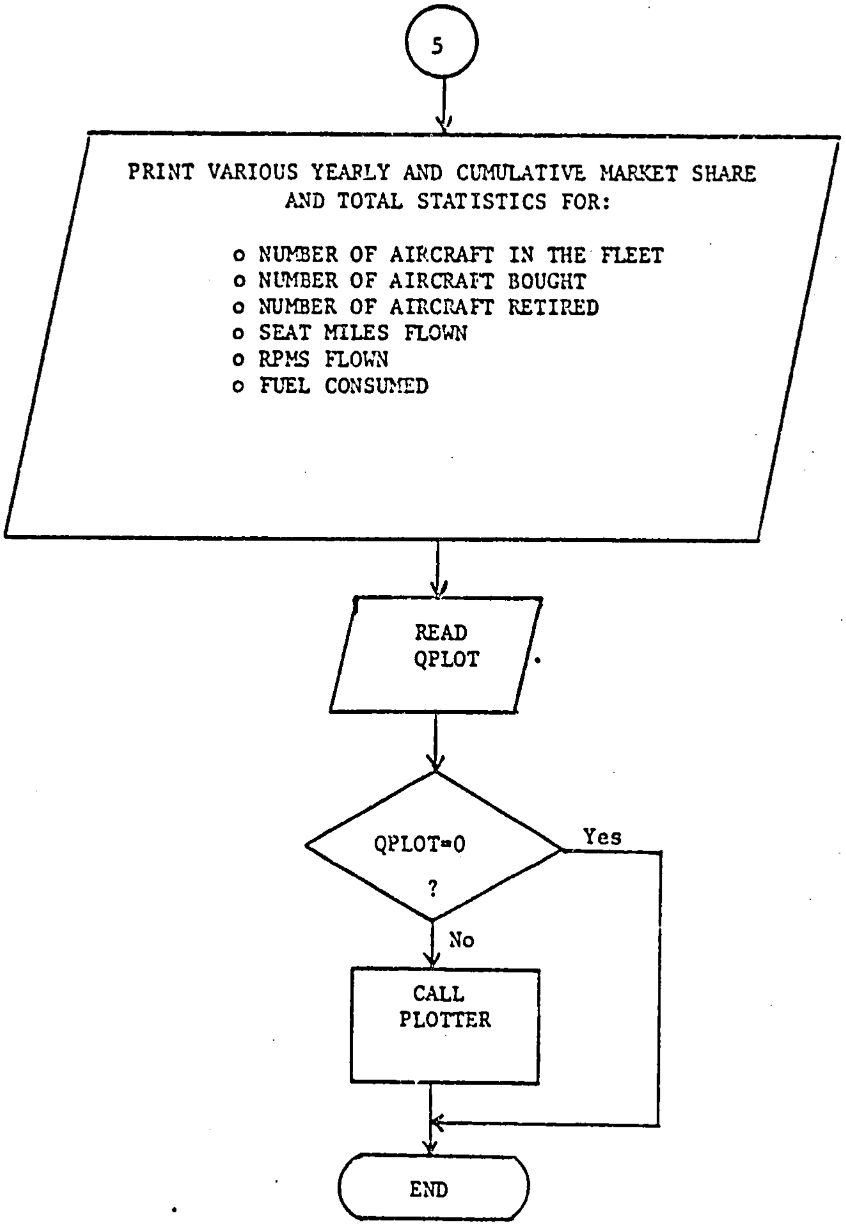

Figure 2 (Concluded)

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.

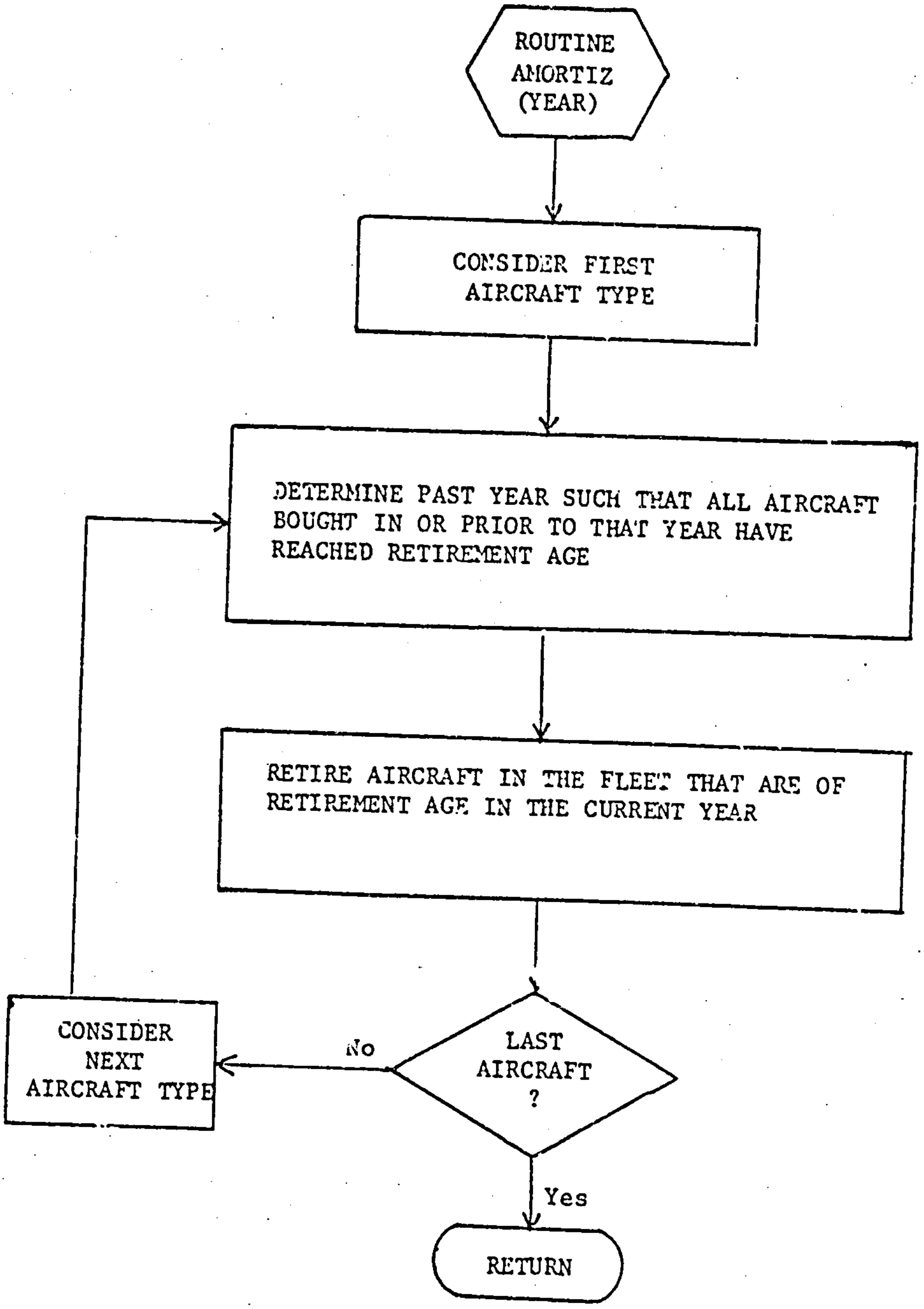

Figure 3 Flowchart of Subroutine AMORTIZ Logic

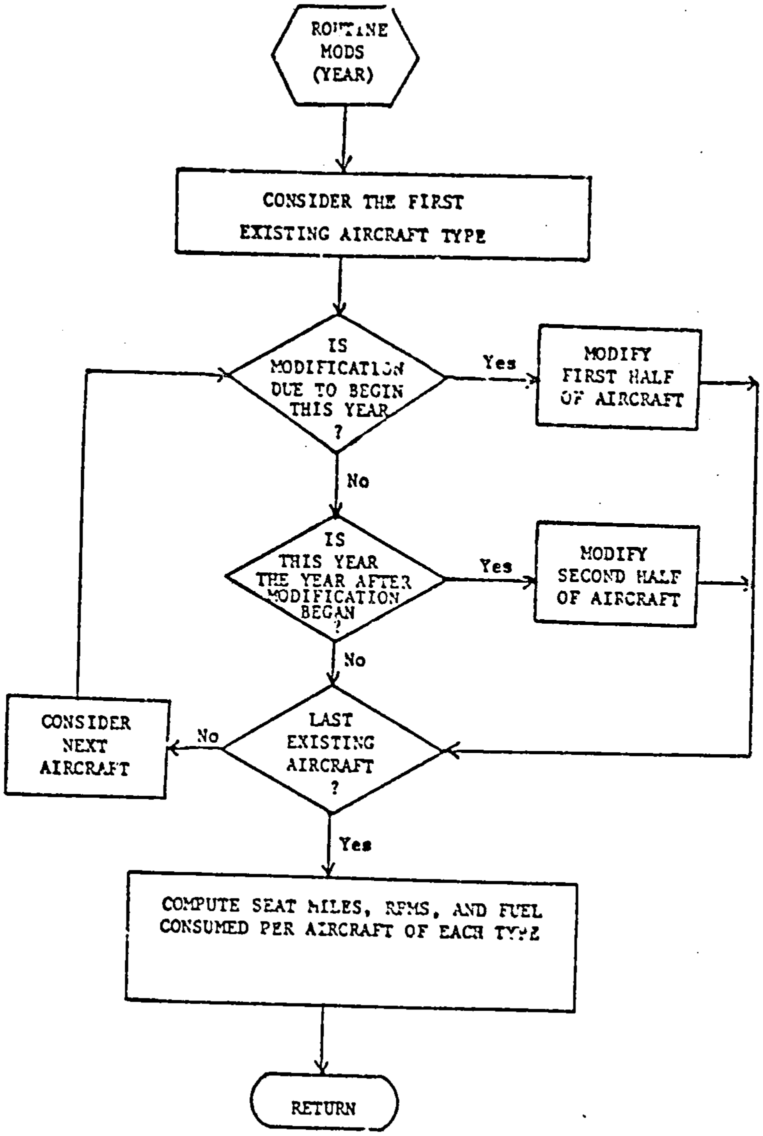

Figure 4 Flowchart of Subroutine MODS Logic

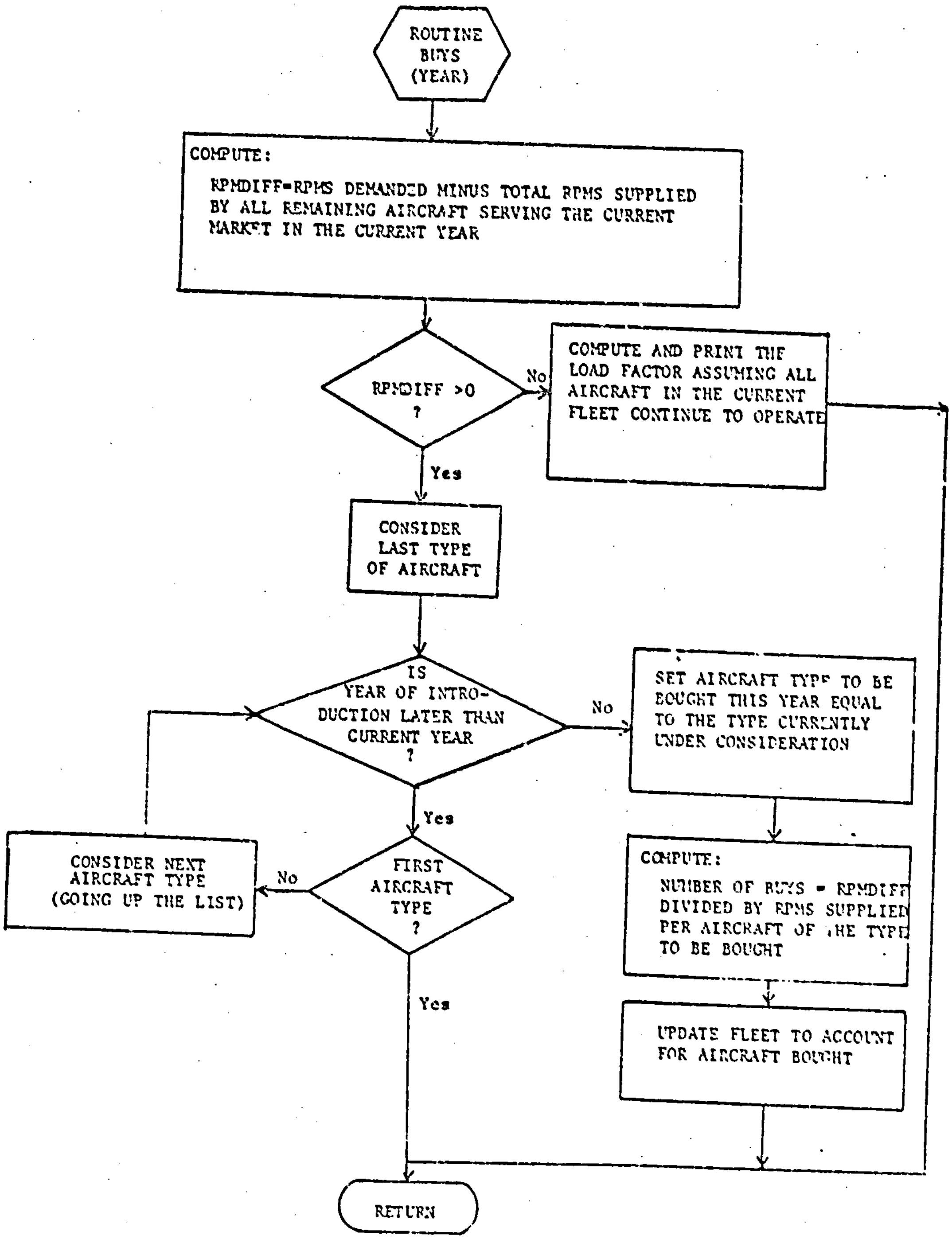

Figure 5 Flowchart of Subroutine BUYS Logic

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.

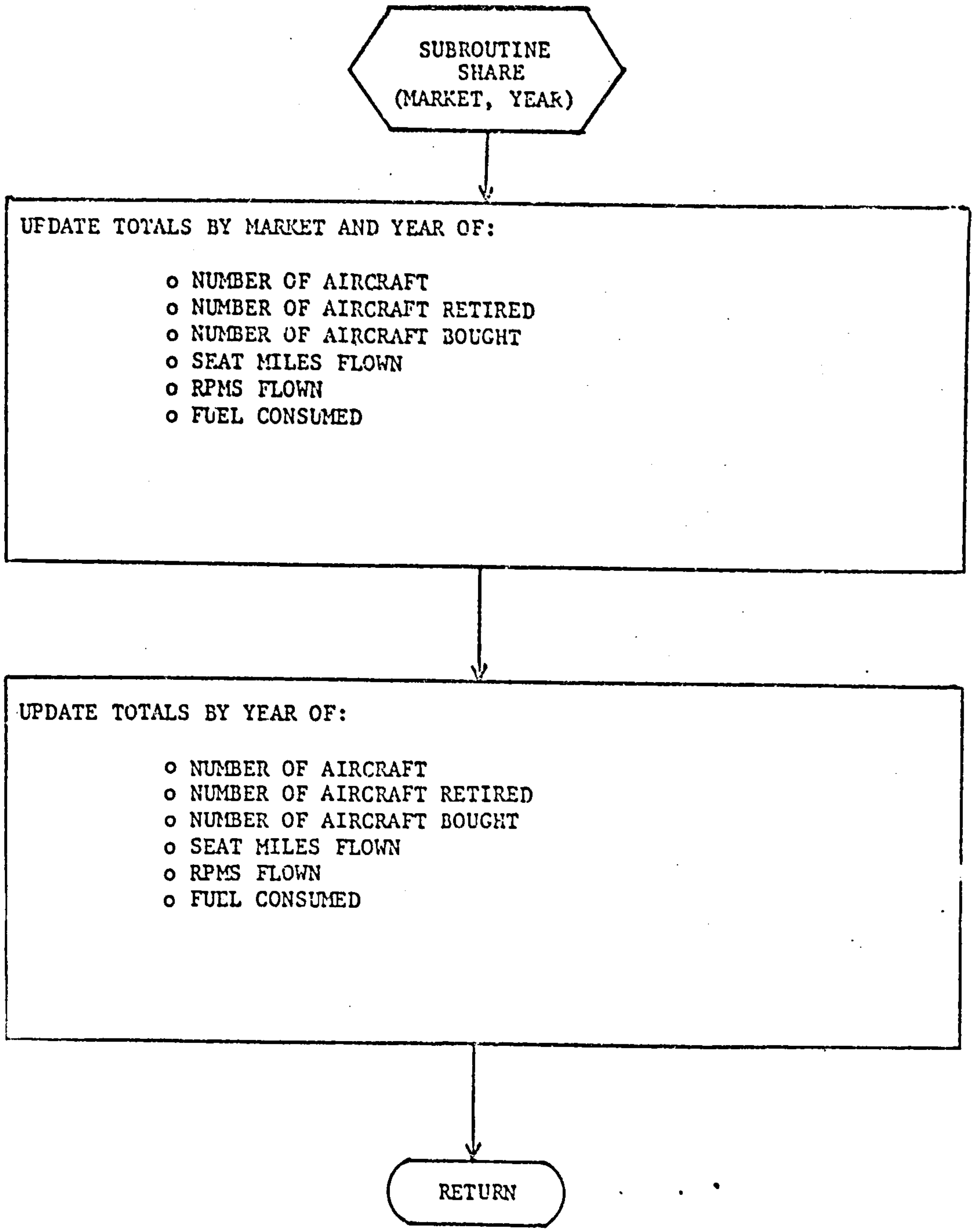

Figure 6 Flowchart of Subroutine SHARE Logic

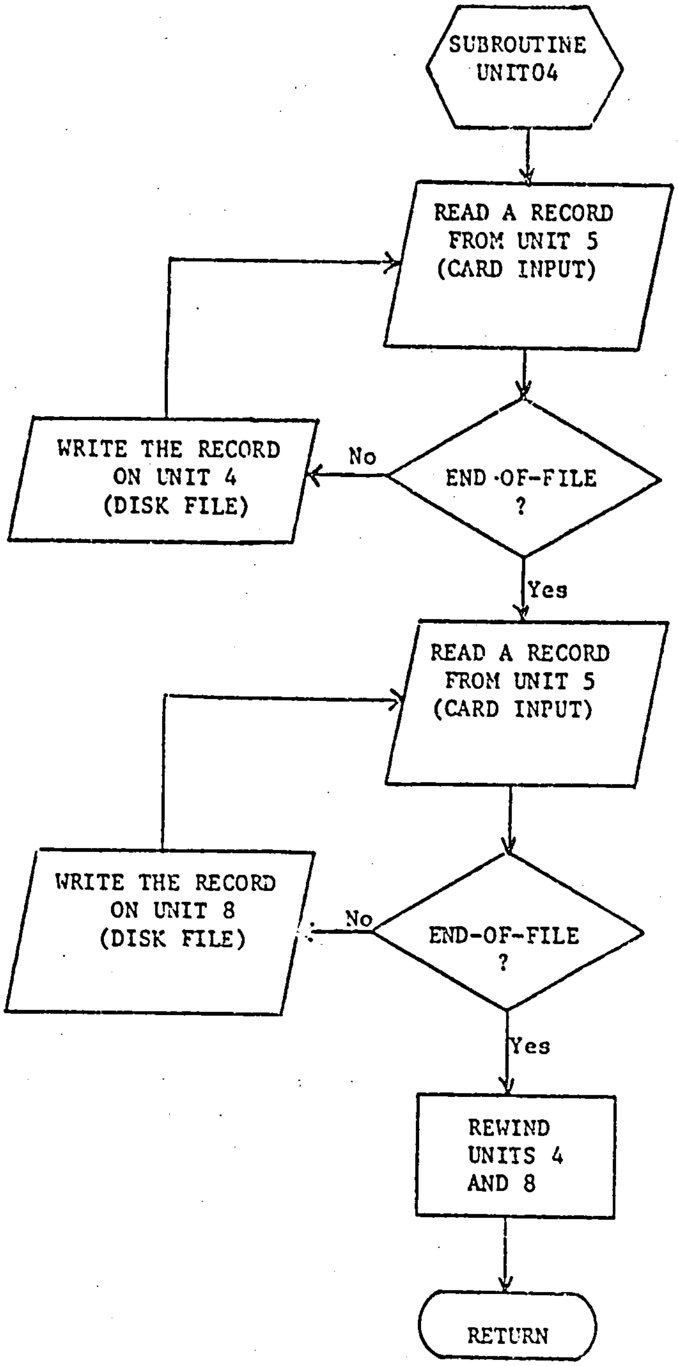

Figure 7 Flowchart of Subroutine UNIT04 Logic

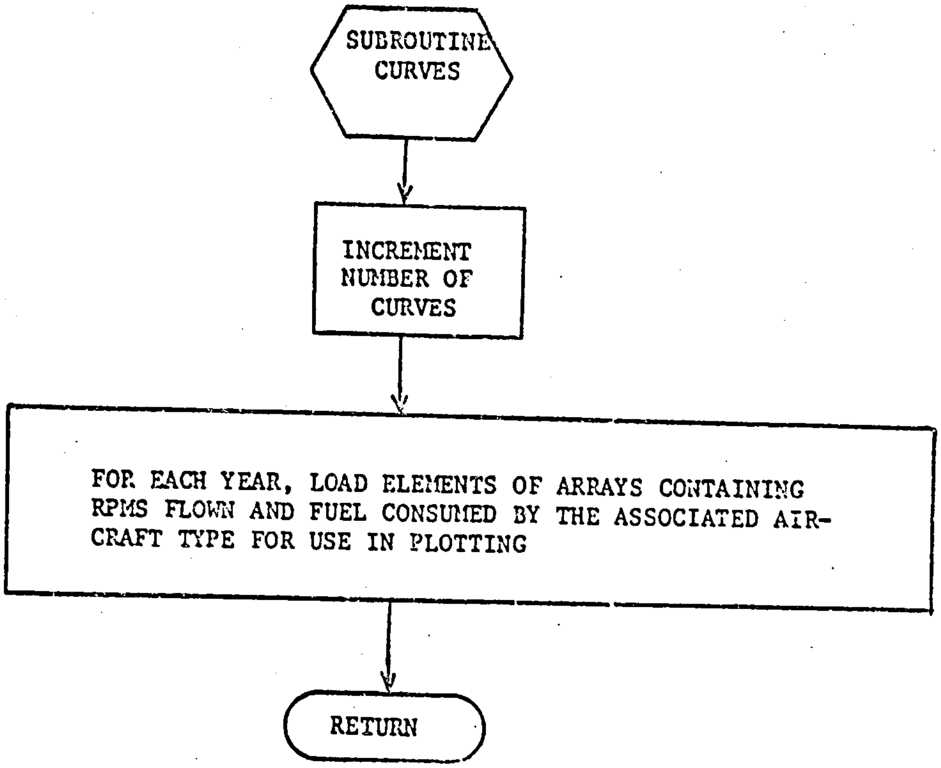

Figure 8 Flowchart of Subroutine CURVES Logic

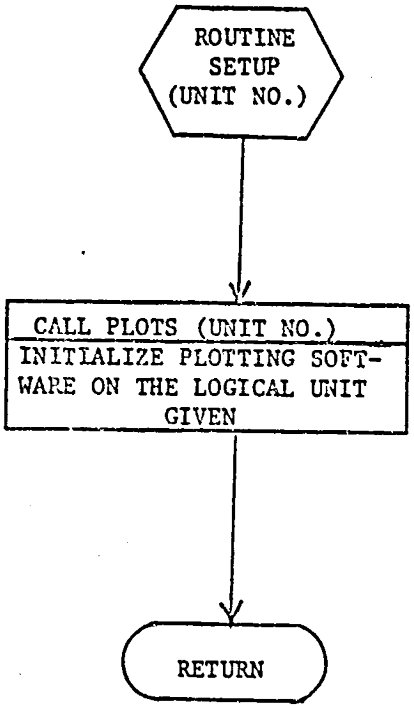

Figure 9 Flowchart of Subroutine SETUP Logic

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.

