R-1854-PR
March 1976

A Computer Model for Estimating Development and Procurement Costs of Aircraft (DAPCA-III)

H. E. Boren, Jr.

A Report prepared for

UNITED STATES AIR FORCE PROJECT RAND

Rand
SANTA MONICA, CA. 90406

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PREFACE

This report describes and provides operating instructions for a substantially revised version of DAPCA-II, the Rand computer model for estimating development and procurement costs of advanced military aircraft. The revised model (DAPCA-III) incorporates the methodological results of Rand's most recent research on aircraft airframe and engine costs. Like its predecessors,* DAPCA-III is intended to facilitate the generation of parametric cost estimates and related sensitivity analyses in the context of planning studies and independent analyses. It is not generally suitable for short-run financial management or budgeting purposes.

It is intended that this report be used as a companion piece to the Rand reports from which the methodology for DAPCA-III is drawn:

- Joseph P. Large, Harry G. Campbell and David Cates, *Parametric Equations for Estimating Aircraft Airframe Costs*, The Rand Corporation, R-1693-1-PA&E, February 1976.
- J. R. Nelson and F. S. Timson, *Relating Technology to Acquisition Costs: Aircraft Turbine Engines*, The Rand Corporation, R-1288-PR, March 1974.

This study--part of the Supporting Research program effort under U.S. Air Force Project RAND--was undertaken as part of the Project RAND research task entitled "Cost Analysis Methods for Air Force Systems." It should be useful to cost analysts at Headquarters, United States Air Force and in the Aeronautical Systems Division, Air Force Systems Command, as well as to others concerned with the estimation and analysis of aircraft development and procurement costs.

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*H. E. Boren, Jr., *DAPCA: A Computer Program for Determining Aircraft Development and Production Costs*, The Rand Corporation, RM-5221-PR, February 1967 [DAPCA-I], and G. S. Levenson, H. E. Boren, Jr., D. P. Tihansky and F. Timson, *Cost-Estimating Relationships for Aircraft Airframes*, The Rand Corporation, R-761-PR (Abridged), February 1972, [DAPCA-II]. This report supersedes R-761-PR.

SUMMARY

This report describes the development of a substantially revised Rand computer model, DAPCA-III (Development and Procurement Costs of Aircraft), which supersedes the previous version reported in Rand report R-761-PR. The model applies parametric estimating relationships to calculate the development and procurement costs of two major flyaway subsystems of the aircraft: airframe and engines. Avionics costs are included in the model but are not derived parametrically. DAPCA-III is based on new airframe and engine methodologies described in Rand reports R-1693-1-PA&E and R-1288-PR, respectively.*

All airframe costs in DAPCA-III are calculated as functions of airframe unit weight and maximum speed at best altitude. The only other explanatory variables found to be significant are time of first flight for manufacturing labor and for manufacturing materials, and a dummy variable designating a cargo or noncargo aircraft for flight-test cost. Options for using these additional variables are incorporated in the program. The engine methodology is based on the predicted time of arrival (TOA) for completing the engine 150-hour Model Qualification Test (MQT); the TOA was found to be a significant function of the engine's technical characteristics. Avionics development cost is entered as a throughput, and the cost of avionics production unit number one is entered with an assumed learning-curve slope in order to obtain avionics production costs for specified aircraft quantities.

The DAPCA-III computer program calculates cumulative average, unit, and total flyaway costs for up to ten specified aircraft production quantities. Flight-test costs are also calculated. No specific relationships are included for prototype costs. The program allows prior procurements for engines and avionics. Also, procurement of spare engines is included to account for the engine buy on the learning curve. In the interest of the user, the costs of spare engines, which are not considered to be flyaway costs, are shown in the output as additional

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*See Preface for citations of these reports.

costs not included in the totals. Any of the calculations of subsystem costs (airframe, engines, or avionics) may be omitted by use of input designators.

DAPCA-III is written in FORTRAN IV and is currently in use on the Rand 370/158 computer. It requires no auxiliary programs or external devices except the standard input/output units. The program requires approximately 42,000 bytes of core and can be compiled at G or H level. The time required to execute one run averages less than one second.

A sample computer output consisting of three hypothetical runs is shown. Appendix A presents a listing of all variables used in DAPCA-III, and Appendix B a FORTRAN-IV source listing of the program.

ACKNOWLEDGMENTS

The author would like to thank the following people at Rand for their contributions and help in the development of the DAPCA-III model and in the preparation of this report. J. B. Large provided overall guidelines for the study including suggestions for some of the approaches used in the model. D. Cates supplied some of the initial programming effort required to develop the model. A. A. Barbour and J. R. Nelson, who reviewed the text, made many constructive comments and suggestions for improvement. Finally, thanks are due to D. Dreyfuss, who helped check all of the calculations in the computer program for technical accuracy.

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I. INTRODUCTION

The DAPCA-III computer program described in this report is an updated version of that reported earlier in Rand report R-761-PR.* The program treats development and procurement costs of the three major flyaway hardware systems of the aircraft, namely, airframe, engines, and avionics. These costs, however, do not constitute the total system cost of the aircraft. To obtain such a cost, one would have to consider, in addition to the DAPCA-generated costs, costs of personnel, spares, aerospace ground equipment (AGE), and any other special support equipment required for the aircraft to fly its mission successfully. Such costs are beyond the scope of the present model.

This report should be treated as a companion piece to R-1693-1-PA&E and R-1288-PR.* Major revisions include:

- o An improved airframe data base.
- o Revised regression procedures used to obtain the airframe cost-estimating relationships (CERs).
- o A new turbine engine CER methodology.

Based on the results reported in R-1693-1-PA&E, by Joseph Large, et al., the major explanatory variables for airframe cost are still AMPR weight, now called airframe unit weight,† and maximum speed in knots at best altitude. Many other variables relating to aircraft characteristics were tried and evaluated but generally were found not to be significant.

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*See citation in Preface.

†Airframe unit weight is defined in the *Aeronautical Manufacturer's Planning Report* as "the empty weight of the airplane less (1) wheels, brakes, tires and tubes, (2) engines, (3) starter, (4) cooling fluid, (5) rubber or nylon fuel cells, (6) instruments, (7) batteries and electrical power supply and conversion equipment, (8) electronic equipment, (9) turret mechanism and power operated gun mounts, (10) remote fire mechanism and sighting and scanning equipment, (11) air-conditioning units and fluid, (12) auxiliary power plant unit, and (13) trapped fuel and oil."

However, for manufacturing labor and materials, the time of first flight in calendar quarters after 1942 was found to be significant. Also, a dummy variable distinguishing between cargo and noncargo aircraft was found to be significant for flight-test cost. Options for using the time variable and for distinguishing cargo and noncargo aircraft are provided in DAPCA-III.

Often, in the airframe and engine studies reported in R-1693-1-PA&E by Large, et al., and in R-1288-PR by Nelson and Timson, several CERs, representing different samples within the same overall data base, or containing different explanatory variables, are presented for the same cost element. However, with the exception of the option of using the time variable, only one set of CERs was chosen to be programmed for DAPCA. For most of the cost elements, preferred CERs were chosen, to be incorporated in DAPCA from among several that were developed in the studies referenced above.

The airframe CERs used in DAPCA-III are based on cumulative lot quantities including prototype aircraft. Efforts to develop separate CERs for prototype aircraft were not successful. In DAPCA-III, prototype costs, estimated from the regression equations, are subtracted from the cumulative totals in order to obtain costs for flight-test and production aircraft. Even though DAPCA-III can be used to estimate costs of very small programs, such costs should be considered carefully and evaluated as "benchmark" values only. DAPCA-III is designed for use as a long-range planning tool for normal, full-scale production programs and not for short-run financial or budget operations. Any attempts to use it for purposes other than for which it is designed may lead to serious errors in the interpretation of the results.

The new engine methodology makes use of a quantitative measure of an engine's technology content, based on the time when the engine is calculated to pass its 150-hour Model Qualification Test (MQT). The CERs used to estimate engine development and production costs are based on more engine performance parameters than in the previous DAPCA model. Because of the paucity of information on turboprop engines, turboprop costs are no longer estimated in DAPCA-III. An option for entering a prior procurement of engines is incorporated in the model.

There are no CERs for avionics in DAPCA-III. Avionics development cost is entered as a throughput and added to the other development costs. For avionics production, the cost is assumed to follow a cumulative average curve for which the user is required to enter the cost of the first production unit. A slope of 95 percent is used as the default value* for the avionics learning curve. Determining a reasonable learning curve slope for avionics is troublesome because the total avionics package is usually a mix of old and new equipment. Some items will have been in production for several years, and little additional cost reduction because of quantity production can be expected. Consequently, although a slope of 90 percent is generally used for avionics equipment, a slope of 95 percent has been chosen as a default value in DAPCA-III as a way of compensating for the older equipment in the avionics package.

Engineering, tooling, and manufacturing labor for airframes are calculated in hours, and hourly dollar rates are applied to them to give costs. Airframe manufacturing materials, flight-test, and all engine costs are calculated directly in 1975 dollars.† For consistency, avionics inputs should be in 1975 dollars, that is, in the same-year dollars as calculated for the other cost elements in the model. In the DAPCA-III output, engineering, tooling, and manufacturing hours are shown in addition to their dollar costs. Quality control, in the default condition, is calculated as 8.5 percent of manufacturing labor hours for cargo aircraft and 12 percent for noncargo aircraft. A quality control dollar rate is then applied to give dollars. Airframe costs with and without fee (profit) are shown. (The default value for airframe fee is 10 percent.) It is assumed that engine and avionics costs each include a fee. All costs are printed in millions of 1975 dollars.

With the use of input designators, the user has the option of omitting the calculations (and hence inputs) relating to any subsystem

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*"Default value" refers to an initial value assigned to an input variable in the computer program. A value subsequently entered as an input for that variable overrides the default value.

†Engine costs are the actual selling price to the Government, with a fee included.

costs (airframes, engines, or avionics). This is very useful when one is interested in, for example, only airframe costs.

Most of the CERs used in DAPCA-III are based on a logarithmic linear (log-log) relationship, namely

$$\log Y = \log a_o + a_1 \log X_1 + a_2 \log X_2 + \ldots$$

The antilog of this form, called the power function, is:

$$Y = a_o \cdot X_1^{a_1} \cdot X_2^{a_2}, \ldots,$$

where Y = cumulative hours or costs (millions)

X_1, X_2, etc. = explanatory variables (weight, speed, etc.)

a_o = initial value term

a_1, a_2, etc. = exponents of explanatory variables.

The question as to whether the regressed power function or its regressed logarithmic form is more appropriate for a set of data depends on many factors, including the error term associated with the data and what criterion is used for a good fit. (Regressions of the two forms produce conceptually different estimates of the parameters a_o, a_1, a_2, etc.) One of the best tests for comparison is to examine the plot of Y-residuals versus calculated Y-values or, for the logarithmic case, the residuals of log Y versus calculated log Y values. The better model shows a more random, normal distribution of the residuals about the zero-residual line. For many of the statistics to be valid, the plot must show such a random distribution.

When both logarithmic and power regressions were made on the data, the plots generally showed a better distribution of the residuals for the logarithmic form. This is consistent with current belief at Rand that (1) the error distribution for cost data tends to be more constant over the range of data for the logarithmic model than for the power model, and (2) the criterion of relative error is more appropriate than one of actual error. (The logarithmic regression minimizes relative errors rather than actual errors as in the power regression.) As a result, all CERs used in DAPCA-III (except for the engine TOA equation) are based on logarithmic-linear regressions even if they are shown in the power form for simplicity and for programming purposes.

DAPCA-III is written in FORTRAN IV and is currently in use on the Rand 370/158 computer. It uses no external devices or programs except the standard input/output units. It requires approximately 42,000 bytes of core and is compiled at G or H level. The time required to execute one run varies with the amount of input data to be entered but averages less than 1.0 second per run. Appendix A is a listing of the input and output variables used in the program, and Appendix B is a FORTRAN IV (EBCDIC) listing of the program.

II. AIRFRAME COSTS

COST ELEMENTS

The revised DAPCA-III model is similar to the previous version in that it allows estimates to be made of individual airframe elements. The breakout of elements is as follows:

Development

1. Total engineering for flight-test aircraft
2. Total tooling for flight-test aircraft
3. Nonrecurring manufacturing labor
4. Recurring manufacturing labor for flight-test aircraft
5. Quality control
6. Nonrecurring manufacturing materials
7. Recurring manufacturing materials for flight-test aircraft
8. Flight test.

Production

1. Total engineering for production aircraft
2. Total tooling for production aircraft
3. Recurring manufacturing labor for production aircraft
4. Recurring manufacturing materials for production aircraft
5. Quality control for production aircraft.

The previously used category of development support has been discontinued because it is not generally used in the airframe industry. In addition, nonrecurring engineering and tooling are not shown because of the difficulty in many cases of separating out such costs from the manufacturer's data. Often, nonrecurring engineering and particularly tooling are included throughout a production program. Therefore, costs for these elements are shown as totals. For manufacturing labor and materials, it was possible to obtain separate regressions for the nonrecurring categories; hence, they are shown as such.

DATA BASE

All data used to derive the CERs for DAPCA-III were taken from both Government and industry sources and verified as much as possible by the industry concerned. The sample consisted of the following 25 aircraft:

A-3	C-5	F-14
A-4	C-130	F-100
A-5	C-133	F-102
A-6	KC-135	F-104
A-7	C-141	F-105
B-52	F-3	F-106
B-58	F-4	F-111
RB-66	F-6	T-38
		T-39

Airframe data used in the study were adjusted to eliminate major model changes. The data, therefore, represent average production programs with the normal small model changes that accompany such programs but not with any major design changes included. Also, wherever possible, all data used were in man-hours rather than costs. This eliminates the problem of attempting to achieve constant dollars over a long time span. The expenditure of labor is probably a better measure of the effort required to develop and produce an aircraft than is the dollar cost of the labor. Dollar costs may vary significantly among contractors and even for one contractor over time.

DERIVATION OF THE ESTIMATING RELATIONSHIPS

In the previous version of DAPCA, airframe quantity was included as one of the independent variables in the regression analyses used to derive airframe estimating relationships. However, data were available for more lot quantities for some aircraft than for others, and this created a major disadvantage from a statistical standpoint. The model was biased toward those aircraft with more lot quantities--often the earlier aircraft. Consequently, this method of regression was discarded for the present model. Instead, logarithmic-linear curves of total hours (or total costs in the case of manufacturing materials), adjusted for major model changes, were plotted against cumulative aircraft quantity for each aircraft used in the sample. Hours or costs were then picked off the curves at quantities 25, 50, 100, and 200 and regressed against various explanatory variables and for various stratifications of weight and speed. As was mentioned before, the only explanatory variables found to be significant were unit weight, maximum speed at best altitude, time of first flight in calendar quarters after 1942 (for manufacturing labor and materials),* and a dummy variable distinguishing between cargo and noncargo aircraft for flight-test cost.

An examination of the cumulative curves for each aircraft showed that the curves were sufficiently linear past quantity 20 so that only one point needed to be used for programming purposes. Quantity 200 was selected as the point to obtain the hours or costs for the regressions that were to be used in DAPCA-III. It was felt that a normal production program should be in a steady-state condition at quantity 200 with all major changes and aberrations having occurred prior to that quantity. For those aircraft whose total production was less than 200, the cumulative line was extended to quantity 200 in order to obtain a value at that quantity.

For DAPCA-III the regressed equation at quantity 200 was adjusted with the use of an average slope so that a value could be obtained at any quantity for an aircraft with the specified explanatory variables (usually weight and speed). This adjustment was made as follows. Assume that the regressed logarithmic-linear (log-log) relationship at quantity 200 is a function of weight and speed. That is,

$$\log Y_{200} = \log a_o + a_1 \log W + a_2 \log S, \qquad (1)$$

or, in the power form,

---

*The base year of 1942 is used because development of the first U.S. jet engines began in that year.

$$Y_{200} = a_o \cdot W^{a_1} \cdot S^{a_2}, \qquad (2)$$

where Y_{200} = total hours or cost for quantity 200

W = airframe unit weight (lb)

S = maximum speed at best altitude (kn)

a_o = constant

a_1 = exponent of W

a_2 = exponent of S.

In order to make use of the learning curve effect, it is assumed that Y_{200} is also a logarithmic-linear function of quantity of the form

$$\log Y = \log Y_1 + (b + 1) \cdot \log Q,$$

or, in the power form,

$$Y = Y_1 \cdot Q^{b+1}, \qquad (3)$$

where Y = total hours or costs

Y_1 = initial hours or cost at quantity 1

Q = cumulative quantity

b = exponent corresponding to cumulative average learning curve slope, s ($s = 2^b$, $b = \log s/\log 2$). Note: if cumulative average curve is log-linear with a coefficient b, then the cumulative curve is also log-linear with a coefficient b+1.

At quantity 200, Eq. (3) becomes

$$Y_{200} = Y_1 \cdot 200^{b+1}. \qquad (3')$$

The two expressions for Y_{200} (Eqs. (2) and (3')) can be set equal to each other, giving

$$Y_1 \cdot 200^{b+1} = a_o \cdot W^{a_1} \cdot S^{a_2},$$

or

$$Y_1 = a_o \cdot W^{a_1} \cdot S^{a_2} \cdot 200^{-(b+1)} \ . \qquad (4)$$

For a given aircraft with a specified unit weight, W, and a maximum speed at best altitude, S, and for a specified learning curve slope, the Y_1 term, called initial hours or initial cost, is a constant. Finally, substituting the value of Y_1 from Eq. (4) into Eq. (3) gives Y as a function of the aircraft physical parameters, the learning curve slope, and quantity. That is,

$$Y = a_o \cdot W^{a_1} \cdot S^{a_2} \cdot 200^{-(b+1)} \cdot Q^{b+1}. \qquad (5)$$

Equation (5) is the basic type of equation used in DAPCA-III for estimating the production hours or costs for the four elements of engineering, tooling, manufacturing labor, and manufacturing materials. The first three are estimated in hours, and then dollar rates are applied to them to obtain costs. Manufacturing materials cost is estimated directly in dollars. All costs are in constant 1975 dollars. As was noted previously, for the latter two elements, an optional CER may be used that includes time of first flight as an additional explanatory variable.

ENGINEERING

Engineering refers both to engineering for the basic airframe and to the system engineering performed by the prime contractor. It includes the following kinds of activities:

1. Design studies and integration
2. Engineering for wind tunnel models, mockups, and engine tests

3. Test engineering, laboratory work on subsystems and static test items, and development testing
4. Release and maintenance of drawings and specifications
5. Shop and vendor liaison
6. Analysis and incorporation of changes
7. Materials and process specifications
8. Reliability.

Engineering hours not directly attributable to design and development of the airframes--including those charged to ground handling equipment, spares, mobile training units, and publications--are excluded. Engineering hours for flight test are included in flight-test costs. Also, engineering hours expended as part of the tool and production-planning function are treated as a *tooling* element.

The equation selected for estimating cumulative engineering hours including nonrecurring and recurring engineering is:*

$$E = 20.032 \cdot W^{.6636} \cdot S^{.9871} \cdot 200^{-(b+1)} \cdot Q^{b+1} \cdot 10^{-6}, \qquad (6)$$

where E = total engineering hours (millions)

W = airframe unit weight (lb)

S = maximum speed at best altitude (kn)

Q = airframe quantity

b = -.8236 (.565 cum avg slope)--default value

b+1 = .1764--default value.

In examining the plots of total engineering hours versus cumulative quantity, it was observed that points representing a quantity of less than about 6 aircraft (usually prototype aircraft) were often significantly below the regression line extended back to quantity 1. It was also observed that this deviation from the regression line varied with quantity and that at quantity 2, the average value was about 50 percent of that on the regression line. This is depicted in

*Statistics for the CERs used in DAPCA-III are given in the airframe and engine reports, R-1693-1-PA&E and R-1288-PR, op. cit.

Fig. 1. In an attempt to account for the deviation, an adjustment is made to Eq. (6) for airframe quantities less than 6, as follows. Assume that the adjusted line still follows a power function. Then, the parameters of its equation can be found by using a value of .5 (50 percent) at quantity 2 and a value of 1.0 (100 percent) at quantity 6. That is,

$$f = a \cdot Q^b,$$

where f = fraction of value on extended regression line.

Therefore,

$$1.0 = a \cdot 6^b$$

$$.5 = a \cdot 2^b.$$

Dividing:

$$2 = 3^b$$

$$b = \frac{\log 2}{\log 3}$$

$$b = .6309$$

$$a = .3229.$$

Once E is determined from Eq. (6) for a given quantity Q, a check is made on Q to determine whether it is less than 6. If so, the following computation is made:

$$E \text{ (adjusted)} = E \text{ (Eq. (6))} \cdot .3229 \cdot Q^{.6309} . \qquad Q < 6$$

The above technique is a rough approximation, which serves to emphasize the point that DAPCA-III is not designed for very small production programs.

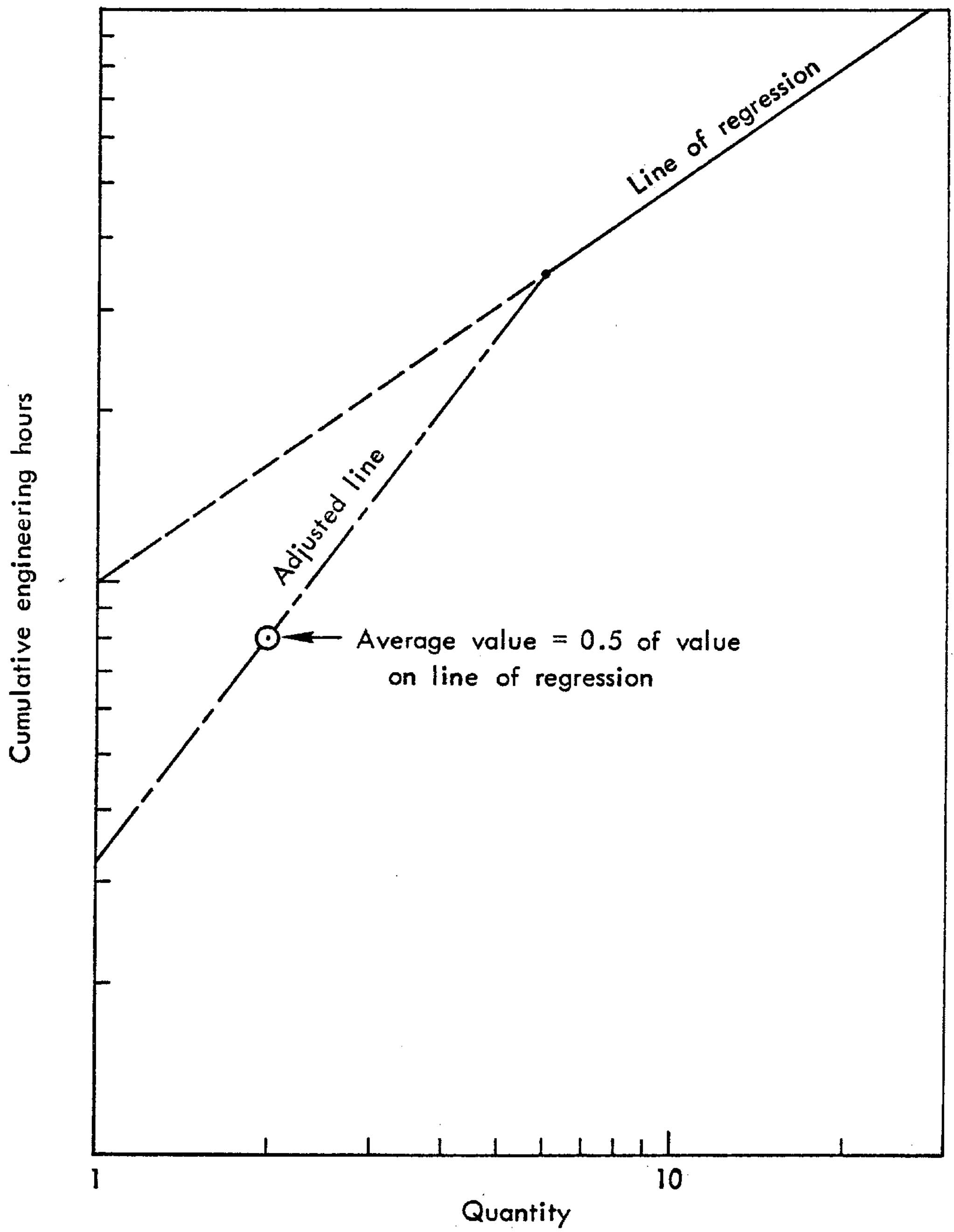

Fig. 1—Adjusted line of regression for total engineering hours

TOOLING

Tooling refers to the tools designed for a particular program. It includes the following items:

1. Assembly tools
2. Dies
3. Jigs
4. Fixtures
5. Work platforms
6. Test and checkout equipment.

General-purpose tools, such as milling machines, presses, routers, and lathes (except for the cutting instruments) are considered capital equipment, which is usually owned by the Government. However, if it is owned by the contractor, an allowance for depreciation is included in the overhead account. Tooling hours refer to all hours expended in the following activities:

1. Tool and production planning
2. Design fabrication
3. Assembly
4. Installation
5. Modification
6. Maintenance
7. Rework of tools
8. Programming and preparation of tapes for numerically controlled machines.

