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INTEGRATED MULTI-PATH PROGRAM ANALYSIS AND COST TECHNIOUE (IMPACT)

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16. ABSTRACT

The purpose of this report is to describe and illustrate a technique developed to assess the impact of multiple program decisions on program cost. The information presented includes a discussion of the problem of determining the effect of decisions on program cost and describes the approach to the problem solution employed by the technique described. For illustration, an application of the technique to a sample problem has been included. This application includes a discussion of the sample problem, a computer program for problem solution, and the output of the program which reflects the cost of alternate solutions to the problem. A discussion of further applications and planned activities for utilization of the technique is also included.

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INTEGRATED MULTI-PATH PROGRAM ANALYSIS AND COST TECHNIQUE (IMPACT)

SUMMARY

The purpose of this report is to describe and illustrate a technique developed to assess the impact of multiple program decisions on program cost. The information presented includes a discussion of the problem of determining the effect of decisions on program cost and describes the approach to the problem solution employed by the technique described. For illustration, an application of the technique to a sample problem has been included. This application includes a discussion of the sample problem, a computer program for problem solution, and the output of the program which reflects the cost of alternate solutions to the problem. A discussion of further applications and planned activities for utilization of the technique is also included.

SECTION I. INTRODUCTION

Most space program technical and managerial decisions impact the cost of the program; however, the relationship of these decisions to the program costs is usually difficult to establish. Under optimum conditions, all possible decisions and their options would be considered before a final decision is made; but, many of the decisions that will be required in a program are not known during the program definition phase. Because of the many possible combinations of decisions and their interactions, decision-makers have difficulty in determining the actual cost impact of their decisions. Another problem is the relationship of increased program value or "goodness" to increased cost and the determination as to where an optimum balance is achieved. Finally, cost estimates often are not changed as the program guidelines change. This further complicates the decision-making problem and likely invalidates the program cost estimate.

In view of the restricted NASA budget, Program Development is attempting to define lowest cost acceptable programs. To do this in the Space

Shuttle Program, for example, questions such as the following must be answered:

1. What is the most economical type of jet engine?

2. What is the effect of competition on cost?

Obviously, these type questions cannot be answered without considering the impact of these decisions on the total program cost. Considering these and similar questions, the Engineering Cost Group developed a cost/decision technique that was applied to the Space Shuttle; but it can be applied as well to any other program or combination of programs. This technique was named the Integrated Multi-Path Program Analysis and Cost Technique (IMPACT).

SECTION II. APPROACH

During the program definition phase, program ground rules and assumptions constantly change. Therefore, when a cost estimate is made, it often does not reflect the latest guidelines. Plans that are in vogue today may be outdated tomorrow and back in style next week. To provide cost estimates that reflect the latest thinking, a fast response system that considers the interrelationship of these decisions must be available. After making several Space Shuttle cost estimates, which lagged the latest guideline decisions, a list was made of the identifiable decisions and all of the options that had been considered. The plans were, at first, to estimate the cost of all possibilities; but it soon became apparent that this was an impossibility. However, the list of decisions and options began to clarify the problem and proved to be quite informative. Some of the benefits of doing this were as follows:

1. All potential decisions were listed, including some plans that were no longer being considered as well as the latest plans. Thus, the advantages of earlier planning could be coupled with the latest planning and were not lost.

2. It became obvious that some options on one decision conflicted with options on other decisions. These conflicts consisted of combinations that were considered impractical, and thus could be ruled out.

3. There were other combinations of options that could be shown to cause a definite increase or decrease in certain segments of the program cost.

4. It was also observed that certain combinations of decisions dictated other decisions which eliminated the other options from that decision.

After making the above observations, the decisions and their options were displayed graphically by subject. An attempt was made to display them in a chronological order, but this did not prove feasible since some of the decisions were made simultaneously and the relative order of other decisions was not known. A true graphical display of this problem, i.e., a separate branch for each option repeated for all preceding options, quickly became uncontrollable. Therefore, the graphical method used, i.e., the return to a single line after each decision, was selected to make the display more manageable (as shown later in Fig. 3).

The relationships of the options on one decision to the options on other decisions were then quantitatively established. This included eliminating certain combinations of decisions, deciding which combination may cause an inherent increase or decrease in certain segments of the program cost, and estimating what that increase or decrease may be, either in absolute cost or in percents. The interrelationship of all the decisions and its effect on the program cost was formulated.

A computer program, which provided a capability for costing any combination, was developed to incorporate all the decisions and their options. Conditional statements were put into the program to eliminate combinations of decisions that were not considered feasible, to activate cost factors that had been included for certain combinations of decisions, and to dictate decisions where certain combinations of other decisions so required. Because of the size of the total program, it is not included or described in detail in this report, but a sample program that uses the programming techniques and a sample output are included.