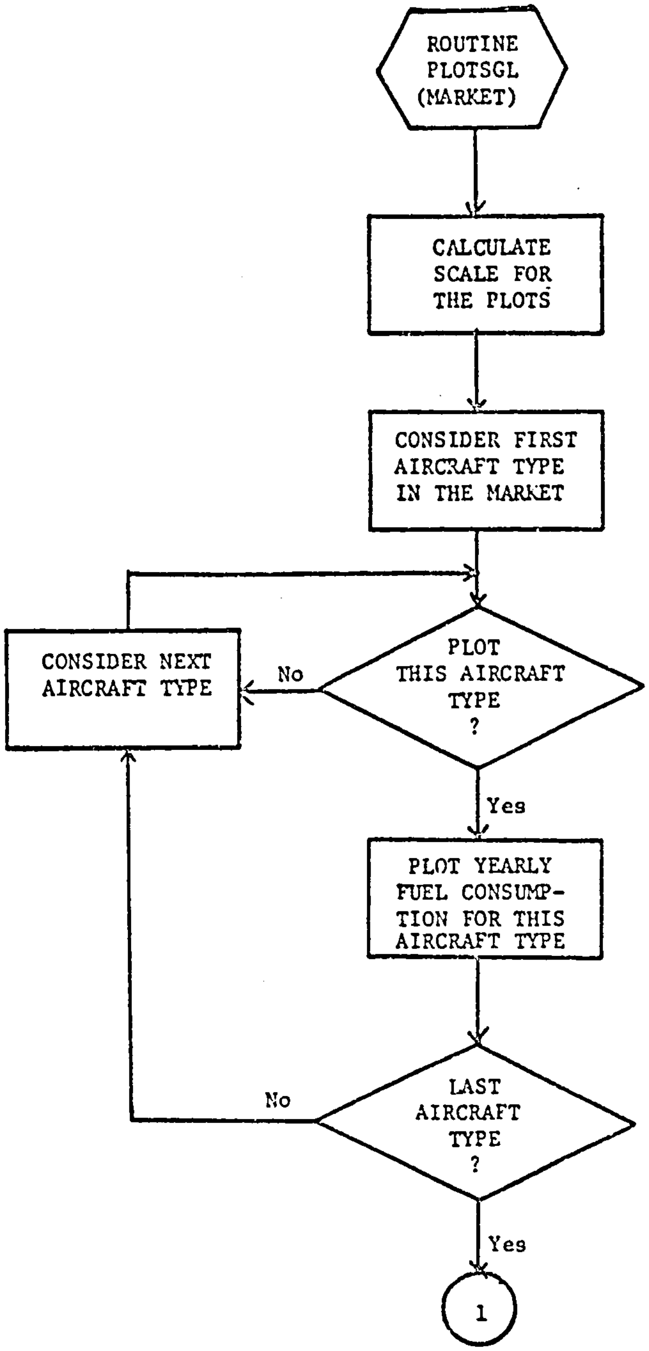

Figure 10 Flowchart of Subroutine PLOTSGL Logic

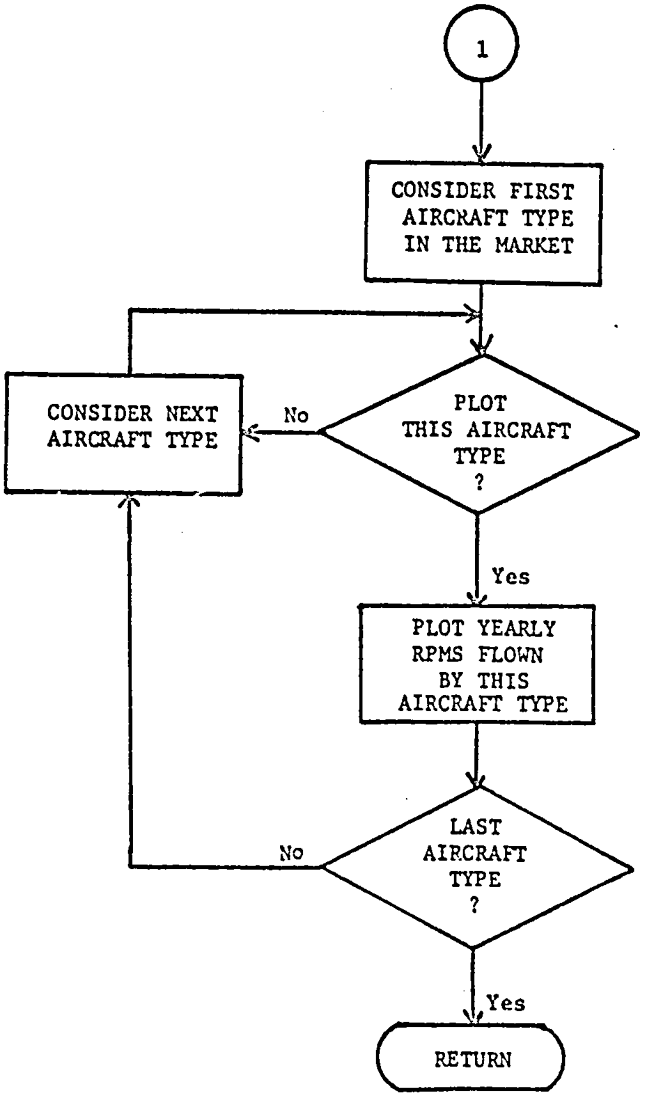

Figure 10 (Concluded)

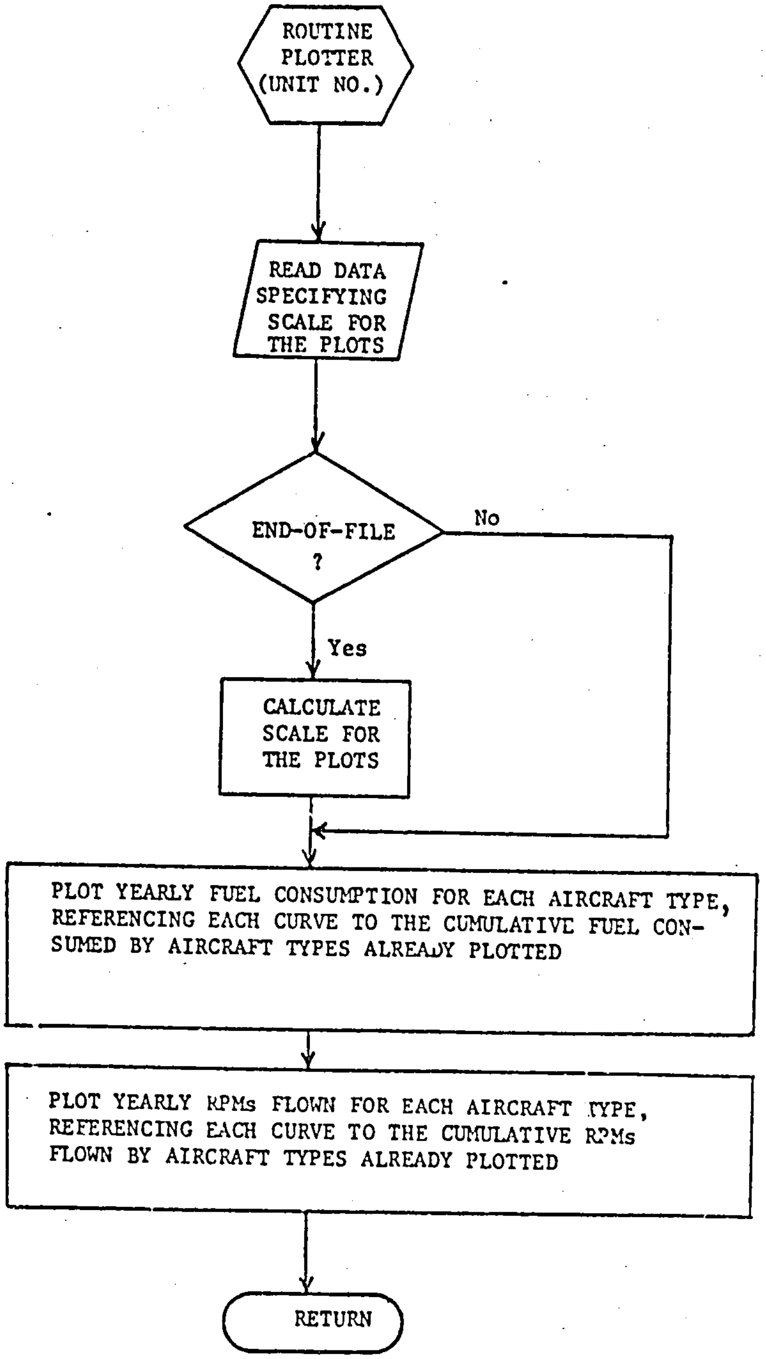

Figure 11 Flowchart of Subroutine PLOTTER Logic

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

Card	Column	Parameter	Format[*]	Description
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[†]	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[†]	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	I5	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)

Card	Column	Parameter	Format*	Description
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‡	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‡	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)

Card	Column	Parameter	Format*	Description
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	TOPFBRN	E10.4	Maximum value of fuel consumption (in barrels) on the fuel axis of the market share plot.

Table 1 (Concluded)

Card	Column	Parameter	Format*	Description
14	11-20	NOMRKSF	I10	Number of tick marks on the fuel axis of the fuel consumption market share plot.
14	21-30	TOPRPMS	E10.4	Maximum value of the RPMs flown (in miles) on the RPM axis of the market share plot.
14	31-40	NOMRKSR	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
GROWTH
    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

 LF
     .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
EXISTING FLEET
   3
4ENGNBTJ   1960.0000  134.0000     .2523  408.0000 2509.0000   16.0000
    0.0000    6.0000    6.0000    6.0000    0.0000    0.0000    0.0000    0.0000
    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
4ENGNBTF   1961.0000  144.3000     .1959  404.0000 3102.0000   16.0000
    0.0000    0.0000    5.0000    7.5000    7.5000    7.5000    9.4000   17.0000
   24.2000   19.6000   23.5000    0.0000    0.0000    0.0000    0.0000    0.0000
    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
3ENGNBTF   1963.0000  112.2000     .2140  338.0000 2679.0000   16.0000
    0.0000    0.0000    0.0000    0.0000   50.0000   74.4000   77.7000   92.1000
  110.1000   92.0000   52.4000   24.4000   13.3000   21.9000   55.0000   26.3000
    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000    0.0000
MODIFICATIONS
   0
NEW AIRCRAFT TYPES
   2
N2ENGWBPF  1987.0000  171.0000     .2140  339.0000 3079.0000   16.0000
N1995AC    1995.0000  171.0000     .2140  358.0000 3079.0000   16.0000
MARKET
      .63214244216473046375E+11    .63427098669765003756E+11    .67556724802077636713E+11    .71714129291216601556E+11
      .76012209598761328125E+11    .81581245746969628906E+11    .85415756251541152344E+11    .90533795962578125000E+11
      .95977357204367207031E+11    .10173069863664992345E+12    .10793454055464814453E+12    .11433451299913816359E+12
      .12115268976742579125E+12    .12843266315347070312E+12    .13612862294267322266E+12    .14430674031923730469E+12
      .15296535673839062500E+12    .16214327814269238281E+12    .17187187483125292969E+12    .18218413732112695312E+12
      .19311523856039355469E+12    .20470215247461562500E+12    .21698428234645317812E+12    .23000333895924121094E+12
      .24381353930739453125E+12    .25844317516658691435E+12    .27393765676576515625E+12    .29037391617173046875E+12
      .30779535114203125000E+12    .32626412322055078125E+12    .34583998014318164062E+12
```

Table 3

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

```
                                          AIRCRAFT TYPE = N2ENGWBPF

 YEAR         SEAT-MILES         FUELBURNED          RPMS          POPULATION         # BUYS/YR          # RETIRED/YR
                (YEAR)             (YEAR)           (YEAR)       AS OF MID-YEAR   (THRU MID-YEAR)   (THRU MID-YEAR)

 1975         0.                 0.                0.             0.               0.                0.
 1976         0.                 0.                0.             0.               0.                0.
 1977         0.                 0.                0.             0.               0.                0.
 1978         0.                 0.                0.             0.               0.                0.
 1979         0.                 0.                0.             0.               0.                0.
 1980         0.                 0.                0.             0.               0.                0.
 1981         0.                 0.                0.             0.               0.                0.
 1982         0.                 0.                0.             0.               0.                0.
 1983         0.                 0.                0.             0.               0.                0.
 1984         0.                 0.                0.             0.               0.                0.
 1985         0.                 0.                0.             0.               0.                0.
 1986         0.                 0.                0.             0.               0.                0.
 1987          .1549E+11          .6274E+07         .6518E+10      .9216E+02        .9216E+02       0.
 1988          .3035E+11          .1230E+08         .1559E+11      .1610E+03        .7885E+02       0.
 1989          .4706E+11          .1906E+08         .2538E+11      .2497E+03        .9864E+02       0.
 1990          .6871E+11          .2734E+08         .3779E+11      .3645E+03        .1149E+03       0.
 1991          .8772E+11          .3553E+08         .4924E+11      .4653E+03        .1009E+03       0.
 1992          .1110E+12          .4495E+08         .6103E+11      .5887E+03        .1234E+03       0.
 1993          .1354E+12          .5527E+08         .7504E+11      .7238E+03        .1351E+03       0.
 1994          .1643E+12          .6656E+08         .9036E+11      .8716E+03        .1479E+03       0.
 1995          .1643E+12          .6656E+08         .9036E+11      .8716E+03       0.                0.
 1996          .1643E+12          .6656E+08         .9036E+11      .8716E+03       0.                0.
 1997          .1643E+12          .6656E+08         .9036E+11      .8716E+03       0.                0.
 1998          .1643E+12          .6656E+08         .9036E+11      .8716E+03       0.                0.
 1999          .1643E+12          .6656E+08         .9036E+11      .8716E+03       0.                0.
 2000          .1643E+12          .6656E+08         .9036E+11      .8716E+03       0.                0.
 2001          .1643E+12          .6656E+08         .9036E+11      .8716E+03       0.                0.
 2002          .1643E+12          .6656E+08         .9036E+11      .8716E+03       0.                0.
 2003          .1488E+12          .6028E+08         .8184E+11      .7895E+03       0.                 .8216E+02
 2004          .1339E+12          .5426E+08         .7367E+11      .7106E+03       0.                 .7895E+02
 2005          .1172E+12          .4749E+08         .6448E+11      .6220E+03       0.                 .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 = N2ENGWBPF

YEAR   ACCUMULATIVE    ACCUMULATIVE    ACCUMULATIVE   ACCUMULATIVE   ACCUMULATIVE
        SEAT-MILES     FUEL-BURNED         RPMS          # BUYS       # 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    .1549E+11       .6274E+07       .9518E+10      .8216E+02     0.
1988    .4584E+11       .1857E+08       .2521E+11      .1610E+03     0.
1989    .9289E+11       .3763E+08       .5109E+11      .2497E+03     0.
1990    .1616E+12       .6547E+08       .8988E+11      .3645E+03     0.
1991    .2493E+12       .1010E+09       .1371E+12      .4653E+03     0.
1992    .3503E+12       .1460E+09       .1981E+12      .5837E+03     0.
1993    .4967E+12       .2012E+09       .2732E+12      .7239E+03     0.
1994    .6610E+12       .2678E+09       .3636E+12      .8716E+03     0.
1995    .8253E+12       .3343E+09       .4539E+12      .8716E+03     0.
1996    .9395E+12       .4009E+09       .5443E+12      .8716E+03     0.
1997    .1154E+13       .4675E+09       .6346E+12      .8716E+03     0.
1998    .1319E+13       .5340E+09       .7250E+12      .8716E+03     0.
1999    .1482E+13       .6006E+09       .8154E+12      .8716E+03     0.
2000    .1647E+13       .6671E+09       .9057E+12      .8716E+03     0.
2001    .1811E+13       .7337E+09       .9961E+12      .8716E+03     0.
2002    .1975E+13       .8002E+09       .1086E+13      .8716E+03     0.
2003    .2124E+13       .8605E+09       .1169E+13      .8716E+03     0.
2004    .2249E+13       .9148E+09       .1242E+13      .8716E+03      .8216E+02
2005    .2375E+13       .9623E+09       .1306E+13      .8715E+03      .1610E+03
                                                                      .2497E+03
```

Table 5

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

```
                               MARKET = MEDIUM    RANGE

   YEAR    ACCUMULATIVE       ACCUMULATIVE       ACCUMULATIVE       ACCUMULATIVE       ACCUMULATIVE
            SEAT-MILES        FUEL-BURNED            RPMS              # BUYS            # RETIRED
        (TO END OF YEAR)   (TO END OF YEAR)   (TO END OF YEAR)   (THRU MID-YEAR)    (THRU MID-YEAR)

   1975     .1395E+12          .8220E+08          .6021E+11          .2630E+02          0.
   1976     .2255E+12          .1694E+09          .1243E+12          .7941E+02          0.
   1977     .3485E+12          .2618E+09          .1917E+12          .1424E+03          .6000E+01
   1978     .4709E+12          .3597E+09          .2634E+12          .2160E+03          .1700E+02
   1979     .6172E+12          .4636E+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          .5014E+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          .9015E+12          .1354E+04          .6110E+03
   1986     .1847E+13          .1394E+10          .1016E+13          .1566E+04          .6869E+03
   1987     .2067E+13          .1556E+10          .1137E+13          .1643E+04          .7113E+03
   1988     .2301E+13          .1723E+10          .1265E+13          .1727E+04          .7246E+03
   1989     .2548E+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          .8808E+03
   1993     .3696E+13          .2624E+10          .2033E+13          .2293E+04          .9438E+03
   1994     .4027E+13          .2817E+10          .2215E+13          .2438E+04          .1017E+04
   1995     .4378E+13          .3015E+10          .2408E+13          .2596E+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     .5563E+13          .3625E+10          .3060E+13          .3247E+04          .1548E+04
   1999     .6007E+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     .7502E+13          .4463E+10          .4126E+13          .4367E+04          .2367E+04
   2003     .8062E+13          .4690E+10          .4434E+13          .4617E+04          .2449E+04
   2004     .8655E+13          .4930E+10          .4753E+13          .4874E+04          .2520E+04
   2005     .9284E+13          .5185E+10          .5106E+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        ACCUMULATIVE       ACCUMULATIVE         ACCUMULATIVE        ACCUMULATIVE
            SEAT-MILES         FUEL-BURNED            RPMS                # BUYS             # RETIRED
        (TO END OF YEAR)    (TO END OF YEAR)    (TO END OF YEAR)     (THRU MID-YEAR)     (THRU MID-YEAR)

  1975     .1421E+12           .1072E+09          .7919E+11           .2630E+02           0.
  1976     .2928E+12           .2210E+09          .1610E+12           .1041E+03           0.
  1977     .5525E+12           .3415E+09          .2499E+12           .1932E+03           .6000E+01
  1978     .6219E+12           .4692E+09          .3420E+12           .2945E+03           .1700E+02
  1979     .8012E+12           .6047E+09          .4427E+12           .4047E+03           .3050E+02
  1980     .9915E+12           .7484E+09          .5453E+12           .5639E+03           .8000E+02
  1981     .1193E+13           .9010E+09          .6562E+12           .7833E+03           .1999E+03
  1982     .1407E+13           .1063E+10          .7737E+12           .1065E+04           .3677E+03
  1983     .1633E+13           .1235E+10          .9283E+12           .1435E+04           .6126E+03
  1984     .1873E+13           .1417E+10          .1030E+13           .1868E+04           .9103E+03
  1985     .2128E+13           .1611E+10          .1170E+13           .2120E+04           .1022E+04
  1986     .2398E+13           .1815E+10          .1319E+13           .2346E+04           .1098E+04
  1987     .2584E+13           .2029E+10          .1476E+13           .2475E+04           .1122E+04
  1988     .2987E+13           .2249E+10          .1643E+13           .2603E+04           .1136E+04
  1989     .3309E+13           .2477E+10          .1829E+13           .2745E+04           .1157E+04
  1990     .3649E+13           .2712E+10          .2037E+13           .2915E+04           .1212E+04
  1991     .4010E+13           .2956E+10          .2236E+13           .3075E+04           .1239E+04
  1992     .4393E+13           .3208E+10          .2416E+13           .3235E+04           .1316E+04
  1993     .4799E+13           .3469E+10          .2639E+13           .3513E+04           .1405E+04
  1994     .5229E+13           .3738E+10          .2876E+13           .3759E+04           .1507E+04
  1995     .5694E+13           .4016E+10          .3126E+13           .4027E+04           .1617E+04
  1996     .6166E+13           .4302E+10          .3392E+13           .4328E+04           .1776E+04
  1997     .6593E+13           .4595E+10          .3674E+13           .4695E+04           .1996E+04
  1998     .722[illegible]+13           .4897E+10          .3973E+13           .5133E+04           .2278E+04
  1999     .7798E+13           .5205E+10          .4289E+13           .5664E+04           .2647E+04
  2000     .84[illegible]E+13           .5520E+10          .4625E+13           .6259E+04           .3080E+04
  2001     .9055E+13           .5844E+10          .4990E+13           .6694E+04           .3332E+04
  2002     .9[illegible]E+13           .5178E+10          .5357E+13           .7128E+04           .3558E+04
  2003     .1047E+14           .6533E+10          .5757E+13           .7544E+04           .3687E+04
  2004     .1124E+14           .6909E+10          .6180E+13           .7977E+04           .3616E+04
  2005     .1205E+14           .7307E+10          .6629E+13           .8441E+04           .3957E+04
```

Table 7
SAMPLE PRINTOUT OF THE FRACTIONAL MARKET SHARE OF CUMULATIVE FLEET COMPOSITION AND ACTIVITY PROJECTIONS FOR A MARKET

```
                                MARKET = MEDIUM    RANGE

   YEAR        FRACTIONAL                FRACTIONAL              FRACTIONAL               FRACTIONAL
               SEAT-MILES                FUEL-BURNED                RPMS                  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                 .7628E+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                .6289E+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                 .6590E+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                 .6392E+00               .7702E+00                .5857E+00
   2004        .7702E+00                 .6392E+00               .7702E+00                .5857E+00
   2005        .7702E+00                 .6392E+00               .7702E+00                .5857E+00
```

Table 8

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

```
                                        MARKET = MEDIUM    RANGE
 YEAR        SEAT-MILES        FUEL BURNED         RPMS           POPULATION        # BUYS/YR         # RETIRED/YR
               (YEAR)             (YEAR)           (YEAR)       AS OF MID-YEAR   (THRU MID-YEAR)   (THRU MID-YEAR)