Nonrecurring tooling refers to the initial set of tools and all duplicate tools produced to attain a specific rate of production. One of the problems of attempting to separate out nonrecurring tooling is that duplicate tools may be procured at any point in an airframe production program and that the labor hours may not be properly categorized. As a result, nonrecurring tooling is not treated as a separate category; the CER for tooling refers to total hours, including both nonrecurring and recurring tooling hours. Therefore,

$$T = 522.39 \cdot W^{.6214} \cdot S^{.5323} \cdot 200^{-(b+1)} \cdot Q^{b+1} \cdot 10^{-6}, \qquad (7)$$

where T = total tooling hours (millions)

W = airframe unit weight (lb)

S = maximum speed at best altitude (kn)

Q = airframe quantity

b = -.8110 (.57 cum avg slope)--default value

b+1 = .1890--default value.

Again, as in engineering, plots of the data show significant average deviations from the regression line for small quantities. For tooling, the deviations begin at higher quantities, around 20, and go down to a lower percentage, about 20 percent of the extended regression line, at quantity 2. If the same technique is used for adjustment as for engineering, one has:

$$1.0 = a \cdot 20^b$$

$$.2 = a \cdot 2^b$$

$$5 = 10^b$$

Dividing:

$$b = \frac{\log 5}{\log 10}$$

$$b = .6990$$

$$a = .1232$$

Therefore, once Eq. (7) is used to calculate total tooling hours for any quantity Q, a check is made on Q. If Q is less than 20, the following adjustment is made.

$$T \text{ (adjusted)} = T \text{ (Eq. (7))} \cdot .1232 \cdot Q^{.6990}, \qquad Q < 20$$

MANUFACTURING LABOR

Nonrecurring manufacturing labor hours are treated here as those man-hours required to produce mockups, models, test parts, static test items, and other items of hardware needed for airframe development, excluding complete flight-test aircraft. Manufacturing labor hours incurred in support of the flight-test program are excluded. The CER developed for the nonrecurring hours is:

$$ML_{NR} = .62597 \cdot W^{.6883} \cdot S^{1.2109} \cdot 10^{-6}, \qquad (8)$$

where ML_{NR} = nonrecurring manufacturing labor hours (millions)
W = airframe unit weight (lb)
S = maximum speed at best altitude (kn).

Recurring manufacturing labor is all of the direct labor required to machine, process, fabricate, and assemble the major structure of an aircraft, and to install purchased parts and equipment, spares, avionics, and ordnance items, whether furnished by the contractor or by the Government. Recurring manufacturing man-hours include the labor component of off-site manufactured assemblies and effort on those parts which, because of their configuration or weight characteristics, are design-controlled for the basic aircraft. These parts usually represent significant proportions of airframe weight and of the manufacturing effort, and hence are always included. Such parts include the following:

1. Actuating hydraulic cylinders
2. Radomes
3. Canopies
4. Ducts
5. Passenger and crew seats
6. Fixed external tanks.

Man-hours required to fabricate purchased parts and materials are excluded; labor is included in the materials cost.

For recurring manufacturing labor, time of first flight in calendar quarters after 1942 (the first quarter of 1943 is quarter number 1) is a significant explanatory variable and improves the statistical properties of the equation. The time variable lends support to the belief that new manufacturing procedures are tending to reduce manufacturing man-hours. In DAPCA-III an option is provided for using the time variable (Eq. (9)). If the date of the first flight is entered as an input, then the equation with the time variable is used. Otherwise, an equation without time is used (Eq. (10)). The equations are:

$$ML_R = 1188.5 \cdot W^{.8306} \cdot S^{.5464} \cdot T^{-.4711} \cdot 200^{-(b+1)} \cdot Q^{b+1} \cdot 10^{-6}, \quad (9)$$

and

$$ML_R = 581.55 \cdot W^{.7830} \cdot S^{.4297} \cdot 200^{-(b+1)} \cdot Q^{b+1} \cdot 10^{-6}, \quad (10)$$

where ML_R = recurring manufacturing labor hours (millions)

W = airframe unit weight (lb)

S = maximum speed at best altitude (kn)

T = time of first flight (calendar quarters after 1942 = $4 \cdot$ [input date - 1942.75])

Q = airframe quantity

b = -.3771 (.77 cum avg slope)--default value

$b+1$ = .6229--default value.

Time of first flight is entered as a calendar-year date with the quarter as a decimal fraction of the year. The first quarter of 1974, for example, would be entered as 1974.00, the second quarter as 1974.25, the third quarter as 1974.50, and the fourth quarter as 1974.75. The program calculates T in quarters after 1942 as 4 times the difference between the input date and 1942.75.

For manufacturing labor, no consistent deviations are observed in the plots at small airframe quantities. Therefore, no adjustment to Eq. (9) or (10) is made for small quantities.

QUALITY CONTROL

Quality control refers to labor hours expended to ensure that established or prescribed standards are met. It includes the following kinds of activities:

1. Receiving inspection
2. In-process and final inspection of tools, parts, subassemblies, and complete assemblies
3. Reliability testing and failure-report reviewing.

The preparation of reports relating to these activities is treated as direct quality-control effort.

Quality control is closely related to direct manufacturing labor and is usually treated as a fraction of it. It was found that for the aircraft sample used to develop the CERs for DAPCA-III, the percentages averaged around 8.5 for cargo aircraft and 12 for all other types (noncargo). Therefore, in the program, one of these average percentages, unless overridden by an input value, is applied to manufacturing labor to obtain quality control hours.

MANUFACTURING MATERIALS

Manufacturing materials include raw and semifabricated materials plus purchased parts used in the manufacture of the airframe. These include standard hardware items such as electrical fittings, valves, and hydraulic fixtures. This category also includes the following types of purchased equipment, whether procured by the contractor or supplied by the Government:

1. Actuators
2. Motors
3. Generators
4. Landing gear
5. Instruments
6. Hydraulic pumps.

If such equipment is designed specifically for a particular aircraft, it is treated as being subcontracted--not as purchased equipment.

Government furnished aeronautical equipment (GFAE), such as landing gear, electrical equipment, and instruments, is not included in contractor reports and hence must be obtained from Government records concerning the particular aircraft. Based on the records of 10 aircraft with known GFAE costs, an equation was developed to estimate GFAE costs for the other aircraft in the sample for which such figures could not be obtained. Although such estimates are not actual data, it seems better to include the calculated estimates than omit them altogether.

To adjust all of the material costs to 1975 dollars, the following indices were used, based on extrapolations of Table 6 in R-1693-1-PA&E.*

Year	Index
1973	1.000
1974	1.165
1975	1.273

Nonrecurring materials are used to produce mockups, test parts, static test items, and other hardware items required for airframe development. The following CER was developed for nonrecurring manufacturing materials cost.

$$MM_{NR} = .030614 \cdot W^{.7240} \cdot S^{1.9240} \cdot 10^{-6} , \qquad (11)$$

where MM_{NR} = nonrecurring manufacturing materials cost (millions of 1975 dollars)

W = airframe weight (lb)

S = maximum speed at best altitude (kn).

As was noted for manufacturing labor, time of first flight is a significant explanatory variable for *recurring materials* cost. The

*Op. cit.

positive exponent of the time variable tends to confirm the fact that costs of airframe materials have been increasing over time. Again, an option is provided in DAPCA-III for using either the CER with the time variable included (Eq. (12)) or the one without the time variable (Eq. (13)). The CERs are:

$$MM_R = 93.409 \cdot W^{.8121} \cdot S^{.6951} \cdot T^{.4744} \cdot 200^{-(b+1)} \cdot Q^{b+1} \cdot 10^{-6} , \quad (12)$$

and

$$MM_R = 191.85 \cdot W^{.8600} \cdot S^{.8126} \cdot 200^{-(b+1)} \cdot Q^{b+1} \cdot 10^{-6} , \quad (13)$$

where MM_R = recurring manufacturing materials cost (millions of 1975 dollars)

W = airframe unit weight (lb)

S = maximum speed at best altitude (kn)

T = time of first flight (calendar quarters after 1942 = 4 • [input date - 1942.75])

Q = airframe quantity

b = -.2260 (.855 cum avg slope)--default value

$b+1$ = .7740--default value.

No significant deviations from the regression line exist for small airframe quantities. Therefore, no adjustment is necessary to Eq. (12) or (13).

FLIGHT TEST

Flight-test cost is treated as a separate element because it is usually kept as a separate account by the contractors. It includes all costs incurred by the contractor in flight-test operations except production of the test aircraft. These include the following:

1. Engineering planning
2. Data reduction
3. Manufacturing support

4. Instrumentation
5. All other materials
6. Fuel and oil
7. Pilot pay
8. Facilities
9. Rental
10. Insurance.

Flight-test costs incurred by the military services are excluded.

The CER for flight-test cost is:

$$FT = 153.25 \cdot W^{.7095} \cdot S^{.5856} \cdot Q_{FT}^{.7160} \cdot DV^{-1.5570} \cdot 10^{-6} , \quad (14)$$

where FT = flight-test cost (millions of 1975 dollars)

W = airframe unit weight (lb)

S = maximum speed at best altitude (kn)

Q_{FT} = number of flight-test aircraft

DV = dummy variable (1 for noncargo aircraft, 2 for cargo aircraft).

As Eq. (14) shows, in addition to weight and speed as explanatory variables, the distinction between cargo and noncargo aircraft is found to be significant. It is denoted by the dummy variable DV. Because the exponent of DV is negative, the equation produces a lower cost for cargo than for noncargo aircraft, which seems reasonable. A major portion of the flight-test cost is instrumenting the test aircraft, which increases as the number of test aircraft increases. Because fighters and bombers usually require more flight testing than cargo aircraft, their flight-test costs should therefore be higher than the corresponding costs for cargo aircraft.

The adjustment factors used to update flight-test costs from 1973 to 1975 dollars are as follows, based on aircraft labor rates:

Year	Index
1973	1.000
1974	1.086
1975	1.179

DAPCA-III COST ADJUSTMENTS

For engineering, tooling, and manufacturing labor, which are first calculated in hours, DAPCA-III allows two sets of hourly dollar rates to be applied to them to obtain costs. One set consists of higher rates, which are used in the development phase, and the other set consists of lower rates, which are used in the production phase. The default values for the rates are shown in Table 1 and also in Appendix A as the first eight input variables. Because the rates are not intended to represent those of any specific contractor, they should always be checked carefully before using them in the DAPCA-III model for any particular aircraft system.

Table 1

DEFAULT VALUES FOR HOURLY DOLLAR RATES
USED IN DAPCA-III

	1975 Dollar Rate	
Cost Element	Development	Production
Engineering	26.50	21.75
Tooling	24.25	22.75
Manufacturing labor	23.75	22.00
Quality control	24.50	23.00

Each CER used in DAPCA-III is multiplied by an input adjustment factor whose default value is 1.0. The curve representing a particular CER in DAPCA-III can thus be adjusted upward or downward as desired by changing its CER adjustment factor accordingly. For example, if the materials content is exceedingly high in titanium, one might want to increase the materials cost by a certain percentage. This could be done by increasing the materials cost adjustment factor from the default value of 1.0 to some appropriate value to reflect the desired increase in cost. The adjustment factors can also be used to adjust costs from the 1975 base year used in DAPCA-III to other-year dollars without having to adjust the basic CERs.

With regard to updating costs in DAPCA-III, because engineering, tooling, manufacturing labor, and quality control are estimated in hours, their costs can be updated by applying new hourly dollar rates to them. Manufacturing materials, flight test, and engines, which are all calculated in dollars, must be adjusted by either changing the adjustment factor as noted above or by applying cost indexes to the CERs, which would involve recompilation of the program.

LEARNING CURVE SLOPES

Production learning curve slopes used as default values in DAPCA-III are based on historical data and usually should not be changed unless the aircraft under consideration differs significantly in physical characteristics, or in the way in which it is produced, from those aircraft used in the DAPCA-III data base. The CERs for engineering, tooling, manufacturing labor, and manufacturing materials are based on regressions at quantity 200. Therefore, a change in slope for the CER of any of these cost elements causes the corresponding cumulative cost line to pivot about the point at quantity 200. In such a case, the change in cumulative cost from the default-slope line to the new-slope line increases as the selected quantity is further removed (in either direction) from quantity 200. If a slope is to be entered, overriding the default value, the user may also wish to adjust the entire CER line away from the value at quantity 200 by changing the adjustment factor accordingly. (Adjustment factors are discussed in the previous paragraphs under DAPCA-III COST ADJUSTMENTS.)

III. COSTS OF AIRCRAFT TURBINE ENGINES

ENGINE COST ELEMENTS

Because of the lack of data and the difficulty of verifying the previous CERs, turboprop costs are not estimated in DAPCA-III. Man-rated turbojet and turbofan engine costs are calculated for three cost elements: development through the 150-hour Model Qualification Test (MQT), recurring development past MQT, and production. The breakout of these elements between aircraft development and production is as follows:

Development

1. Development through MQT
2. Recurring development past MQT for engines on flight-test aircraft
3. Production costs (selling price to the Government) for engines on flight-test aircraft.

Production

1. Recurring development past MQT for engines on production aircraft
2. Production cost of engines on production aircraft.

Engine recurring development cost is treated as a production cost in DAPCA because it varies with quantity; hence, it is added to the calculated engine production cost.

Engine costs shown in the Nelson and Timson report are in 1973 dollars. To update the costs to 1975 dollars, the following indices were used, based on hourly labor rates.*

Year	Index
1973	1.000
1974	1.073
1975	1.146

*Extrapolated from indexes listed in a report by H. G. Campbell, *Aerospace Price Indexes*, The Rand Corporation, R-568-PR, December 1970.

ENGINE PROCUREMENT

Because spare engines are bought concurrently with the engines that go on the airframes, their procurement affects the engine buy on the learning curve. As a result, procurement of spare engines is treated in DAPCA even though the cost of spare engines is not treated as a fly-away cost.* A 50 percent spares factor is used in DAPCA-III as the default value for engines that are bought for the prototype and flight-test aircraft. For the production aircraft, a 25 percent spares factor is used for the default value. The effect of spare engines is as follows. Suppose an aircraft program consists of 2 prototype, 10 flight-test, and 100 production aircraft, with 4 engines per aircraft. Table 2 shows the buy with and without spare engines. The spares factors are assumed to be 50 percent for the prototype and flight-test aircraft and 25 percent for the production aircraft. It is also assumed that the buys are for the prototype aircraft first, then for the flight-test aircraft, and finally for the production aircraft.

Table 2

EFFECT OF SPARE ENGINES ON ENGINE PROCUREMENT

(Four Engines per Aircraft)

		Without Spares		With Spares	
Aircraft Type	Aircraft Quantity	Engines Required	Cumulative Engine Quantity	Engines Required	Cumulative Engine Quantity
Prototype	2	8	8	12	12
Flight-test	10	40	48	60	72
Production	100	400	448	500	572

Because installed and spare engines are bought together in lots, there is no way to distinguish which engines are spares and thus no way to differentiate them on the learning curve. All engine costs are therefore averaged together. In the example shown in Table 2, engines 73

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*Only whole spare engines are considered here; spare parts for engines are not included.

through 572, a quantity of 500, are bought for the 100 production aircraft. However, only 400 are actually required for the aircraft, the extra 100 being the spares. The question then is which 400 units on the learning curve from 73 through 572 should be used to represent the flyaway costs. In DAPCA-III, the procedure is to divide the cost of the whole 500 units from unit 73 through 572 by 1 plus the spares factor, in this case 1.25. This calculation produces an average flyaway cost of the 400 units across the 500 units procured.

The DAPCA-III program allows for the case in which a new aircraft may use engines already in production for other aircraft. The user may specify the entry point on the learning curve to account for prior procurement.

METHODOLOGY

Turbine engine costs are based on the methodology described in Rand report R-1288-PR.* As was mentioned previously, the time of arrival (TOA) for completing the engine 150-hour MQT was found to be a significant function of the engine's technical characteristics. The difference between the calculated TOA and the planned (or actual) TOA, called ΔTOA, represents the interval between the time when an engine is predicted to pass its MQT and the planned time for passing the MQT. A positive ΔTOA implies that an engine is technically advanced; thus its development and production costs will be higher. A negative ΔTOA implies a program for which the technology is well in hand; hence cost will be lower. The signs of the coefficients in the TOA equations are consistent with intuitive notions of what constitutes more technologically advanced achievement--positive coefficients on variables for which larger values are more difficult to achieve and negative coefficients on variables for which smaller values are more difficult to achieve.

The engine data base used to develop the CERs for DAPCA-III consisted of 26 military turbojet and turbofan types and 13 product-improvement models. Many engines have both afterburning and nonafterburning models. The model that first passed its 150-hour MQT is the

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*Op. cit.

model used in the TOA equation for military engines. Table 3, extracted from R-1288-PR,* lists the data base. (Table 4 in R-1288-PR lists the physical and performance characteristics of the engines used in that study.)

Table 3

TURBINE ENGINE DATA BASE

	Early 1940s	Late 1940s	Early 1950s	Late 1950s	Early 1960s	Late 1960s
Basic Engine Models						
	J30 W[a] J31 GE J33 GE/A J34 W J35 GE/A	J40 W J42 PW J46 W J47 GE J48 PW J57 J71 A J73 GE	J52 PW J65 CW J69 C J75 PW J79 GE	J58 PW J60 PW J85 GE TF30 PW TF33 PW		TF34 GE TF39 GE TF41 A
Total	5	8	5	5		3
Product-Improvement Models						
			J33 A J35 A J47 GE J57 PW	J71 A J75 PW J69 C	TF33 PW	J52 PW J60 PW J79 GE J85 GE TF30 PW
Total			4	3	1	5

[a]Engine manufacturer is indicated as follows: W = Westinghouse; GE = General Electric; A = Allison; PW = Pratt & Whitney; CW = Curtiss-Wright; C = Continental.

Predicted TOA

The first calculation in the aircraft turbine engine methodology is to determine the predicted TOA in calendar quarters from the third quarter of 1942. (The fourth quarter of 1942 is quarter number 1.) The CER selected for DAPCA-III is:

*Op. cit.

$$TOA = -856.38 + 110.10 \cdot \ln(TEMP) + 11.407 \cdot \ln(TOTPRS) - 26.077 \cdot \ln(WGT) - 16.024 \cdot \ln(SFCMIL) + 18.369 \cdot \ln(THRMAX) , \quad (15)$$

where TOA = predicted Time of Arrival (150-hr MQT of a demonstrated level of performance, in calendar quarters from third quarter of 1942)

TEMP = maximum turbine inlet temperature (degrees Rankine)

TOTPRS = pressure term equal to product of maximum dynamic pressure in flight envelope (lb/ft^2) and pressure ratio at sea level static

WGT = weight of engine at configuration of interest (lb)

SFCMIL = specific fuel consumption at military thrust, sea-level static (lb/hr/lb)

THRMAX = maximum thrust, with afterburner if afterburner configuration (lb)

ln = natural logarithm to base e (e = 2.71828...).

MQT Development

Once TOA is calculated from Eq. (15), the planned TOA is subtracted from it to obtain the ΔTOA. The ΔTOA is used along with various engine technical characteristics to obtain development and production costs. The engine development cost through MQT is calculated as follows:

$$DEVMQT = EXP(-1.3096 + .08538 \cdot DEVTIME + .04099 \cdot \Delta TOA) \cdot THRMAX^{.4963} \cdot MACH^{.4137} , \quad (16)$$

where DEVMQT = engine development cost through MQT (millions of 1975 dollars)

EXP = exponent of base e; e.g., EXP (a + b) = e^{a+b}

DEVTIME = development time from start to MQT (calendar quarters)

ΔTOA = difference between calculated TOA date (calendar quarters from third quarter 1942) and planned MQT date (calendar quarters from third quarter 1942)

THRMAX = maximum thrust, with afterburner if afterburning configuration (lb)

MACH = maximum speed at best altitude (Mach number).

Total Development

Next, *total development cost* including recurring development cost from MQT is calculated. This equation is only used to obtain recurring development costs past MQT.*

$$TOTDEV = 2.5440 \cdot THRMAX^{.3988} \cdot MACH^{1.2867} \cdot QE^{.08146} \cdot (1 + F), \quad (17)$$

where TOTDEV = engine total development cost (MQT + recurring) (millions of 1975 dollars), including cost of spare engines

THRMAX = maximum thrust, with afterburner if afterburning configuration (lb)

MACH = maximum speed at best altitude (Mach number)

QE = cumulative engine quantity including spares

F = appropriate spares factor.