In summary, the approach to a cost analysis solution used by IMPACT is as follows:

- Identify the decisions to be made in the program.

- Identify the options that will be considered before a decision is made.

- Assign costs or cost factors to the various options of each decision.

- Display the decisions and their options graphically by subject; i. e., Rocket Engines, Jet Engines, etc.

- Identify combinations of decisions that may:

  - not be practical, and eliminate.
  - cause an increase in cost, and assign cost factors.
  - cause a cost savings, and assign cost factors.

- Develop a computer program that will cost all the possible combinations.

- Utilize the computer program to run likely program cases.

- Analyze the computer outputs and select the resulting lowest cost acceptable program.

SECTION III. IMPACT METHODOLOGY

The IMPACT methodology, as shown in Figure 1, consists of using a three-dimensional array of data that interacts to develop the program cost estimate. The three dimensions of data are (1) Data Bank, (2) Program Decisions, and (3) Vehicle Selection. From this methodology, the output indicated in Figure 2 is obtained.

A. Data Bank

The Data Bank consists of data that are stored in the program and used as required by both Program Decisions and Vehicle Selection.

Vehicle Physical Data consist of subsystem weights, total thrust requirements for rocket engines and jet engines, and other physical data for all vehicle configurations in the Vehicle Selection array. These data are obtained from a parametric vehicle sizing model, which is not discussed in this report but is operational in Program Development. Table 1 is a sample of the Vehicle Physical Data that are stored in the Data Bank.