 1975        .1095E+12         .8220E+08        .6021E+11        .8277E+03        .2630E+02        0.
 1976        .1160E+12         .8719E+08        .6383E+11        .8808E+03        .5311E+02        0.
 1977        .1230E+12         .9237E+08        .6766E+11        .9372E+03        .6295E+02         .6000E+01
 1978        .1304E+12         .9793E+08        .7172E+11        .1000E+04        .7364E+02         .1100E+02
 1979        .1382E+12         .1039E+09        .7602E+11        .1068E+04        .8088E+02         .1350E+02
 1980        .1465E+12         .1103E+09        .8058E+11        .1138E+04        .1280E+03         .5750E+02
 1981        .1553E+12         .1170E+09        .8542E+11        .1213E+04        .1564E+03         .8190E+02
 1982        .1646E+12         .1242E+09        .9054E+11        .1292E+04        .1653E+03         .8610E+02
 1983        .1745E+12         .1319E+09        .9597E+11        .1300E+04        .1968E+03         .1091E+03
 1984        .1850E+12         .1402E+09        .1017E+12        .1476E+04        .2301E+03         .1343E+03
 1985        .1961E+12         .1488E+09        .1078E+12        .1574E+04        .2104E+03         .1116E+03
 1986        .2078E+12         .1580E+09        .1143E+12        .1680E+04        .1819E+03         .7590E+02
 1987        .2203E+12         .1620E+09        .1212E+12        .1738E+04        .8216E+02         .2440E+02
 1988        .2335E+12         .1668E+09        .1284E+12        .1804E+04        .7805E+02         .1330E+02
 1989        .2475E+12         .1715E+09        .1361E+12        .1871E+04        .5864E+02         .2100E+02
 1990        .2624E+12         .1751E+09        .1443E+12        .1930E+04        .1149E+03         .5500E+02
 1991        .2781E+12         .1803E+09        .1530E+12        .2005E+04        .1008E+03         .2630E+02
 1992        .2948E+12         .1848E+09        .1621E+12        .2075E+04        .1234E+03         .5311E+02
 1993        .3125E+12         .1892E+09        .1719E+12        .2147E+04        .1351E+03         .6295E+02
 1994        .3312E+12         .1935E+09        .1822E+12        .2222E+04        .1478E+03         .7364E+02
 1995        .3511E+12         .1980E+09        .1931E+12        .2299E+04        .1585E+03         .8088E+02
 1996        .3722E+12         .2009E+09        .2047E+12        .2367E+04        .1959E+03         .1280E+03
 1997        .3945E+12         .2031E+09        .2170E+12        .2432E+04        .2211E+03         .1564E+03
 1998        .4182E+12         .2054E+09        .2300E+12        .2500E+04        .2341E+03         .1653E+03
 1999        .4433E+12         .2069E+09        .2438E+12        .2566E+04        .2623E+03         .1968E+03
 2000        .4699E+12         .2076E+09        .2584E+12        .2628E+04        .2921E+03         .2301E+03
 2001        .4981E+12         .2093E+09        .2739E+12        .2705E+04        .2876E+03         .2104E+03
 2002        .5280E+12         .2139E+09        .2904E+12        .2801E+04        .2779E+03         .1819E+03
 2003        .5596E+12         .2267E+09        .3078E+12        .2969E+04        .2503E+03         .8216E+02
 2004        .5932E+12         .2403E+09        .3263E+12        .3147E+04        .2579E+03         .7805E+02
 2005        .6288E+12         .2547E+09        .3458E+12        .3336E+04        .2775E+03         .8864E+02
```

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        FUELBURNED         RPMS          POPULATION         # BUYS/YR        # RETIRED/YR
                (YEAR)            (YEAR)          (YEAR)       AS OF MID-YEAR   (THRU MID-YEAR)   (THRU MID-YEAR)

 1975         .1421E+12         .1072E+09       .7910E+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       .1399E+04         .8909E+02         .6000E+01
 1978         .1693E+12         .1277E+09       .9311E+11       .1490E+04         .1013E+03         .1100E+02
 1979         .1794E+12         .1355E+09       .9870E+11       .1587E+04         .1102E+03         .1350E+02
 1980         .1902E+12         .1438E+09       .1046E+12       .1688E+04         .1591E+03         .5750E+02
 1981         .2016E+12         .1525E+09       .1109E+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       .2170E+04         .4328E+03         .2977E+03
 1985         .2545E+12         .1937E+09       .1400E+12       .2310E+04         .2522E+03         .1116E+03
 1986         .2698E+12         .2055E+09       .1484E+12       .2460E+04         .2261E+03         .7590E+02
 1987         .2860E+12         .2124E+09       .1573E+12       .2565E+04         .1290E+03         .2440E+02
 1988         .3032E+12         .2202E+09       .1667E+12       .2680E+04         .1283E+03         .1330E+02
 1989         .3214E+12         .2281E+09       .1767E+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         .5755E+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         .7266E+12         .3547E+09       .3996E+12       .5069E+04         .4159E+03         .1290E+03
 2004         .7702E+12         .3760E+09       .4236E+12       .5374E+04         .4326E+03         .1285E+03
 2005         .8164E+12         .3985E+09       .4490E+12       .5696E+04         .4636E+03         .1412E+03
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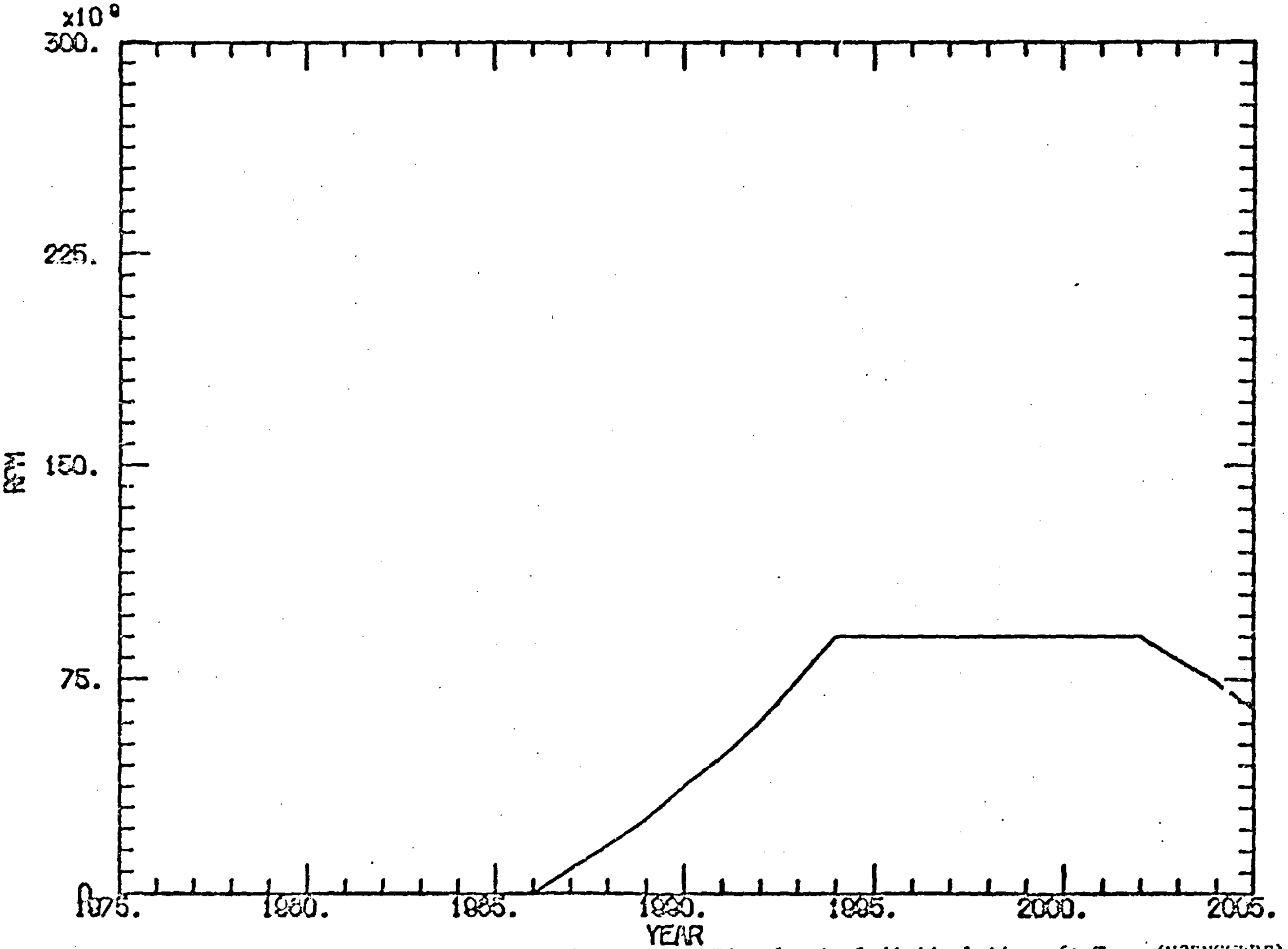

Figure 12 Sample Plotted Output of RPMs Flown versus Time for An Individual Aircraft Type (N2ENGWBPF)

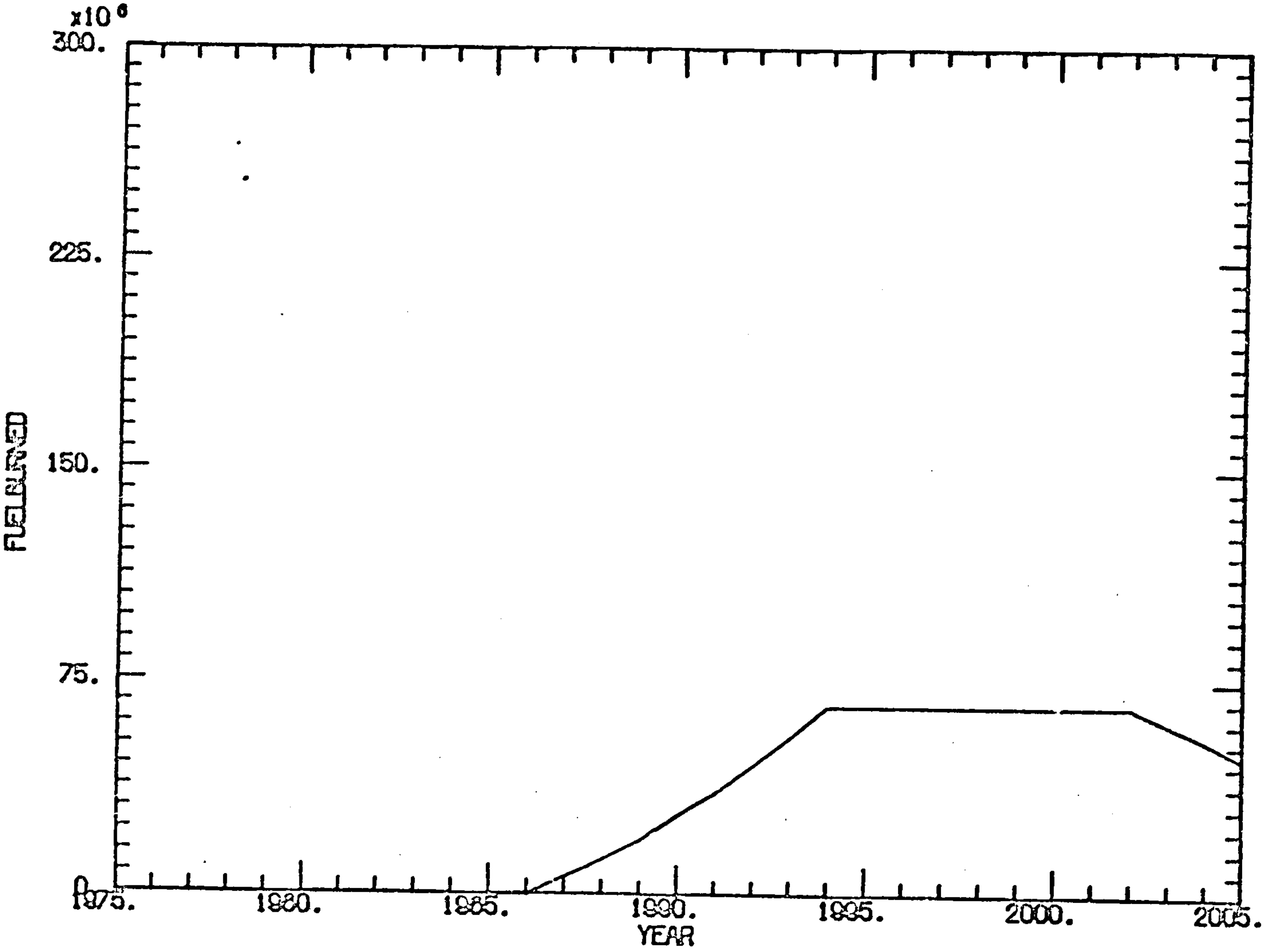

Figure 13 Sample Plotted Output of Fuel Consumed versus Time for an Individual Aircraft Type (H2EHCWBPF)

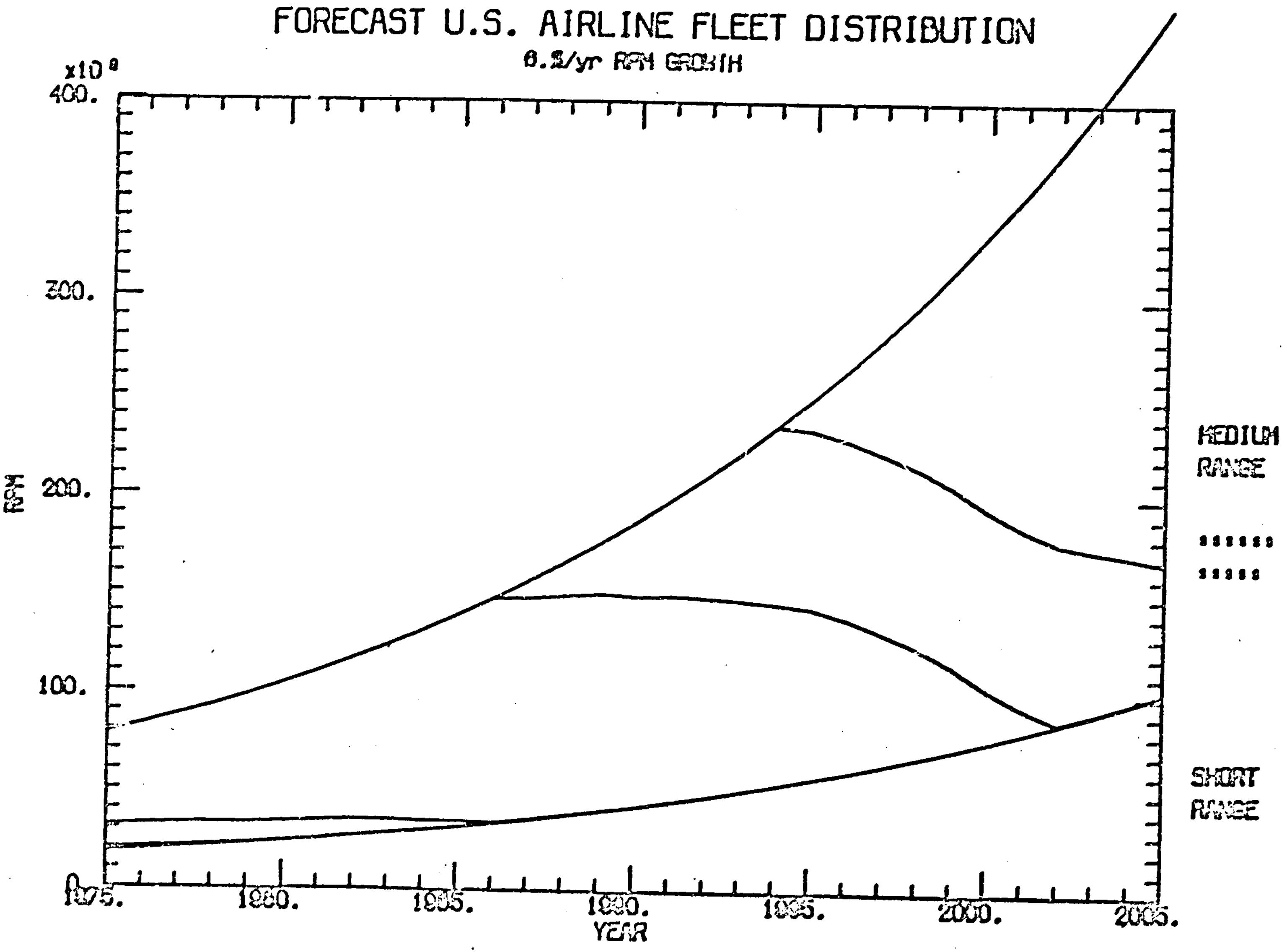

Figure 14 Sample Plotted Output of RPMs Flown versus Time Accumulated over Aircraft Types

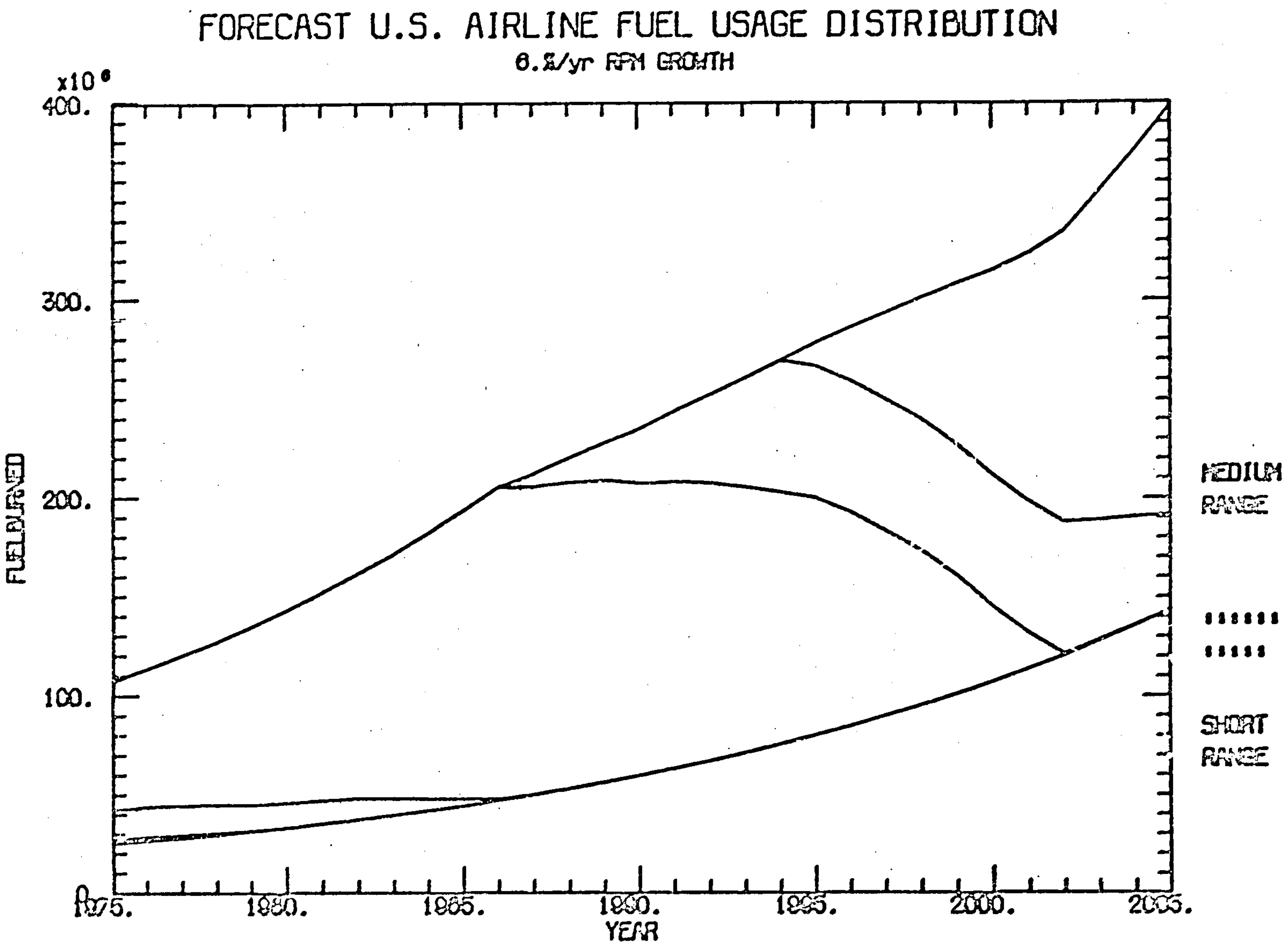

Figure 15 Sample Plotted Output of Fuel Consumed versus Time Accumulated over Aircraft Types

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 vehciles 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)); 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, for subsonic production aircraft

= RE * 3145. * WA ** 0.5825 * 1.0E -06 * CONFIG, for subsonic 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 + AGEP + 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, for prototype

        aircraft or if IPROP = 0

      where

        VMAX = 660.0 * MACH

        RATE = maximum monthly aircraft production rate

FLIGHT TEST OPERATIONS (FTO)

  FTO = FTOI, if FTOI ≠ .1

      = .90 * NFV ** 1.1 * VMAX ** .9 * 1.E - [illegible] WGROSS ** .8,

      otherwise

GROUND SUPPORT EQUIPMENT (AGEP)

  AGEP = AGEPI, if AGEPI = 0.1

       = .15 * FV + .05 * ADDE, otherwise

TECHNICAL DATA (TDP)

  TDP = .02 * FV

      where

        FLIGHT TEST VEHICLES ((FV = CAFFC + CAVFV + CPFV) * (1.0 +
                                                            XFASSY))
          FLT. TEST AIRFRAME (CAFFV)

            CAFFV = AMFG (for 1st unit) * NFV ** ZETA
```

FLT. TEST VEH. AVIONICS (CAVFV)

CAVFV = CAVION (for 1st unit) * NFV ** ZETAA

FLT. TEST PROPULSION SYSTEM (CPFV)

CPFV = PROPU (for 1st unit) * NFV ** ZETAP

- RDT&E FEE (RDFEE)

  RDFEE = RDTE * FEE

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

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

WING (CWING)

CWING = .036 * WWING ** .451 * Z * CFWING

EMPENNAGE (CEMP)

CEMP = .01023 * WEMP ** .451 * Z * CFEMP

BODY (CBODY)

CBODY = .0561 * WBODY ** .451 * Z * CFBODY

LANDING GEAR (CLG)

CLG = .01043 * WLG ** .541 * Z * CFLG

NACELLES GROUP (CNACEL)

CNACEL = .0561 * WNACEL ** .451 * Z * CFNAC

AERODYNAMIC CONTROLS (CAERO)

CAERO = .004 * WAERO * Z * CFAERO

HYDRAULICS (CHYCAD)

CHYCAD = .00197 * WHYCAD ** 0.766 * Z * CFHYCD

ELECTRICAL SYSTEMS (CELCAD)

CELCAD = .00197 * WELCAD ** 0.766 * Z * 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 * CFANTC

AUXILIARY POWER SOURCE (CPOWER)

CPOWER = .000243 * WPOWER * Z * CFPOW

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 + AGEO + 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 ≠ 0.00`

  `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 <u>not</u> 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)

  EDEVA = 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 ** 0.862 * (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):

  EAIRFP = 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):

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

  GENERAL AVIATION TYPES (IAIRPL = 5):

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

  SUPERSONIC TRANSPORTS (IAIRPL = 6):

  EAIRFP = 176890. * WAIRFR ** 0.4506 * (1.0 + API) ** (YEAR - 1975.) * C

- ESTIMATED AIRPLANE PRICE (EAIRPR)

  EAIRPR = EAIRFP + 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:

$$\text{SUM} = \left(\frac{1}{1+R}\right) CF_1 + \left(\frac{1}{1+R}\right)^2 CF_2 + \dots + \left(\frac{1}{1+R}\right)^n CF_n \qquad (9)$$

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 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.