Recurring Development

Recurring development cost for any engine quantity is the difference between the total development cost at the total quantity point on the curve and the cost at the point representing the total quantity less the number of engines under consideration. For example, the recurring development cost for 400 engines beginning with the 501st engine on the total development curve is

$$\text{Recurring development cost} = TOTDEVCOST_{900} - TOTDEVCOST_{500}.$$

Flyaway cumulative average recurring development cost for engines on the production aircraft is calculated as follows:

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*Engine costs calculated in DAPCA-III are generally based on the preferred TOA equations shown in R-1288-PR, by Nelson and Timson. However, for simplicity, the standard model equation for total engine development cost is preferred here. Its statistics are as good as those for the TOA model.

$$CUMAVG_{RECDEV} = (TOTDEV_{QE} - TOTDEV_{P+FT})/(1 + F)/QP \ , \qquad (18)$$

where $CUMAVG_{RECDEV}$ = flyaway cumulative average recurring development cost for engines on production aircraft

$TOTDEV_{QE}$ = total development cost (MQT + recurring development) for engines on prototype, flight-test, and production aircraft, including cost of spare engines

$TOTDEV_{P+FT}$ = total development cost (MQT + recurring development) for engines on prototype and flight-test aircraft, including cost of spare engines

F = production spares factor

QP = number of production aircraft.

Flyaway unit recurring development cost for engines on an aircraft is:

$$UNIT_{RECDEV} = \left[TOTDEV_{QE} - TOTDEV_{QE-EA\cdot(1+F)}\right]/(1 + F), \qquad (19)$$

where $UNIT_{RECDEV}$ = flyaway unit recurring development cost for engines on one aircraft (millions of 1975 dollars)

$TOTDEV_{QE}$ = total development cost (MQT + recurring development) for cumulative engine quantity QE, including cost of spare engines (millions of 1975 dollars)

$TOTDEV_{QE-EA\cdot(1+F)}$ = total development cost (MQT + recurring development) for cumulative engine quantity QE less the number of engines per aircraft, including spare engines (millions of 1975 dollars).

Production

Engine production cost is based on an equation for the 1000th engine production cost derived from a cumulative average curve. A cumutive engine production cost was also developed. However, it is not used here because quantity was one of the independent variables, thus allowing no flexibility in choosing different slopes for the engine production curve. Consequently, all engine production costs are based on the regression of engine production cost of the 1000th unit on a log-linear cumulative average curve. The CER is:

$$UPROD_{1000} = EXP(-8.2068 + .00674 \cdot TOA + .01804 \cdot \Delta TOA) \cdot THRMAX^{.7053} \cdot MACH^{.4571}, \quad (20)$$

where $UPROD_{1000}$ = engine production cost (selling price to Government) of 1000th unit (millions of 1975 dollars)

TOA = calculated time of arrival to MQT (calendar quarters from third quarter of 1942)

ΔTOA = difference between calculated TOA and planned MQT

THRMAX = maximum thrust, with afterburner if afterburning configuration (lb)

MACH = maximum speed at best altitude (Mach number).

In order that engine production cost be comparable to the other DAPCA-III costs, it must be converted to a total production cost as a function of quantity. This is done as follows. First, because Eq. (20) is derived from data on a logarithmic-linear cumulative average curve, it can also be represented as the difference between successive values on the cumulative power curve. That is,

$$UPROD_{1000} = Y_1 \cdot (1000^{b+1} - 999^{b+1}), \quad (21)$$

where $UPROD_{1000}$ = engine production cost of 1000th unit on a cumulative power curve

Y_1 = cost of unit 1

b = exponent corresponding to the cumulative average slope, s ($s = 2^b$), from which the unit cost relation (Eq. 20) was derived.

Therefore,

$$Y_1 = \frac{UPROD_{1000}}{1000^{b+1} - 999^{b+1}}. \quad (22)$$

The total cost on the cumulative curve as a power function of quantity QE is:

$$TOTPROD = Y_1 \cdot QE^{b+1} ,$$

or, substituting for Y_1 from Eq. (22),

$$TOTPROD = \frac{UPROD_{1000}}{1000^{b+1} - 999^{b+1}} \cdot QE^{b+1} , \tag{23}$$

where TOTPROD = total engine production cost for any engine quantity QE (millions of 1975 dollars), including cost of spare engines

$UPROD_{1000}$ = engine production cost of 1000th unit (millions of 1975 dollars--Eq. (20))

QE = cumulative engine quantity including spare engines

b = -.1520 (.90 cum avg slope)--default value

b+1 = .8480--default value.

Flyaway cumulative average production cost for engines on the production aircraft is:

$$CUMAVG_{PROD} = (TOTPROD_{QE} - TOTPROD_{P+FT})/(1 + F)/QP, \tag{24}$$

where $CUMAVG_{PROD}$ = flyaway cumulative average production cost for engines on production aircraft

$TOTPROD_{QE}$ = total production cost of engines on prototype, flight-test, and production aircraft, including cost of spare engines

$TOTPROD_{P+FT}$ = total production cost of engines on prototype and flight-test aircraft, including cost of spare engines

F = production spares factor

QP = number of production aircraft.

Flyaway unit production costs for engines on an aircraft is

$$UNIT_{PROD} = \left[TOTPROD_{QE} - TOTPROD_{QE-EA\cdot(1+F)} \right] /(1 + F), \tag{25}$$

where $UNIT_{PROD}$ = flyaway unit production costs for engines on an aircraft

$TOTPROD_{QE}$ = total engine production cost for cumulative engine quantity QE (millions of 1975 dollars), including cost of pare engines

$TOTPROD_{QE-EA\cdot(1+F)}$ = total engine production cost for cumulative engine quantity QE less the number of engines per aircraft including spare engines (millions of 1975 dollars)

QE = cumulative engine quantity, including spare engines

EA = number of engines per aircraft

F = production spares factor.

In terms of Eqs. (23) and (25),

$$UNIT_{PROD} = \left[\frac{UPROD_{1000}}{1000^{b+1} - 999^{b+1}}\right] \cdot \left[QE^{b+1} - [QE - EA \cdot (1 + F)]^{b+1}\right] / (1 + F). \tag{26}$$

Total Engine Production Costs

Total flyaway cumulative average and unit costs for engines on the production aircraft is the sum of the recurring development and production costs. Therefore,

Cumulative Average

$$CUMAVG_{TOTAL} = CUMAVG_{RECDEV} + CUMAVG_{PROD},$$

Unit

$$UNIT_{TOTAL} = UNIT_{RECDEV} + UNIT_{PROD}.$$

IV. AVIONICS COSTS

No CERs have been used in the previous DAPCA programs to obtain avionics costs, and the same applies to the present model. Consequently, the following assumptions are used to calculate avionics cost in DAPCA-III.

1. Avionics development cost is entered as a throughput.
2. Avionics packages are bought on a learning curve (95 percent slope--default condition).*
3. The avionics packages go on the prototype aircraft first, then on the flight-test aircraft, and finally on the production aircraft.
4. Spare avionics packages may be bought (default spares factor is zero). However, like engine spares, their cost is not treated as a flyaway cost. The spares procurement is only considered in order to account for the buy, as is done for engines.
5. A prior procurement is allowed for avionics. The default condition is zero.

As a result of the above assumptions, the basic inputs required for the avionics costs in DAPCA-III are the initial avionics development cost (millions of 1975 dollars) and the cost of the first production unit produced (millions of 1975 dollars). The initial avionics development cost is the cost of the basic development of the avionics package itself. It does not include the production cost of the avionics packages that go on the flight-test aircraft. That cost is treated as a separate development cost in DAPCA-III. The breakout of avionics costs in DAPCA-III is as follows:

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*As was mentioned previously, the relatively flat slope of 95 percent is used to account for the fact that an avionics package usually consists of old as well as new equipment.

<u>Development</u>

1. Avionics development cost
2. Production cost of avionics packages for flight-test aircraft.

<u>Production</u>

Production cost of avionics packages for production aircraft.

V. COMPUTER PROGRAM

PROGRAM STRUCTURE

The DAPCA-III computer program retains essentially the same operating features as used in the previously reported program in R-761-PR.* The program is structured to handle a series of back-to-back runs with a minimum of input effort.† All input data entered are retained from run to run unless superseded by new values. Thus, if the same value for an input is to be used for a series of runs--for example, aircraft unit weight--then it must be entered only for the first run. This feature makes the program highly suitable for sensitivity analyses in which iterations are made on a base case to study the effects of certain input variables.

Figure 2 is a flow chart showing the general flow of operations through the program. The program is essentially an infinite loop, and when one run (one set of data) representing one aircraft configuration is completed and the output printed, the program returns to the beginning to read and process another set of data representing the next run. This continues indefinitely until a termination designator is read, terminating the whole job. After a set of data is read for a run, all of the calculations and printouts are performed on that set before the next set of data is read and processed.

INPUT CONSIDERATIONS

All variables used in DAPCA-III, both input and output, are in the form of an F-array dimensioned 360. A listing of the array is given in Appendix A. The first 65 variables, F(1), F(2), . . . , F(65) represent the inputs. Each input variable is set to zero or a default value at the start of the first run, and remains at that value until superseded by a new input value.

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*Op. cit.

†In this section, a set of data representing one aircraft system is defined as a *run*, and a series of runs constituting one session with the computer is defined as a *job*.

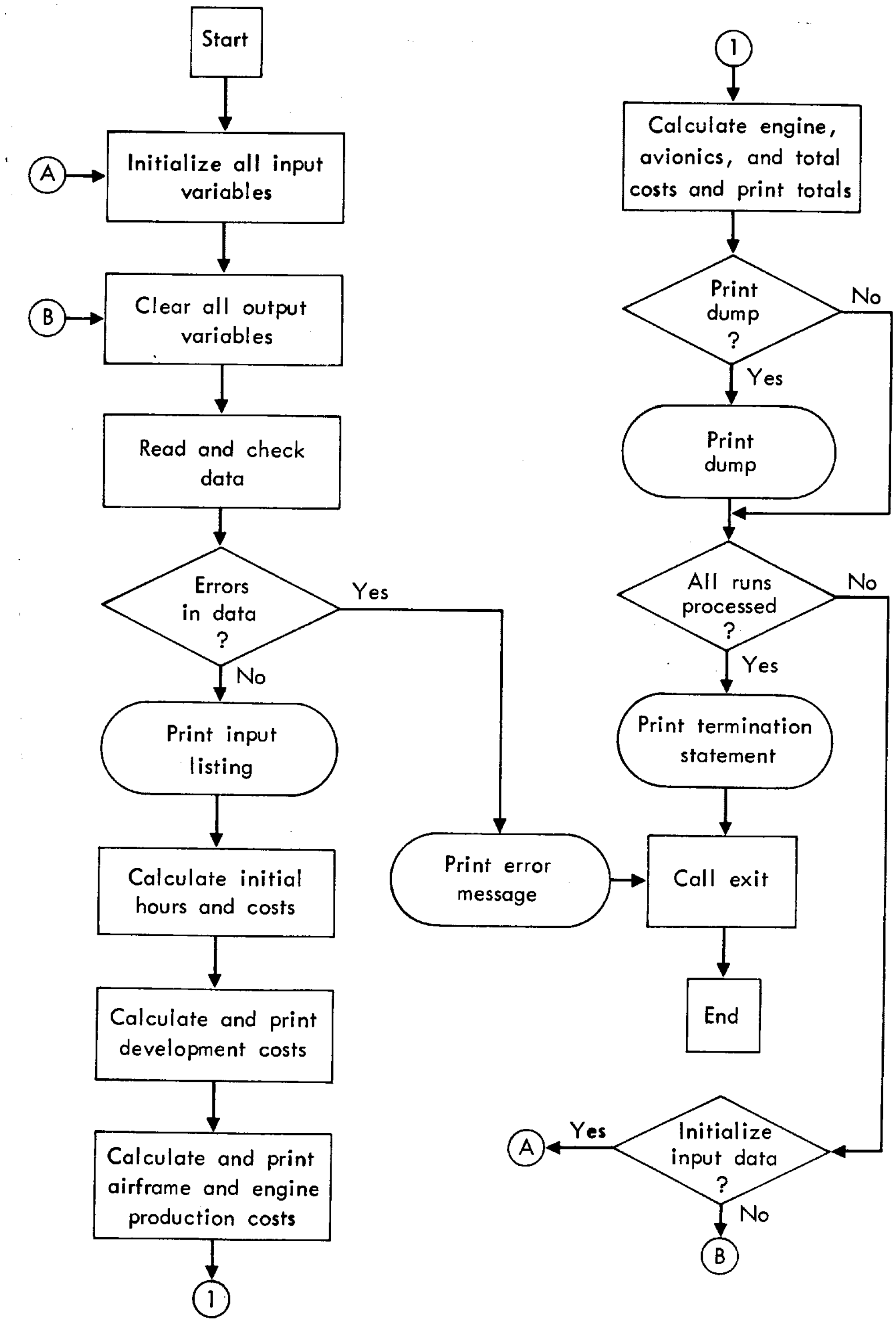

Fig. 2—Flow of operations in DAPCA-III

Up to ten production quantities may be entered, starting with F(11). The first quantity must be entered as F(11), the second as F(12), etc., up to and including F(20), if 10 production quantities are to be used. A fee for airframe costs may be entered (in decimal form, such as .09, 0.1, .12, etc.). If no fee is entered, a fee of 0.1 (10 percent) is used. It is assumed that engine and avionics costs include fees.

All engine development and production costs can be calculated in the program. However, an option is provided to allow the user to enter engine development cost through MQT as a throughput. This is done with use of variable F(35). If a value other than zero is entered for it, then that value is used in the program instead of being calculated. Note that engine recurring development past MQT is still calculated in the program even if the MQT development cost is entered as a throughput or set to zero. For purposes of output, engine recurring development cost is included with engine production cost because it varies with quantity. Therefore, the engine production costs shown in the totals are always higher than might be expected because of the inclusion of recurring development cost. The engine development cost shown in the output represents development through MQT plus the recurring development and production costs for the engines of the flight-test aircraft.

Cumulative average production curve slopes are now treated as inputs in DAPCA-III for all of the cost elements. Each has a default condition, as shown in the input listing of Appendix A, which can be overridden by an input value.

Any of the three subsystem calculations, namely, airframe, engines, and avionics, can be bypassed by means of skip designators, F(51), F(52), F(53), respectively. A value of 1.0 for any one of them causes all of the calculations for the subsystem which the designator represents to be bypassed. Thus, if one is interested only in airframe costs, a value of 1.0 for F(52) and F(53) causes DAPCA-III to skip all engine and avionics calculations.

A DUMP designator, F(63), has been included as an input variable. A value of 1.0 for this variable causes the program to print a listing of the entire F array, including both the input and output variables. This listing is printed in the form of an indexed array. With the use of Appendix A, showing the F-variables and their indexes, and the dump listing of the F array, the user is provided with the value of every F element used in the program for any run. Such a listing can be very useful when one is interested in examining the intermediate calculations that are performed in the program.

The CLEAR designator, F(64), is used to re-initialize all input variables. Usually, this variable is left at zero, that is, not entered at all. However, after many runs, the user may wish to start over again with all input variables set to their initial values. This is done by entering a 1.0 for F(63) for the last run before which all input values are to be re-initialized. The value of 1.0 does not carry over to any following runs as values do for the other input variables. Otherwise, the program would be re-initializing the input variables after each run.

It is important to note again that the value of each input variable, except for the CLEAR designator, F(64), is carried over to the next run. Unless superseded by a new input value, the same value will be used again.

INPUT PROCEDURES

Title Card

The first card of each set of data must be a title card. This card is used to identify the run by a name, and any alphanumeric symbols may be used. All 80 columns are available; no data are entered on this card.

Data Cards

In entering the F input variables, the same procedures are used as for the previous DAPCA program. The index of F is entered together with the value of F as a pair--the index an integer number and the F value a real number. The pair may be entered in any order of index as long as they are entered in their prescribed fields. Six pairs may be entered on one card. Figure 3 shows an example of a DAPCA input sheet used for entering the data for keypunch. The implied decimal point location is at the right end of each F value field. A punched decimal point overrides the implied decimal point location. Three columns are allowed for each index and eight for each value. All costs are entered in millions of dollars except the hourly rates, which are entered in dollars.

The data shown in Fig. 3 are for three runs involving hypothetical aircraft. For the first run, the value of index 9, the prototype quantity, is 2; and the value of index 10, the number of flight-test aircraft, is 20. Aircraft production quantities of 10, 50, 100, 200, 250, 300 and 400 are entered for indexes 11 through 17, respectively. The value for index 21, the aircraft type, is 1.0, designating a noncargo aircraft. Index 22 is the airframe unit weight in pounds (25,000). Index 24 is the maximum speed at best altitude in Mach number (2.2) and index 23 is the speed in knots (1250). The latter two pairs of inputs are purposely entered out of order with respect to the indexes to show that such ordering is not important.

The remaining inputs for the first run relate to engines and avionics. Index 32 is the number of engines per aircraft (2). Index 38 is the maximum dynamic pressure in-flight envelope (3000 lb/ft^2), and index 39 is the engine pressure ratio (25). Index 40 is the maximum turbine inlet temperature (3100° Rankine); index 41 is the engine weight at configuration of interest (3500 lb); index 42 is the specific fuel consumption at military thrust, sea-level static (0.65 lb/hr/lb thrust); and index 43 is the maximum thrust per engine including afterburner (30,000 lb). Index 44 is the planned MQT date (1975.50), and index 45 is the starting date of development (1971.50).

For index 44, the planned MQT date of 1975.50 is converted to planned TOA in calendar quarters beginning in fourth quarter 1942 as follows:

$$\text{TOA} = 4 \cdot (1975.50-1942.50) = 4 \cdot 33 = 132 \text{ quarters.}$$

The starting date of development (1971.50) is converted to development quarters as follows:

DAPCA INPUT SHEET

Analyst ______ Dept. ______ Job No. ______ Project No. ______ Date ______

Field 1 Index	Field 1 Value	Field 2 Index	Field 2 Value	Field 3 Index	Field 3 Value	Field 4 Index	Field 4 Value	Field 5 Index	Field 5 Value	Field 6 Index	Field 6 Value
TEST RUN 1 -- NØ DATE ØF FIRST FLIGHT, NØ PRIØR ENGINE PRØCUREMENT											
009	2	010	20	011	10	012	50	013	100	014	200
015	250	016	300	017	400	021	1	022	25,000	024	2.2
023	1,250	032	2	038	3,000	039	25	040	3,100	041	3,500
042	0.65	043	30,000	044	1,975.50	045	1,971.50	046	50	047	5
063	1										
555											
TEST RUN 2 -- DATE ØF FIRST FLIGHT: 1958.25, NØ PRIØR ENGINE PRØCUREMENT											
025	1,958.25	555									
TEST RUN 3 -- NØ DATE ØF FIRST FLIGHT, PRIØR ENGINE PRØCUREMENT ØF 975											
025	0	033	975	999							

Fig. 3 — Example of a DAPCA input sheet

$$DEVTIME = 4 \cdot (1975.50-1971.50) = 4 \cdot 4 = 16 \text{ quarters.}$$

Index 46 is the avionics development cost (50 million dollars), and index 47 is the avionics first-unit production cost (5.0 million dollars). The last index entered, 63, is the DUMP designator. Its value is 1.0, signifying that the dump printout of the F array is to be printed. As one may observe, many of the inputs are skipped on the input sheet, either because their default values are to be used, or because they are not required.

One of two designators is used to terminate the reading of a set of data representing one run. Either a 555 or 999 is entered in any index field following the last F value entered. A 555 signifies the end of one set of data with more sets to follow, in which each set represents a run. A 999 is used after the last set signifying that the job is completed and will be terminated after the run is processed. A termination designator must be the last entry on the card. Data for the next run must begin on a new card. In the example shown in Fig. 3, data for the first two runs each end with a 555 because another run is to follow. Data for the third run end with a 999 because no more runs follow. Thus, the job is to end after completion of the third run.

The only new input used for the second run is index 25, date of first flight in calendar years and quarters. Its value is 1958.25. With all other inputs remaining the same, the user can compare the differences in airframe costs in using the optional method of calculating recurring manufacturing labor and material costs involving time of first flight as an explanatory variable. Date of first flight is converted to time of first flight in calendar quarters beginning with first quarter 1943 as follows:

$$TFF = 4 \cdot (1958.25-1942.75) = 4 \cdot 15.5 = 62 \text{ quarters.}$$

For the third run, a prior procurement of 975 engines (index 33) is used to modify the learning curve effect for engines.

When both the index and its F value fields are completely blank--read as 0 and 0., respectively--they are skipped by the program.

Therefore, if a change is required for a variable, the user may simply enter the index and the new value in the first pair of fields on a separate card and insert the card anywhere after the card containing the old value and before the card containing the end designator for that set of data. It is usually a good idea to enter the end designator of each set of data in the first index field of a separate card and place the card in the last position of that set of data (first run in Fig. 3). This allows for better maneuverability of the data cards, particularly if several data cards are being used for the run. Within a set of data representing one run, the cards may be shuffled in any order as long as the title card is first and the end card containing the end designator is last. An index less than 1 or greater than 64 (except for the index and F value pair 0 and 0., respectively) results in an error statement.

PROGRAM OUTPUTS

Figures 4 through 19, listed at the end of this section, are examples of the outputs generated from the inputs shown in Fig. 3. The results shown are for demonstration purposes only and do not intentionally represent any real aircraft system. The first page of the first run, Fig. 4, lists all of the program inputs. Five production quantities are printed per line.

Figure 5 shows the development costs and also hours where appropriate. All costs associated with flight-test aircraft are treated as development costs in DAPCA-III. Production cost of the spare engines associated with the flight-test aircraft is shown at the bottom in parentheses. This cost is not treated as a flyaway cost and is not included in the totals. It is shown for interest only. Figure 6 shows the output for airframe production costs and hours; they are printed both as cumulative average and unit values. The costs are shown with and without fee. A breakout of the engine "production" costs is also shown below the airframe production cost table. Cumulative average and unit costs are listed for engine production, recurring development, and total cost. The engine cumulative average and unit total costs are the same as the engine costs listed in the summary table on the next page of the output.

Total costs are shown in Fig. 7. Development costs are shown at the top of the page, and production costs below as cumulative average and unit costs. Engine and avionics costs each represent an aggregate cost for the number of units required for the aircraft. This is done so that their costs can be added to the airframe cost to give a total aircraft cost. Cumulative costs are shown without RDTE (Research, Development, Test, and Evaluation) and with RDTE, including fee. Costs of the spare engines associated with the production aircraft are shown in the right column. As on the development page (Fig. 5), they are not added into the totals because they are not considered to be fly-away costs. The engine costs listed in the production totals are the sum of production and recurring development as listed on the previous output page (Fig. 6).

The last page of output for the first run, Fig. 8, lists the dump printout of the F array. Ten F values are listed per line with the index range listed in the right column. The numbers 1, 2, ..., 10 across the top are used as an aid to locating a particular value. For example, F(102), initial manufacturing labor hours, is found to have a value of 1.27507 million from the dump listing. Its value is found by going to the row containing 101-110 in the right column and to the second column in that row, under the heading 2.

Figures 9 through 13 are the outputs for the second run in which the date of first flight is entered as 1958.25 for index 25. As was stated previously, this date converts into 62 quarters beginning with the first quarter of 1943. The only cost elements that are calculated differently when using the data of first flight are recurring manufacturing labor, recurring manufacturing materials, and quality control because it is calculated as a fraction of manufacturing labor. As can be seen in comparing the two runs, the results agree very closely.