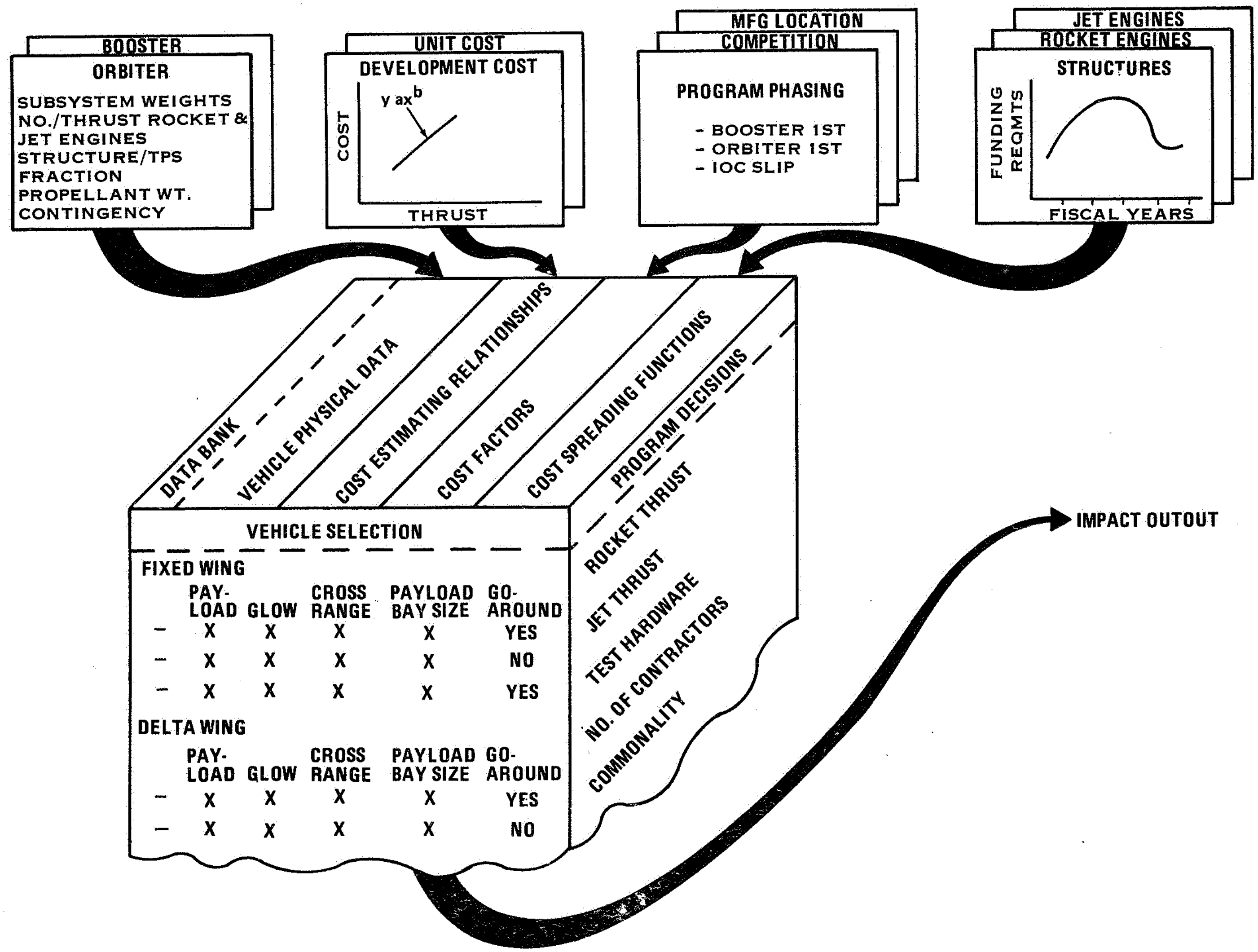

Figure 1. IMPACT methodology.

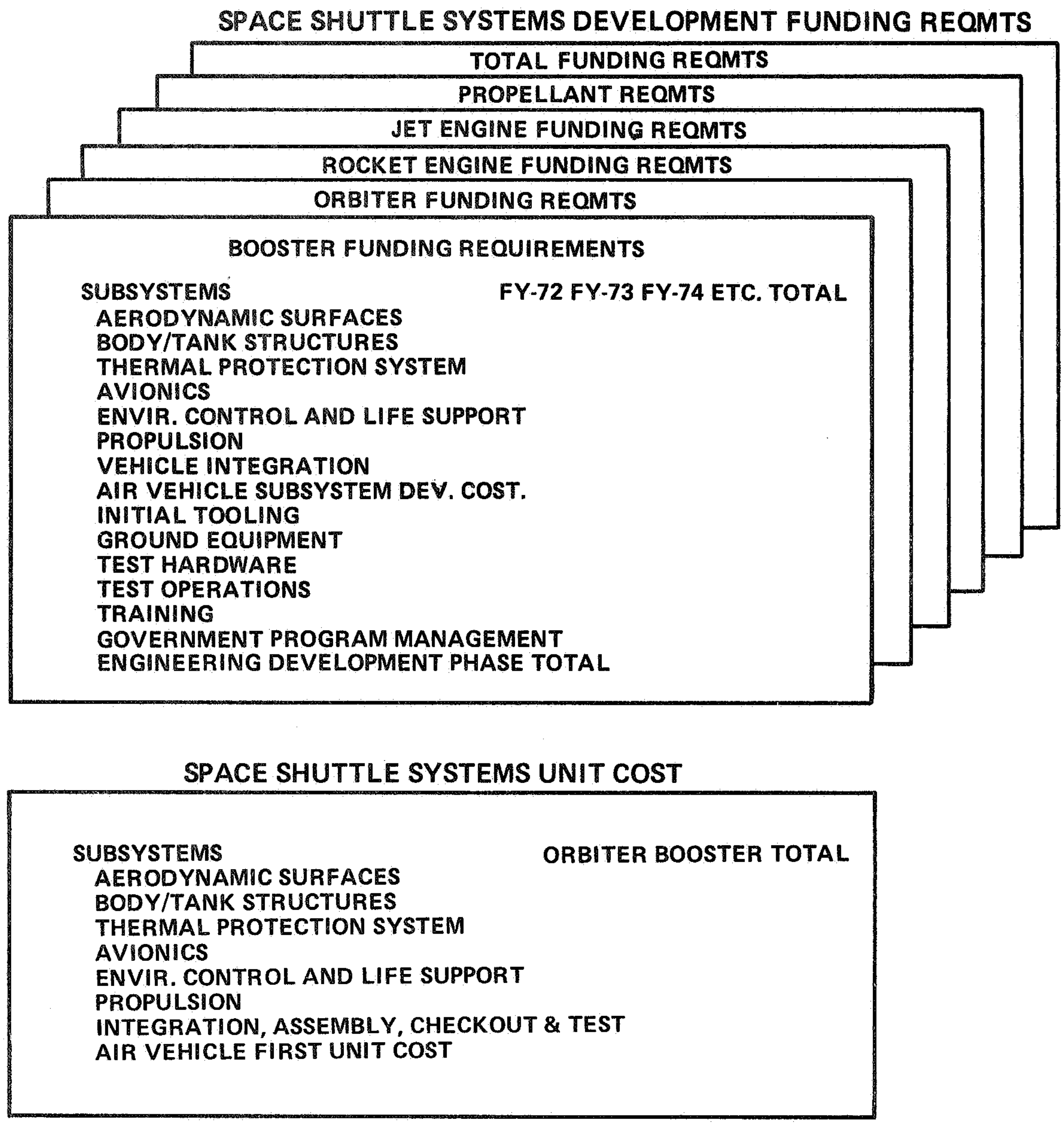

Figure 2. IMPACT output.