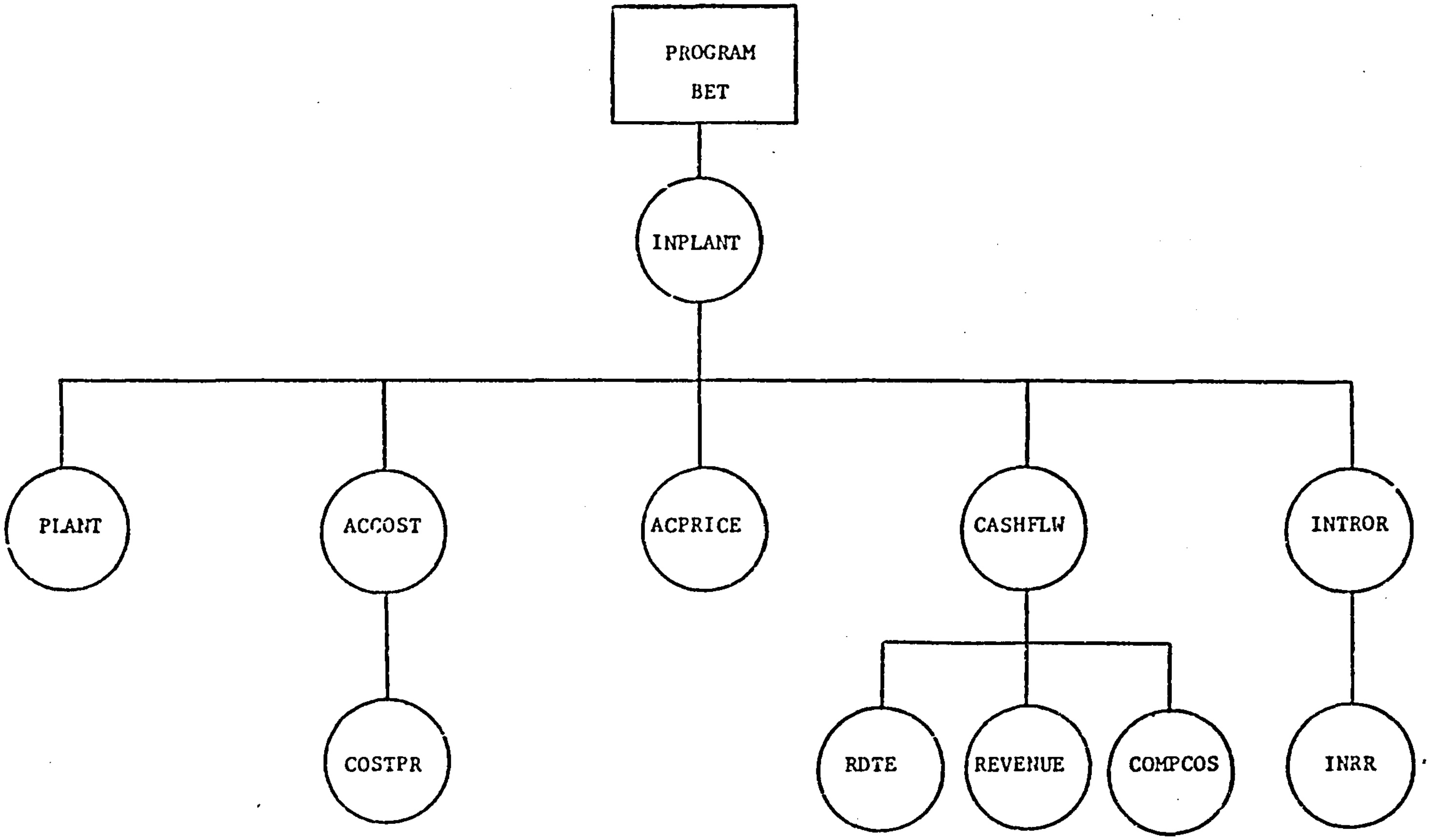

Figure 16 Program Structure of the Airframe Manufacturer Module

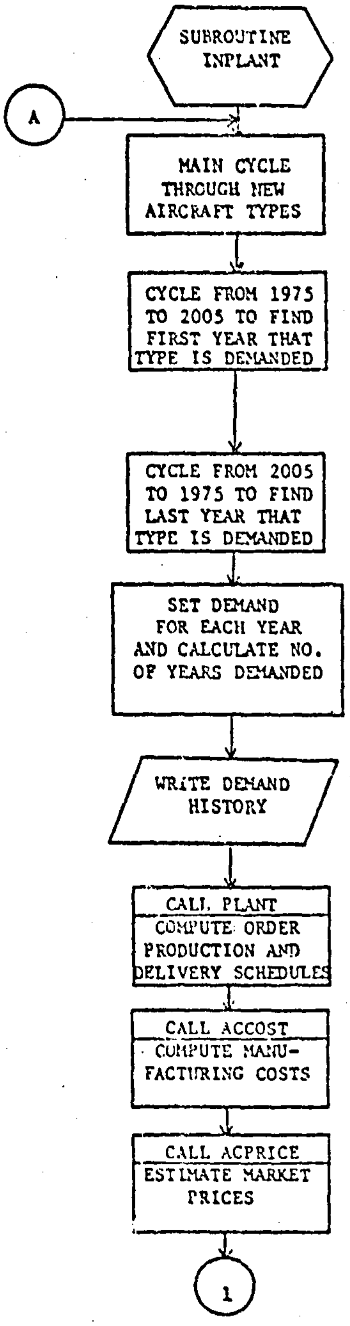

Figure 17 Flowchart of Subroutine INPLANT Logic

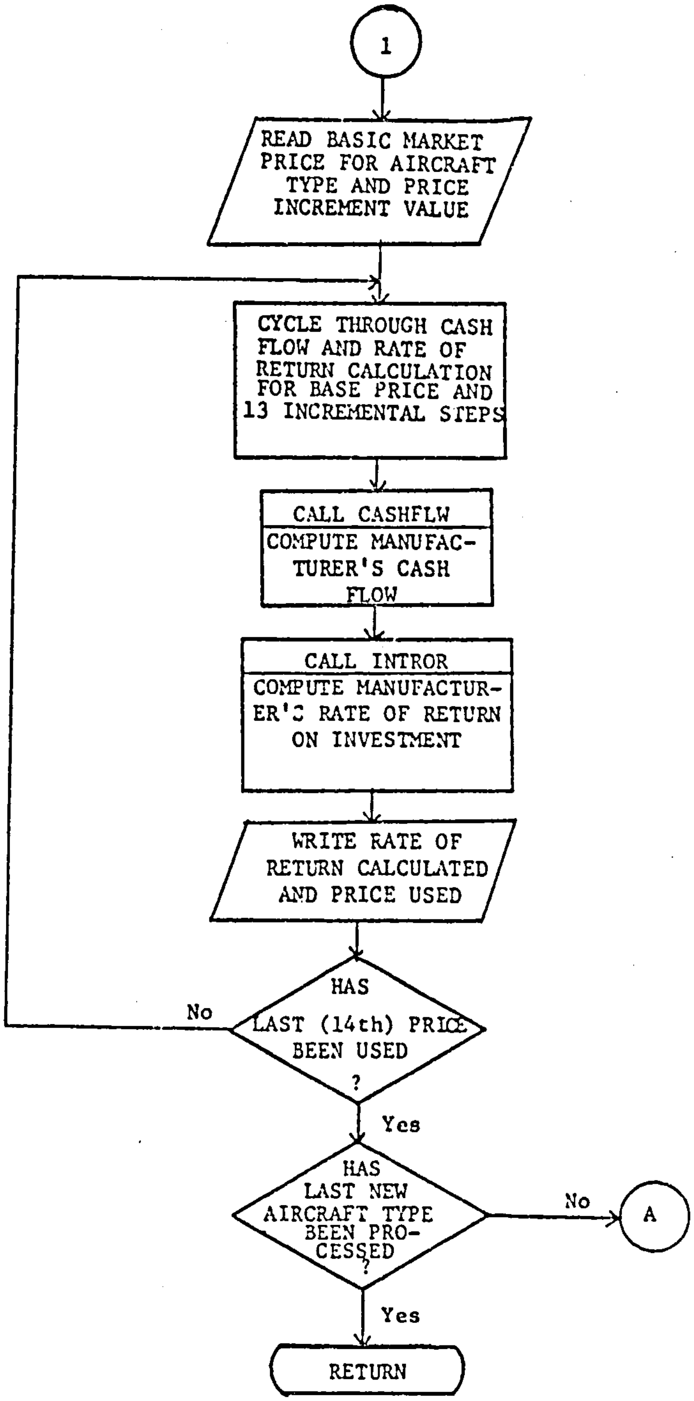

Figure 17 (Concluded)

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

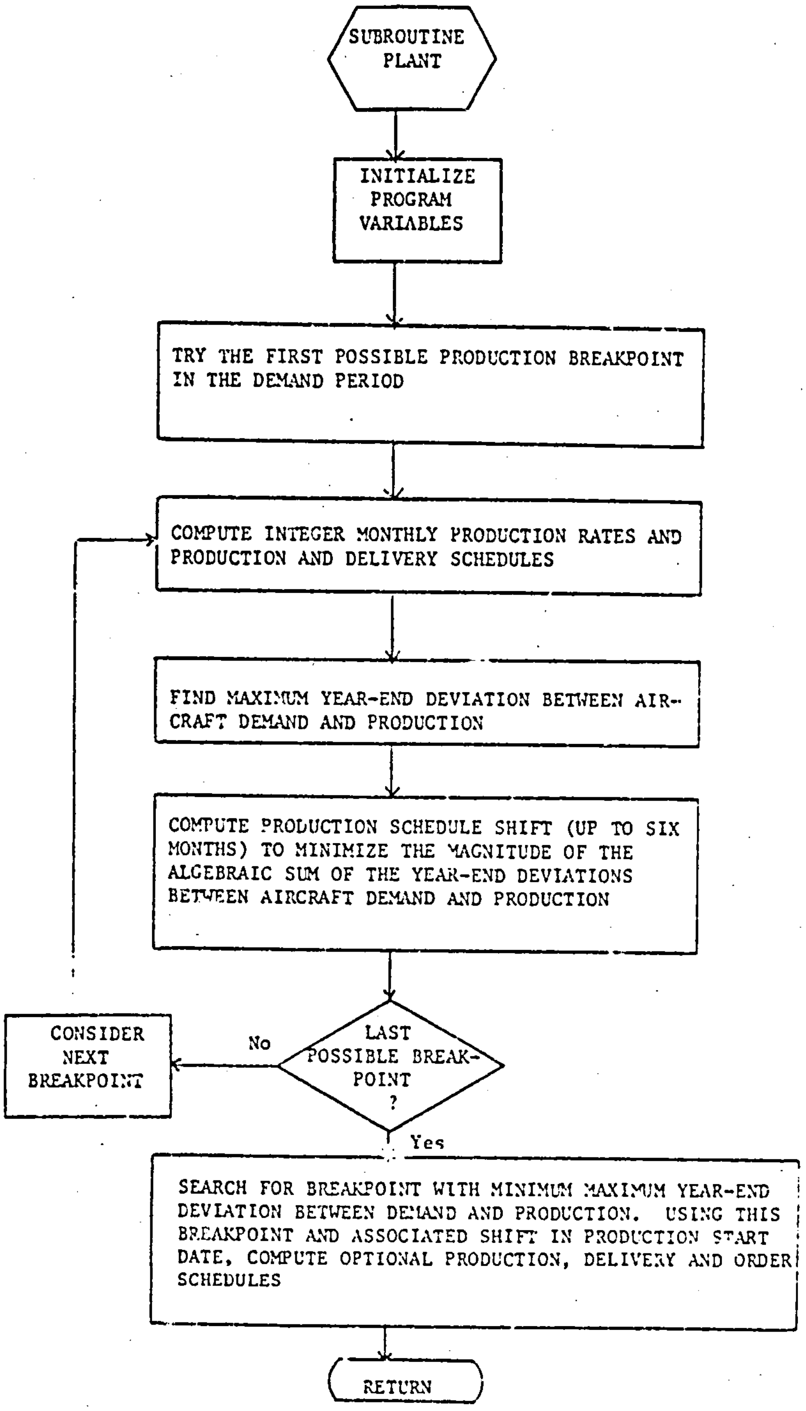

Figure 18 Flowchart of Subroutine PLANT Logic

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.

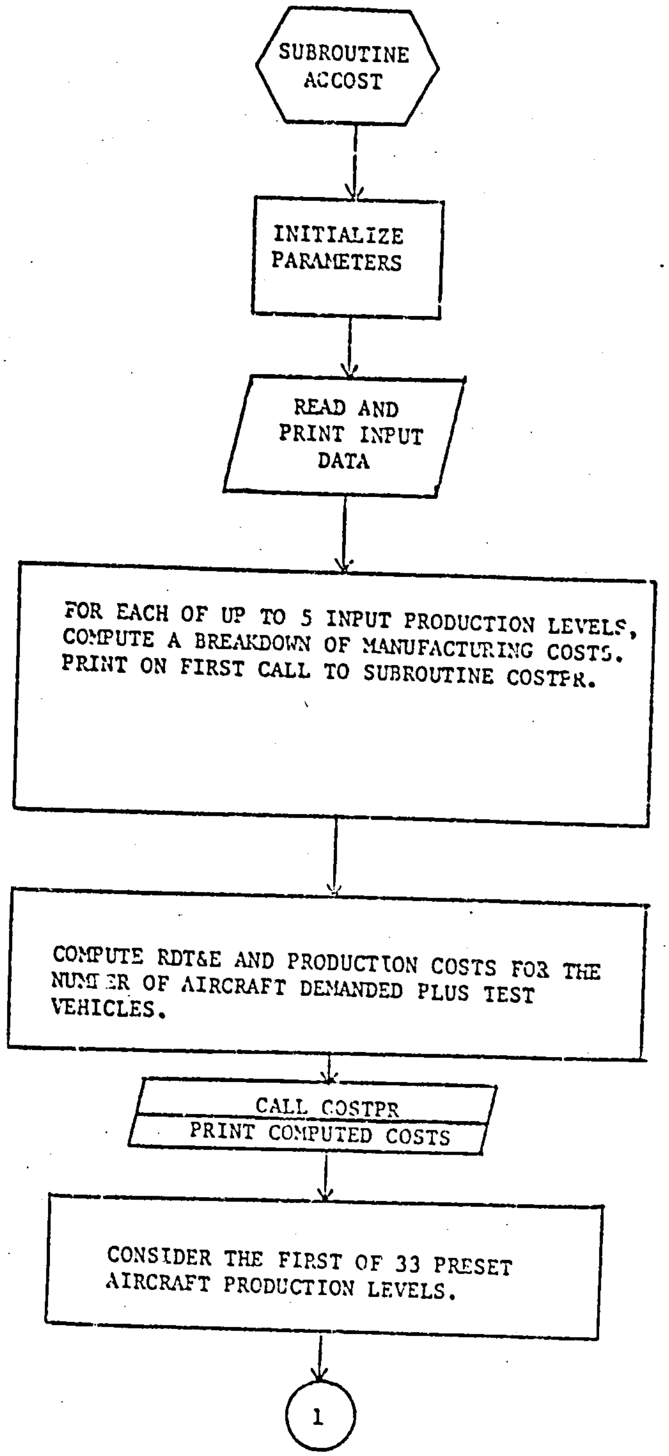

Figure 19 Flowchart of Subroutine ACCOST Logic

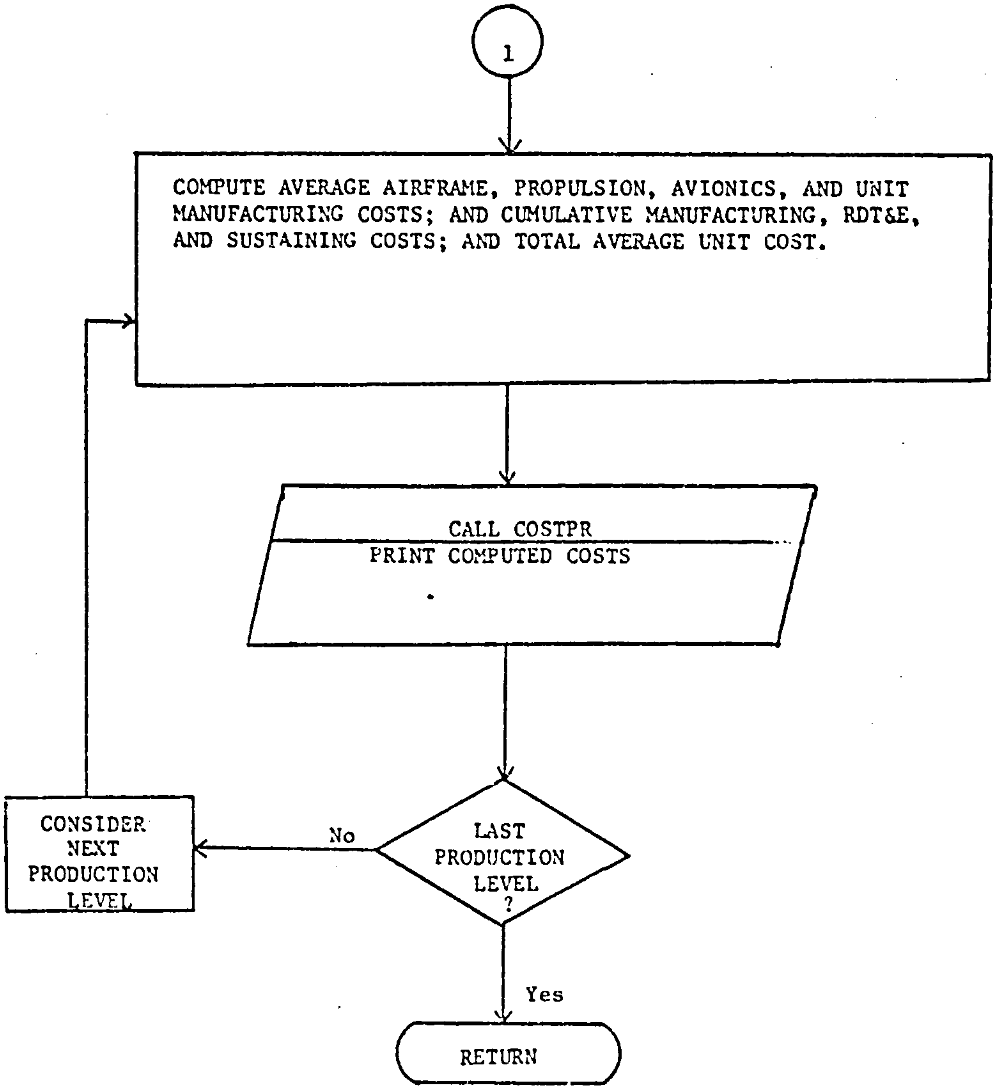

Figure 19 (Concluded)

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 cosrs 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.

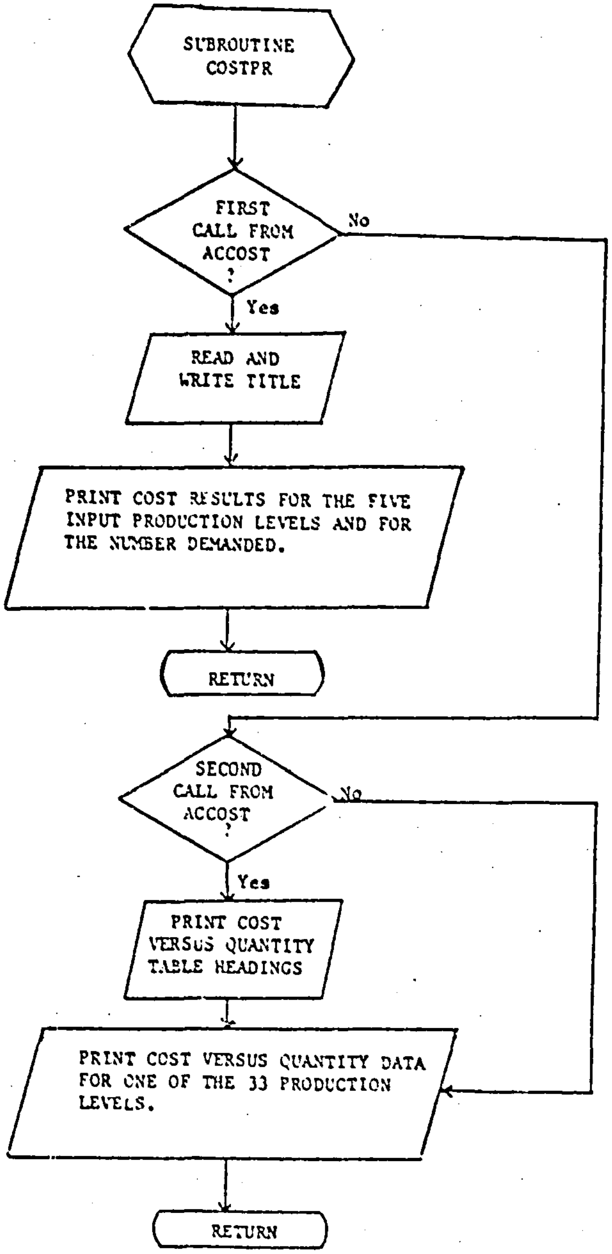

Figure 20 Flowchart of Subroutine COSTPR Logic

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).