For the third run, the date of first flight is set back to zero, and a prior engine procurement of 975 is used. As a result, the output from the third run differs from that of the first run only in the engine costs, because engine production costs are calculated starting at engine quantity 976 instead of at quantity 1, as was the case for the first run. Also, because of the engine prior procurement, no MQT development cost is calculated. As a check on the results, the engine unit costs at quantity 25, shown in Fig. 16 for the third run, should be comparable to the corresponding engine unit costs at quantity 1000 in the first run (Fig. 6). Because of the prior procurement of 975 for the third run, engine quantity 25 is actually at the cumulative engine quantity 1000 on the learning curve. A comparison of the figures does show that the engine unit production and unit recurring development costs at quantity 25 in the third run check exactly with those of the 1000th engine in the first run. Figure 19 shows the termination statement DONE printed on a separate page after the output for the last run is printed. This statement signifies that all data have been processed and printed and that the job has been completed.

```
                              DAPCA-III COMPUTER PROGRAM (OCTOBER 1975)
TEST RUN 1 -- NO DATE OF FIRST FLIGHT, NO PRIOR ENGINE PROCUREMENT                                          PAGE    1

                                        INPUT LISTING

 1      DEVELOPMENT ENGINEERING RATE ($/HOUR)                                          26.50
 2      DEVELOPMENT TOOLING RATE ($/HOUR)                                              24.25
 3      DEVELOPMENT MFG LABOR RATE ($/HOUR)                                            23.75
 4      DEVELOPMENT QUALITY CONTROL RATE ($/HOUR)                                      24.50
 5      PRODUCTION ENGINEERING RATE ($/HOUR)                                           21.75
 6      PRODUCTION TOOLING RATE ($/HOUR)                                               22.75
 7      PRODUCTION MFG LABOR RATE ($/HOUR)                                             22.00
 8      PRODUCTION QUALITY CONTROL RATE ($/HOUR)                                       23.00
 9      NUMBER OF PROTOTYPE AIRCRAFT                                                    2.
10      NUMBER OF FLIGHT-TEST AIRCRAFT                                                 20.
11-17   AIRCRAFT PRODUCTION QUANTITIES                                                 10.     50.    100.    200.    250.
                                                                                      300.    400.
21      AIRCRAFT TYPE (NONCARGO: 1, CARGO: 2)                                           1.
22      AIRFRAME UNIT WEIGHT (POUNDS)                                               25000.
23      MAXIMUM SPEED AT BEST ALTITUDE (KNOTS)                                       1250.
24      MAXIMUM SPEED AT BEST ALTITUDE (MACH NO.)                                       2.200
25      DATE OF FIRST FLIGHT (CALENDAR YEAR AND QUARTER)                                0.0
26      AIRFRAME COST FEE (DECIMAL)                                                     0.100
27      ENGINEERING CUM AVG PRODUCTION CURVE SLOPE (DECIMAL)                            0.565
28      TOOLING CUM AVG PRODUCTION CURVE SLOPE (DECIMAL)                                0.570
29      MANUFACTURING LABOR CUM AVG PRODUCTION CURVE SLOPE (DECIMAL)                    0.770
30      MANUFACTURING MATERIALS CUM AVG PRODUCTION CURVE SLOPE (DECIMAL)                0.855
31      QUALITY CONTROL FACTOR (DECIMAL)                                                0.0
32      NUMBER OF ENGINES PER AIRCRAFT                                                  2.
33      ENGINE PRIOR PROCUREMENT QUANTITY                                               0.
34      ENGINE CUM AVG PRODUCTION CURVE SLOPE (DECIMAL)                                 0.900
35      ENGINE MQT DEVELOPMENT THROUGHPUT COST                                          0.0
36      ENGINE PROTOTYPE AND FLIGHT-TEST SPARES FACTOR (DECIMAL)                        0.500
37      ENGINE PRODUCTION SPARES FACTOR (DECIMAL)                                       0.250
38      MAXIMUM DYNAMIC PRESSURE IN-FLIGHT ENVELOPE (LB/SQ FT)                       3000.000
39      ENGINE PRESSURE RATIO                                                          25.000
40      MAXIMUM TURBINE INLET TEMPERATURE (DEGREES RANKINE)                          3100.
41      WEIGHT OF ENGINE AT CONFIGURATION OF INTEREST (POUNDS)                       3500.
42      SPECIFIC FUEL CONSUMPTION AT MILITARY THRUST, SEA-LEVEL STATIC (LB/HR/LB THRUST)  0.650
43      MAXIMUM THRUST PER ENGINE, INCLUDING AFTERBURNER (POUNDS)                   30000.
44      DATE OF PLANNED MQT (CALENDAR YEAR AND QUARTER)                              1975.50
45      DATE OF START OF ENGINE DEVELOPMENT (CALENDAR YEAR AND QUARTER)              1971.50
46      AVIONICS DEVELOPMENT THROUGHPUT COST                                           50.000
47      AVIONICS FIRST-UNIT PRODUCTION THROUGHPUT COST                                  5.000
48      AVIONICS CUM AVG PRODUCTION CURVE SLOPE (DECIMAL)                               0.950
49      AVIONICS SPARES FACTOR (DECIMAL)                                                0.0
50      AVIONICS PRIOR PROCUREMENT QUANTITY                                             0.
51      AIRFRAME SKIP DESIGNATOR                                                        0.
52      ENGINE SKIP DESIGNATOR                                                          0.
53      AVIONICS SKIP DESIGNATOR                                                        0.

                                     ADJUSTMENT FACTORS

54      ENGINEERING HOURS                1.                      55     TOOLING HOURS                      1.
56      NONRECUR MFG LABOR HOURS         1.                      57     RECUR MFG LABOR HOURS              1.
58      NONRECUR MFG MATERIALS COST      1.                      59     RECUR MFG MATERIALS COST           1.
60      FLIGHT-TEST COST                 1.                      61     ENGINE DEVELOPMENT COST            1.
62      ENGINE PRODUCTION COST           1.
```

Fig. 4—First page of output for first run

TEST RUN 1 -- NO DATE OF FIRST FLIGHT, NO PRIOR ENGINE PROCUREMENT PAGE 2

DEVELOPMENT COSTS

	COSTS (MILLIONS $)	HOURS (MILLIONS)
AIRFRAMES		
ENGINEERING	228.557	8.625
TOOLING	175.316	7.230
NONRECURRING MFG LABOR	88.995	3.747
RECURRING MFG LABOR	161.063	6.782
QUALITY CONTROL	30.954	1.263
NONRECURRING MFG MATERIALS	42.509	
RECURRING MFG MATERIALS	58.340	
FLIGHT TEST	112.452	
TOTAL AIRFRAME WITHOUT FEE	898.186	
FEE	89.819	
TOTAL AIRFRAME WITH FEE	988.004	
ENGINES		
MQT DEVELOPMENT	342.716	
RECURRING DEVELOPMENT	71.263	
PRODUCTION	114.431	
TOTAL ENGINES	528.410	
AVIONICS		
DEVELOPMENT	50.000	
PRODUCTION	78.009	
TOTAL AVIONICS	128.009	
TOTAL DEVELOPMENT COST	1644.423	
(COST OF SPARE ENGINES FOR FLIGHT-TEST AIRCRAFT	92.847)	

Fig. 5 — Second page of output for first run

AIRFRAME PRODUCTION COSTS AND HOURS
(ALL COSTS AND HOURS IN MILLIONS)
- - FEE = 0.100 - -

CUMULATIVE AVERAGE

AIRFRAME QUANTITY	ENGINEERING COSTS	ENGINEERING HOURS	TOOLING COSTS	TOOLING HOURS	MFG LABOR COSTS	MFG LABOR HOURS	QUALITY CONTROL COSTS	QUALITY CONTROL HOURS	MFG MATERIALS	TOTAL WITHOUT FEE	FEE	TOTAL WITH FEE
10	1.9055	0.0876	1.3830	0.0608	5.0580	0.2299	0.6345	0.0276	2.3264	11.3074	1.1307	12.4382
50	1.2974	0.0596	0.9467	0.0416	4.2054	0.1912	0.5276	0.0229	2.0792	9.0563	0.9056	9.9620
100	0.9838	0.0452	0.7205	0.0317	3.6687	0.1668	0.4602	0.0200	1.9122	7.7453	0.7745	8.5199
200	0.7019	0.0323	0.5163	0.0227	3.0982	0.1408	0.3887	0.0169	1.7234	6.4285	0.6428	7.0713
250	0.6227	0.0286	0.4587	0.0202	2.9167	0.1326	0.3659	0.0159	1.6605	6.0245	0.6025	6.6270
300	0.5627	0.0259	0.4150	0.0182	2.7710	0.1260	0.3476	0.0151	1.6090	5.7054	0.5705	6.2759
400	0.4767	0.0219	0.3523	0.0155	2.5479	0.1158	0.3196	0.0139	1.5280	5.2245	0.5225	5.7470

UNIT

AIRFRAME QUANTITY	ENGINEERING COSTS	ENGINEERING HOURS	TOOLING COSTS	TOOLING HOURS	MFG LABOR COSTS	MFG LABOR HOURS	QUALITY CONTROL COSTS	QUALITY CONTROL HOURS	MFG MATERIALS	TOTAL WITHOUT FEE	FEE	TOTAL WITH FEE
10	1.6638	0.0765	1.2103	0.0532	4.7582	0.2163	0.5969	0.0260	2.2432	10.4724	1.0472	11.5196
50	0.8468	0.0389	0.6224	0.0274	3.4929	0.1588	0.4382	0.0191	1.8636	7.2638	0.7264	7.9902
100	0.5473	0.0252	0.4049	0.0178	2.8604	0.1300	0.3589	0.0156	1.6536	5.8250	0.5825	6.4075
200	0.3339	0.0154	0.2488	0.0109	2.2804	0.1037	0.2861	0.0124	1.4436	4.5928	0.4593	5.0520
250	0.2821	0.0130	0.2109	0.0093	2.1122	0.0960	0.2650	0.0115	1.3792	4.2493	0.4249	4.6742
300	0.2456	0.0113	0.1837	0.0081	1.9809	0.0900	0.2485	0.0108	1.3267	3.9854	0.3985	4.3840
400	0.1965	0.0090	0.1480	0.0065	1.7896	0.0813	0.2245	0.0098	1.2485	3.6071	0.3607	3.9678

ENGINE PRODUCTION COSTS

AIRFRAME QUANTITY	ENGINE QUANTITY	<- -CUMULATIVE AVERAGE- -> PROD	RECUR DEV	TOTAL	<- - - - - UNIT - - - - -> PROD	RECUR DEV	TOTAL
10	25	4.9467	1.2777	6.2244	4.8433	1.1217	5.9650
50	125	4.6208	0.8715	5.4923	4.3227	0.5639	4.8865
100	250	4.3823	0.6558	5.0380	4.0025	0.3543	4.3568
200	500	4.0969	0.4610	4.5579	3.6619	0.2070	3.8689
250	625	3.9983	0.4064	4.4048	3.5525	0.1723	3.7248
300	750	3.9162	0.3652	4.2815	3.4639	0.1480	3.6119
400	1000	3.7848	0.3065	4.0912	3.3258	0.1156	3.4414

Fig. 6 — Third page of output for first run

TEST RUN 1 -- NO DATE OF FIRST FLIGHT, NO PRIOR ENGINE PROCUREMENT

TOTAL AIRCRAFT COSTS
(MILLIONS OF DOLLARS)
(ENGINE PRIOR PROCUREMENT = 0 ; AVIONICS PRIOR PROCUREMENT = 0)

DEVELOPMENT

AIRFRAMES	ENGINES	AVIONICS	TOTAL WITH FEE
988.0042	528.4102	128.0089	1644.4231

PRODUCTION

AIRFRAME QUANTITY	ENGINE QUANTITY	<- - - CUMULATIVE AVERAGE: AIRFRAMES	ENGINES	AVIONICS	TOTAL WITH FEE - - ->	<- - CUMULATIVE TOTALS: CUM TOTAL WITHOUT FEE	CUM TOTAL WITH RDTE - ->	(SPARE) (ENGINES)
10	25	12.4382	6.2244	3.6296	22.2921	222.9210	1867.3440	15.5609
50	125	9.9620	5.4923	3.4965	18.9508	947.5410	2591.9641	68.6541
100	250	8.5199	5.0380	3.3999	16.9578	1695.7825	3340.2056	125.9509
200	500	7.0713	4.5579	3.2835	14.9127	2982.5386	4626.9609	227.8951
250	625	6.6270	4.4048	3.2428	14.2746	3568.6404	5213.0625	275.2979
300	750	6.2759	4.2815	3.2087	13.7661	4129.8320	5774.2539	321.1089
400	1000	5.7470	4.0912	3.1537	12.9919	5196.7656	6841.1875	409.1230

UNIT

AIRFRAME QUANTITY	ENGINE QUANTITY	AIRFRAMES	ENGINES	AVIONICS	TOTAL WITH FEE
10	25	11.5196	5.9650	3.5867	21.0714
50	125	7.9902	4.8865	3.3757	16.2525
100	250	6.4075	4.3568	3.2458	14.0102
200	500	5.0520	3.8689	3.1050	12.0260
250	625	4.6742	3.7248	3.0588	11.4578
300	750	4.3840	3.6119	3.0200	11.0159
400	1000	3.9678	3.4414	2.9602	10.3694

Fig. 7 — Fourth page of output for first run

TEST RUN 1 -- NO DATE OF FIRST FLIGHT, NO PRIOR ENGINE PROCUREMENT

PROGRAM VALUES

1	2	3	4	5	6	7	8	9	10	INDEXES
26.50000	24.25000	23.75000	24.50000	21.75000	22.75000	22.00000	23.00000	2.00000	20.00000	1- 10
10.00000	50.00000	100.00000	200.00000	250.00000	300.00000	400.00000	0.0	0.0	0.0	11- 20
1.00000	25000.00000	1250.00000	2.20000	0.0	0.10000	0.56500	0.57000	0.77000	0.85500	21- 30
0.0	2.00000	0.0	0.90000	0.0	0.50000	0.25000	3000.00000	25.00000	3100.00000	31- 40
3500.00000	0.65000	30000.00000	1975.50000	1971.50000	50.00000	5.00000	0.95000	0.0	0.0	41- 50
0.0	0.0	0.0	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	51- 60
1.00000	1.00000	1.00000	0.0	0.0	1.50000	1.25000	1.00000	22.00000	0.17632	61- 70
0.18903	0.62293	0.77400	0.08146	0.84800	0.92600	75000.00000	140.24364	8.24364	7.00000	71- 80
0.69315	0.0	132.00000	16.00000	0.0	0.0	0.0	0.0	0.0	4.20241	81- 90
12.82720	1.05274	8.28228	1.96361	8.74521	10.80802	69.14809	0.12000	0.00000	7.43759	91-100
4.61729	1.27507	6.32048	6.00000	66.00000	428.24121	5.65708	2.00000	22.00000	8.62479	101-110
7.22954	3.74715	6.78160	1.26345	228.55698	175.31633	88.99486	161.06293	30.95448	42.50916	111-120
58.34006	112.45209	898.18579	89.81854	988.00415	342.71606	71.26334	114.43112	528.41016	78.00893	121-130
128.00893	1644.42310	602.43262	25.85010	87.50893	495.53760	197.49678	9.50000	92.84723	0.0	131-140
12.43816	9.96195	8.51987	7.07132	6.62698	6.27592	5.74699	0.0	0.0	0.0	141-150
11.51962	7.99023	6.40755	5.05203	4.67420	4.38396	3.96777	0.0	0.0	0.0	151-160
32.00000	72.00000	122.00000	222.00000	272.00000	322.00000	422.00000	0.0	0.0	0.0	161-170
13.70327	15.80964	17.35020	19.28180	19.98489	20.58846	21.59406	0.0	0.0	0.0	171-180
8.89019	10.36300	11.44931	12.82115	13.32301	13.75486	14.47637	0.0	0.0	0.0	181-190
11.04429	18.30302	25.42091	36.91042	41.88913	46.53223	55.07079	0.0	0.0	0.0	191-200
92.41237	173.10832	260.36621	413.82666	484.28101	551.84961	680.34985	0.0	0.0	0.0	201-210
91.00000	191.00000	316.00000	566.00000	691.00000	816.00000	1066.00000	0.0	0.0	0.0	211-220
259.33032	486.29688	745.27954	1221.72168	1446.97510	1666.08301	2089.87964	0.0	0.0	0.0	221-230
618.40356	656.90332	684.40479	717.68335	729.44458	739.39209	755.66528	0.0	0.0	0.0	231-240
4.94668	4.62080	4.38226	4.09690	3.99833	3.91623	3.78477	0.0	0.0	0.0	241-250
1.27768	0.87153	0.65578	0.46100	0.40644	0.36523	0.30647	0.0	0.0	0.0	251-260
6.22436	5.49233	5.03804	4.55790	4.40477	4.28145	4.09123	0.0	0.0	0.0	261-270
62.24358	274.61646	503.80371	911.58032	1101.19189	1284.43628	1636.49219	0.0	0.0	0.0	271-280
15.56089	68.65411	125.95093	227.89508	275.29785	321.10889	409.12305	0.0	0.0	0.0	281-290
4.84333	4.32266	4.00254	3.66191	3.55254	3.46387	3.32578	0.0	0.0	0.0	291-300
1.12168	0.56387	0.35430	0.20703	0.17227	0.14805	0.11562	0.0	0.0	0.0	301-310
5.96501	4.88652	4.35684	3.86895	3.72480	3.61191	3.44141	0.0	0.0	0.0	311-320
32.00000	72.00000	122.00000	222.00000	272.00000	322.00000	422.00000	0.0	0.0	0.0	321-330
123.80486	262.33643	427.50171	744.20313	898.21289	1050.12939	1348.98682	0.0	0.0	0.0	331-340
3.62959	3.49655	3.39993	3.28347	3.24282	3.20873	3.15369	0.0	0.0	0.0	341-350
3.58673	3.37573	3.24585	3.10498	3.05884	3.02002	2.96021	0.0	0.0	0.0	351-360

Fig. 8 — Fifth page of output for first run

TEST RUN 2 -- DATE OF FIRST FLIGHT: 1958.25, NO PRIOR ENGINE PROCUREMENT

INPUT LISTING

1	DEVELOPMENT ENGINEERING RATE ($/HOUR)	26.50
2	DEVELOPMENT TOOLING RATE ($/HOUR)	24.25
3	DEVELOPMENT MFG LABOR RATE ($/HOUR)	23.75
4	DEVELOPMENT QUALITY CONTROL RATE ($/HOUR)	24.50
5	PRODUCTION ENGINEERING RATE ($/HOUR)	21.75
6	PRODUCTION TOOLING RATE ($/HOUR)	22.75
7	PRODUCTION MFG LABOR RATE ($/HOUR)	22.00
8	PRODUCTION QUALITY CONTROL RATE ($/HOUR)	23.00
9	NUMBER OF PROTOTYPE AIRCRAFT	2.
10	NUMBER OF FLIGHT-TEST AIRCRAFT	20.
11-17	AIRCRAFT PRODUCTION QUANTITIES	10. 50. 100. 200. 250. 300. 400.
21	AIRCRAFT TYPE (NONCARGO: 1, CARGO: 2)	1.
22	AIRFRAME UNIT WEIGHT (POUNDS)	25000.
23	MAXIMUM SPEED AT BEST ALTITUDE (KNOTS)	1250.
24	MAXIMUM SPEED AT BEST ALTITUDE (MACH NO.)	2.200
25	DATE OF FIRST FLIGHT (CALENDAR YEAR AND QUARTER)	1958.25
26	AIRFRAME COST FEE (DECIMAL)	0.100
27	ENGINEERING CUM AVG PRODUCTION CURVE SLOPE (DECIMAL)	0.565
28	TOOLING CUM AVG PRODUCTION CURVE SLOPE (DECIMAL)	0.570
29	MANUFACTURING LABOR CUM AVG PRODUCTION CURVE SLOPE (DECIMAL)	0.770
30	MANUFACTURING MATERIALS CUM AVG PRODUCTION CURVE SLOPE (DECIMAL)	0.855
31	QUALITY CONTROL FACTOR (DECIMAL)	0.0
32	NUMBER OF ENGINES PER AIRCRAFT	2.
33	ENGINE PRIOR PROCUREMENT QUANTITY	0.
34	ENGINE CUM AVG PRODUCTION CURVE SLOPE (DECIMAL)	0.900
35	ENGINE MQT DEVELOPMENT THROUGHPUT COST	0.0
36	ENGINE PROTOTYPE AND FLIGHT-TEST SPARES FACTOR (DECIMAL)	0.500
37	ENGINE PRODUCTION SPARES FACTOR (DECIMAL)	0.250
38	MAXIMUM DYNAMIC PRESSURE IN-FLIGHT ENVELOPE (LB/SQ FT)	3000.000
39	ENGINE PRESSURE RATIO	25.000
40	MAXIMUM TURBINE INLET TEMPERATURE (DEGREES RANKINE)	3100.
41	WEIGHT OF ENGINE AT CONFIGURATION OF INTEREST (POUNDS)	3500.
42	SPECIFIC FUEL CONSUMPTION AT MILITARY THRUST, SEA-LEVEL STATIC (LB/HR/LB THRUST)	0.650
43	MAXIMUM THRUST PER ENGINE, INCLUDING AFTERBURNER (POUNDS)	30000.
44	DATE OF PLANNED MQT (CALENDAR YEAR AND QUARTER)	1975.50
45	DATE OF START OF ENGINE DEVELOPMENT (CALENDAR YEAR AND QUARTER)	1971.50
46	AVIONICS DEVELOPMENT THROUGHPUT COST	50.000
47	AVIONICS FIRST-UNIT PRODUCTION THROUGHPUT COST	5.000
48	AVIONICS CUM AVG PRODUCTION CURVE SLOPE (DECIMAL)	0.950
49	AVIONICS SPARES FACTOR (DECIMAL)	0.0
50	AVIONICS PRIOR PROCUREMENT QUANTITY	0.
51	AIRFRAME SKIP DESIGNATOR	0.
52	ENGINE SKIP DESIGNATOR	0.
53	AVIONICS SKIP DESIGNATOR	0.

ADJUSTMENT FACTORS

54	ENGINEERING HOURS	1.	55	TOOLING HOURS	1.
56	NONRECUR MFG LABOR HOURS	1.	57	RECUR MFG LABOR HOURS	1.
58	NONRECUR MFG MATERIALS COST	1.	59	RECUR MFG MATERIALS COST	1.
60	FLIGHT-TEST COST	1.	61	ENGINE DEVELOPMENT COST	1.
62	ENGINE PRODUCTION COST	1.			

Fig. 9 — First page of output for second run

TEST RUN 2 -- DATE OF FIRST FLIGHT: 1958.25, NO PRIOR ENGINE PROCUREMENT PAGE 7

DEVELOPMENT COSTS

	COSTS (MILLIONS $)	HOURS (MILLIONS)
AIRFRAMES		
ENGINEERING	228.557	8.625
TOOLING	175.316	7.230
NONRECURRING MFG LABOR	88.995	3.747
RECURRING MFG LABOR	175.293	7.381
QUALITY CONTROL	32.716	1.335
NONRECURRING MFG MATERIALS	42.509	
RECURRING MFG MATERIALS	53.599	
FLIGHT TEST	112.452	
TOTAL AIRFRAME WITHOUT FEE	909.436	
FEE	90.944	
TOTAL AIRFRAME WITH FEE	1000.379	
ENGINES		
MQT DEVELOPMENT	342.716	
RECURRING DEVELOPMENT	71.263	
PRODUCTION	114.431	
TOTAL ENGINES	528.410	
AVIONICS		
DEVELOPMENT	50.000	
PRODUCTION	78.009	
TOTAL AVIONICS	128.009	
TOTAL DEVELOPMENT COST	1656.798	
(COST OF SPARE ENGINES FOR FLIGHT-TEST AIRCRAFT	92.847)	

Fig. 10—Second page of output for second run

TEST RUN 2 -- DATE OF FIRST FLIGHT: 1958.25, NO PRIOR ENGINE PROCUREMENT

AIRFRAME PRODUCTION COSTS AND HOURS
(ALL COSTS AND HOURS IN MILLIONS)
- - FEE = 0.100 - -

CUMULATIVE AVERAGE

AIRFRAME QUANTITY	ENGINEERING COSTS	ENGINEERING HOURS	TOOLING COSTS	TOOLING HOURS	MFG LABOR COSTS	MFG LABOR HOURS	QUALITY CONTROL COSTS	QUALITY CONTROL HOURS	MFG MATERIALS	TOTAL WITHOUT FEE	FEE	TOTAL WITH FEE
10	1.9055	0.0876	1.3830	0.0608	5.5049	0.2502	0.6906	0.0300	2.1374	11.6213	1.1621	12.7834
50	1.2974	0.0596	0.9467	0.0416	4.5770	0.2080	0.5742	0.0250	1.9102	9.3055	0.9305	10.2360
100	0.9838	0.0452	0.7205	0.0317	3.9928	0.1815	0.5009	0.0218	1.7568	7.9547	0.7955	8.7502
200	0.7019	0.0323	0.5163	0.0227	3.3719	0.1533	0.4230	0.0184	1.5833	6.5965	0.6596	7.2561
250	0.6227	0.0286	0.4587	0.0202	3.1743	0.1443	0.3982	0.0173	1.5256	6.1796	0.6180	6.7975
300	0.5627	0.0259	0.4150	0.0182	3.0159	0.1371	0.3784	0.0165	1.4782	5.8502	0.5850	6.4352
400	0.4767	0.0219	0.3523	0.0155	2.7730	0.1260	0.3479	0.0151	1.4038	5.3537	0.5354	5.8891

UNIT

AIRFRAME QUANTITY	ENGINEERING COSTS	ENGINEERING HOURS	TOOLING COSTS	TOOLING HOURS	MFG LABOR COSTS	MFG LABOR HOURS	QUALITY CONTROL COSTS	QUALITY CONTROL HOURS	MFG MATERIALS	TOTAL WITHOUT FEE	FEE	TOTAL WITH FEE
10	1.6638	0.0765	1.2103	0.0532	5.1786	0.2354	0.6497	0.0282	2.0609	10.7632	1.0763	11.8395
50	0.8468	0.0389	0.6224	0.0274	3.8011	0.1728	0.4769	0.0207	1.7121	7.4592	0.7459	8.2052
100	0.5473	0.0252	0.4049	0.0178	3.1129	0.1415	0.3905	0.0170	1.5190	5.9746	0.5975	6.5721
200	0.3339	0.0154	0.2488	0.0109	2.4818	0.1128	0.3114	0.0135	1.3264	4.7022	0.4702	5.1725
250	0.2821	0.0130	0.2109	0.0093	2.2985	0.1045	0.2884	0.0125	1.2668	4.3467	0.4347	4.7813
300	0.2456	0.0113	0.1837	0.0081	2.1562	0.0980	0.2705	0.0118	1.2190	4.0750	0.4075	4.4825
400	0.1965	0.0090	0.1480	0.0065	1.9477	0.0885	0.2443	0.0106	1.1470	3.6835	0.3683	4.0518

ENGINE PRODUCTION COSTS

AIRFRAME QUANTITY	ENGINE QUANTITY	<- -CUMULATIVE AVERAGE- -> PROD	RECUR DEV	TOTAL	<- - - - - UNIT - - - - -> PROD	RECUR DEV	TOTAL
10	25	4.9467	1.2777	6.2244	4.8433	1.1217	5.9650
50	125	4.6208	0.8715	5.4923	4.3227	0.5639	4.8865
100	250	4.3823	0.6558	5.0380	4.0025	0.3543	4.3568
200	500	4.0969	0.4610	4.5579	3.6619	0.2070	3.8689
250	625	3.9983	0.4064	4.4048	3.5525	0.1723	3.7248
300	750	3.9162	0.3652	4.2815	3.4639	0.1480	3.6119
400	1000	3.7848	0.3065	4.0912	3.3258	0.1156	3.4414

Fig. 11 — Third page of output for second run

TEST RUN 2 -- DATE OF FIRST FLIGHT: 1958.25, NO PRIOR ENGINE PROCUREMENT

TOTAL AIRCRAFT COSTS
(MILLIONS OF DOLLARS)
(ENGINE PRIOR PROCUREMENT = 0 ; AVIONICS PRIOR PROCUREMENT = 0)

DEVELOPMENT

AIRFRAMES	ENGINES	AVIONICS	TOTAL WITH FEE
1000.3794	528.4102	128.0089	1656.7983

PRODUCTION

AIRFRAME QUANTITY	ENGINE QUANTITY	<- - - CUMULATIVE AVERAGE - - - > AIRFRAMES	ENGINES	AVIONICS	TOTAL WITH FEE	<- - CUMULATIVE TOTALS - -> CUM TOTAL WITHOUT FEE	CUM TOTAL WITH RDTE	(SPARE) (ENGINES)
10	25	12.7834	6.2244	3.6296	22.6374	226.3736	1883.1719	15.5609
50	125	10.2360	5.4923	3.4965	19.2249	961.2463	2618.0447	68.6541
100	250	8.7502	5.0380	3.3999	17.1881	1718.8140	3375.6123	125.9509
200	500	7.2561	4.5579	3.2835	15.0975	3019.4995	4676.2969	227.8951
250	625	6.7975	4.4048	3.2428	14.4451	3611.2825	5268.0781	275.2979
300	750	6.4352	4.2815	3.2087	13.9254	4177.6055	5834.4023	321.1089
400	1000	5.8891	4.0912	3.1537	13.1340	5253.5977	6910.3945	409.1230

UNIT

AIRFRAME QUANTITY	ENGINE QUANTITY	AIRFRAMES	ENGINES	AVIONICS	TOTAL WITH FEE
10	25	11.8395	5.9650	3.5867	21.3913
50	125	8.2052	4.8865	3.3757	16.4674
100	250	6.5721	4.3568	3.2458	14.1748
200	500	5.1725	3.8689	3.1050	12.1464
250	625	4.7813	3.7248	3.0588	11.5650
300	750	4.4825	3.6119	3.0200	11.1144
400	1000	4.0518	3.4414	2.9602	10.4534

Fig. 12 — Fourth page of output for second run

TEST RUN 2 -- DATE OF FIRST FLIGHT: 1958.25, NO PRIOR ENGINE PROCUREMENT

PROGRAM VALUES

1	2	3	4	5	6	7	8	9	10	INDEXES
26.50000	24.25000	23.75000	24.50000	21.75000	22.75000	22.00000	23.00000	2.00000	20.00000	1- 10
10.00000	50.00000	100.00000	200.00000	250.00000	300.00000	400.00000	0.0	0.0	0.0	11- 20
1.00000	25000.00000	1250.00000	2.20000	1958.25000	0.10000	0.56500	0.57000	0.77000	0.85500	21- 30
0.0	2.00000	0.0	0.90000	0.0	0.50000	0.25000	3000.00000	25.00000	3100.00000	31- 40
3500.00000	0.65000	30000.00000	1975.50000	1971.50000	50.00000	5.00000	0.95000	0.0	0.0	41- 50
0.0	0.0	0.0	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	51- 60
1.00000	1.00000	1.00000	0.0	0.0	1.50000	1.25000	1.00000	22.00000	0.17632	61- 70
0.18903	0.62293	0.77400	0.08146	0.84800	0.92600	75000.00000	140.24364	8.24364	7.00000	71- 80
0.69315	62.00000	132.00000	16.00000	0.0	0.0	0.0	0.0	0.0	4.20241	81- 90
12.82720	1.05274	8.28228	2.13709	9.51783	9.92969	63.52863	0.12000	0.00000	7.43759	91-100
4.61729	1.38772	5.80683	6.00000	66.00000	428.24121	5.65708	2.00000	22.00000	8.62479	101-110
7.22954	3.74715	7.38074	1.33535	228.55698	175.31633	88.99486	175.29262	32.71597	42.50916	111-120
53.59894	112.45209	909.43604	90.94356	1000.37939	342.71606	71.26334	114.43112	528.41016	78.00893	121-130
128.00893	1656.79834	602.43262	25.85010	87.50893	495.53760	197.49678	9.50000	92.84723	0.0	131-140
12.78341	10.23605	8.75019	7.25613	6.79755	6.43517	5.88908	0.0	0.0	0.0	141-150
11.83953	8.20515	6.57210	5.17247	4.78132	4.48246	4.05180	0.0	0.0	0.0	151-160
32.00000	72.00000	122.00000	222.00000	272.00000	322.00000	422.00000	0.0	0.0	0.0	161-170
13.70327	15.80964	17.35020	19.28180	19.98489	20.58846	21.59406	0.0	0.0	0.0	171-180
8.89019	10.36300	11.44931	12.82115	13.32301	13.75486	14.47637	0.0	0.0	0.0	181-190
12.02004	19.92006	27.66681	40.17140	45.58997	50.64330	59.93622	0.0	0.0	0.0	191-200
84.90228	159.04031	239.20708	380.19629	444.92480	507.00244	625.05981	0.0	0.0	0.0	201-210
91.00000	191.00000	316.00000	566.00000	691.00000	816.00000	1066.00000	0.0	0.0	0.0	211-220
259.33032	486.29688	745.27954	1221.72168	1446.97510	1666.08301	2089.87964	0.0	0.0	0.0	221-230
618.40356	656.90332	684.40479	717.68335	729.44458	739.39209	755.66528	0.0	0.0	0.0	231-240
4.94668	4.62080	4.38226	4.09690	3.99833	3.91623	3.78477	0.0	0.0	0.0	241-250
1.27768	0.87153	0.65578	0.46100	0.40644	0.36523	0.30647	0.0	0.0	0.0	251-260
6.22436	5.49233	5.03804	4.55790	4.40477	4.28145	4.09123	0.0	0.0	0.0	261-270
62.24358	274.61646	503.80371	911.58032	1101.19189	1284.43628	1636.49219	0.0	0.0	0.0	271-280
15.56089	68.65411	125.95093	227.89508	275.29785	321.10889	409.12305	0.0	0.0	0.0	281-290
4.84333	4.32266	4.00254	3.66191	3.55254	3.46387	3.32578	0.0	0.0	0.0	291-300
1.12168	0.56387	0.35430	0.20703	0.17227	0.14805	0.11562	0.0	0.0	0.0	301-310
5.96501	4.88652	4.35684	3.86895	3.72480	3.61191	3.44141	0.0	0.0	0.0	311-320
32.00000	72.00000	122.00000	222.00000	272.00000	322.00000	422.00000	0.0	0.0	0.0	321-330
123.80486	262.33643	427.50171	744.20313	898.21289	1050.12939	1348.98682	0.0	0.0	0.0	331-340
3.62959	3.49655	3.39993	3.28347	3.24282	3.20873	3.15369	0.0	0.0	0.0	341-350
3.58673	3.37573	3.24585	3.10498	3.05884	3.02002	2.96021	0.0	0.0	0.0	351-360

Fig. 13 — Fifth page of output for second run

TEST RUN 3 -- NO DATE OF FIRST FLIGHT, PRIOR ENGINE PROCUREMENT OF 975 PAGE 11

INPUT LISTING

1	DEVELOPMENT ENGINEERING RATE ($/HOUR)	26.50
2	DEVELOPMENT TOOLING RATE ($/HOUR)	24.25
3	DEVELOPMENT MFG LABOR RATE ($/HOUR)	23.75
4	DEVELOPMENT QUALITY CONTROL RATE ($/HOUR)	24.50
5	PRODUCTION ENGINEERING RATE ($/HOUR)	21.75
6	PRODUCTION TOOLING RATE ($/HOUR)	22.75
7	PRODUCTION MFG LABOR RATE ($/HOUR)	22.00
8	PRODUCTION QUALITY CONTROL RATE ($/HOUR)	23.00
9	NUMBER OF PROTOTYPE AIRCRAFT	2.
10	NUMBER OF FLIGHT-TEST AIRCRAFT	20.
11-17	AIRCRAFT PRODUCTION QUANTITIES	10. 50. 100. 200. 250. 300. 400.
21	AIRCRAFT TYPE (NONCARGO: 1, CARGO: 2)	1.
22	AIRFRAME UNIT WEIGHT (POUNDS)	25000.
23	MAXIMUM SPEED AT BEST ALTITUDE (KNOTS)	1250.
24	MAXIMUM SPEED AT BEST ALTITUDE (MACH NO.)	2.200
25	DATE OF FIRST FLIGHT (CALENDAR YEAR AND QUARTER)	0.0
26	AIRFRAME COST FEE (DECIMAL)	0.100
27	ENGINEERING CUM AVG PRODUCTION CURVE SLOPE (DECIMAL)	0.565
28	TOOLING CUM AVG PRODUCTION CURVE SLOPE (DECIMAL)	0.570
29	MANUFACTURING LABOR CUM AVG PRODUCTION CURVE SLOPE (DECIMAL)	0.770
30	MANUFACTURING MATERIALS CUM AVG PRODUCTION CURVE SLOPE (DECIMAL)	0.855
31	QUALITY CONTROL FACTOR (DECIMAL)	0.0
32	NUMBER OF ENGINES PER AIRCRAFT	2.
33	ENGINE PRIOR PROCUREMENT QUANTITY	975.
34	ENGINE CUM AVG PRODUCTION CURVE SLOPE (DECIMAL)	0.900
35	ENGINE MQT DEVELOPMENT THROUGHPUT COST	0.0
36	ENGINE PROTOTYPE AND FLIGHT-TEST SPARES FACTOR (DECIMAL)	0.500
37	ENGINE PRODUCTION SPARES FACTOR (DECIMAL)	0.250
38	MAXIMUM DYNAMIC PRESSURE IN-FLIGHT ENVELOPE (LB/SQ FT)	3000.000
39	ENGINE PRESSURE RATIO	25.000
40	MAXIMUM TURBINE INLET TEMPERATURE (DEGREES RANKINE)	3100.
41	WEIGHT OF ENGINE AT CONFIGURATION OF INTEREST (POUNDS)	3500.
42	SPECIFIC FUEL CONSUMPTION AT MILITARY THRUST, SEA-LEVEL STATIC (LB/HR/LB THRUST)	0.650
43	MAXIMUM THRUST PER ENGINE, INCLUDING AFTERBURNER (POUNDS)	30000.
44	DATE OF PLANNED MQT (CALENDAR YEAR AND QUARTER)	1975.50
45	DATE OF START OF ENGINE DEVELOPMENT (CALENDAR YEAR AND QUARTER)	1971.50
46	AVIONICS DEVELOPMENT THROUGHPUT COST	50.000
47	AVIONICS FIRST-UNIT PRODUCTION THROUGHPUT COST	5.000
48	AVIONICS CUM AVG PRODUCTION CURVE SLOPE (DECIMAL)	0.950
49	AVIONICS SPARES FACTOR (DECIMAL)	0.0
50	AVIONICS PRIOR PROCUREMENT QUANTITY	0.
51	AIRFRAME SKIP DESIGNATOR	0.
52	ENGINE SKIP DESIGNATOR	0.
53	AVIONICS SKIP DESIGNATOR	0.

ADJUSTMENT FACTORS

54	ENGINEERING HOURS	1.	55	TOOLING HOURS	1.
56	NONRECUR MFG LABOR HOURS	1.	57	RECUR MFG LABOR HOURS	1.
58	NONRECUR MFG MATERIALS COST	1.	59	RECUR MFG MATERIALS COST	1.
60	FLIGHT-TEST COST	1.	61	ENGINE DEVELOPMENT COST	1.
62	ENGINE PRODUCTION COST	1.			

Fig. 14 — First page of output for third run

TEST RUN 3 -- NO DATE OF FIRST FLIGHT, PRIOR ENGINE PROCUREMENT OF 975

DEVELOPMENT COSTS

	COSTS (MILLIONS $)	HOURS (MILLIONS)
AIRFRAMES		
ENGINEERING	228.557	8.625
TOOLING	175.316	7.230
NONRECURRING MFG LABOR	88.995	3.747
RECURRING MFG LABOR	161.063	6.782
QUALITY CONTROL	30.954	1.263
NONRECURRING MFG MATERIALS	42.509	
RECURRING MFG MATERIALS	58.340	
FLIGHT TEST	112.452	
TOTAL AIRFRAME WITHOUT FEE	898.186	
FEE	89.819	
TOTAL AIRFRAME WITH FEE	988.004	
ENGINES		
MQT DEVELOPMENT	0.0	
RECURRING DEVELOPMENT	2.426	
PRODUCTION	67.038	
TOTAL ENGINES	69.464	
AVIONICS		
DEVELOPMENT	50.000	
PRODUCTION	78.009	
TOTAL AVIONICS	128.009	
TOTAL DEVELOPMENT COST	1185.476	
(COST OF SPARE ENGINES FOR FLIGHT-TEST AIRCRAFT	34.732)	

Fig. 15 — Second page of output for third run

TEST RUN 3 -- NO DATE OF FIRST FLIGHT, PRIOR ENGINE PROCUREMENT OF 975

AIRFRAME PRODUCTION COSTS AND HOURS
(ALL COSTS AND HOURS IN MILLIONS)
- - FEE = 0.100 - -

CUMULATIVE AVERAGE

AIRFRAME QUANTITY	ENGINEERING COSTS	ENGINEERING HOURS	TOOLING COSTS	TOOLING HOURS	MFG LABOR COSTS	MFG LABOR HOURS	QUALITY CONTROL COSTS	QUALITY CONTROL HOURS	MFG MATERIALS	TOTAL WITHOUT FEE	FEE	TOTAL WITH FEE
10	1.9055	0.0876	1.3830	0.0608	5.0580	0.2299	0.6345	0.0276	2.3264	11.3074	1.1307	12.4382
50	1.2974	0.0596	0.9467	0.0416	4.2054	0.1912	0.5276	0.0229	2.0792	9.0563	0.9056	9.9620
100	0.9838	0.0452	0.7205	0.0317	3.6687	0.1668	0.4602	0.0200	1.9122	7.7453	0.7745	8.5139
200	0.7019	0.0323	0.5163	0.0227	3.0982	0.1408	0.3887	0.0169	1.7234	6.4285	0.6428	7.0713
250	0.6227	0.0286	0.4587	0.0202	2.9167	0.1326	0.3659	0.0159	1.6605	6.0245	0.6025	6.6270
300	0.5627	0.0259	0.4150	0.0182	2.7710	0.1260	0.3476	0.0151	1.6090	5.7054	0.5705	6.2759
400	0.4767	0.0219	0.3523	0.0155	2.5479	0.1158	0.3196	0.0139	1.5280	5.2245	0.5225	5.7470

UNIT

AIRFRAME QUANTITY	ENGINEERING COSTS	ENGINEERING HOURS	TOOLING COSTS	TOOLING HOURS	MFG LABOR COSTS	MFG LABOR HOURS	QUALITY CONTROL COSTS	QUALITY CONTROL HOURS	MFG MATERIALS	TOTAL WITHOUT FEE	FEE	TOTAL WITH FEE
10	1.6638	0.0765	1.2103	0.0532	4.7582	0.2163	0.5969	0.0260	2.2432	10.4724	1.0472	11.5196
50	0.8468	0.0389	0.6224	0.0274	3.4929	0.1588	0.4382	0.0191	1.8636	7.2638	0.7264	7.9902
100	0.5473	0.0252	0.4049	0.0178	2.8604	0.1300	0.3589	0.0156	1.6536	5.8250	0.5825	6.4075
200	0.3339	0.0154	0.2488	0.0109	2.2804	0.1037	0.2861	0.0124	1.4436	4.5928	0.4593	5.0520
250	0.2821	0.0130	0.2109	0.0093	2.1122	0.0960	0.2650	0.0115	1.3792	4.2493	0.4249	4.6742
300	0.2456	0.0113	0.1837	0.0081	1.9809	0.0900	0.2485	0.0108	1.3267	3.9854	0.3985	4.3840
400	0.1965	0.0090	0.1480	0.0065	1.7896	0.0813	0.2245	0.0098	1.2485	3.6071	0.3607	3.9678

ENGINE PRODUCTION COSTS

AIRFRAME QUANTITY	ENGINE QUANTITY	<- -CUMULATIVE AVERAGE- -> PROD	RECUR DEV	TOTAL	<- - - - - UNIT - - - - -> PROD	RECUR DEV	TOTAL
10	25	3.3311	0.1167	3.4478	3.3258	0.1156	3.4414
50	125	3.3079	0.1120	3.4199	3.2816	0.1066	3.3883
100	250	3.2811	0.1067	3.3878	3.2307	0.0971	3.3277
200	500	3.2332	0.0980	3.3311	3.1445	0.0824	3.2270
250	625	3.2115	0.0942	3.3058	3.1061	0.0768	3.1828
300	750	3.1912	0.0909	3.2821	3.0760	0.0719	3.1479
400	1000	3.1539	0.0850	3.2389	3.0129	0.0637	3.0766

Fig. 16—Third page of output for third run

TEST RUN 3 -- NO DATE OF FIRST FLIGHT, PRIOR ENGINE PROCUREMENT OF 975

TOTAL AIRCRAFT COSTS
(MILLIONS OF DOLLARS)
(ENGINE PRIOR PROCUREMENT = 975 ; AVIONICS PRIOR PROCUREMENT = 0)

DEVELOPMENT

AIRFRAMES	ENGINES	AVIONICS	TOTAL WITH FEE
988.0042	69.4635	128.0089	1185.4763

PRODUCTION

AIRFRAME QUANTITY	ENGINE QUANTITY	AIRFRAMES (CUMULATIVE AVERAGE)	ENGINES (CUMULATIVE AVERAGE)	AVIONICS (CUMULATIVE AVERAGE)	TOTAL WITH FEE (CUMULATIVE AVERAGE)	CUM TOTAL WITHOUT FEE (CUMULATIVE TOTALS)	CUM TOTAL WITH RDTE (CUMULATIVE TOTALS)	(SPARE) (ENGINES)
10	25	12.4382	3.4478	3.6296	19.5155	195.1553	1380.6316	8.6195
50	125	9.9620	3.4199	3.4965	16.8784	843.9177	2029.3940	42.7482
100	250	8.5199	3.3878	3.3999	15.3076	1530.7588	2716.2351	84.6948
200	500	7.0713	3.3311	3.2835	13.6859	2737.1807	3922.6570	166.5556
250	625	6.6270	3.3058	3.2428	13.1756	3293.8943	4479.3672	206.6115
300	750	6.2759	3.2821	3.2087	12.7668	3830.0291	5015.5039	246.1580
400	1000	5.7470	3.2389	3.1537	12.1396	4855.8359	6041.3086	323.8904