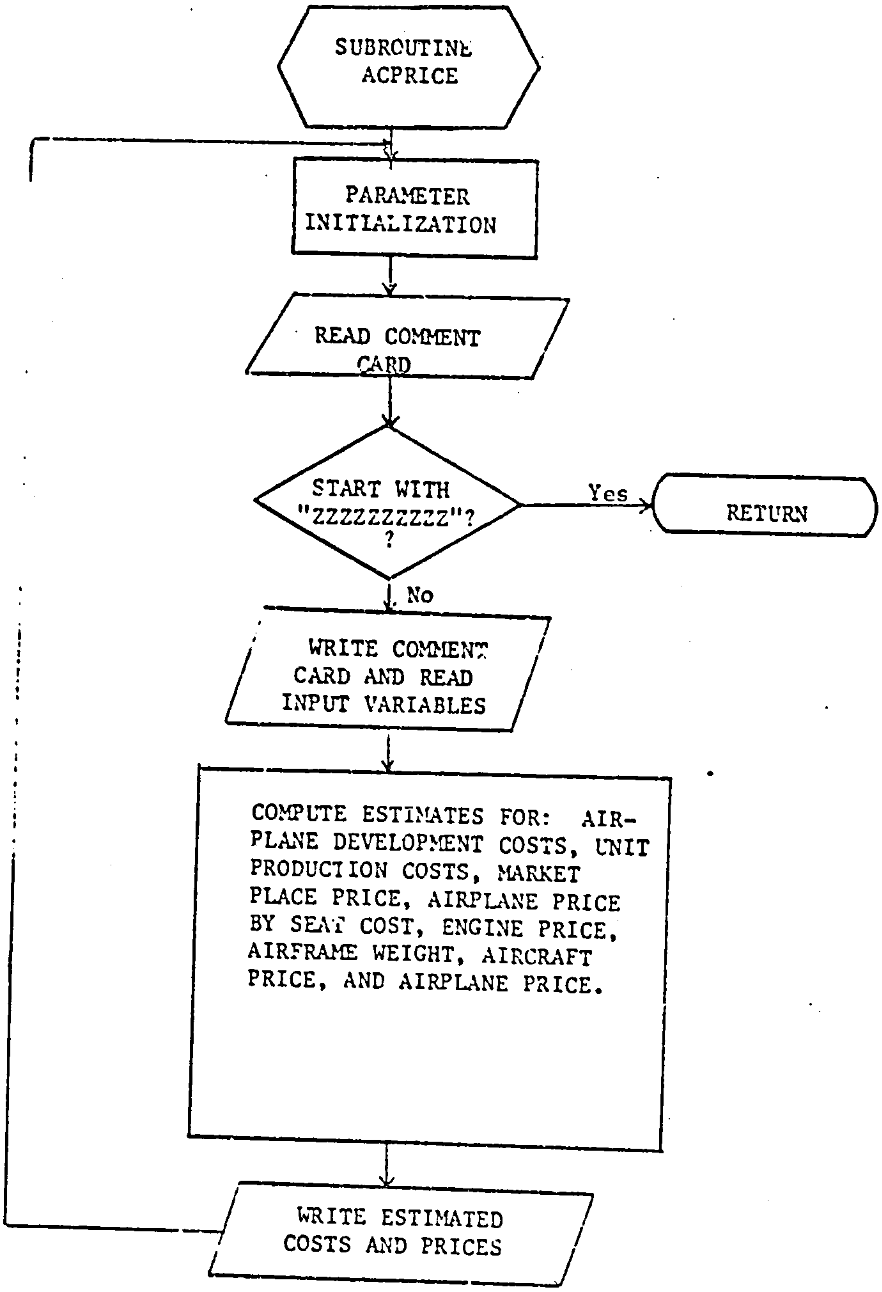

Figure 21 Flowchart of Subroutine ACPRICE Logic

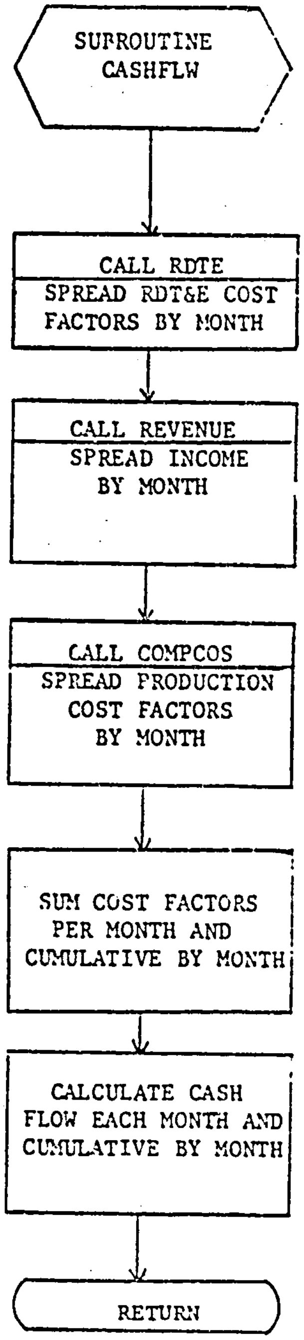

Figure 22 Flowchart of Subroutine CASHFLW Logic

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

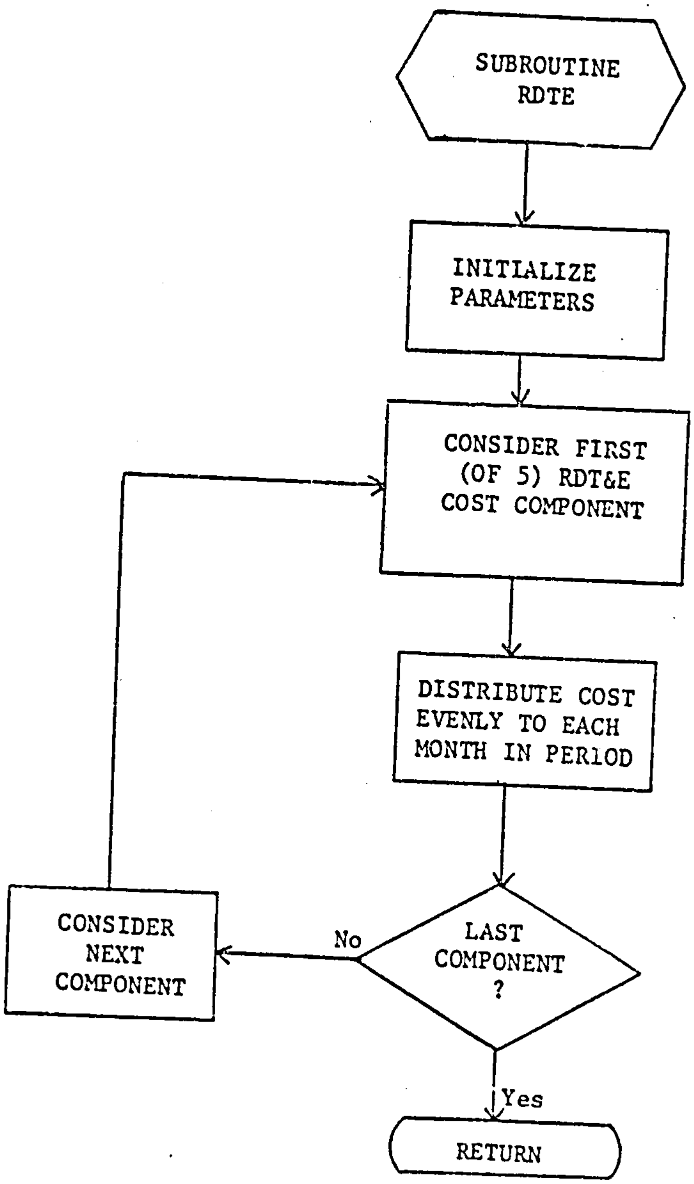

Figure 23 Flowchart of Subroutine RDTE Logic

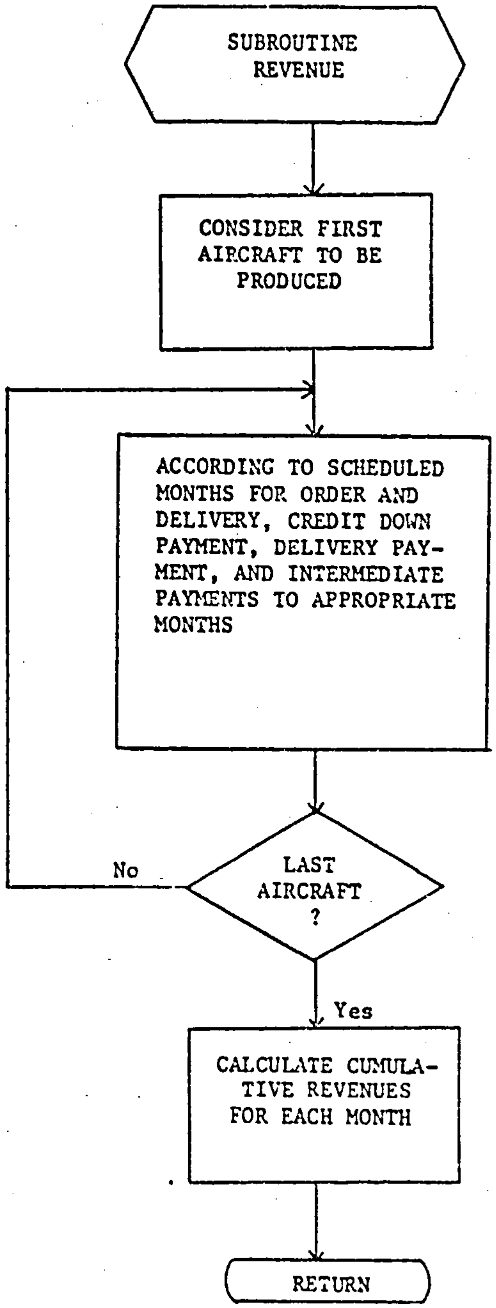

Figure 24 Flowchart of Subroutine REVENUE Logic

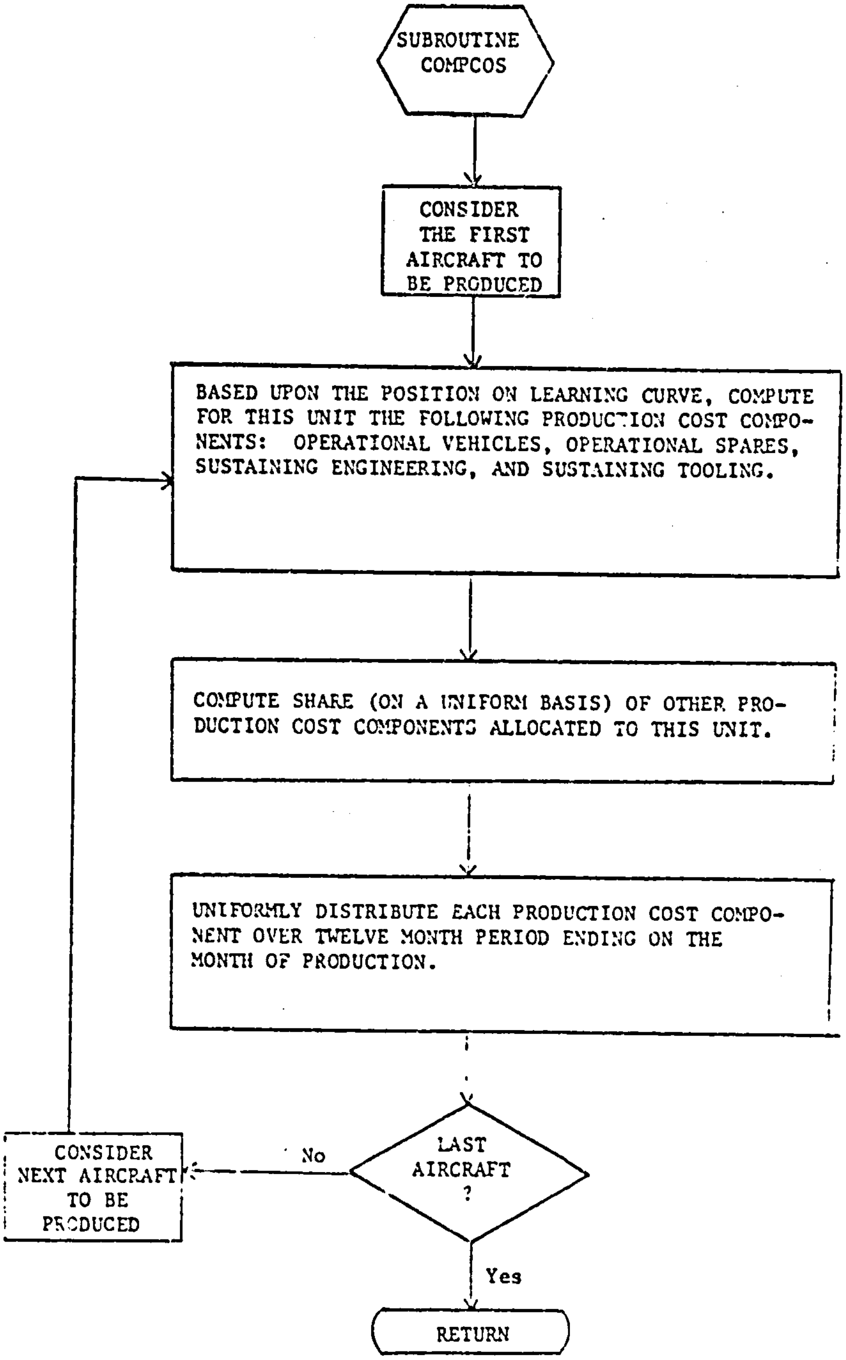

Figure 25 Flowchart of Subroutine COMCOS Logic

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

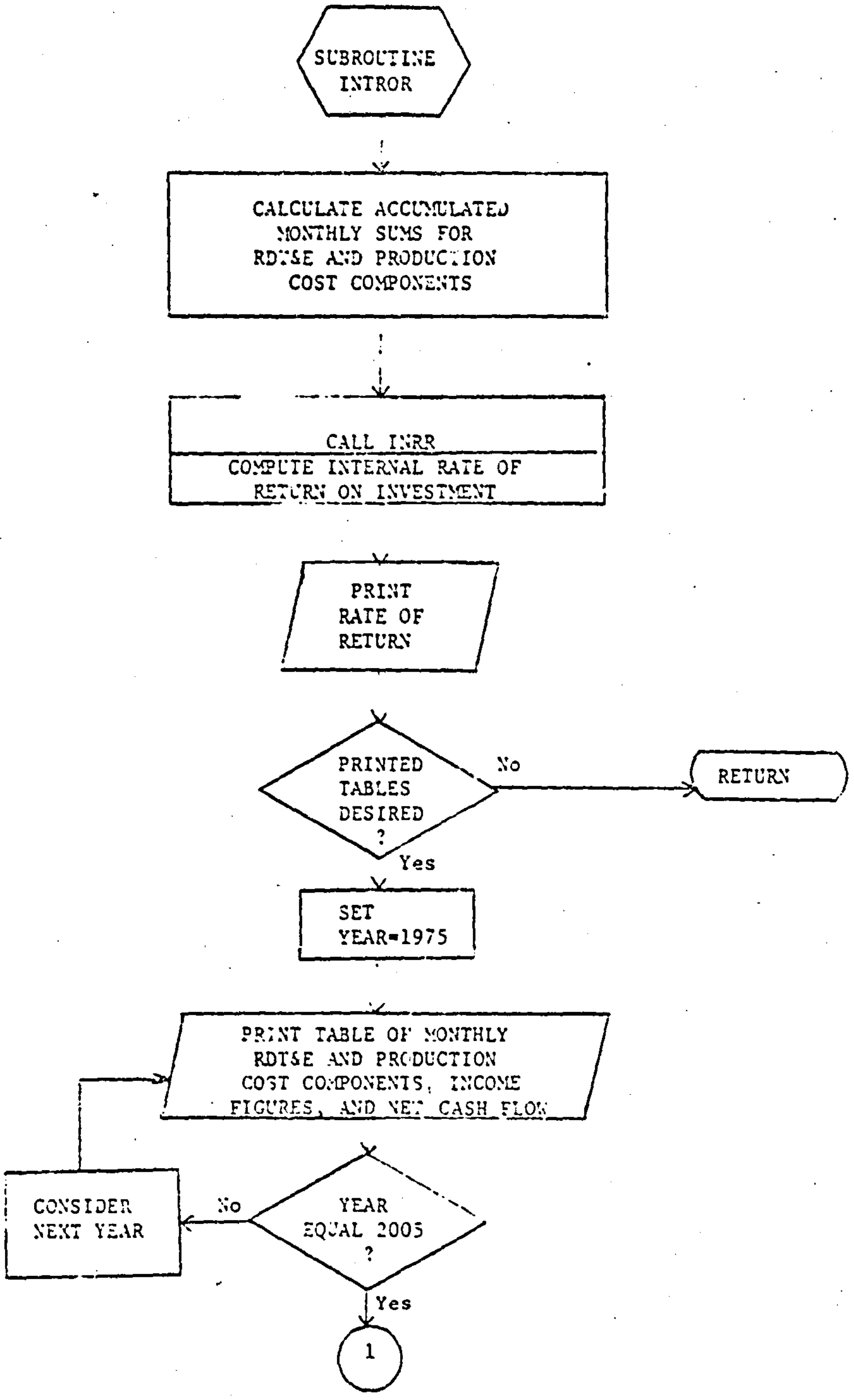

Figure 26 Flowchart of Subroutine INTROR Logic

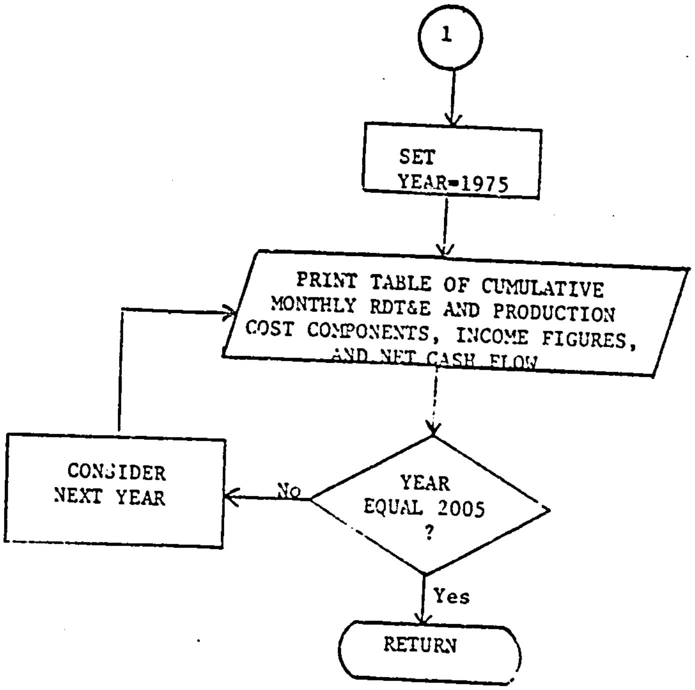

Figure 26 (Concluded)

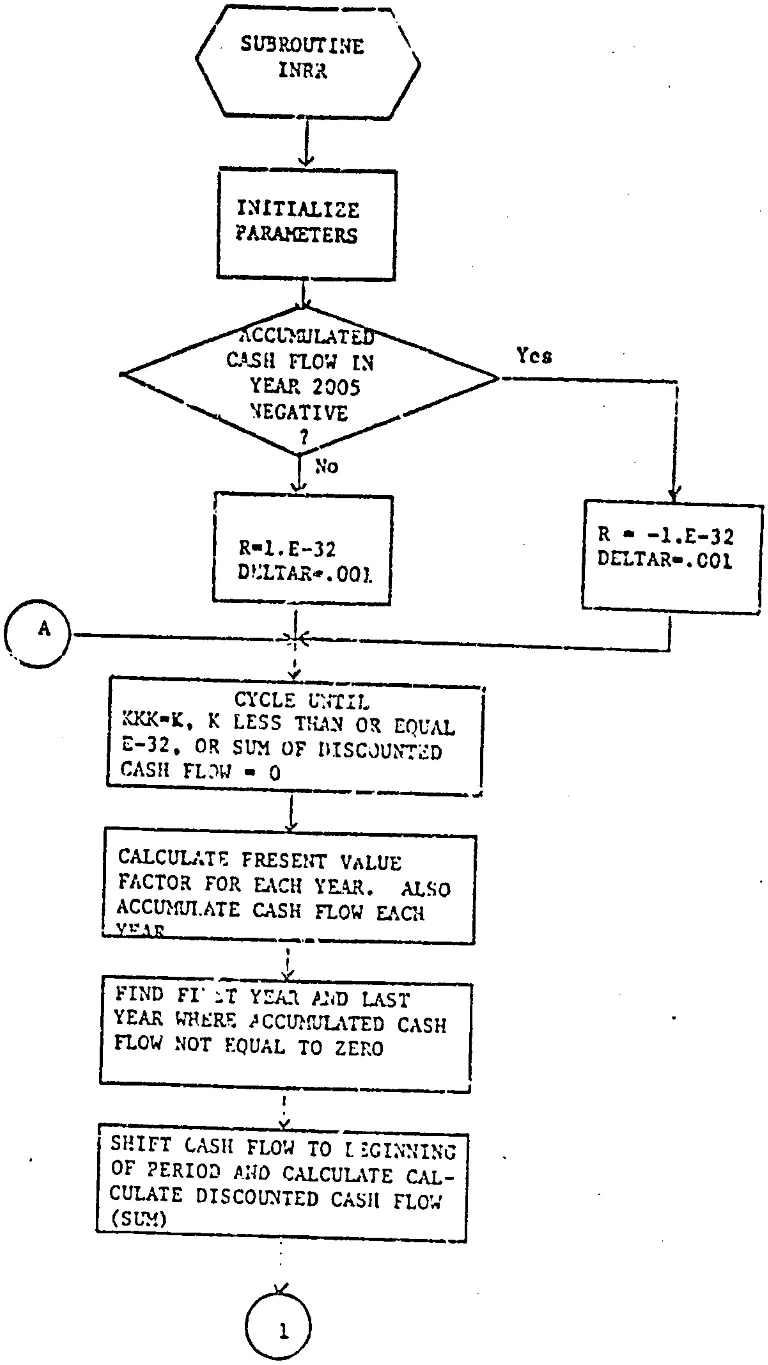

Figure 27 Flowchart of Subroutine INRR Logic

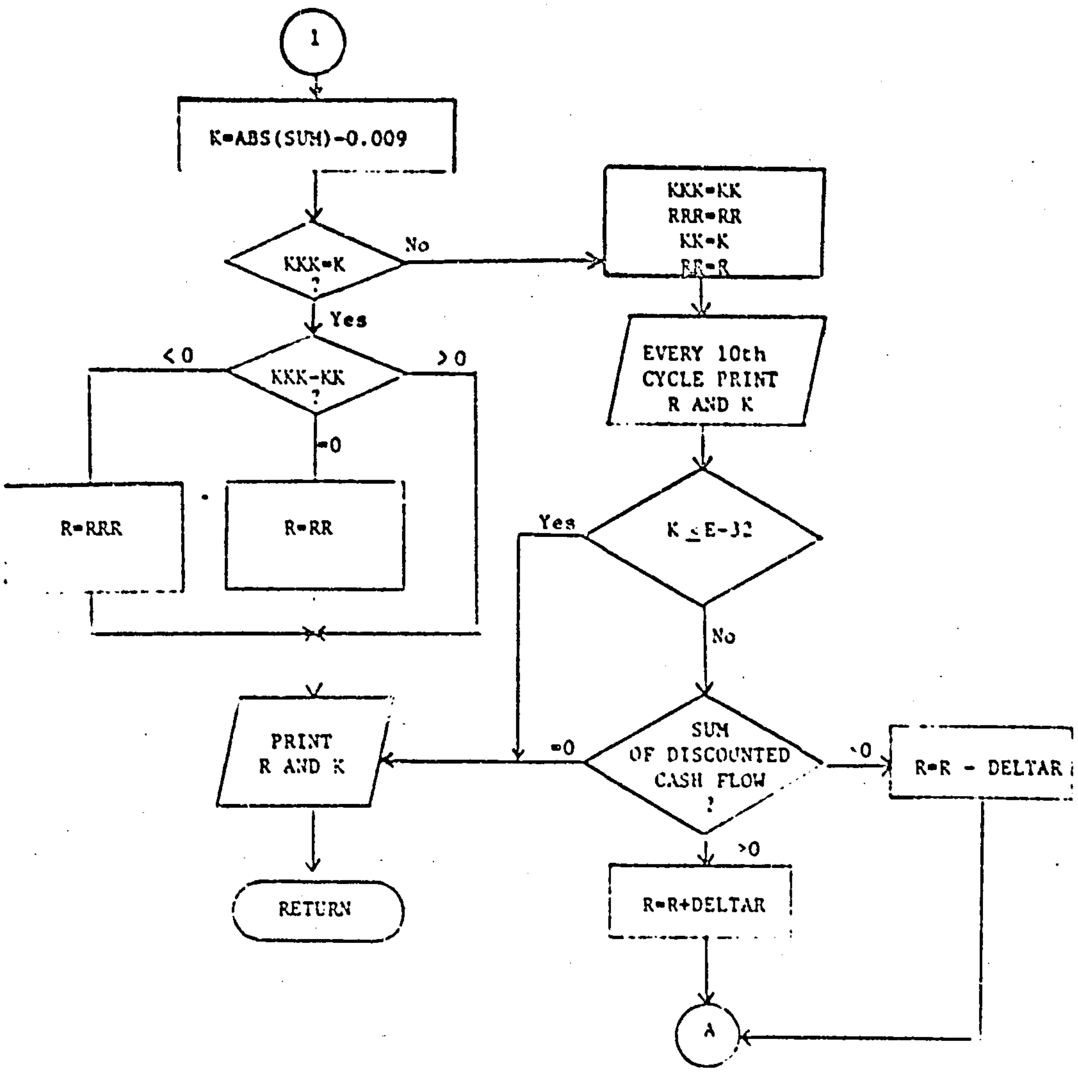

Figure 27 (Concluded)

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

---

*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

Card	Default Value	Parameter	Format	Description[*]
1[†]	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	WEMP	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)

Card	Default Value	Parameter	Format	Description
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 ≥ 1, then WLG is computed as the sum of WLGSTR, WLGCON, WLGWHL, and WLGTRS.)
2[§]	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	CFHNDL	Real	Complexity factor for the loadings and handling system.

Table 10 (Continued)

Card	Default Value	Parameter	Format	Description
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	AFSPAO	Real	Airframe spares factor for production phase.
2	0.4	ENSPAO	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	FTOI	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	IDATA	Integer	Not used.
2	2	IPOWER	Integer	Not used.

Table 10 (Continued)

Card	Default Value	Parameter	Format	Description
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 by 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	NOENG1	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)

Card	Default Value	Parameter	Format	Description
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	IENGS	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	WENGS	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)

Card	Default Value	Parameter	Format	Description
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 ACPRICE 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.

[§] 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

```
 .82164049277422E+02  .78951098965504E+02
 .12339017442541E+03  .13514953042455E+03  .38635737790341E+02
0.                   0.                    .14779342007706E+03  .12437953231700E+03
0.                   0.                   0.                   0.                    .13277551196797E+03
0.                   0.                   0.                   0.                   0.
0.                   0.                   0.                   0.                   0.
PERIOD =           6                      0.                   0.                   0.
                                                               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 =         293
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 =         293
TOTAL DEMAND FOR THIS AIRCRAFT =         872
PRODUCTION RATE FOR 1ST & 2ND PERIOD RESPECTIVELY IS =      8,    12
TIME FOR START-UP OF PRODUCTION = 157
```

Table 13

SAMPLE PRINTOUT OF VALUES OF VARIABLES IN NAMELISTS INPUT1 AND INPUT2

```
$INPUT1
RN      = .2E+01,
MACH    = .8E+00,
PN      = .1E+01,
T       = .45E+05,
WACS    = .295E+04,
WAERO   = .389E+04,
WANTIC  = .5E+03,
WAVION  = .212E+04,
WBODY   = .3632E+05,
WELCAD  = .252E+04,
WEMP    = .916E+04,
WENACC  = .126E+04,
WENGS   = .2611E+05,
WFUSYS  = .54E+03,
WFUTOT  = .4863E+05,
WGROSS  = .2691E+06,
WHANDL  = .1E+03,
WHYCAD  = .377E+04,
WINST   = .67E+03,
WLG     = .1557E+05,
WLGCON  = 0.0,
WLGSTR  = 0.0,
WLGTR[illegible] = 0.0,
WLGWHL  = 0.0,
WNACEL  = .1129E+05,
WPACCD  = .1937E+05,
WPNCAD  = 0.0,
WPOWER  = .206E+04,
WTPEUS  = .559E+04,
WWING   = .4073E+05,
WPAYL   = .4573E+05,
IWLG    = 0,
$END
```

Table 13 (Continued)

```
$INPUT2
ADI     = .1E+00,
AGEOI   = .1E+00,
AGEPI   = .1E+00,
CFACS   = .27E+01,
CFAERO  = .65E+00,
CFANTC  = .1E+01,
CFAVON  = .1E+01,
CFBODY  = .7E+00,
CFELCD  = .8E+00,
CFEMP   = .19E+01,
CFENAC  = .4E+00,
CFENG   = .1E+01,
CFFUSY  = .1E+00,
CFHNDL  = .1E+01,
CFHYCO  = .55E+00,
CFINST  = .7E+00,
CFLG    = .7E+00,
CFNAC   = .1E+01,
CFPACC  = .31E+01,
CFPNCO  = .1E+01,
CFPOW   = .32E+01,
CFTREV  = .1E+01,
CFWING  = .9E+00,
CONFIG  = .1E+01,
CTJI    = .1E+01,
AESPAD  = .13E+00,
ENSPAD  = .4E+00,
ENSPAR  = .4E+00,
FACT    = 0.0,
FEE     = 0.0,
FTOI    = .1E+00,
```

Table 13 (Concluded)

```
 FVSPAR  = .2E+00,
 GTSPAR  = .1E+00,
 ICONFG  = 6,
 IDATA   = 1,
 IPOWER  = 2,
 IPROD   = 1,
 IOPS    = 0,
 LEARN   = .9185E+02,
 LEARNA  = .5185E+02,
 LEARNP  = .6818E+02,
 NCREW   = .3E+01,
 NDATA   = 5,
 NFV     = .5E+01,
 NG      = .1E+01,
 NOCON   = 0.0,
 NOCON1  = 0.0,
 NOENG   = .15E+03,
 NOENG1  = .5E+03,
 NOYRS   = .75E+00,
 NOYRS1  = .1E+01,
 NV      = .967E+03,
 NVEH    = .1E+01, .5E+01, .1E+03, .3E+03, .5E+03,
 POTJT   = .1E+00,
 RATE    = .12E+02,
 RE      = .17E+02,
 RT      = .15E+02,
 SUBSYI  = 0.0,
 TOOLC   = .1E+01,
 XAVD    = 0.0,
 XFASSY  = .5E-01,
 XNEW    = .2E+00,
 $END
```