UNIT

AIRFRAME QUANTITY	ENGINE QUANTITY	AIRFRAMES	ENGINES	AVIONICS	TOTAL WITH FEE
10	25	11.5196	3.4414	3.5867	18.5477
50	125	7.9902	3.3883	3.3757	14.7542
100	250	6.4075	3.3277	3.2458	12.9811
200	500	5.0520	3.2270	3.1050	11.3840
250	625	4.6742	3.1828	3.0588	10.9159
300	750	4.3840	3.1479	3.0200	10.5518
400	1000	3.9678	3.0766	2.9602	10.0045

Fig. 17 — Fourth page of output for third run

TEST RUN 3 -- NO DATE OF FIRST FLIGHT, PRIOR ENGINE PROCUREMENT OF 975

PROGRAM VALUES

1	2	3	4	5	6	7	8	9	10	INDEXES
26.50000	24.25000	23.75000	24.50000	21.75000	22.75000	22.00000	23.00000	2.00000	20.00000	1- 10
10.00000	50.00000	100.00000	200.00000	250.00000	300.00000	400.00000	0.0	0.0	0.0	11- 20
1.00000	25000.00000	1250.00000	2.20000	0.0	0.10000	0.56500	0.57000	0.77000	0.85500	21- 30
0.0	2.00000	975.00000	0.90000	0.0	0.50000	0.25000	3000.00000	25.00000	3100.00000	31- 40
3500.00000	0.65000	30000.00000	1975.50000	1971.50000	50.00000	5.00000	0.95000	0.0	0.0	41- 50
0.0	0.0	0.0	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	51- 60
1.00000	1.00000	1.00000	0.0	0.0	1.50000	1.25000	1.00000	22.00000	0.17632	61- 70
0.18903	0.62293	0.77400	0.08146	0.84800	0.92600	75000.00000	140.24364	8.24364	7.00000	71- 80
0.69315	0.0	132.00000	16.00000	0.0	0.0	0.0	0.0	0.0	4.20241	81- 90
12.82720	1.05274	8.28228	1.96361	8.74521	10.80802	69.14809	0.12000	0.00000	7.43759	91-100
4.61729	1.27507	6.32048	981.00000	1041.00000	428.24121	5.65708	2.00000	22.00000	8.62479	101-110
7.22954	3.74715	6.78160	1.26345	228.55698	175.31633	88.99486	161.06293	30.95448	42.50916	111-120
58.34006	112.45209	898.18579	89.81854	988.00415	0.0	2.42562	67.03792	69.46353	78.00893	121-130
128.00893	1185.47632	754.20605	1947.68457	87.50893	750.56763	2048.24146	9.50000	34.73177	0.0	131-140
12.43816	9.96195	8.51987	7.07132	6.62698	6.27592	5.74699	0.0	0.0	0.0	141-150
11.51962	7.99023	6.40755	5.05203	4.67420	4.38396	3.96777	0.0	0.0	0.0	151-160
32.00000	72.00000	122.00000	222.00000	272.00000	322.00000	422.00000	0.0	0.0	0.0	161-170
13.70327	15.80964	17.35020	19.28180	19.98489	20.58846	21.59406	0.0	0.0	0.0	171-180
8.89019	10.36300	11.44931	12.82115	13.32301	13.75486	14.47637	0.0	0.0	0.0	181-190
11.04429	18.30302	25.42091	36.91042	41.88913	46.53223	55.07079	0.0	0.0	0.0	191-200
92.41237	173.10832	260.36621	413.82666	484.28101	551.84961	680.34985	0.0	0.0	0.0	201-210
1066.00000	1166.00000	1291.00000	1541.00000	1666.00000	1791.00000	2041.00000	0.0	0.0	0.0	211-220
2089.87364	2254.98340	2458.37598	2856.53198	3051.84790	3244.94824	3625.17578	0.0	0.0	0.0	221-230
755.66528	761.20532	767.54614	778.69385	783.65723	788.28931	796.72437	0.0	0.0	0.0	231-240
3.33105	3.30787	3.28107	3.23316	3.21154	3.19122	3.15387	0.0	0.0	0.0	241-250
0.11674	0.11199	0.10672	0.09795	0.09424	0.09089	0.08504	0.0	0.0	0.0	251-260
3.44779	3.41986	3.38779	3.33111	3.30578	3.28211	3.23890	0.0	0.0	0.0	261-270
34.47792	170.99297	338.77930	666.22241	826.44580	984.63184	1295.56201	0.0	0.0	0.0	271-280
8.61948	42.74823	84.69482	166.55560	206.61145	246.15796	323.89038	0.0	0.0	0.0	281-290
3.32578	3.28164	3.23066	3.14453	3.10605	3.07598	3.01289	0.0	0.0	0.0	291-300
0.11562	0.10664	0.09707	0.08242	0.07676	0.07187	0.06367	0.0	0.0	0.0	301-310
3.44141	3.38828	3.32773	3.22695	3.18281	3.14785	3.07656	0.0	0.0	0.0	311-320
32.00000	72.00000	122.00000	222.00000	272.00000	322.00000	422.00000	0.0	0.0	0.0	321-330
123.80486	262.33643	427.50171	744.20313	898.21289	1050.12939	1348.98682	0.0	0.0	0.0	331-340
3.62959	3.49655	3.39993	3.28347	3.24282	3.20873	3.15369	0.0	0.0	0.0	341-350
3.38673	3.37573	3.24585	3.10498	3.05884	3.02002	2.96021	0.0	0.0	0.0	351-360

Fig. 18—Fifth page of output for third run

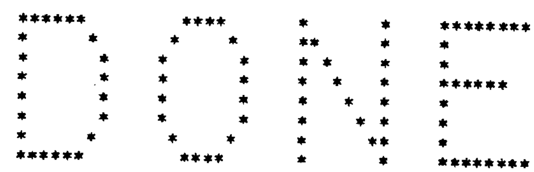

Fig. 19 — Termination statement

Appendix A

DAPCA-III PROGRAM VARIABLES

DAPCA-III PROGRAM VARIABLES
(ALL YEARS ARE CALENDAR YEARS)
(ALL COSTS EXCEPT RATES ARE IN MILLIONS OF DOLLARS)

INPUT VARIABLES

001	DEVELOPMENT ENGINEERING RATE (1975 $/HR) -- DEFAULT: $26.50
002	DEVELOPMENT TOOLING RATE (1975 $/HR) -- DEFAULT: $24.25
003	DEVELOPMENT MFG LABOR RATE (1975 $/HR) -- DEFAULT: $23.75
004	DEVELOPMENT QUALITY CONTROL RATE (1975 $/HR) -- DEFAULT: $24.50
005	PRODUCTION ENGINEERING RATE (1975 $/HR) -- DEFAULT: $21.75
006	PRODUCTION TOOLING RATE (1975 $/HR) -- DEFAULT: $22.75
007	PRODUCTION MFG LABOR RATE (1975 $/HR) -- DEFAULT: $22.00
008	PRODUCTION QUALITY CONTROL RATE (1975 $/HR) -- DEFAULT: $23.00
009	NUMBER OF PROTOTYPE AIRCRAFT
010	NUMBER OF FLIGHT-TEST AIRCRAFT
011-020	AIRFRAME PRODUCTION QUANTITIES
021	AIRCRAFT TYPE (NONCARGO=1, CARGO=2)
022	AIRFRAME UNIT WEIGHT (POUNDS)
023	MAXIMUM SPEED AT BEST ALTITUDE (KNOTS)
024	MAXIMUM SPEED AT BEST ALTITUDE (MACH NUMBER)
025	DATE OF FIRST FLIGHT (YEAR AND QUARTER; E.G., 1971.25) -- OPTIONAL
026	AIRFRAME COST FEE (DECIMAL) -- DEFAULT: .1
027	ENGINEERING CUM AVG CURVE SLOPE (DECIMAL) -- DEFAULT: .565
028	TOOLING CUM AVG CURVE SLOPE (DECIMAL) -- DEFAULT: .57
029	MFG LABOR CUM AVG CURVE SLOPE (DECIMAL) -- DEFAULT: .77
030	MFG MATERIALS CUM AVG CURVE SLOPE (DECIMAL) -- DEFAULT: .855
031	QUALITY CONTROL FACTOR (DECIMAL) -- DEFAULT: CARGO=.085, NONCARGO=.12
032	NUMBER OF ENGINES PER AIRCRAFT
033	ENGINE PRIOR PROCUREMENT QUANTITY
034	ENGINE CUM AVG PRODUCTION CURVE SLOPE (DECIMAL) -- DEFAULT: .9
035	ENGINE MQT DEVELOPMENT THROUGHPUT COST
036	ENGINE FLIGHT-TEST SPARES FACTOR (DECIMAL) -- DEFAULT: .5
037	ENGINE PRODUCTION SPARES FACTOR (DECIMAL) -- DEFAULT: .25
038	MAXIMUM DYNAMIC PRESSURE IN FLIGHT ENVELOPE (LB/SQ FT)
039	PRESSURE RATIO
040	MAXIMUM TURBINE INLET TEMPERATURE (DEGREES RANKINE)
041	WEIGHT OF ENGINE AT CONFIGURATION OF INTEREST (POUNDS)
042	SPECIFIC FUEL CONSUMPTION AT MIL THRUST, SEA-LEVEL STATIC (LB/HR/LB)
043	MAXIMUM THRUST INCLUDING AFTEBURNER -- SEA-LEVEL STATIC (POUNDS)
044	PLANNED DATE OF MQT (YEAR AND QUARTER; E.G., 1971.25)
045	STARTING DATE OF ENGINE DEVELOPMENT (YEAR AND QUARTER; E.G., 1966.75)
046	AVIONICS DEVELOPMENT THROUGHPUT COST
047	AVIONICS FIRST-UNIT PRODUCTION COST
048	AVIONICS PRODUCTION CUM AVG CURVE SLOPE (DECIMAL) -- DEFAULT: .95
049	AVIONICS SPARES FACTOR (DECIMAL) -- DEFAULT: 0
050	AVIONICS PRIOR PROCUREMENT QUANTITY
051	AIRFRAME SKIP DESIGNATOR (SKIP: 1; OTHERWISE: 0)
052	ENGINE SKIP DESIGNATOR (SKIP: 1; OTHERWISE: 0)
053	AVIONICS SKIP DESIGNATOR (SKIP: 1; OTHERWISE: 0)
054	ENGINEERING HOURS ADJUSTMENT FACTOR -- DEFAULT: 1.0
055	TOOLING HOURS ADJUSTMENT FACTOR -- DEFAULT: 1.0
056	NONRECURRING MFG LABOR HOURS ADJUSTMENT FACTOR -- DEFAULT: 1.0
057	RECURRING MFG LABOR HOURS ADJUSTMENT FACTOR -- DEFAULT: 1.0
058	NONRECURRING MFG MATERIALS COST ADJUSTMENT FACTOR -- DEFAULT: 1.0
059	RECURRING MFG MATERIALS COST ADJUSTMENT FACTOR -- DEFAULT: 1.0
060	FLIGHT-TEST COST ADJUSTMENT FACTOR -- DEFAULT: 1.0
061	ENGINE MQT DEVELOPMENT COST ADJUSTMENT FACTOR -- DEFAULT: 1.0
062	ENGINE PRODUCTION COST ADJUSTMENT FACTOR -- DEFAULT: 1.0

063	DUMP DESIGNATOR (PRINT ALL PROGRAM VARIABLES: 1; OTHERWISE: 0)
064	CLEAR DESIGNATOR (INITIALIZE ALL PROGRAM VARIABLES: 1; OTHERWISE: 0))
065	NOT USED

OUTPUT VARIABLES

066	1.+F(36)
067	1.+F(37)
068	1.+F(49)
069	PROTOTYPE PLUS FLIGHT-TEST AIRCRAFT
070	B+1 VALUE FOR CUMULATIVE ENGINEERING LEARNING CURVE
071	B+1 VALUE FOR CUMULATIVE TOOLING LEARNING CURVE
072	B+1 VALUE FOR CUMULATIVE RECURRING MFG LABOR LEARNING CURVE
073	B+1 VALUE FOR CUMULATIVE RECURRING MFG MATERIALS LEARNING CURVE
074	B+1 VALUE FOR ENGINE CUMULATIVE DEVELOPMENT LEARNING CURVE
075	B+1 VALUE FOR ENGINE CUMULATIVE PRODUCTION LEARNING CURVE
076	B+1 VALUE FOR AVIONICS CUMULATIVE PRODUCTION LEARNING CURVE
077	PRESSURE TERM FOR TURBOJET ENGINES -- F(38)*F(39)
078	CALCULATED TIME OF ARRIVAL FOR TURBOJET ENGINES (QUARTERS FROM 1943.50)
079	DIFFERENCE IN CALCULATED AND PLANNED TOA'S FOR TURBOJET ENGINES
080	NUMBER OF AIRFRAME PRODUCTION QUANTITIES
081	NATURAL LOGARITHM OF 2
082	TIME OF FIRST FLIGHT IN QUARTERS BEGINNING WITH FIRST QUARTER 1943
083	TIME OF ARRIVAL TO MQT IN QUARTERS BEGINNING WITH FOURTH QUARTER 1943
084	DEVELOPMENT TIME TO MQT IN QUARTERS
085-089	NOT USED
090	ENGINEERING HOURS FOR PROTOTYPE AIRCRAFT
091	ENGINEERING HOURS FOR PROTOTYPE + FLIGHT-TEST AIRCRAFT
092	TOOLING HOURS FOR PROTOTYPE AIRCRAFT
093	TOOLING HOURS FOR PROTOTYPE + FLIGHT-TEST AIRCRAFT
094	RECURRING MFG LABOR HOURS FOR PROTOTYPE AIRCRAFT
095	RECURRING MFG LABOR HOURS FOR PROTOTYPE + FLIGHT-TEST AIRCRAFT
096	RECURRING MFG MATERIALS COST FOR PROTOTYPE AIRCRAFT
097	RECURRING MFG MATERIALS COST FOR PROTOTYPE + FLIGHT-TEST AIRCRAFT
098	QUALITY CONTROL FACTOR
099	SCALE FACTOR TO CONVERT FROM UNITS TO MILLIONS (.000001)
100	INITIAL ENGINEERING HOURS
101	INITIAL TOOLING HOURS
102	INITIAL MANUFACTURING LABOR HOURS
103	INITIAL MANUFACTURING MATERIALS COST
104	TOTAL ENGINE QUANTITY (PRIOR + ENGINES FOR PROTOTYPE AIRCRAFT)
105	TOTAL ENGINE QUANTITY (PRIOR + ENGINES FOR PROTOTYPE AND FT ACFT)
106	INITIAL ENGINE DEVELOPMENT COST
107	INITIAL ENGINE PRODUCTION COST
108	TOTAL AVIONICS PKGS (PRIOR + AVIONICS FOR PROTO ACFT, INCL SPARE AV)
109	TOTAL AVIONICS PKGS (PRIOR + AV FOR PROTO AND FT ACFT, INCL SPARE AV)
110	ENGINEERING HOURS FOR FLIGHT-TEST AIRCRAFT
111	TOOLING HOURS FOR FLIGHT-TEST AIRCRAFT
112	NONRECURRING MFG LABOR HOURS
113	RECURRING MFG LABOR HOURS FOR FLIGHT-TEST AIRCRAFT
114	QUALITY CONTROL HOURS FOR FLIGHT-TEST AIRCRAFT
115	ENGINEERING COST FOR FLIGHT-TEST AIRCRAFT
116	TOOLING COST FOR FLIGHT-TEST AIRCRAFT
117	NONRECURRING MFG LABOR COST
118	RECURRING MFG LABOR COST FOR FLIGHT-TEST AIRCRAFT
119	QUALITY CONTROL COST FOR FLIGHT-TEST AIRCRAFT
120	NONRECURRING MFG MATERIALS COST
121	RECURRING MFG MATERIALS COST FOR FLIGHT-TEST AIRCRAFT
122	FLIGHT-TEST COST

123	TOTAL AIRFRAME DEVELOPMENT COST WITHOUT FEE
124	AIRFRAME FEE
125	TOTAL AIRFRAME DEVELOPMENT COST WITH FEE
126	MQT DEVELOPMENT COST FOR ENGINES
127	ENGINE RECURRING DEVELOPMENT FLYAWAY COST FOR FLIGHT-TEST AIRCRAFT
128	ENGINE PRODUCTION FLYAWAY COST FOR FLIGHT-TEST AIRCRAFT
129	TOTAL ENGINE DEVELOPMENT FLYAWAY COST
130	AVIONICS PRODUCTION FLYAWAY COST FOR FLIGHT-TEST AIRCRAFT
131	TOTAL AVIONICS DEVELOPMENT FLYAWAY COST
132	TOTAL AIRCRAFT DEVELOPMENT FLYAWAY COST WITH FEE
133	TOTAL DEV COST OF PRIOR ENGINES + ENG FOR PROTO+FT, INCL SPARE ENGINES
134	PROD COST OF PRIOR ENGINES AND ENG FOR PROTO ACFT, INCL SPARE ENGINES
135	PROD COST OF AVIONICS FOR PROTOTYPE AND FT ACFT, INCL SPARE AVIONICS
136	TOTAL DEV COST OF PRIOR ENGINES + ENGINES FOR PROTO, INCL SPARE ENGINES
137	PROD COST OF PRIOR ENGINES AND ENGINES FOR PROTO+FT, INCL SPARE ENGINES
138	PRODUCTION COST OF AVIONICS FOR PROTOTYPE ACFT, INCL SPARE AVIONICS
139	COST OF SPARE ENGINES FOR FLIGHT-TEST AIRCRAFT
140	NOT USED
141-150	AIRFRAME CUMULATIVE AVERAGE PRODUCTION COST WITH FEE
151-160	AIRFRAME UNIT PRODUCTION COST WITH FEE
161-170	TOTAL AIRFRAME QUANTITY (PROTOTYPE + FLIGHT TEST + PRODUCTION)
171-180	TOTAL ENGINEERING HOURS (PROTOTYPE + FLIGHT TEST + PRODUCTION)
181-190	TOTAL TOOLING HOURS (PROTOTYPE + FLIGHT TEST + PRODUCTION)
191-200	TOTAL RECUR MFG LABOR HOURS (PROTOTYPE + FLIGHT TEST + PRODUCTION)
201-210	TOTAL RECUR MFG MATERIALS COST (PROTOTYPE + FLIGHT TEST + PRODUCTION)
211-220	TOTAL ENGINE QUANT (PRIOR+ENGINES FOR PROTO,FT,PROD,INCL SPARE ENGINES)
221-230	TOTAL PROD COST OF PRIOR ENGINES + ENG FOR PROTO,FT,PROD ACFT+SPARE ENG
231-240	TOTAL DEV COST OF PRIOR ENGINES + ENG FOR PROTO,FT,PROD ACFT+SPARE ENG
231-240	TOTAL DEV COST OF ENGINES FOR PROTO,FT,PROD ACFT, INCL SPARE ENGINES
241-250	CUM AVG PRODUCTION FLYAWAY COST FOR ENGINES ON PRODUCTION AIRCRAFT
251-260	CUM AVG RECUR DEV FLYAWAY COST FOR ENGINES ON PRODUCTION AIRCRAFT
261-270	SUM OF CUM AVG PROD + RECUR DEV FLYAWAY COSTS FOR ENGINES ON PROD ACFT
271-280	TOTAL FLYAWAY COST FOR ENGINES ON PRODUCTION AIRCRAFT
281-290	COST OF SPARE ENGINES FOR PRODUCTION AIRCRAFT
291-300	UNIT PRODUCTION FLYAWAY COST FOR ENGINES ON PRODUCTION AIRCRAFT
301-310	UNIT RECURRING DEVELOPMENT FLYAWAY COST FOR ENGINES ON PRODUCTION ACFT
311-320	SUM OF UNIT PROD AND RECUR DEV FLYAWAY COSTS FOR ENGINES ON PROD ACFT
321-330	TOTAL AVIONICS QUANT (PRIOR+AV FOR PROTO,FT,PROD ACFT,INCL SPARE AV)
331-340	TOTAL PROD COST OF AVIONICS FOR PROTO,FT,PROD ACFT,INCL SPARE AVIONICS
341-350	CUMULATIVE AVERAGE FLYAWAY COST FOR AVIONICS
351-360	UNIT FLYAWAY COST FOR AVIONICS