Table 14

SAMPLE PRINTOUT OF PROGRAM VARIABLES

```
     MVEH =              1.0             5.0           100.0           300.0           600.0
    NDATA =  5    ICONFG =  6    IDATA =  1    IPOWER =  2    IPROD =  1

     ADI  =      .100      NG =   1.000      CONFIG =    1.000      LEARN =  81.856      NOCON =   0.000      NOCON1 =   0.000
     FACI =     0.000      NV = 867.000      ENSPAD =     .400      LEARN*=  88.186      NOENG = 150.000      NOENG1 = 500.000
     FEE  =     0.000      RE =  17.000      ENSPAR =     .400      LEARNA=  91.850      NOYRS =    .750      NOYRS1 =   1.000
     MACH =      .800      RT =  15.000      FTOI   =     .100      NFV    =  5.000      XNEW  =    .200      YAYD   =   6.000
     RATE =    12.000                        TOOLC  =    1.000      CFACS  =  2.700      XFASSY=    .050

     AREOI =     .100      FVSPAR =     .200      POTJ   =    0.000      SUBSYS =   0.000      IOPS =        0       PN     =    1.000
     AGEPI =     .100      GTSPAR =     .200      POTJI  =     .100      SUBSYI -   0.000                           NCREW  =    3.000

                CFAERO =    .650      CFANTC =   1.000      CFAVON =   1.000      CFBODY =    .700      CFELCD =    .80
                CFENG  =   1.000      CFEMP  =   1.900      CFENAC =    .400      CFHYCD =    .556      CFFUSY =    .100
                CFINST =    .700      CFLG   =    .700      CFNAC  =   1.000      CFPNCD =   1.000      CFPOW  =   3.20
                CFHNDL =   1.000      CFTREV =   1.000      CFWING =    .900      CFPACS =   3.106      CFACS  =   2.7

  TOYERV= .33545E+00        EM =   .20000E+01

  Z= 45000.0     MACH=    .800     NV= 867.000     NFV=    5.000     EM=    2.000
  ENSPAR=     .400     ENSPAD=     .400     AFSPAD=     .133
  POTJ =    .456325E+03
```

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

Tables 15 though 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)


                     BREAKDOWN OF CUMULATIVE MANUFACTURING COST,    MILLIONS OF DOLLARS
 NUMBER OF VEHICLES
                                                     1.           5.          100.          300.          600.
 WING
                                                  3.8870      12.2076      132.7366      224.3933      367.3101
 EMPENNAGE
                                                  1.1293       3.5466       29.9475       65.1882      106.7132
 BODY STRUCTURE
                                                  4.4739      14.0505      118.2484      259.2594      422.7690
 LANDING GEAR
                                                  1.3534       4.2503       35.7700       79.1229      127.8872
 NACELLES, PODS, PYLONS, SUPPORTS
                                                  3.7734      11.8504       99.7324      217.8149      356.5696
 PROPULSION SYSTEM
     ENGINES                                  (   5.9827) (   22.3368) (  259.3843) (  637.4977) ( 1124.2969)
     THRUST REVERSER                              3.4311      12.8103      148.7593      365.6107      644.7911
     FUEL SYSTEM                                  2.4662       9.2377      106.9238      262.7902      463.4568
     ENGINE ACCESSORIES                            .0050        .0148         .1719         .4221         .7445
                                                   .3814        .3039        3.5295        8.6746       15.2985
 AERODYNAMIC CONTROLS (SURFACE CONTROLS)
                                                  1.6134       3.1764       26.7320       58.3936       95.5739
 HYDRAULIC
                                                   .5947       1.8677       15.7186       34.3330       56.1983
 ELECTRICAL POWER CONVERSION AND DISTRIBUTION
                                                   .6354       1.9954       16.7934       36.6773       60.0407
 PNEUMATIC
                                                  0.0000       0.0000        0.0000        0.0000        0.0000
 AIR CONDITIONING
                                                   .9932       3.1192       26.2511       57.3334       93.8547
 ANTI-ICING
                                                   .1150        .3612        3.0395        6.6386       10.8671
 AUXILIARY POWER SOURCE
                                                  1.6019       5.0307       42.3352       92.4693      151.3700
 PASSENGER ACCOMMODATIONS
                                                  6.9354      21.6968      182.5147      398.6195      652.5377
 INSTRUMENTATION
     EQUIPMENT                                (    .4887) (    1.5349) (   12.9165) (   28.2103) (   46.1803)
     INSTALLATION                                  .4526       1.4214       11.9621       26.1257       42.7678
                                                   .0361        .1134         .9545        2.0845        3.4126
 AVIONICS
     EQUIPMENT                                (   2.2090) (    6.9376) (   58.3865) (  127.5193) (  208.7469)
     INSTALLATION                                 2.0458       6.4249       54.0719      118.0960      193.3213
                                                   .1632        .5127        4.3145        9.4233       15.4256
 LOAD AND HANDLING
                                                   .0123        .0387         .3256         .7111        1.1640
 FINAL ASSEMBLY AND CHECKOUT
                                                  1.7583       5.6995       91.5369      115.1077      194.1037
 VEHICLE TOTAL
                                                 36.9249     119.6598     1092.2724     2439.2519     4076.1772
```

Table 16

SAMPLE PRINTOUT OF COST BREAKDOWN FOR NUMBER OF VEHICLES DEMANDED

```
                                                       COST(MILLIONS OF DOLLARS)
REAEARCH,DEVELOPMENT,TEST,AND EVALUATION
        AIRFRAME DESIGN AND ENGINEERING DEVELOPMENT
                CONCEPT FORMULATION                                           223.73            1279.84
                CONTRACT DEFINITION                                0.00
                AIRFRAME ENGINEERING                               0.00
        SUBSYSTEMS DEVELOPMENT                                   223.73
        AVIONICS DEVELOPMENT                                                  129.12
        PROPULSION DEVELOPMENT                                                  0.00
        DEVELOPMENT SUPPORT                                                   466.32
                GROUND TEST VEHICLES ( 1.0)                                   459.68
                GROUND TEST SPARES                                26.49
                FLIGHT TEST SPARES                                 2.65
                TOOLING AND SPECIAL TEST EQUIPMENT                23.94
                FLIGHT TEST OPERATIONS                           342.15
                GROUND SUPPORT EQUIPMENT                          32.92
                TECHNICAL DATA                                    29.14
        FEE                                                        2.39
                                                                                0.00

               (MANUFACTURING--FIRST UNIT)                (     36.92)
                        AIRFRAME                   (     26.49)
                        AVIONICS PROCUREMENT       (      2.70)
                        PROPULSION PROCUREMENT     (      5.98)
                        FINAL ASSEMBLY AND CHECKOUT(      1.76)

AIRCRAFT PRODUCTION,
        OPERATIONAL VEHICLES ( 872.0)                                                           8774.91
        SPARES                                                       5200.59
        FACILITIES                                                    951.79
        SUSTAINING ENGINEERING                                          0.00
        SUSTAINING TOOLING                                            642.89
        GROUND SUPPORT EQUIPMENT                                      540.72
        TECHNICAL DATA                                                807.09
        MISCELLANEOUS EQUIPMENT                                       207.61
        TRAINING EQUIPMENT                                             10.46
        INITIAL TRAINING                                               36.24
        INITIAL TRANSPORTATION                                        251.60
        FEE                                                            35.93
                                                                        0.00

TOTAL COST
                                                                                               10053.75
TOTAL NUMBER OF FLIGHT VEHICLES PRODUCED
                                                                                                 872.00
AVERAGE UNIT AIRPLANE COST
                                                                                                  11.53
```

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    867.    PRODUCTION RATE AC/MO   12.00    TEST AC    5.    PROGRAM TYPE  PRODUCTION    PERCENT PROFIT     0.0

                    AVERAGE MANUFACTURING COSTS                                          R D T & E     SUSTAINING    AVERAGE
 QUANTITY   AIRFRAME   PROPULSION   AVIONICS    UNIT COST      CUMULATIVE      COSTS         COSTS         COST

      1     26.4862     5.9827      2.6977       36.92            36.92        1049.46         17.87      1104.26
      2     21.6789     5.2735      2.2081       30.62            61.24        1066.57         95.61       611.66
      3     19.2822     4.9013      1.9646       27.45            82.35        1076.97        147.55       435.63
      4     17.7442     4.6520      1.8073       25.41           101.65        1084.69        187.90       343.56
      5     16.6362     4.4674      1.6945       23.94           119.69        1090.83        221.49       285.40
      6     15.7825     4.3220      1.6075       22.80           136.79        1095.95        250.59       247.22
      7     15.0950     4.2027      1.5375       21.88           153.14        1100.36        276.47       218.57
      8     14.5236     4.1021      1.4793       21.11           168.88        1104.23        299.92       195.63
      9     14.0377     4.0154      1.4298       20.46           184.11        1107.68        321.44       179.25
     10     13.6168     3.9393      1.3869       19.89           198.90        1110.61        341.41       165.11
     20     11.1453     3.4737      1.1352       16.54           330.84        1132.22        492.84        97.79
     30      9.9131     3.2273      1.0097       14.86           445.75        1145.45        601.89        73.10
     40      9.1224     3.0631       .9292       13.77           550.82        1155.16        691.37        59.93
     50      8.5528     2.9415       .8711       12.98           649.19        1162.90        769.17        51.63
     60      8.1139     2.8458       .8264       12.38           742.53        1169.34        839.07        45.85
     70      7.7604     2.7673       .7904       11.88           831.89        1174.89        903.22        41.57
     80      7.4667     2.7010       .7605       11.47           917.97        1179.76        962.94        38.26
     90      7.2169     2.6439       .7351       11.13          1001.31        1184.11       1019.13        35.61
    100      7.0005     2.5938       .7130       10.82          1082.27        1188.04       1072.43        33.43
    200      5.7299     2.2873       .5836        9.13          1806.15        1215.00       1512.46        22.67
    300      5.0964     2.1250       .5191        8.13          2439.26        1231.65       1866.69        19.46
    400      4.6899     2.0169       .4777        7.54          3017.49        1243.88       2170.62        16.10
    500      4.3971     1.9369       .4479        7.12          3560.44        1253.62       2464.10        14.56
    600      4.1714     1.8738       .4249        6.79          4076.19        1261.73       2731.01        13.45
    700      3.9597     1.8221       .4064        6.53          4570.37        1268.71       2983.94        12.60
    800      3.8387     1.7785       .3910        6.31          5046.88        1274.84       3225.83        11.93
    900      3.7103     1.7409       .3779        6.12          5509.45        1280.32       3458.71        11.39
   1000      3.5996     1.7079       .3665        5.96          5957.17        1285.28       3684.04        10.93
   1200      3.4143     1.6523       .3478        5.69          6822.15        1293.97       4116.19        10.19
   1400      3.2656     1.6067       .3326        5.47          7651.25        1301.45       4528.51         9.63
   1600      3.1420     1.5683       .3200        5.28          8450.87        1308.63       4925.04         9.18
   1800      3.0368     1.5351       .3093        5.13          9225.61        1313.90       5309.59         8.80
   2000      2.9458     1.5060       .3000        4.99          9975.92        1319.21       5681.18         8.49
```

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.

F urteen 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 (DELTAP).

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,(ESEPRI(1))
                                                                       13.0379
ESTIMATED ENGINES TOTAL PRICE
                                                                        0.0000
ESTIMATED AIRFRAME PRICE
                                                                       25.9882
AIRFRAME WEIGHT
                                                                   145570.0000
ESTIMATED AIRPLANE PRICE
                                                                       25.9882
```

Table 19

SAMPLE PRINTOUT OF INTERNAL RATE OF RETURN RESULTS

```
.3692E+02  .9518E+03 0.
                                       .6429E+03  .5407E+03  .8671E+03  .1076E+03  .1046E+02  .3624E+02  .2616E+03  .3593E+02
           -.0090000         4125.9352410
           -.0190000         4334.4032739
           -.0290000         4557.3094323
           -.0390000         4795.8648175
           -.0490000         5051.3944698
           -.0590000         5325.3483609
           -.0690000         5619.3116433
           -.0790000         5935.0202430
           -.0890000         6274.3712457
           -.0990000         6639.4384762
           -.1090000         7032.4867953
           -.1190000         7455.9869431
           -.1290000         7912.6302197
           -.1390000         8405.3424083
           -.1490000         8937.2963988
           -.1590000         9521.9202282
           -.1690000        10132.9352943
           -.1790000        10804.2013654
           -.1890000        11530.0077144
           -.1990000        12314.7467657
           -.2090000        13163.0198773
           -.2190000        14079.5354674
           -.2290000        15068.9998731
           -.2390000        16135.9570582
           -.2490000        17284.5596079
           -.2590000        18518.2393180
           -.2690000        19839.2625216
           -.2790000        21248.0967792
           -.2090000        22742.5503867
           -.2990000        24316.5928047
           -.3090000        25958.7473681
           -.3190000        27649.8967747
           -.3290000        29360.3037796
           -.3390000        31045.5584459
           -.3490000        32641.0676870
           -.3590000        34054.5566477
           -.3690000        35135.8521650
           -.3790000        35762.9401343
           -.3890000        35622.9989547
           -.3990000        34385.7632592
           -.4090000        31568.5902796
           -.4190000        26505.9665889
           -.4290000        18281.4031161
           -.4390000         5632.2681395
           -.4420000          729.8042879
R =  -.442E+00
ROIM =   -.442000 PMAN =    7.000000
```

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

AIRFMDE1992 0.         0.         0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
SUBSYSD1992 0.         0.         0.         0.         0.         0.         0.         0.         0.         0.         0.         0.
AVONICS1992 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  [illegible]3E+02 1.642E+02  1.651E+02  1.660E+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  [illegible]6E+01 4.329E+01  4.309E+01  4.290E+01  4.272E+01  4.254E+01  4.235E+01  4.219E+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
FACILIT1992 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
SUSTOOL1992 2.115E+00  2.081E+00  2.049E+00  2.017E+00  1.986E+00  1.936E+00  1.920E+00  1.990E+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
MISCEQU1992 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
TRAINEC1992 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
ITILTRN1992 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
ITILTRA1992 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
CASHFLO1992 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
```

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

AIRFMDE1992 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
SUBSYSD1992 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.
PROPULS1992 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 6.218E+02 6.294E+02 6.370E+02
FACILIT1992 0.        0.        0.        0.        0.        0.        0.        0.        0.        0.        0.        0.
SUSENGR1992 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 4.589E+02 4.609E+02 4.629E+02 4.649E+02 4.669E+02 4.688E+02 4.707E+02 4.726E+02 4.744E+02 4.762E+02 4.780E+02
GSEQUIP1992 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
MISCEQU1992 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
TRAINEQ1992 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
ITILTSH1992 1.284E+02 1.308E+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
ITILTRA1992 1.764E+01 1.797E+01 1.830E+01 1.862E+01 1.895E+01 1.928E+01 1.951E+01 1.994E+01 2.027E+01 2.060E+01 2.093E+01 2.126E+01
CASHFLO1992 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)

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

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

BLOCK TIME (hours)

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

BLOCK SPEED (mph)

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

BLOCK FUEL (pounds)

$$\mathrm{BF(I)} = \mathrm{WGR} * 0.01 + ((\mathrm{F1} - \mathrm{F2})/(\mathrm{D2} - \mathrm{D1})) * \mathrm{SL(I)} + 0.033\ ((\mathrm{F1} - \mathrm{F2})/(\mathrm{D2} - \mathrm{D1})) * \mathrm{CRS}$$

FLIGHT TIME (hours)

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

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

FLIGHT CREW COSTS ($/mile)

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

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

FUEL AND OIL COSTS ($/mile)

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

HULL INSURANCE COSTS ($/mile)

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

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

TOTAL FLIGHT OPERATIONS COSTS ($/mile)

CFOP(I) = CFC(I) + CFO(I) + CI(I)

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

AIRFRAME MAINTENANCE LABOR COSTS ($/mile)

CLA(I) = RL * (FHAL * FLTT(I) + FCAL)/SL(I)

where WA = WEM - WEN * NRENGN

FCAL = (WA * (5.0E - 5) + 6.0 - 630.0/(120.0 + WA * 1.0E-3))

FHAL = 0.59 * FCAL

AIRFRAME MAINTENANCE MATERIAL COSTS ($/mile)

CMA(I) = (FHAM * FLTT(I) + FCAM)/SL(I)

where FCAM = VA * 6.24E - 6 * 0.5

FHAM = VA * 3.08E - 6 * 0.5

ENGINE MAINTENANCE LABOR COSTS ($/mile)

CLE(I) = RL * (FHEL * FLTT(I) + FCEL)/SL(I)

where FCEL = (0.3 + T * 3.0E-5) * NRENGN * 0.5

FHEL = (0.6 + T * 2.7E-5) * NRENGN * 0.5

ENGINE MAINTENANCE MATERIAL COSTS ($/mile)

CME(I) = (FHEM * FLTT(I) + FCEM)/SL(I)

where FCEM = VE * NRENGN * 2.0E-5

CHEM = VE * NRENGN * 2.5E-5

MAINTENANCE BURDEN ($/mile)

CMB(I) = 1.8 * (CLA(I) + CLE(I))

TOTAL DIRECT MAINTENANCE COSTS ($/mile)

CM(I) = CLA(I) + CMA(I) + CLE(I) + CME(I) + 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 = SCTO + 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.

AI21 = General and administrative expense factor.

AMT = Air maneuver time, hours.

BAG = Baggage per passenger in pounds.

CF(I) = Passenger trip circuitry factor for stage length I, I = 1 to NSL.

CLF(I) = Coach load factor (decimal) for stage length I, I = 1 to NSL.

CLS = Climb speed, mph.

CRS = Cruise speed, mph.

CS = Number of coach seats.

CSTEW = Average number of stewardessess in coach.

DESS = Descent speed, mph.

DIS(I) = Passenger trip length in miles for stage length I, I = 1 to NSL.

DPT(I) = Departures per passenger-trip (flight basis) for stage length I, I = 1 to NSL.

FLF(I) = First class load factor (decimal) for stage length I, I = 1 to NSL.

FOODR = First class food expense factor.

FS = Number of first class seats.

FSTEW = Average number of stewardesses in first class.

GMT = Ground maneuver time, hours.

H = Cruise altitude, feet.

NRSEAT = Total number of seats in the aircraft.

NSL = Number of state lengths (up to 17).

RCH = Rate of climb at cruise altitude, feet per minute.

RCSL = Rate of climb at sea level, feet per minute.

RTM = Tons of mail per flight.

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, if SL(I) $\leq$ 1400

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

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) = AI1 * 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 * LAC/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 * DIS(I) * CF(I)) * (FS * FLF(I) + CS * CLF(I))

RESERVATION AND SALES EXPENSE FOR PROPERTY

C27(I) = RTP * AI15 * DIS(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)

ADVERTISITNG AND PUBLICITY EXPENSE FOR PROPERTY

C31(I) = RTP * 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

CAM(I) = C36(I)/SL(I)

INDIRECT COST PER FLIGHT HOUR

CFH(I) = C36(I)/FLTT(I)

INDIRECT COST PER BLOCK HOUR

CBH(I) = C36(I)/TB(I)

INDIRECT COST PER AVAILABLE SEAT MILE

CASM(I) = CAM(I)/NRSEAT

INDIRECT COST PER CRUISE MILE

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

INDIRECT COST PER TAKEOFF

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

INDIRECT COST PER AIRCRAFT TRIP = CTO plus CACM per mile

INDIRECT COST PER CRUISE MILE PER SEAT

CSCM = CACM/NRSEAT

INDIRECT COST PER TAKEOFF PER SEAT

CSTO = CTO/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., 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:

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

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 if $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:

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

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.