Appendix B

DAPCA-III FORTRAN-IV COMPUTER PROGRAM

```
C      A COMPUTER MODEL FOR ESTIMATING DEVELOPMENT AND PROCUREMENT
C       COSTS OF AIRCRAFT (DAPCA-III), RAND REPORT R-1854-PR,
C       BY H.E. BOREN, JR., OCTOBER 1975
C
       COMMON     F(360), TITLE(20), IQ(10), IQE(10), INDT, N, NPAGE
C
C      SET PAGE NUMBER TO 1.
   10 NPAGE = 1
C      NATURAL LOGARITHM OF 2
       F81 = ALOG(2.)
C      SCALE FACTOR TO CONVERT UNITS TO MILLIONS
       F99 = .000001
C      PRINT HEADING.
       WRITE (6, 20)
   20 FORMAT (1H1, T47, 'DAPCA-III COMPUTER PROGRAM (OCTOBER 1975)' )
   30 CALL START
C      CLEAR ALL OUTPUT VARIABLES.
   40 DO 50 I = 66, 360
       F(I) = 0.
   50 CONTINUE
C      RESTORE VALUES OF F(81) AND F(99).
       F(81) = F81
       F(99) = F99
       CALL READ
       CALL LIST
       CALL CALC
       CALL DEVCO
       CALL AIRF
       CALL TOTAL
   60 IF (F(63) .EQ. 1.) CALL DUMP
       IF (INDT .EQ. 999) GO TO 70
       IF (F(64) - 1.) 40, 30, 40
C      WRITE TERMINATION STATEMENT AND STOP.
   70 WRITE (6, 80)
   80 FORMAT (1H1 / 10(1H0/),
     1 44X, '******       ****     *      *   ********' /
     2 44X, '*     *     *    *    **     *   *       ' /
     3 44X, '*      *   *      *   * *    *   *       ' /
     4 44X, '*      *   *      *   *  *   *   ******  ' /
     5 44X, '*      *   *      *   *   *  *   *       ' /
     6 44X, '*      *   *      *   *    * *   *       ' /
     7 44X, '*     *     *    *    *     **   *       ' /
     8 44X, '******       ****     *      *   ********' )
      STOP
      END
```

```
      SUBROUTINE START
      COMMON     F(360), TITLE(20), IQ(10), IQE(10), INDT, N, NPAGE
C
C     SUBROUTINE FOR INITIALIZING INPUTS
C
C     CLEAR MOST OF INPUT VARIABLES.
   10 DO 20 I = 9, 53
      F(I) = 0.
   20 CONTINUE
      F(65) = 0.
C
C     SET DEFAULT VALUES.
C
C     DEVELOPMENT ENGINEERING RATE
      F(1) = 26.50
C     DEVELOPMENT TOOLING RATE
      F(2) = 24.25
C     DEVELOPMENT MANUFACTURING LABOR RATE
      F(3) = 23.75
C     DEVELOPMENT QUALITY CONTROL RATE
      F(4) = 24.50
C     PRODUCTION ENGINEERING RATE
      F(5) = 21.75
C     PRODUCTION TOOLING RATE
      F(6) = 22.75
C     PRODUCTION MANUFACTURING LABOR RATE
      F(7) = 22.00
C     PRODUCTION QUALITY CONTROL RATE
      F(8) = 23.00
C     AIRFRAME COST FEE
      F(26) = 0.1
C     ENGINEERING CUM AVG PRODUCTION CURVE SLOPE
      F(27) = .565
C     TOOLING CUM AVG PRODUCTION CURVE SLOPE
      F(28) = .57
C     MFG LABOR CUM AVG PRODUCTION CURVE SLOPE
      F(29) = .77
C     MFG MATERIALS CUM AVG PRODUCTION CURVE SLOPE
      F(30) = .855
C     ENGINE CUM AVG PRODUCTION CURVE SLOPE
      F(34) = .9
C     ENGINE FLIGHT-TEST SPARES FACTOR
      F(36) = 0.5
C     ENGINE PRODUCTION SPARES FACTOR
      F(37) = 0.25
C     AVIONICS CUM AVG PRODUCTION CURVE SLOPE
      F(48) = .95
C     ADJUSTMENT FACTORS
      DO 120 I = 54, 62
      F(I) = 1.0
  120 CONTINUE
C     SET CLEAR AND DUMP DESIGNATORS TO ZERO.
      F(63) = 0.
      F(64) = 0.
      RETURN
      END
```

```
      SUBROUTINE READ
      COMMON    F(360), TITLE(20), IQ(10), IQE(10), INDT, N, NPAGE
      DIMENSION  FDATA(6), INDEX(6)
C
C     SUBROUTINE FOR READING INPUT DATA
C
C     READ TITLE FOR RUN.  TITLE IS ENTERED IN COLUMNS 1 THROUGH 72 AS
C      REQUIRED.
   10 READ (5, 20) TITLE
   20 FORMAT (20A4)
      I = 0
C     READ INPUT DATA.
   30 READ (5, 40) (INDEX(K), FDATA(K), K = 1, 6)
   40 FORMAT (6(I3, F8.0, 1X))
      DO 50 K = 1, 6
      IF (INDEX(K) .EQ. 0 .AND. FDATA(K) .EQ. 0.) GO TO 50
      IF (INDEX(K) .LT. 1 .OR. INDEX(K) .GT. 64) GO TO 60
      I = INDEX(K)
      F(I) = FDATA(K)
   50 CONTINUE
      GO TO 30
   60 INDT = INDEX(K)
      IF (INDT .EQ. 555 .OR. INDT .EQ. 999) GO TO 70
C     WRITE ERROR MESSAGE AND STOP.
      WRITE (6, 160) TITLE, NPAGE, I
      STOP
C     PRINT TITLE AND PAGE NUMBER.
   70 IF (NPAGE .EQ. 1) WRITE (6, 80) TITLE, NPAGE
   80 FORMAT (1H0, T6, 20A4, T122, 'PAGE ', I4)
      IF (NPAGE .GT. 1) WRITE (6, 90) TITLE, NPAGE
   90 FORMAT (1H1/ T6, 20A4, T122, 'PAGE ', I4)
C     STEP PAGE NUMBER BY 1.
      NPAGE = NPAGE + 1
C     QUALITY CONTROL FACTOR
      F(98) = .12
      IF (F(21) .EQ. 2.) F(98) = .085
      IF (F(31) .GT. 0.) F(98) = F(31)
C     SET DEVELOPMENT COST THROUGH MQT TO THROUGHPUT VALUE.
      IF (F(52) .NE. 1.) F(126) = F(35)
C     CHECK CRITICAL INPUTS.
      IF (F(51) .EQ. 1.) GO TO 110
      IF (F(22) .GT. 0.) GO TO 100
      WRITE (6, 170)
      STOP
  100 IF (F(23) .GT. 0.) GO TO 110
      WRITE (6, 180)
      STOP
  110 IF (F(52) .EQ. 1.) GO TO 130
      IF (F(24) .GT. 0.) GO TO 120
      WRITE (6, 190)
      STOP
  120 IF (F(32) .GT. 0.) GO TO 130
      WRITE (6, 200)
      STOP
C     DETERMINE HOW MANY AIRCRAFT PRODUCTION QUANTITIES HAVE BEEN
C      ENTERED.
  130 DO 140 I = 11, 20
      IF (F(I)  .EQ. 0.) GO TO 150
C     INITIALIZE AIRFRAME AND ENGINE QUANTITIES.
      IQ(I-10) = F(I)
```

```
      IQE(I-10) = 0
  140 CONTINUE
      I = 21
  150 F(80) = I - 11
      N = F(80)+.5
      RETURN
C
C     ERROR MESSAGES
C
  160 FORMAT (1HO// T6, 20A4, T122, 'PAGE ', I4 //// T6, '***** AN ',
     1 'INDEX (ADDRESS) FOR AN INPUT VARIABLE HAS NOT BEEN ENTERED ',
     2 'CORRECTLY.  THE LAST CORRECT INDEX WAS ', I3, '. *****')
  170 FORMAT (1HO// T6, '***** AIRFRAME UNIT WEIGHT (POUNDS) HAS NOT ',
     1 'BEEN ENTERED. *****')
  180 FORMAT (1HO// T6, '***** MAXIMUM SPEED AT BEST ALTITUDE (KNOTS) ',
     1 'HAS NOT BEEN ENTERED. *****')
  190 FORMAT (1HO// T6, '***** MAXIMUM SPEED AT BEST ALTITUDE (MACH ',
     1 'NUMBER) HAS NOT BEEN ENTERED. *****')
  200 FORMAT (1HO// T6, '***** NUMBER OF ENGINES PER ARCRAFT HAS NOT ',
     1 'BEEN ENTERED. *****')
      END
```

```
      SUBROUTINE LIST
      COMMON     F(360), TITLE(20), IQ(10), IQE(10), INDT, N, NPAGE
C
C     SUBROUTINE FOR PRINTING MAJOR INPUTS
C
   10 WRITE (6, 20)
   20 FORMAT (1H0/ T61, 'INPUT LISTING' / )
      WRITE (6, 30) ((I, F(I)), I = 1, 8)
   30 FORMAT (1H ,
     1 T5,I2,T16,'DEVELOPMENT ENGINEERING RATE ($/HOUR)       ',T98,F8.2/
     2 T5,I2,T16,'DEVELOPMENT TOOLING RATE ($/HOUR)           ',T98,F8.2/
     3 T5,I2,T16,'DEVELOPMENT MFG LABOR RATE ($/HOUR)         ',T98,F8.2/
     4 T5,I2,T16,'DEVELOPMENT QUALITY CONTROL RATE ($/HOUR)   ',T98,F8.2/
     5 T5,I2,T16,'PRODUCTION ENGINEERING RATE ($/HOUR)        ',T98,F8.2/
     6 T5,I2,T16,'PRODUCTION TOOLING RATE ($/HOUR)            ',T98,F8.2/
     7 T5,I2,T16,'PRODUCTION MFG LABOR RATE ($/HOUR)          ',T98,F8.2/
     8 T5,I2,T16,'PRODUCTION QUALITY CONTROL RATE ($/HOUR)    ',T98,F8.2)
      WRITE (6, 40) ((I, F(I)), I = 9, 10)
   40 FORMAT (1H , T5, I2, T16, 'NUMBER OF PROTOTYPE AIRCRAFT', T96,
     1 F8.0 / T5, I2, T16, 'NUMBER OF FLIGHT-TEST AIRCRAFT', T96, F8.0)
      N1 = F(80) + 10.5
      WRITE (6, 50) N1, (F(I), I = 11, N1)
   50 FORMAT (1H , T5, '11-', I2, T16, 'AIRCRAFT PRODUCTION QUANTITIES',
     1        (T98, 5(F6.0, 1X)))
      WRITE (6, 60) ((I, F(I)), I = 21, 26)
   60 FORMAT (1H ,
     1 T5,I2,T16,'AIRCRAFT TYPE (NONCARGO: 1, CARGO: 2)       ',T96,F8.0/
     2 T5,I2,T16,'AIRFRAME UNIT WEIGHT (POUNDS)               ',T96,F8.0/
     3 T5,I2,T16,'MAXIMUM SPEED AT BEST ALTITUDE (KNOTS)      ',T96,F8.0/
     4 T5,I2,T16,'MAXIMUM SPEED AT BEST ALTITUDE (MACH NO.) ',T96,F11.3/
     5 T5,I2,T16,'DATE OF FIRST FLIGHT (CALENDAR YEAR AND QUARTER)',
     6 T98, F8.2/T5,I2,T16,'AIRFRAME COST FEE (DECIMAL)      ',T96,F11.3)
      WRITE (6, 70) ((I, F(I)), I = 27, 31)
   70 FORMAT (1H , T5, I2, T16, 'ENGINEERING CUM AVG PRODUCTION CURVE ',
     1 'SLOPE (DECIMAL)', T96, F11.3 / T5, I2, T16, 'TOOLING CUM AVG ',
     2 'PRODUCTION CURVE SLOPE (DECIMAL)', T96, F11.3 / T5, I2, T16,
     3 'MANUFACTURING LABOR CUM AVG PRODUCTION CURVE SLOPE (DECIMAL)',
     4 T96, F11.3 / T5, I2, T16, 'MANUFACTURING MATERIALS CUM AVG ',
     5 'PRODUCTION CURVE SLOPE (DECIMAL)', T96, F11.3 / T5, I2, T16,
     6 'QUALITY CONTROL FACTOR (DECIMAL)', T96, F11.3)
      WRITE (6, 80) ((I, F(I)), I = 32, 35)
   80 FORMAT (1H , T5, I2, T16, 'NUMBER OF ENGINES PER AIRCRAFT',
     1 T96, F8.0 / T5, I2, T16, 'ENGINE PRIOR PROCUREMENT QUANTITY',
     2 T96, F8.0 / T5, I2, T16, 'ENGINE CUM AVG PRODUCTION CURVE ',
     3 'SLOPE (DECIMAL)', T96, F11.3 / T5, I2, T16, 'ENGINE MQT ',
     4 'DEVELOPMENT THROUGHPUT COST', T96, F11.3)
      WRITE (6, 90) ((I, F(I)), I = 36, 40)
   90 FORMAT (1H , T5, I2, T16, 'ENGINE PROTOTYPE AND FLIGHT-TEST ',
     1 'SPARES FACTOR (DECIMAL)', T96, F11.3 / T5, I2, T16, 'ENGINE ',
     2 'PRODUCTION SPARES FACTOR (DECIMAL)', T96, F11.3 / T5, I2, T16,
     3 'MAXIMUM DYNAMIC PRESSURE IN-FLIGHT ENVELOPE (LB/SQ FT)', T96,
     4 F11.3 / T5, I2, T16, 'ENGINE PRESSURE RATIO', T96, F11.3 / T5,
     5 I2, T16, 'MAXIMUM TURBINE INLET TEMPERATURE (DEGREES RANKINE)',
     6 T96, F8.0)
      WRITE (6, 100) ((I, F(I)), I = 41, 45)
  100 FORMAT (1H , T5, I2, T16, 'WEIGHT OF ENGINE AT CONFIGURATION ',
     1 'OF INTEREST (POUNDS)', T96, F8.0 / T5, I2, T16, 'SPECIFIC ',
     2 'FUEL CONSUMPTION AT MILITARY THRUST, SEA-LEVEL STATIC ',
     3 '(LB/HR/LB THRUST)', T96, F11.3 / T5, I2, T16, 'MAXIMUM THRUST ',
     4 'PER ENGINE, INCLUDING AFTERBURNER (POUNDS)', T96, F8.0 /
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     5 T5, I2, T16, 'DATE OF PLANNED MQT (CALENDAR YEAR AND QUARTER)',
     6 T98, F8.2 / T5, I2, T16, 'DATE OF START OF ENGINE DEVELOPMENT ',
     7 '(CALENDAR YEAR AND QUARTER)', T98, F8.2)
      WRITE (6, 110) ((I, F(I)), I = 46, 50)
  110 FORMAT (1H , T5, I2, T16, 'AVIONICS DEVELOPMENT THROUGHPUT COST',
     1 T96, F11.3 / T5, I2, T16, 'AVIONICS FIRST-UNIT PRODUCTION ',
     2 'THROUGHPUT COST', T96, F11.3 / T5, I2, T16, 'AVIONICS ',
     3 'CUM AVG PRODUCTION CURVE SLOPE (DECIMAL)', T96, F11.3 /
     4 T5, I2, T16, 'AVIONICS SPARES FACTOR (DECIMAL)', T96, F11.3 /
     5 T5, I2, T16, 'AVIONICS PRIOR PROCUREMENT QUANTITY', T96, F8.0)
      WRITE (6, 120) ((I, F(I)), I = 51, 53)
  120 FORMAT (1H , T5, I2, T16, 'AIRFRAME SKIP DESIGNATOR', T96, F8.0 /
     1 T5, I2, T16, 'ENGINE SKIP DESIGNATOR', T96, F8.0 / T5, I2, T16,
     2 'AVIONICS SKIP DESIGNATOR', T96, F8.0)
      WRITE (6, 130)
  130 FORMAT (1H0, T58, 'ADJUSTMENT FACTORS'/)
      WRITE (6, 140) ((I, F(I)), I = 54, 62)
  140 FORMAT (1H , T5, I2, T16, 'ENGINEERING HOURS', T44, F8.0, T87, I2,
     1 T98, 'TOOLING HOURS', T124, F8.0 / T5, I2, T16, 'NONRECUR MFG ',
     2 'LABOR HOURS', T44, F8.0, T87, I2, T98, 'RECUR MFG LABOR HOURS',
     3 T124, F8.0 / T5, I2, T16, 'NONRECUR MFG MATERIALS COST', T44,
     4 F8.0, T87, I2, T98, 'RECUR MFG MATERIALS COST', T124, F8.0 / T5,
     5 I2, T16, 'FLIGHT-TEST COST', T44, F8.0, T87, I2, T98, 'ENGINE ',
     6 'DEVELOPMENT COST', T124, F8.0 / T5, I2, T16, 'ENGINE ',
     7 'PRODUCTION COST', T44, F8.0)
      RETURN
      END
```

```
      SUBROUTINE CALC                                                   CALC0010
      COMMON     F(360), TITLE(20), IQ(10), IQE(10), INDT, N, NPAGE     CALC0020
C                                                                       CALC0030
C     SUBROUTINE FOR CALCULATING VARIOUS CONSTANT TERMS AND FACTORS     CALC0040
C                                                                       CALC0050
C     VARIOUS FACTORS                                                   CALC0060
   10 F(66) = 1. + F(36)                                                CALC0070
      F(67) = 1. + F(37)                                                CALC0080
      F(68) = 1. + F(49)                                                CALC0090
C     NUMBER OF PROTOTYPE PLUS FLIGHT-TEST AIRCRAFT                     CALC0100
      F(69) = F(9) + F(10)                                              CALC0110
C     CALCULATE B+1 VALUES FOR LEARNING CURVES                          CALC0120
      DO 20 I = 1, 4                                                    CALC0130
   20 F(I+69) = ALOG(F(I+26)) / F(81) + 1.0                             CALC0140
      F(75) = ALOG(F(34)) / F(81) + 1.0                                 CALC0150
      F(76) = ALOG(F(48)) / F(81) + 1.0                                 CALC0160
      IF (F(51) .EQ. 1.) GO TO 40                                       CALC0170
C                                                                       CALC0180
C     AIRFRAMES                                                         CALC0190
C                                                                       CALC0200
C     INITIAL ENGINEERING HOURS                                         CALC0210
      F(100)=20.032*F(22)**.6636*F(23)**.9871*200.**(-F(70))*F(54)*F(99)CALC0220
C     INITIAL TOOLING HOURS                                             CALC0230
      F(101)=522.39*F(22)**.6214*F(23)**.5323*200.**(-F(71))*F(55)*F(99)CALC0240
      IF (F(25) .GT. 0.) GO TO 30                                       CALC0250
C     INITIAL MANUFACTURING LABOR HOURS                                 CALC0260
      F(102)=581.55*F(22)**.7830*F(23)**.4297*200.**(-F(72))*F(57)*F(99)CALC0270
C     INITIAL MATERIALS COST                                            CALC0280
      F(103)=191.85*F(22)**.8600*F(23)**.8126*200.**(-F(73))*F(59)*F(99)CALC0290
      GO TO 40                                                          CALC0300
C     OPTION USING TIME OF FIRST FLIGHT                                 CALC0310
   30 IDATE = 4. * (F(25) - 1942.75) + 0.5                              CALC0320
      IF (IDATE .LT. 0) IDATE = 0                                       CALC0330
      F(82) = IDATE                                                     CALC0340
      F(102) = 1188.5*F(22)**.8306*F(23)**.5464*F(82)**(-.4711)*        CALC0350
     1         200.**(-F(72))*F(57)*F(99)                               CALC0360
      F(103) = 93.409*F(22)**.8121*F(23)**.6951*F(82)**.4744*           CALC0370
     1         200.**(-F(73))*F(59)*F(99)                               CALC0380
C                                                                       CALC0390
   40 IF (F(52) .EQ. 1.) GO TO 50                                       CALC0400
C                                                                       CALC0410
C     ENGINES                                                           CALC0420
C                                                                       CALC0430
      TEMP = F(32) * F(66)                                              CALC0440
C     PRIOR ENGINE QUANTITY PLUS NUMBER OF ENGINES FOR PROTOTYPE        CALC0450
C      AIRCRAFT, INCLUDING SPARE ENGINES                                CALC0460
      F(104) = F(33)+TEMP*F(9)                                          CALC0470
C     PRIOR ENGINE QUANTITY PLUS NUMBER OF ENGINES FOR PROTOTYPE AND    CALC0480
C      FLIGHT-TEST AIRCRAFT, INCLUDING SPARE ENGINES                    CALC0490
      F(105) = F(104) + TEMP * F(10)                                    CALC0500
      THRMAX = ALOG(F(43))                                              CALC0510
      SMACH = ALOG(F(24))                                               CALC0520
C     CALCULATE PRESSURE TERM                                           CALC0530
      F(77) = F(38)*F(39)                                               CALC0540
C     CALCULATE TIME OF ARRIVAL TERM                                    CALC0550
      F(78) = -856.38+110.10*ALOG(F(40))+11.407*ALOG(F(77))-26.077*     CALC0560
     X ALOG(F(41))-16.024*ALOG(F(42))+18.369*THRMAX                     CALC0570
C     TIME OF ARRIVAL TO MQT IN CALENDAR QUARTERS BEGINNING WITH        CALC0580
C      FOURTH QUARTER 1942                                              CALC0590
      IDATE = 4. * (F(44) - 1942.50) + 0.5                              CALC0600
```

```
      IF (IDATE .LT. 0) IDATE = 0
      F(83) = IDATE
C     DELTA TIME OF ARRIVAL
      F(79) = F(78) - F(83)
C     INITIAL DEVELOPMENT COST
      F(106) = EXP(.93374+.3988*THRMAX+1.2867*SMACH)*F(61)
C     DEVELOPMENT TIME TO MQT IN CALENDAR QUARTERS
      IDATE = 4. * (F(44) - F(45)) + 0.5
      IF (IDATE .LT. 0) IDATE = 0
      F(84) = IDATE
      F35 = 0.
      IF (F(35) .NE. 0.) F35 = F(35)
C     DEVELOPMENT COST THROUGH MQT
      IF (F(33) .EQ. 0. .AND. F35 .EQ. 0.) F(126) = EXP(-1.3096+
     1 .08538*F(84)+.04099*F(79)+.4963*THRMAX+.4137*SMACH)*F(61)
C     INITIAL PRODUCTION COST
      F(107) = EXP(-8.2068+.7053*THRMAX+.00674*F(78)+.45710*SMACH+
     1 .01804*F(79))*F(62)/(1000.**F(75)-999.**F(75))
C     STORE B+1 VALUE FOR DEVELOPMENT
      F(74) = .08146
C
   50 IF (F(53) .EQ. 1.) RETURN
C
C     AVIONICS
C
C     PRIOR AVIONICS PLUS AVIONICS FOR PROTOTYPE AIRCRAFT, INCLUDING
C      SPARE AVIONICS
      F(108) = F(50) + F(9) * F(68)
C     PRIOR AVIONICS PLUS AVIONICS FOR PROTOTYPE AND FLIGHT-TEST
C      AIRCRAFT, INCLUDING SPARE AVIONICS
      F(109) = F(108) + F(10) * F(68)
      RETURN
      END
```

```
      SUBROUTINE DEVCO
      COMMON      F(360), TITLE(20), IQ(10), IQE(10), INDT, N, NPAGE
C
C     SUBROUTINE FOR CALCULATING AND PRINTING DEVELOPMENT COSTS,
C      INCLUDING COSTS FOR FLIGHT-TEST AIRCRAFT
C
   10 IF (F(51) .EQ. 1.) GO TO 30
C
C     AIRFRAME HOURS AND COSTS
C
C     ENGINEERING HOURS FOR PROTOTYPE AIRCRAFT
      F(90) = F(100)*F(9)**F(70)
C     ENGINEERING HOURS FOR PROTOTYPE AND FLIGHT-TEST AIRCRAFT
      F(91) = F(100)*F(69)**F(70)
      IF (F(9) .LT. 6.) F(90) = F(90)*.3229*F(9)**.6309
      IF (F(69) .LT. 6.) F(91) = F(91)*.3229*F(69)**.6309
C     ENGINEERING HOURS FOR FLIGHT-TEST AIRCRAFT
      F(110) = F(91)-F(90)
C     TOOLING HOURS FOR PROTOTYPE AIRCRAFT
      F(92) = F(101)*F(9)**F(71)
C     TOOLING HOURS FOR PROTOTYPE AND FLIGHT-TEST AIRCRAFT
      F(93) = F(101)*F(69)**F(71)
      IF (F(9) .LT. 20.) F(92) = F(92)*.1232*F(9)**.6990
      IF (F(69) .LT. 20.) F(93) = F(93)*.1232*F(69)**.6990
C     TOOLING HOURS FOR FLIGHT-TEST AIRCRAFT
      F(111) = F(93)-F(92)
C     NONRECURRING MANUFACTURING LABOR HOURS
      F(112) =  .62597*F(22)**.6883*F(23)**1.2109*F(56)*F(99)
C     RECURRING MANUFACTURING LABOR HOURS FOR PROTOTYPE AIRCRAFT
      F(94) = F(102)*F(9)**F(72)
C     RECURRING MFG LABOR HOURS FOR PROTOTYPE AND FLIGHT-TEST AIRCRAFT
      F(95) = F(102)*F(69)**F(72)
C     RECURRING MANUFACTURING LABOR HOURS FOR FLIGHT-TEST AIRCRAFT
      F(113) = F(95)-F(94)
C     QUALITY CONTROL HOURS FOR FLIGHT-TEST AIRCRAFT
      F(114) = F(98)*(F(112)+F(113))
C     ENGINEERING COST FOR FLIGHT-TEST AIRCRAFT
      F(115) = F(110)*F(1)
C     TOOLING COST FOR FLIGHT-TEST AIRCRAFT
      F(116) = F(111)*F(2)
C     NONRECURRING MANUFACTURING LABOR COST
      F(117) = F(112)*F(3)
C     RECURRING MANUFACTURING LABOR COST FOR FLIGHT-TEST AIRCRAFT
      F(118) = F(113)*F(3)
C     QUALITY CONTROL COST FOR FLIGHT-TEST AIRCRAFT
      F(119) = F(114)*F(4)
C     NR MFG MATERIALS COST
      F(120) = .030614*F(22)**.7240*F(23)**1.9240*F(58)*F(99)
C     RECURRING MANUFACTURING MATERIALS COST FOR FLIGHT-TEST AIRCRAFT
      F(96) = F(103)*F(9)**F(73)
C     RECUR MFG MATERIALS COST FOR PROTOTYPE AND FLIGHT-TEST AIRCRAFT
      F(97) = F(103)*F(69)**F(73)
C     RECURRING MANUFACTURING MATERIALS COST FOR FLIGHT-TEST AIRCRAFT
      F(121) = F(97)-F(96)
C     FLIGHT-TEST COST
      F(122) = 153.25*F(22)**.7095*F(23)**.5856*F(10)**.7160*
     1 F(21)**(-1.5570)*F(60)*F(99)
C     TOTAL AIRFRAME DEVELOPMENT COST WITHOUT FEE
      DO 20 I = 1,8
   20 F(123) = F(123)+F(I+114)
```

```
C     FEE
      F(124) = F(26)*F(123)
C     TOTAL AIRFRAME DEVELOPMENT COST WITH FEE
      F(125) = F(123)+F(124)
C
   30 IF (F(52) .EQ. 1.) GO TO 40
C
C     ENGINE COSTS
C
C     TOTAL DEVELOPMENT COST OF PRIOR ENGINES AND ENGINES FOR PROTOTYPE
C      AIRCRAFT, INCLUDING COST OF SPARE ENGINES
      F(136) = F(106)*F(104)**F(74)
C     TOTAL DEVELOPMENT COST OF PRIOR ENGINES AND ENGINES FOR PROTOTYPE
C      AND FLIGHT-TEST AIRCRAFT, INCLUDING COST OF SPARE ENGINES
      F(133) = F(106)*F(105)**F(74)
C     RECURRING DEVELOPMENT FLYAWAY COST OF ENGINES FOR FLIGHT-TEST
C      AIRCRAFT
      F(127) = (F(133)-F(136))/F(66)
C     PRODUCTION COST OF PRIOR ENGINES AND ENGINES FOR PROTOTYPE
C      AIRCRAFT, INCLUDING COST OF SPARE ENGINES
      F(134) = F(107)*F(104)**F(75)
C     PRODUCTION COST OF PRIOR ENGINES AND ENGINES FOR PROTOTYPE AND
C      FLIGHT-TEST AIRCRAFT, INCLUDING COST OF SPARE ENGINES
      F(137) = F(107)*F(105)**F(75)
C     TOTAL PRODUCTION FLYAWAY COST OF ENGINES FOR FLIGHT-TEST AIRCRAFT
      F(128) = (F(137)-F(134))/F(66)
C     TOTAL ENGINE DEVELOPMENT FLYAWAY COST
      F(129) = F(126)+F(127)+F(128)
C     COST OF SPARE ENGINES FOR FLIGHT-TEST AIRCRAFT
      F(139) = F(36) * (F(127) + F(128))
C
   40 F46 = 0
      IF (F(53) .EQ. 1.) GO TO 50
      F46 = F(46)
C
C     AVIONICS COSTS
C
C     PRODUCTION COST OF AVIONICS FOR PROTOTYPE AIRCRAFT, INCLUDING
C      COST OF SPARE AVIONICS
      F(138) = F(47)*F(108)**F(76)
C     PRODUCTION COST OF AVIONICS FOR PROTOTYPE AND FLIGHT-TEST
C      AIRCRAFT, INCLUDING COST OF SPARE AVIONICS
      F(135) = F(47)*F(109)**F(76)
C     TOTAL PRODUCTION FLYAWAY COST OF AVIONICS FOR FLIGHT-TEST AIRCRAFT
      F(130) = (F(135)-F(138))/F(68)
C     TOTAL AVIONICS DEVELOPMENT FLYAWAY COST
      F(131) = F(46)+F(130)
C     TOTAL AIRCRAFT DEVELOPMENT FLYAWAY COST WITH FEE
   50 F(132) = F(125)+F(129)+F(131)
C
      WRITE (6, 60) TITLE, NPAGE
      WRITE (6, 70)
      WRITE (6, 80) (F(I+114), F(I+109), I = 1, 5), (F(I), I = 120, 125)
      WRITE (6, 90) (F(I), I = 126, 129)
      WRITE (6, 100) F46, F(130), F(131)
      WRITE (6, 110) F(132), F(139)
      NPAGE = NPAGE + 1
      RETURN
C
C     FORMATS
C
```

```
 60 FORMAT (1H1/T6,20A4,T122,'PAGE ', I4)
 70 FORMAT (1H // T57, 'DEVELOPMENT COSTS' //// T86, 'COSTS', T100,
   1 'HOURS' / T82, '(MILLIONS $)', T98, '(MILLIONS)')
 80 FORMAT (1H /T31,'AIRFRAMES'//T33,'ENGINEERING',T83,2(F9.3,4X)/T33,
   1 'TOOLING',T83,2(F9.3,4X)/T33,'NONRECURRING MFG LABOR', T83,
   2 2(F9.3,4X)/T33,'RECURRING MFG LABOR',T83,2(F9.3,4X)/T33,
   3 'QUALITY CONTROL',T83,2(F9.3,4X)/T33,'NONRECURRING MFG ',
   4 'MATERIALS',T83,F9.3/T33,'RECURRING MFG MATERIALS',T83,F9.3/T33,
   5 'FLIGHT TEST',T83,F9.3//T35,'TOTAL AIRFRAME WITHOUT FEE',T83,
   6 F9.3/T35,'FEE',T83,F9.3/T35,'TOTAL AIRFRAME WITH FEE',T83,F9.3)
 90 FORMAT (1H ///T31,'ENGINES'//T33,'MQT DEVELOPMENT ',T83,F9.3/T33,
   1 'RECURRING DEVELOPMENT ',T83,F9.3/T33,'PRODUCTION',T83,F9.3//
   2 T35,'TOTAL ENGINES',T83,F9.3)
100 FORMAT (1H ///T31,'AVIONICS'//T33,'DEVELOPMENT ',T83,F9.3/T33,
   1 'PRODUCTION',T83,F9.3//T35,'TOTAL AVIONICS',T83,F9.3)
110 FORMAT (1H ///T31,'TOTAL DEVELOPMENT COST',T83,F9.3///////T30,
   1 '(COST OF SPARE ENGINES FOR FLIGHT-TEST AIRCRAFT',T83,F9.3,')')
    END
```

```
      SUBROUTINE AIRF
      COMMON     F(360), TITLE(20), IQ(10), IQE(10), INDT, N, NPAGE
      DIMENSION  CF(12)
C
C     SUBROUTINE FOR CALCULATING AND PRINTING AIRFRAME AND ENGINE
C      PRODUCTION COSTS
C
   10 WRITE (6, 40) TITLE, NPAGE
      NPAGE = NPAGE + 1
      IF (F(51) .EQ. 1.) RETURN
      WRITE (6, 50) F(26)
      WRITE (6, 60)
      WRITE (6, 70)
      N = F(80) + 0.5
      DO 20 I = 1, N
C     TOTAL AIRFRAME QUANTITY (PROTOTYPE + FLIGHT-TEST + PRODUCTION)
      F(I+160) = F(69)+F(I+10)
C     SET TOTAL AIRFRAME QUANTITY TO Q.
      Q = F(I+160)
C     TOTAL ENGINEERING HOURS (PROTOTYPE + FLIGHT-TEST + PRODUCTION)
      F(I+170) = F(100)*Q**F(70)
      IF (Q .LT. 6.) F(I+170) = F(I+170)*.3229*Q**.6309
C     TOTAL TOOLING HOURS (PROTOTYPE + FLIGHT-TEST + PRODUCTION)
      F(I+180) = F(101)*Q**F(71)
      IF (Q .LT. 20.) F(I+180) = F(I+180)*.1232*Q**.6990
C     TOTAL RECURRING MFG LABOR HOURS (PROTOTYPE + FLIGHT-TEST
C    1 + PRODUCTION)
      F(I+190) = F(102)*Q**F(72)
C     TOTAL RECURRING MFG MATL COSTS (PROTOTYPE + FLIGHT-TEST
C      + PRODUCTION)
      F(I+200) = F(103)*Q**F(73)
C
C     CUMULATIVE AVERAGE HOURS
C
C     ENGINEERING
      CF(9) = (F(I+170) - F(91)) / F(I+10)
C     TOOLING
      CF(10) = (F(I+180) - F(93)) / F(I+10)
C     MANUFACTURING LABOR
      CF(11) = (F(I+190) - F(95)) / F(I+10)
C     QUALITY CONTROL
      CF(12) = F(98) * CF(11)
C
C     CUMULATIVE AVERAGE COSTS
C
C     ENGINEERING
      CF(1) = F(5) * CF(9)
C     TOOLING
      CF(2) = F(6) * CF(10)
C     MANUFACTURING LABOR
      CF(3) = F(7) * CF(11)
C     QUALITY CONTROL
      CF(4) = F(8) * CF(12)
C     MANUFACTURING MATERIALS
      CF(5) = (F(I+200) - F(97)) / F(I+10)
C     TOTAL WITHOUT FEE
      CF(6) = CF(1) + CF(2) + CF(3) + CF(4) + CF(5)
C     FEE
      CF(7) = F(26) * CF(6)
```

```
C     TOTAL CUMULATIVE AVERAGE PRODUCTION COST WITH FEE
      F(I+140) = CF(6) + CF(7)
      CF(8) = F(I+140)
C
C     PRINT RESULTS.
C
      WRITE (6, 80) IQ(I),(CF(J),CF(J+8),J = 1,4),(CF(J),J = 5,8)
   20 CONTINUE
      WRITE (6, 90)
      DO 30 I = 1, N
C     TOTAL AIRFRAME QUANTITY LESS 1
      Q = F(I+160) - 1.
C
C     UNIT HOURS
C
C     ENGINEERING
      TEMP = F(100)*Q**F(70)
      IF (Q .LT. 6.) TEMP = TEMP*.3229*Q**.6309
      CF(9) = F(I+170)-TEMP
C     TOOLING
      TEMP = F(101)*Q**F(71)
      IF (Q .LT. 20.) TEMP = TEMP*.1232*Q**.6990
      CF(10) = F(I+180)-TEMP
C     MANUFACTURING LABOR
      CF(11) = F(I+190) - F(102) * Q**F(72)
C     QUALITY CONTROL
      CF(12) = F(98) * CF(11)
C
C     UNIT COSTS
C
C     ENGINEERING
      CF(1) = F(5) * CF(9)
C     TOOLING
      CF(2) = F(6) * CF(10)
C     MANUFACTURING LABOR
      CF(3) = F(7) * CF(11)
C     QUALITY CONTROL
      CF(4) = F(8) * CF(12)
C     MATERIALS
      CF(5) = F(I+200) - F(103) * Q**F(73)
C     TOTAL WITHOUT FEE
      CF(6) = CF(1) + CF(2) + CF(3) + CF(4) + CF(5)
C     FEE
      CF(7) = F(26) * CF(6)
C     TOTAL UNIT COST WITH FEE
      F(I+150) = CF(6) + CF(7)
      CF(8) = F(I+150)
C
C     PRINT RESULTS.
C
      WRITE (6, 80) IQ(I),(CF(J),CF(J+8),J = 1,4),(CF(J),J = 5,8)
   30 CONTINUE
      RETURN
C
C     FORMATS
C
   40 FORMAT (1H1, T6, 20A4, T122, 'PAGE ', I4)
   50 FORMAT (1H // T49, 'AIRFRAME PRODUCTION COSTS AND HOURS' / T50,
     1 '(ALL COSTS AND HOURS IN MILLIONS)' / T57, '- - FEE = ', F5.3,
     2 ' - -')
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60 FORMAT (1H /// T57, 'CUMULATIVE AVERAGE' )                           AIRF1200
70 FORMAT (1H0,'AIRFRAME',T17,'ENGINEERING',T39,'TOOLING',T58,          AIRF1210
  1 'MFG LABOR',T75,'QUALITY CONTROL',T96,'MFG',T107,'TOTAL',T127,      AIRF1220
  2 'TOTAL'/T2,'QUANTITY',T15,'COSTS      HOURS',T35,'COSTS      HOURS'AIRF1230
  3,T55,'COSTS      HOURS',T75,'COSTS      HOURS',T93,'MATERIALS',T104,AIRF1240
  4 'WITHOUT FEE',T118,'FEE',T125,'WITH FEE'/)                          AIRF1250
80 FORMAT (1H ,T3,I4,3X,9(1X,F9.4),3X,F9.4,2(1X,F9.4) )                 AIRF1260
90 FORMAT (1H /// T64, 'UNIT'/ )                                        AIRF1270
   END                                                                  AIRF1280
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      SUBROUTINE TOTAL
      COMMON    F(360), TITLE(20), IQ(10), IQE(10), INDT, N, NPAGE
      DIMENSION  CF(6)
C
C     SUBROUTINE FOR CALCULATING AND PRINTING ENGINE, AVIONICS, AND
C      TOTAL COSTS
C
   10 IF (F(52) .EQ. 1.) GO TO 30
      WRITE (6, 100)
      DO 20 I = 1, N
C     ENGINE QUANTITY FOR PRODUCTION AIRCRAFT, INCLUDING SPARE ENGINES
      IQE(I) = F(32)*F(I+10)*F(67)+.5
C     TOTAL ENGINE QUANTITY (PRIOR ENGINES PLUS ENGINES FOR PROTOTYPE.
C      FLIGHT-TEST, AND PRODUCTION AIRCRAFT, INCLUDING SPARE ENGINES)
      F(I+210) = F(105) + IQE(I)
C     TOTAL PRODUCTION COST OF PRIOR ENGINES AND ENGINES FOR PROTOTYPE,
C      FLIGHT-TEST, AND PRODUCTION AIRCRAFT, PLUS COST OF SPARE ENGINES
      F(I+220) = F(107)*F(I+210)**F(75)
C     TOTAL DEVELOPMENT COST OF PRIOR ENGINES AND ENGINES FOR PROTOTYPE,
C      FLIGHT-TEST, AND PRODUCTION AIRCRAFT, PLUS COST OF SPARE ENGINES
      F(I+230) = F(106)*F(I+210)**F(74)
C     TOTAL PRODUCTION FLYAWAY COST FOR ENGINES ON PRODUCTION AIRCRAFT
      PROD = (F(I+220) - F(137)) / F(67)
C     TOTAL RECURRING DEVELOPMENT FLYAWAY COST FOR ENGINES ON
C      PRODUCTION AIRCRAFT
      RECDEV = (F(I+230) - F(133)) / F(67)
C     CUMULATIVE AVERAGE PRODUCTION FLYAWAY COST FOR ENGINES ON
C      PRODUCTION AIRCRAFT
      F(I+240) = PROD / F(I+10)
C     CUMULATIVE AVERAGE RECURRING DEVELOPMENT FLYAWAY COST FOR ENGINES
C      ON PRODUCTION AIRCRAFT
      F(I+250) = RECDEV / F(I+10)
C     SUM OF CUMULATIVE AVERAGE PRODUCTION AND RECURRING DEVELOPMENT
C      FLYAWAY COSTS FOR ENGINES ON PRODUCTION AIRCRAFT
      F(I+260) = F(I+240) + F(I+250)
C     TOTAL FLYAWAY COST FOR ENGINES ON PRODUCTION AIRCRAFT
      F(I+270) = PROD + RECDEV
C     COST OF SPARE ENGINES FOR PRODUCTION AIRCRAFT
      F(I+280) = F(37) * F(I+270)
      Q = F(I+210)-F(32)*F(67)
C     UNIT PRODUCTION FLYAWAY COST FOR ENGINES
      F(I+290) = (F(I+220)-F(107)*Q**F(75))/F(67)
C     UNIT RECURRING DEVELOPMENT FLYAWAY COST FOR ENGINES
      F(I+300) = (F(I+230)-F(106)*Q**F(74))/F(67)
C     SUM OF UNIT PRODUCTION AND RECURRING DEVELOPMENT FLYAWAY COSTS
C      FOR ENGINES ON PRODUCTION AIRCRAFT
      F(I+310) = F(I+290) + F(I+300)
      WRITE (6, 110) IQ(I), IQE(I), (F(I+J), J = 240, 260, 10),
     1               (F(I+J), J = 290, 310, 10)
   20 CONTINUE
   30 DO 40 I = 1, 6
   40 CF(I) = 0.
      IF33 = F(33)+.5
      IF50 = F(50)+.5
      IF (F(51)+F(52) .EQ. 2.) GO TO 50
      WRITE (6, 120) TITLE, NPAGE
      NPAGE = NPAGE + 1
   50 WRITE (6, 130)
      WRITE (6, 140) IF33, IF50
      WRITE (6, 150) F(125), F(129), F(131), F(132)
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      WRITE (6, 160)
      IF (F(53) .EQ. 1.) GO TO 70
      DO 60 I = 1, N
C     TOTAL AVIONICS QUANTITY (PRIOR AVIONICS PLUS AVIONICS PACKAGES
C      FOR PROTOTYPE, FLIGHT-TEST, AND PRODUCTION AIRCRAFT, INCLUDING
C      SPARE AVIONICS)
      F(I+320) = F(109) + F(I+10) * F(68)
C     TOTAL PRODUCTION COST OF AVIONICS FOR PROTOTYPE, FLIGHT-TEST,
C      AND PRODUCTION AIRCRAFT, INCLUDING COST OF SPARE AVIONICS
      F(I+330) = F(47) * F(I+320)**F(76)
C     CUMULATIVE AVERAGE FLYAWAY COST FOR AVIONICS
      F(I+340) = (F(I+330)-F(135))/(F(68)*F(I+10))
      Q = F(I+320)-F(68)
C     UNIT FLYAWAY COST FOR AVIONICS
      F(I+350) = (F(I+330)-F(47)*Q**F(76))/F(68)
   60 CONTINUE
   70 DO 80 I = 1, N
      CF(1) = F(I+260)
      CF(2) = F(I+340)
C     AIRCRAFT CUMULATIVE AVERAGE FLYAWAY COST WITH FEE
      CF(3) = F(I+140)+CF(1)+CF(2)
C     CUMULATIVE TOTAL WITHOUT RDT&E
      CF(4) = CF(3)*F(I+10)
C     CUMULATIVE TOTAL WITH RDT&E
      CF(5) = CF(4)+F(132)
      WRITE (6, 170) IQ(I),IQE(I),F(I+140),(CF(J),J = 1,5), F(I+280)
   80 CONTINUE
      WRITE (6, 180)
      DO 90 I = 1, N
      CF(1) = F(I+310)
      CF(2) = F(I+350)
      CF(3) = F(I+150)+CF(1)+CF(2)
      WRITE (6, 170) IQ(I),IQE(I),F(I+150),(CF(J),J = 1,3)
   90 CONTINUE
      RETURN
C
C     FORMATS
C
  100 FORMAT (1H //// T55, 'ENGINE PRODUCTION COSTS' / T2, 'AIRFRAME',
     1 T14, 'ENGINE' / T2, 2('QUANTITY', 3X) / T34, '<- -CUMULATIVE ',
     2 'AVERAGE- ->', T74, '<- - - - - UNIT - - - - ->' / T19,
     3 2(16X, 'PROD', 3X, 'RECUR DEV', 3X, 'TOTAL') / )
  110 FORMAT (1H , T2, I5, T14, I5, T30, 3(1X, F9.4), T70, 3(1X, F9.4))
  120 FORMAT (1H1/ T6, 20A4, T122, 'PAGE ', I4)
  130 FORMAT (1H0/ T55, 'TOTAL AIRCRAFT COSTS' / T55, '(MILLIONS OF ',
     1 'DOLLARS)' )
  140 FORMAT (1H ,T32,'(ENGINE PRIOR PROCUREMENT =',I5,' ; AVIONICS ',
     1 'PRIOR PROCUREMENT  = ', I5, ')' )
  150 FORMAT (1H // T61, 'DEVELOPMENT' // T31, 'AIRFRAMES', T51,
     1 'ENGINES', T71, 'AVIONICS', T87, 'TOTAL WITH FEE' / T19,
     2 4(10X, F10.4) )
  160 FORMAT (1H // T61, 'PRODUCTION' // T31, '< - - - - - - - - - ',
     1 'CUMULATIVE AVERAGE - - - - - - - - - >   <- - CUMULATIVE ',
     2 'TOTALS - ->' // T5, 'AIRFRAME', T18, 'ENGINE', T79, 'TOTAL ',
     3 2(6X, 'CUM TOTAL'), T122, '( SPARE )'/T5, 2('QUANTITY',4X), T31,
     4 'AIRFRAMES', T48, 'ENGINES', T62, 'AVIONICS', T77, 'WITH FEE',
     5 T90, 'WITHOUT FEE', T106, 'WITH RDTE', T122, '(ENGINES)' / )
  170 FORMAT (1H , T5, I5, T18, I5, 1X, 4(5X, F10.4), 6X, F10.4,
     1 2(5X, F10.4) )
  180 FORMAT (1H // T57, 'UNIT' / )
      END
```

```
      SUBROUTINE DUMP
      COMMON     F(360), TITLE(20), IQ(10), IQE(10), INDT, N, NPAGE
C
C     SUBROUTINE FOR PRINTING F ARRAY LISTED IN COMMON
C
   10 WRITE (6, 20) TITLE, NPAGE
   20 FORMAT (1H1/T6, 20A4, T122, 'PAGE ', I4///T60, 'PROGRAM VALUES'/
     1 T125, 'INDEXES' / T8, '1', T19, '2', T31, '3', T43, '4', T55,
     2 '5', T67, '6', T79, '7', T91, '8', T103, '9', T115, '10' / )
      NPAGE = NPAGE + 1
      LINES = 0
      DO 50 I = 1, 351, 10
      LINES = LINES + 1
      J = I + 9
      WRITE (6, 30) (F(K), K = I, J), I, J
   30 FORMAT (1X, 10(F11.5, 1X), 3X, I3, '-', I3)
      IF (LINES/5*5 .EQ. LINES) WRITE (6, 40)
   40 FORMAT (1H )
   50 CONTINUE
      RETURN
      END
```