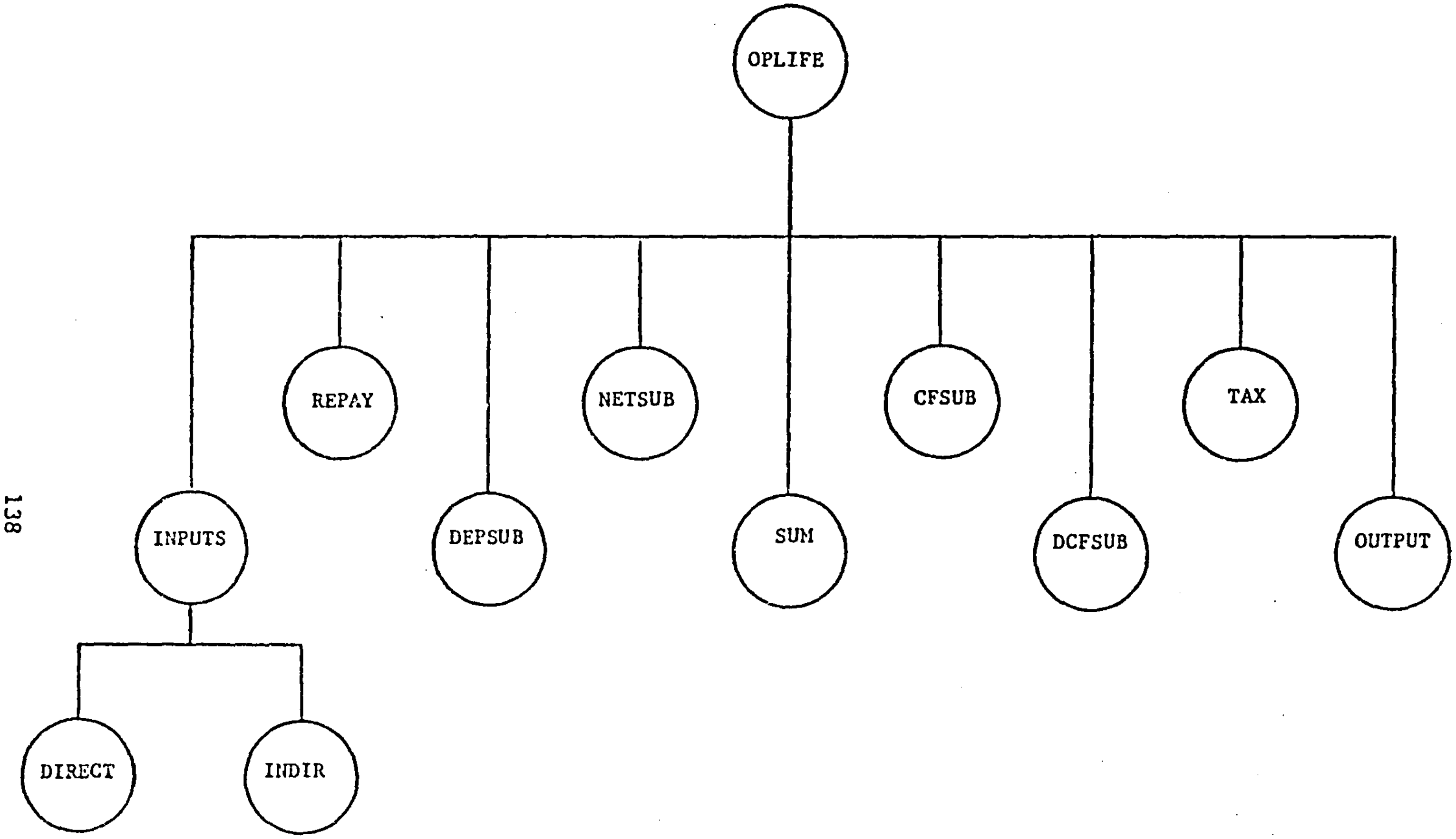

Figure 28   Program Structure of the Air Carrier Module

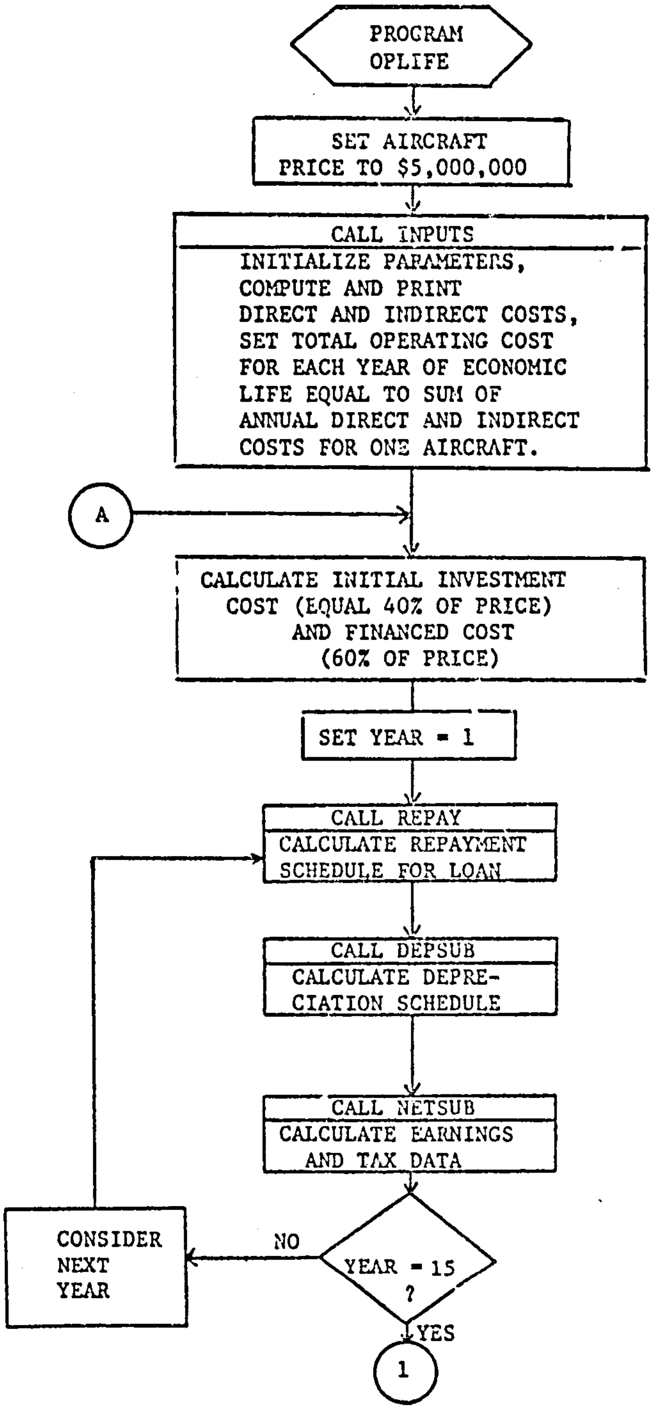

Figure 29 Flowchart of Program OPLIFE Logic

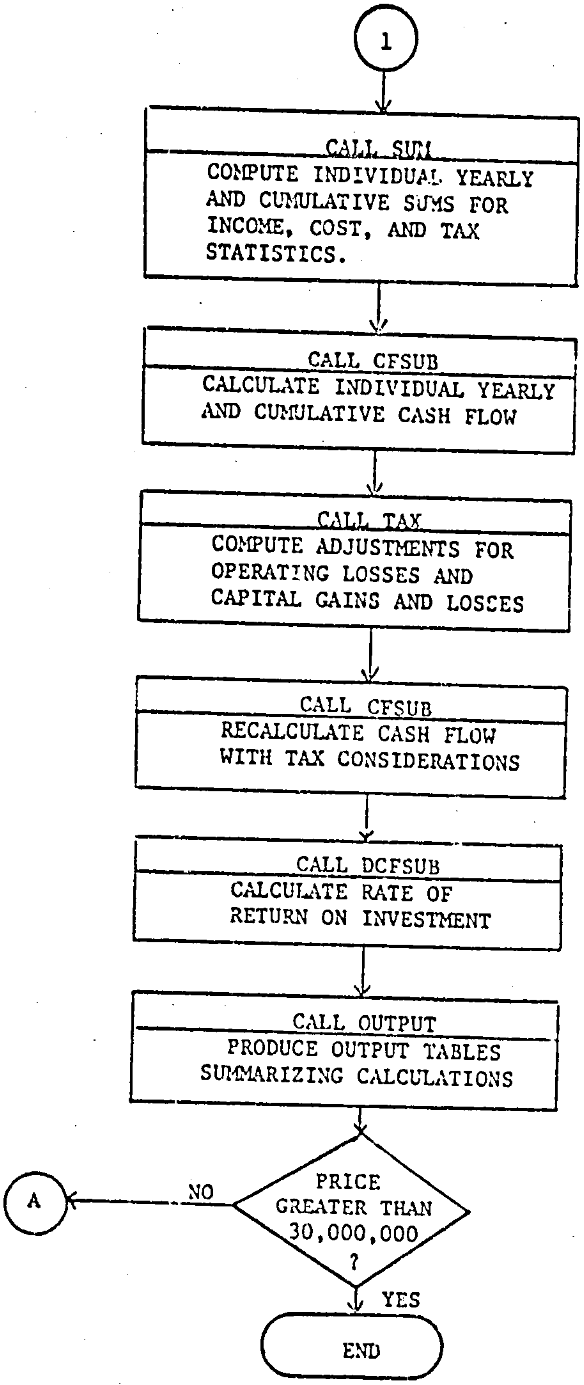

Figure 29 (Concluded)

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

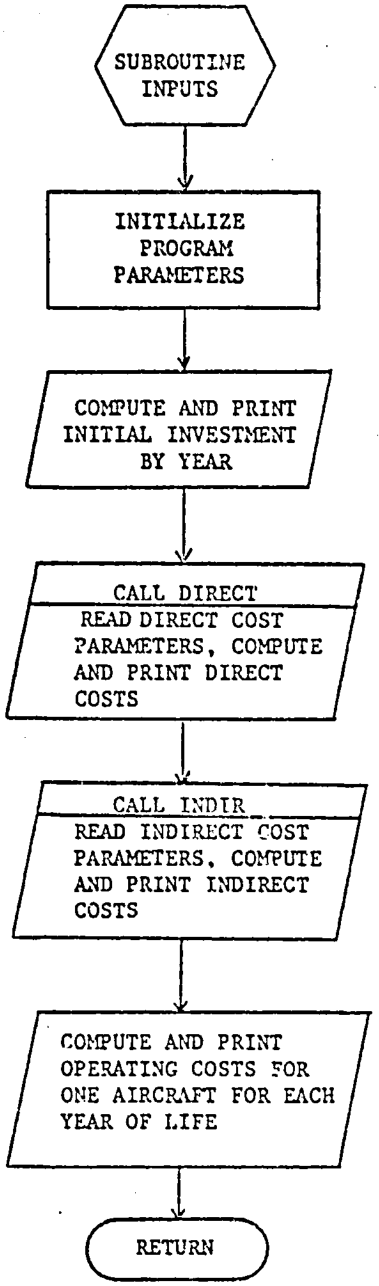

Figure 30 Flowchart of Subroutine INPUTS Logic

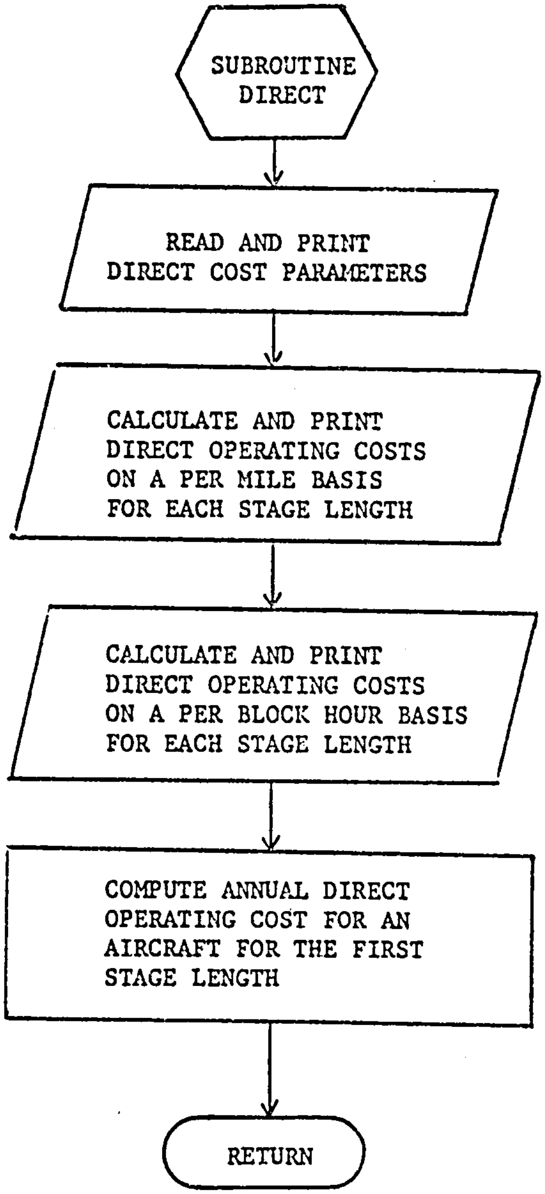

Figure 31 Flowchart of Subroutine DIRECT Logic

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 Calculations). 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 on 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

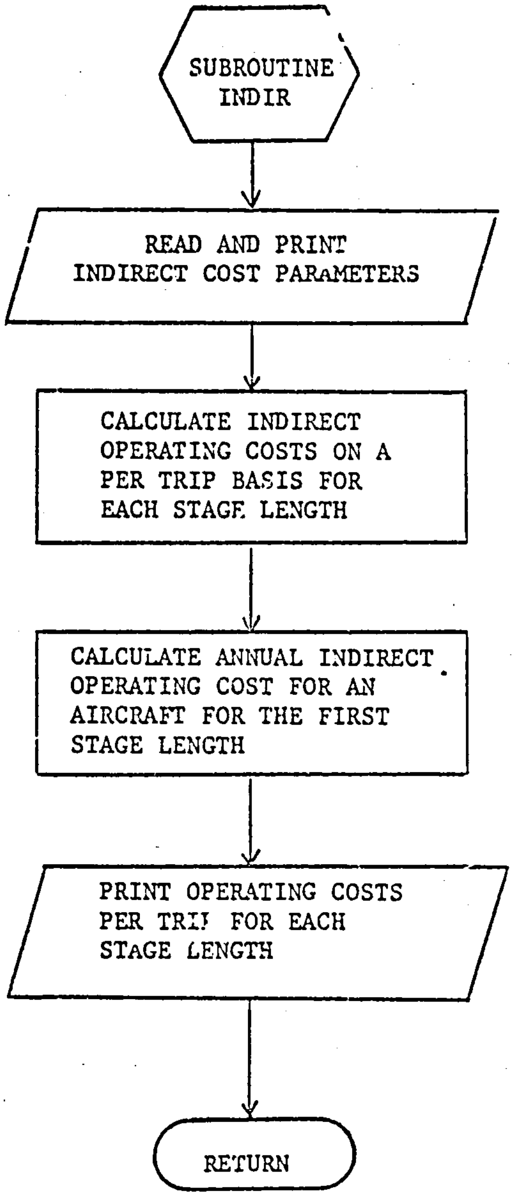

Figure 32 Flowchart of Subroutine INDIR Logic

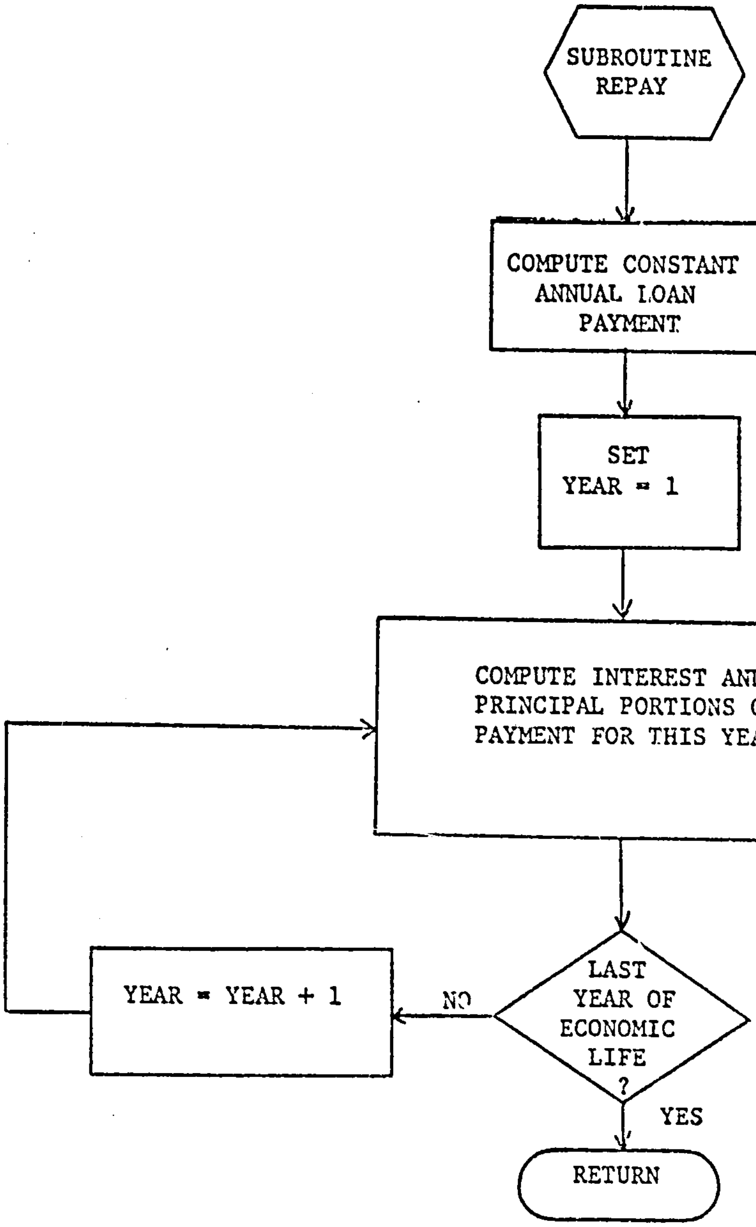

Figure 33 Flowchart of Subroutine REPAY Logic

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.

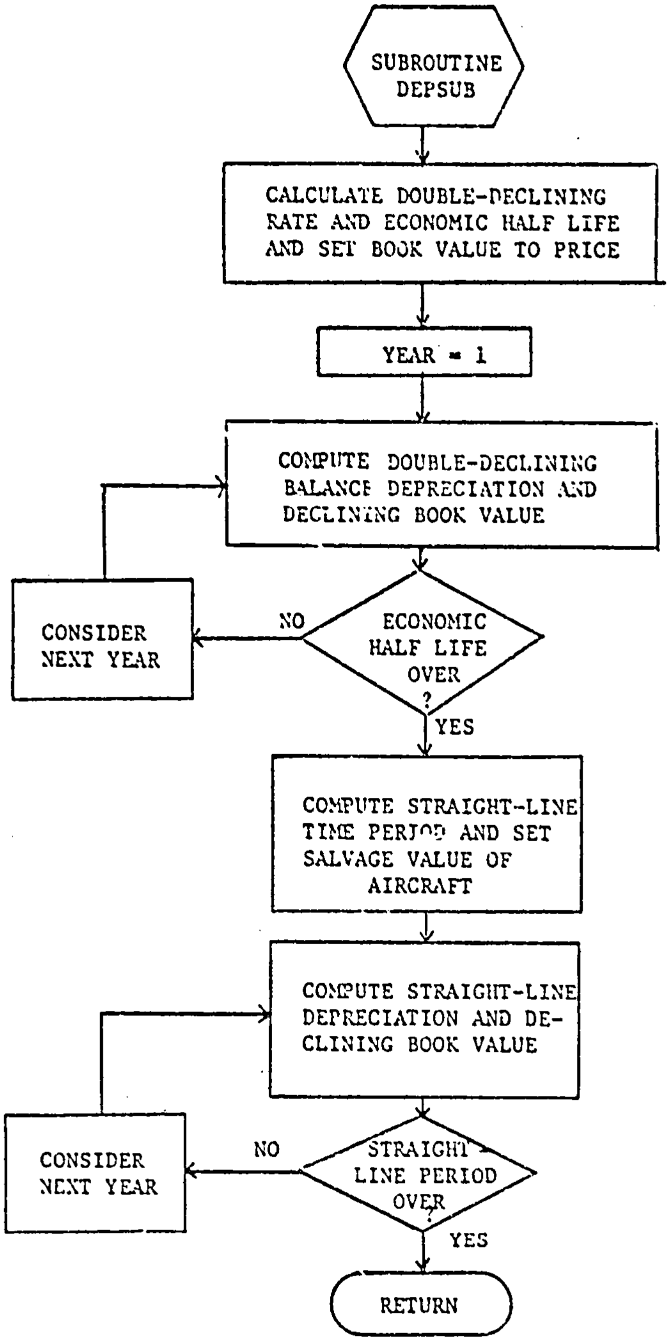

Figure 34 Flowchart of Subroutine DEPSUB Logic

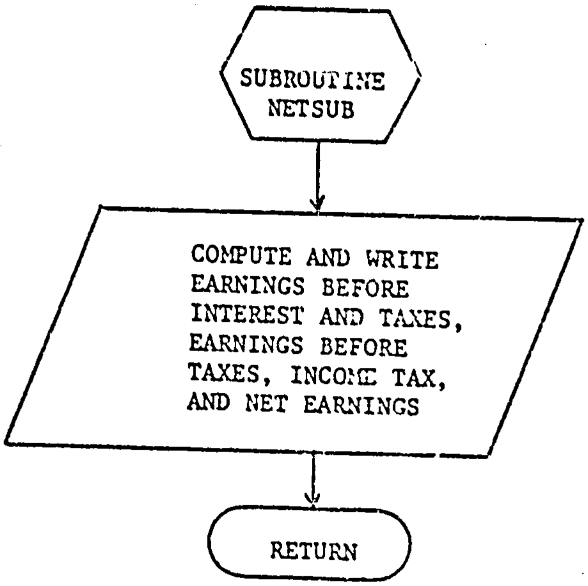

Figure 35 Flowchart of Subroutine NETSUB Logic

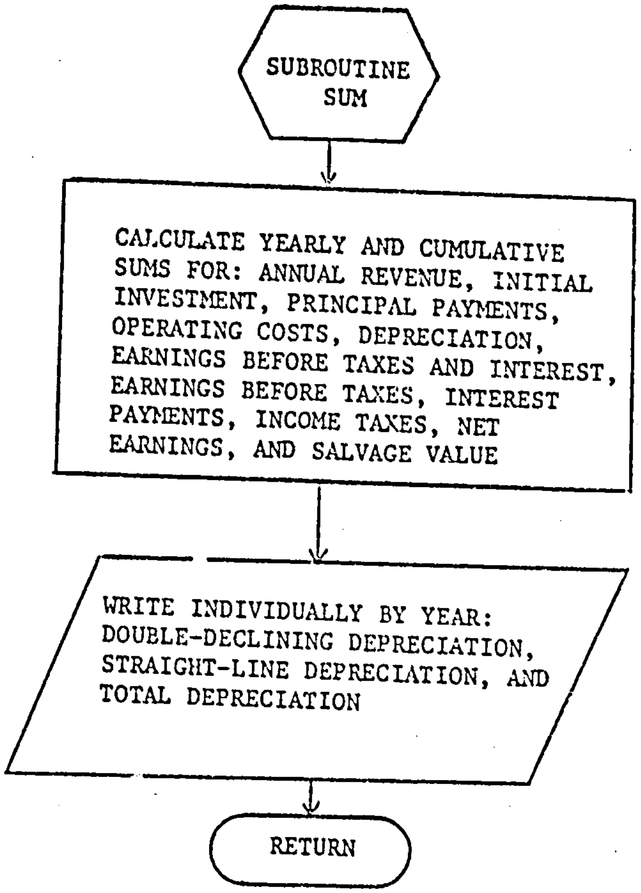

Figure 36 Flowchart of Subroutine SUM Logic

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.

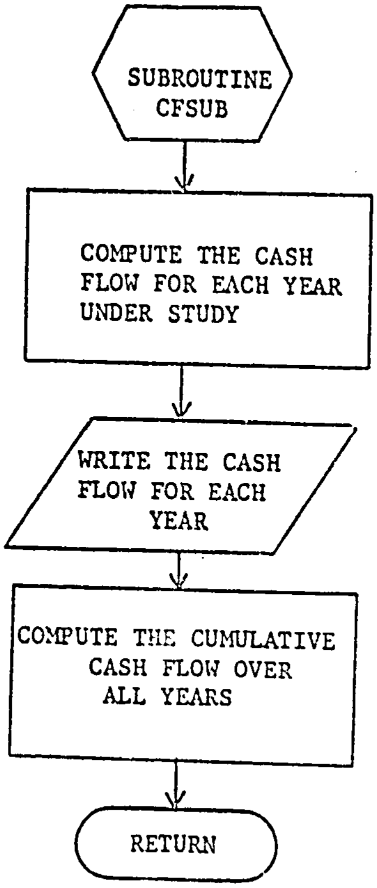

Figure 37 Flowchart of Subroutine CFSUB Logic

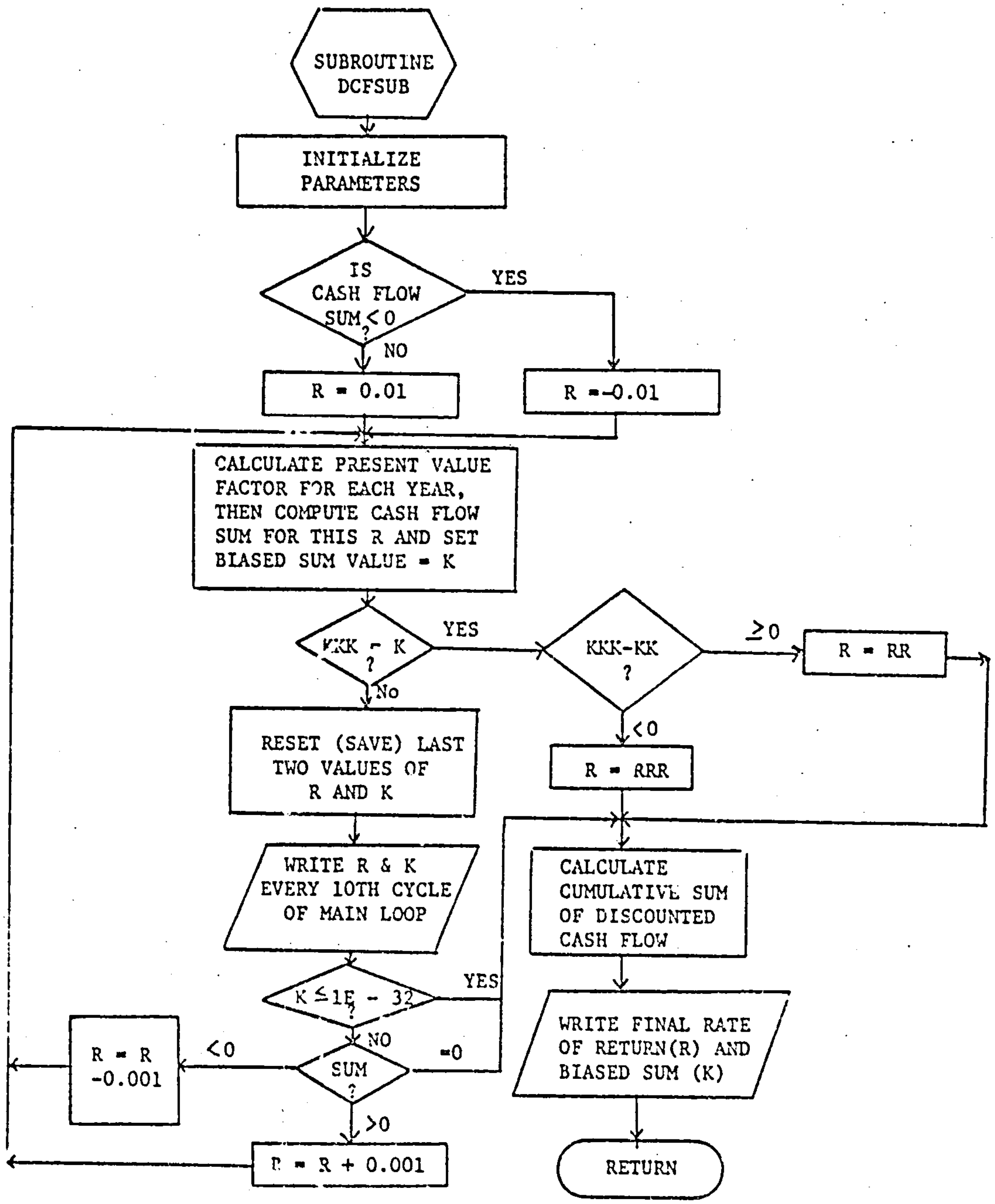

Figure 38 Flowchart of Subroutine DCFSUB Logic

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 subprogram; 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.

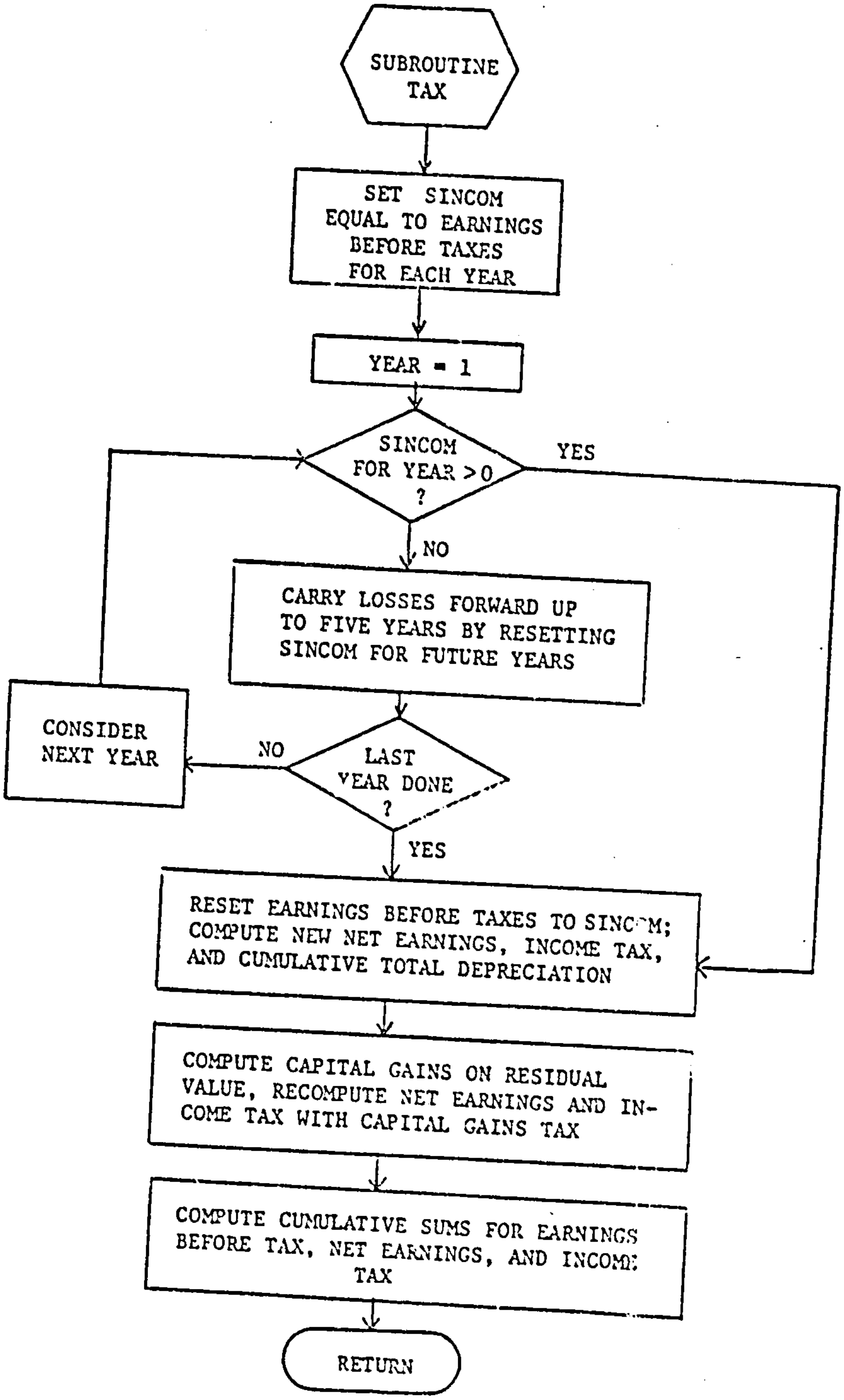

Figure 39 Flowchart of Subroutine TAX Logic

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.

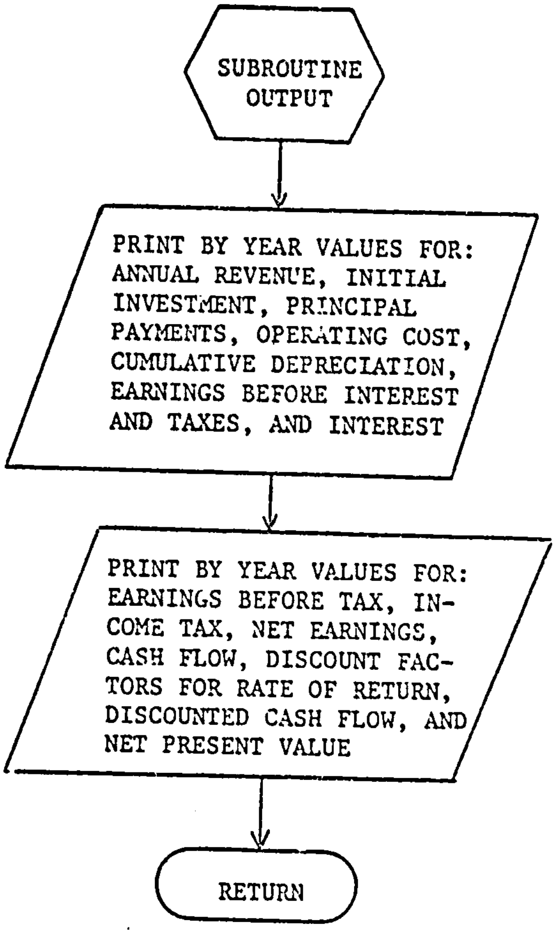

Figure 40 Flowchart of Subroutine OUTPUT Logic

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 mod[illegible]s the input of constant values for all or only some of the varia[illegible]ging to the named list. The associated namelist is shown for each of these ca[illegible] 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

Card*	Parameter	Format	Description
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.
	RCSL	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)

Card	Parameter	Format	Description
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.
	WEM	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.)
	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.
4 (Namelist NSTAGE)	--	--	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)

Card	Parameter	Format	Description
6 (Namelist NPLANE)			Same as for card 3, except only variables H, RCSL, RCH, CLS, CRS, DESS, CMT, AMT, and NRSEAT may be entered. CMT and AMT are set to 0.16 regardless of input values.
7 (Namelist PSTAGE)	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 STEWS	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)

Card	Parameter	Format	Description
11 (Namelist ACSERV)	AI8	Real	Aircraft line servicing expense in dollars per departure.
	AI9	Real	Aircraft control servicing expense in dollars per block hour.
	AI10	Real	Landing fee per departure in dollars.
12 (Namelist TRAFF)	AI11	Real	Passenger traffic servicing expense in dollars per passenger.
	AI12	Real	Baggage traffic servicing expense in dollars per ton.
	AI12A	Real	Cargo traffic servicing expense in dollars per ton.
	BAG	Real	Baggage per passenger in pounds.
	RTM	Real	Tons of mail carried per flight.
	RTP	Real	Tons of property (cargo) carried per flight.
13 (Namelist RES)	AI13	Real	Reservation and sales expense per passenger in dollars.
	AI14	Real	Reservation and sales expense per passenger-mile in dollars.
	AI15	Real	Reservation and sales expense for property in dollars per ton-mile.
	EXP	Real	Fraction of RTP that is express cargo. (The value input does not affect costs.)
14 (Namelist ADV)	AI16	Real	Advertising and publicity expense per passenger-mile in dollars.
	AI17	Real	Advertising and publicity expense for property in dollars per ton-mile.
15 (Namelist MAINT)	AI18	Real	Maintenance expense for ground property and equipment per departure in dollars.
	AI19	Real	Expense for depreciation of general ground property and equipment and amortization in dollars per departure.

Table 22 (Concluded)

Card	Parameter	Format	Description
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+07  0.          0.          0.          0.          0.          0.          0.          0.          0.
INTINV=   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, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,

FCK      = .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
          H        = .3E+05,
          RCSL     = .376E+04,
          RCH      = .175E+04,
          CLS      = .4E+03,
          CRS      = .542E+03,
          DESS     = .3E+03,
          GMT      = .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,
          NRCREW   = 2,
          NRENGN   = 2,
          NRSEAT   = 171,
          NPLANE   = 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.     462.     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)= 3079.  LABOR RATE($/HR)= 8.00

 DIRECT OPERATING COSTS

 FLYING OPERATIONS COSTS
FLIGHT CREW                    .566     .483     .462     .440
FUEL AND OIL                   .952     .841     .815     .621
HULL INSURANCE                 .020     .017     .016     .016
TOTAL FLIGHT OPS              1.538    1.341    1.293    1.076

 DIRECT MAINTENANCE COSTS
LABOR AIRFRAME                 .288     .194     .165     .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   1048.1    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.   28300.   34300.

D.O.C. FACTORS (INPUT) - ANN UTILIZATION(HR)= 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 AIFFRAME              108.424  85.920  76.260  68.944
MATERIAL AIRFRAME            67.450  52.093  45.500  40.507
LABOR ENGINES                18.985  16.458  15.373  14.552
MATERIAL ENGINES            125.277 109.955 103.377  98.395
MAINT. BURDEN               229.336 184.282 164.940 150.293
TOTAL MAINTENANCE           549.472 448.708 405.450 372.693
```

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,
$END

$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,
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,
$END
```

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,
$END
```

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)
BLOCK TIME (HOURS)                                       377.    442.    462.
FLIGHT TIME (HOURS)                                     1.525   2.602   3.734
DEP/PAX TRIP (FLIGHT BASIS)                             1.355   2.442   3.574
PASSENGER TRIP CIRCUITRY FACTOR                         1.100   1.000   1.200
COACH LOAD FACTOR                                       1.010   1.010   1.010
FIRST CLASS LOAD FACTOR                                  .640    .600    .670
FLYING OPERATIONS(LESS RENTALS) EXP                      .370    .350    .400
MAINTENANCE EXPENSE FLY EQUIPMENT             C1      583.901 995.0881429.213
RENTALS FLT EQUIP                             C2      235.815 403.988 579.653
                                              C4       36.884  52.921  90.280
PASSENGER IN FLY EXPENSE
STEWS
FOOD                                          C8      101.545 173.227 248.551
OTHER                                         C11     152.537 250.325 418.019
                                              C14      55.993 123.733 207.653
AIRCRAFT SERVICING EXP
LINE SERVICE
CONTROL                                       C15      75.580  53.800  82.560
LANDING FEES                                  C16      30.172  51.471  73.852
TOTAL AIRCRAFT SERVICING                      C17      37.796  34.360  41.232
                                              TAS     143.548 154.531 197.644
TRAFFIC SERVICING EXP
PAX - BAGGAGE
CARGO                                         C22     371.265 343.192 389.199
TOTAL TRAFFIC SERVICING                       C23      59.435  59.436  59.435
                                              TTS     430.701 407.628 448.635
RESERVATION - SALES
PAX
PROPERTY                                      C25     420.845 553.8651054.635
TOTAL RESERVATION - SALES                     C27       1.452   2.904   4.358
                                              TRS     422.295 571.7691058.993
ADVERTISING - PUBLICITY
PAX
PROPERTY                                      C30      87.579 154.273 275.590
TOTAL ADVERTISING - PUBLICITY                 C31       1.220   2.439   3.661
MAINTENANCE EXP- GRD PROP - EQUIP             TAP      93.799 165.712 279.250
DEPR-GENERAL GRD PROP - EQUIP - AMORT         C32      25.752  24.320  29.134
DEPR-MAINTENANCE EQUIP                        C33      23.057  20.970  25.154
GENERAL - ADM EXPENSE                         C34       4.557   7.405  10.527
TOTAL INDIRECT OPERATING EXPENSE              C35     124.359 135.292 259.652
INDIRECT COST PER AIRCRAFT MILE               C36    1594.3552197.0533193.281
INDIRECT COST PER FLIGHT HOUR                           2.773   1.910   1.850
INDIRECT COST PER BLOCK HOUR                            1158.    900.    894.
INDIRECT COST PER AV. SEAT MILES                     1045.217 814.316 855.255
                                                         .016    .011    .011
 COST PER AIRCRAFT TRIP = $ 991.65 PLUS $  1.05/MILE

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

Table 30

SAMPLE PRINTOUT OF TOTAL OPERATING COSTS BY YEAR

```
OPCOST($)
   6694873.    6694873.    6694873.    6694873.    6694873.    6694873.    6694873.    6694873.    6694873.    6694873.
   6694873.    6694873.    6694873.    6694873.    6694873.
```

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=   0.
STDEP=     .1755E+06
EBIAT=     .6296E+06
EBT =     .4192E+06
DEPR=   0.
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=   0.
STDEP=     .1755E+06
EBIAT=     .6296E+06
EBT =     .5046E+06
DEPR=   0.
STDEP=     .1755E+06
EBIAT=     .6296E+06
EBT =     .5315E+06
DEPR=   0.
STDEP=     .1755E+06
EBIAT=     .6296E+06
EBT =     .5611E+06
DEPR=   0.
STDEP=     .1755E+06
EBIAT=     .6296E+06
EBT =     .5937E+06
```

Table 32

SAMPLE PRINTOUT OF TOTAL INITIAL INVESTMENT COSTS BY YEAR

```
SINTIN=    .2000E+07  0.          0.          0.          0.          0.          0.          0.          0.          0.
SINTIN=   0.          0.          0.          0.          0.
```

Table 33

SAMPLE PRINTOUT OF DOUBLE-DECLINING, STRAIGHT-LINE AND TOTAL AIRCRAFT DEPRECIATION BY YEAR

```
DEPR=      .5667E+06
DEPR=      .5024E+06
DEPR=      .4455E+06
DEPR=      .3950E+06
DEPR=      .3502E+06
DEPR=      .3105E+06
DEPR=      .2754E+06
DEPR=     0.
DEPR=     0.
DEPR=     0.
DEPR=     0.
DEPR=     0.
DEPR=     0.
DEPR=     0.
DEPR=     0.
STDEP=    0.
STDEP=    0.
STDEP=    0.
STDEP=    0.
STDEP=    0.
STDEP=    0.
STDEP=    0.
STDEP=     .1755E+06
STDEP=     .1755E+06
STDEP=     .1755E+06
STDEP=     .1755E+06
STDEP=     .1755E+06
STDEP=     .1755E+06
STDEP=     .1755E+06
STDEP=     .1755E+06
DEPREC=     .5667E+06
DEPREC=     .5024E+06
DEPREC=     .4455E+06
DEPREC=     .3950E+06
DEPREC=     .3502E+06
DEPREC=     .3105E+06
DEPREC=     .2754E+06
DEPREC=     .1755E+06
DEPREC=     .1755E+06
DEPREC=     .1755E+06
DEPREC=     .1755E+06
DEPREC=     .1755E+06
DEPREC=     .1755E+06
DEPREC=     .1755E+06
DEPREC=     .1755E+06
```

Table 34

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

```
CASH FLOW=   -.1560E+07   .4049E+06   .3726E+06   .3428E+06   .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 in 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 35

SAMPLE PRINTOUT OF CAPITAL GAINS BY YEAR

```
CG =    0.
CG =    0.
CG =    0.
CG =    0.
CG =    0.
CG =    0.
CG =    0.
CG =    0.
CG =    0.
CG =    0.
CG =    0.
CG =    0.
CG =    0.
CG =    0.
CG =     .5250E+06
```

Table 36

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

```
CASH FLOW=   -.1589E+07   .4107E+06   .3963E+06   .3284E+06   .2331E+05   .1120E+06   .2654E+06   .2095E+06   .2007E+06   .1910E+05
CASH FLOW=    .1803E+06   .1685E+06   .1556E+06   .1414E+06   .6507E+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        886328.6796901
.0690000        750115.1137735
.0790000        626259.3143743
.0890000        513371.5913789
.0990000        410239.4516678
.1090000        315802.9055015
.1190000        229133.4634741
.1290000        149416.2423242
.1390000         75934.6815863
.1490000          8057.4816714
.1510000         -4895.6622882
```

Table 38

SAMPLE PRINTOUT OF SUMMARY FINANCIAL ANALYSIS STATISTICS (PART 1)

YEAR	ANNUAL REVENUE ($)	INVESTMENT INITIAL ($)	INVESTMENT PRINCIPAL PAY ($)	OPERATING COST ($)	DEPRECIATION ($)	EARNING BEFORE INTEREST AND TAX ($)	INTEREST ($)
1	7500000.00	2000000.00	94421.33	6694873.45	566656.67	238459.88	300000.00
2	7500000.00	0.00	103353.45	6694873.45	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	6694873.45	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	244904.51	6694873.45	3547883.49	629597.42	149516.72
12	7500000.00	0.00	269395.08	6694873.45	3723412.62	629597.42	125025.25
13	7500000.00	0.00	296334.58	6694873.45	3898941.75	629597.42	98086.75
14	7500000.00	0.00	325969.04	6694873.45	4074470.87	629597.42	68453.29
15	7500000.00	0.00	358564.85	6694873.45	4250000.00	629597.42	35856.48
TOTALS	112500000.00	2000000.00	3000000.00	100423101.78	4250000.00	7826835.22	2916319.96

Table 39

SAMPLE PRINTOUT OF SUMMARY FINANCIAL ANALYSIS STATISTICS (PART 2)

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	410705.22	.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	-717955.44
5	.37E+06	177653.98	192458.48	233051.24	.5698	132785.34	-585170.11
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	210636.77	227539.93	200668.45	.3246	65144.31	-272147.77
10	.46E+06	219751.99	238064.65	190953.23	.2820	53857.85	-218289.91
11	.48E+06	230438.74	249641.97	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	155580.39	.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	2056425.70	.33E+07	2054152.56		4104.34	

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

The remainder of printed output of the Air Carrier Modules cons of a repeat of Tables 31 through 39 for each of the other 10 aircra 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=I, 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,  MACH=0.8,
   T=45000.,
    WACS=2950.,  WAERO=3890.,  WBODY=36320.,
   WELCAN=2520., WEMP=8140., WENACC=1280., WENGS=20110.,
   WFUSYS=640.,  WFUTOT=4863..                           WGROSS=269100.,  WHYCAD=3770.,
  WINST=47 ..  WLG=15570.,  WNACEL=11290.,  WPACCU=19370.,  WPOWER=2060.,
                   WWING=40730.,  WPAYL=45730.,
   WHANDL=110.0,  WANTIC=500.0,  WAVION=2120.0,  WTREVS=6990.0,
 $END
 $INPUT2
  ADI=0.1, AGEOT=0.1,  AGEPI=0.1,  CFACS=2.7,  CFAERO=0.65,  CFBODY=0.70,
                              CFFLCD=0.80, CFEMP=1.9,  CFENAC=0.40,
                 CFHYCD=0.55,  CFINST=0.70,  CFLG=0.70,  CFPACC=3.10,  CFPOW=3.2,
                CFWING=2.9,  CONFIG=1.0,  CTJI=1.0,  ENSPAO=0.4,  ENSPAR=.40,
  FACI=0.0,  FEE=0.00,  FTOI=0.10,  FVSPAR=0.2,  GTSPAR=0.10,  ICONFG=6,
  IDATA=1,  IPOWER=2,  IPROD=1,
  IOPS=0, NCREW=3, NDATA=5, NFV=5.0, NG=1,
  NOENG1=500.0,  NOYRS=0.75,  NOYRS1=1.0,
  NV=867.0,  NVFM=1.0,5.0,100.0,300.0,600.0,
  PUTJI=0.10,  RATE=11.,  RE=17.0,  RT=15.0,  TOOLC=1.0,
  XFASSY =0.05,  XNF=0.20,
   LEARNP=80.10,  LEARN=81.85,  LEARNA=81.85,
   CFFUSY=0.10,
 $END
   REDUCED ENERGY PROP-FAN (767-762)

 $IN
        YEAR = 1985.,  VE = 165570.,  FEE = 0.00,  NVMF =872. ,  IAIRPL=3,
     APT = 0.06,  IENGS = 2,  PM = 171.,  EN = 2.,  T = 42420.,
    WENGS = 20000.,
 $END
ZZZZZZZZZZ
 $INPUT1
  EN=2.0,  MACH=0.8,
   T=45000.,
    WACS=2950.,  WAERO=3890.,  WBODY=36320.,
   WELCAN=2520., WEMP=8150., WENACC=1280., WENGS=20110.,
   WFUSYS=640.,  WFUTOT=48630.,                         WGROSS=269100.,  WHYCAD=3770.,
  WINST=470.,  WLG=15570.,  WNACEL=11290.,  WPACCU=19370.,  WPOWER=2060.,
                   WWING=40730.,  WPAYL=45730.,
   WHANDL=1200..,  WANTIC=500.0,  WAVION=2120.0,  WTREVS=6990.0,
 $END
```

Table 40 (Continued)

```
$INPUT2
 AUI=0.1, AGCOI=0.1,  AGEPI=0.1,  CFACS=2.7,  CFAERO=0.65,  CFBODY=0.70,
                          CFELCO=0.80, CFEMP=1.9,  CFEMAC=0.40,
                CFHYCD=0.55,  CFINST=0.70,  CFLG=0.70,  CFPACC=3.10,  CFPOW=3.2,
               CFWING=0.9,  CONFIG=1.0,  CTJI=1.0,  ENSPAC=0.4,  ENSPAR=.40,
 FACI=0.0,  FEE=0.05,  FTOI=0.10,  FVSPAR=0.2,  GTSPAR=0.10,  ICONFG=6,
 IDATA=1,  IFUNFR=2,  IPROD=1,
 IOPS=0, NCREW=3, NDATA=5, NFV=5.0, NG=1,
 NUENGI=530.0,  NOYRS=0.75,  NOYRSI=1.0,
 NV=867.0,  NVFR=1.0,5.0,100.0,300.0,600.0,
 PUTJI=0.1,  RATE=11.,  RE=17.0,  RT=15.0,  TOOLC=1.0,
 XFASSY =4.00,  XNFR=0.20,
  LEARNO=55.10,  LEARN=81.85,  LEARNA=81.85,
  CFFUSY=0.1,
$END
  REDUCED ENERGY PROP-FAN (767-762)

$IN
        YEAR = 1985.,  WE = 165570.,  FEE = 0.00,  NVHF =872. ,  IAIRPL=3,



      AFT = 0.04,  IENGS = 2,  RN = 171.,  EN = 2.,  T = 42420.,
     WENGS = [illegible].,
 $END
ZZZZZZZZZZ
END OF FILE
7.                  1.
7.                  1.
END OF FILE
SHORT       RANGE
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         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
```

Table 40 (Concluded)

```
    1
2ENGNBTF  1964.     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       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      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
    3
4ENGNBTJ  1966.     134.0    .2523    408.     2509.0   16.
0.        6.0       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.
4ENGNBTF  1961.     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  1963.     112.2    .2140    358.     3079.    16.
0.        0.        0.       0.       50.      74.4     77.7     92.1
110.1     97.       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
    2
N2ENGWBPF 1967.     171.     .114     358.     3079.    16.      N2ENGWBPF
N1995AC   1995.     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=6., NSL=4,
 SL=575.,1150.,1726.,2700.,0.,0.,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,
 FCK=200.,ADDC=70.,COFL=.04779,COIL=2.778,
$END
   *PROD FAM *
$NPLANE
 H=30000., HCSL=376.., HCM=1750., CLS=400., CRS=542., DESS=300., GMT=.16,
 AMT=.16, WGR=269100., F1=11200., D1=575., F2=19800., D2=11150.,
 VA=1970000., VF=1765000., WEN=18500., WEN=14030., T=37400., NMCREW=2,
 NMENGN=2, NMSEAT=171, NPLANE=1, NUSTAG=0,
$END
   *PROD FAM *
$NPLANE
 H=30000., HCSL=3760., HCM=1750., CLS=600., CRS=542., DESS=300., GMT=.16,
 AMT=.16, NMSEAT=171,
$END
$NSTAGE
 NSL=3,
 FLF=.37,.55,.40,.0,.0,.0,.0,.0,.0,.0,.0,.0,.0,.0,.0,
 CLF=.64,.65,.67,.0,.0,.0,.0,.0,.0,.0,.0,.0,.0,.0,.0,
 DIS=575.,1150.,1726.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,
 CF=1.01,1.01,1.01,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,
 DPT=1.1,1.1,1.2,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,0.,
 U=3079.,
$END
$STEWS
 AI5=22.14, FSTEW=1.2, CSTEW=1.8,
$END
$FOOD
 AI6=.94995, FS=12., CS=159., FOODW=2.36,
$END
$PAXFLT
 AI7=.00167,
$END
$ACSERV
 AI8=66.8, AI9=19.78, AI10=34.36,
$END
$TRAFF
 AI11=2.51, AI12=99.76, AI12A=09.06, BAG=30., RTM=.2, RTP=.4,
$END
$RES
 AI13=1.21, AI14=.0474, AI15=.00625, EXP=.14,
$END
$ADV
 AI16=.06142, AI17=.00525,
$END
$MAINT
 AI18=24.42, AI19=2 .97, AI20=.01729, AI2=155.25,
$END
$GENADM
 AI21=.05407, AI1=362.79, AI2=155.25, AI4=24.18,
$END
END OF FILE
```