The Cost Estimating Relationships (CERs) are mathematical expressions that formulate historical costs of subsystems as functions of their physical parameters. The costs of new systems are estimated by using their physical parameters as independent variables in the CERs. The CERs used in this particular case were developed for Space Shuttle applications by Aerospace Corporation. Thus, the Vehicle Physical Data that are dictated by the Vehicle Selection are the independent variables used in the CERs to obtain the basic subsystems cost estimate of the vehicle selected.

TABLE 1. VEHICLE PHYSICAL DATA

Item	Weight (lb)	
	Booster	Orbiter
Body Structure/Aerodynamic Surfaces/ Thermal Protection	211 206	118 847
Deployable Wings	0	0
Landing Gear	25 719	11 402
Thrust Structure	41 831	3 810
Launch Gear/Docking Systems	2 618	1 000
Main Tankage Integral (Bulkheads and Insulation)	21 284	11 075
Main Tankage Nonintegral	0	0
Tankage On-Orbit Propulsion	0	2 608
Tankage — Airbreathing Engines	12 666	1 156
Main Engines/Accessories	76 087	11 720
On-Orbit Propulsion System	0	1 200
Propulsion System Accessories	44 370	9 342
Airbreathing Engine/Accessories	45 975	10 132
Main Gimbal Control System Contained in Main Engine	0	0
Aerodynamic Controls	12 196	4 244
Reaction Control System	6 742	5 473
Avionics (Guidance Control/Instrumentation Communication/Control	1 400	3 615
Separation System Interface	9 382	2 237
Primary Power System	2 064	3 044
Power Converter/Distributor	2 751	2 423
Environmental Control System	2 500	3 444
Personnel Provisions	340	503
Range Safety Abort	0	0
Contingency	51 913	20 607
Total Weight — Dry	571 042	227 881

TABLE 1. (Concluded)

Item	Weight (lb) Booster	Weight (lb) Orbiter
Personnel	480	480
Cargo	0	25 015
Total Weight at Landing	571 522	253 376
Residuals and Service Items	23 664	4 982
Reaction Control Propellants	3 127	5 440
Thrust Decay Propellants	12 549	1 714
Airbreathing Engine Fuel	170 944	6 509
Total Weight at Reentry	781 807	272 022
On-Orbit Propellants	0	30 117
Total Weight at Cutoff	781 807	302 139
Main Stage Propellants	2 958 000	592 659
Total Weight at Ignition	3 739 807	894 798
Gross Lift-off Weight	4 634 604	
Mass Fraction	0.7909	0.7160
Number of Main Engines	15	2
Vacuum Thrust (lb)	464 785	476 213
Number of Jet Engines	14	3
Fly-Back Range (n.mi.)	375	
Area Wetted (ft^2)	37 893	25 150
Planform Area (ft^2)	11 381	9 311
Vehicle Length	225	192
Planform Loading Act. (lb/ft^2)	68.69	29.22

Examples of the basic CERs used in the program are shown below:

Aerodynamic Surfaces

$$\text{Development Cost (\$)} = 2.502 \times 10^5 \text{ (Wt of Aero Surfaces)}^{0.608}$$

$$\text{First Unit Cost (\$)} = 2.98 \times 10^4 \text{ (Wt of Aero Surfaces)}^{0.610}$$

Jet Engines

$$\text{Development Cost (\$)} = 2.185 \times 10^5 \text{ (Sea Level Thrust)}^{0.726}$$

$$\text{Unit Cost (\$)} = (5 \times 10^4) + 119 \text{ (Sea Level Thrust)}^{0.901}$$

The Cost Factors are factors that are either derived from historical cost or from estimates and act on the basic cost developed by the CERs. Certain Program Decisions or combinations of decisions will activate these factors, which will either increase or decrease the basic cost estimate.

Cost Spreading Functions are beta distributions that distribute the development cost of each subsystem according to a development schedule and spread the unit cost of each vehicle over a period of time, as dictated by the delivery schedule. There are 40 basic spreading functions in the program; these can vary the cumulative subsystem cost expended by 50 percent of the time in the cost spread from 20 percent to 80 percent of the system cost, depending upon the curve selected. The equation shown below is used to determine the cumulative percent of system cost expended at any time (t) in the cost spread. The variables A and B are dependent upon the type of spreading function selected for the cost element.

$$FX = \{A\,T^2\}\,\{10T[(15-4T)\,(T-20)]\} + B\,T^3\{10 + T\,[6T - 15]\}$$
$$+ \{1 - [A + B]\}\,T^4\{5 - 4T\} \quad .$$

A basic spreading function and funding starting and ending dates have been assigned to each subsystem based on a certain schedule, but a change in program phasing will change the starting and ending dates for funding.

B. Vehicle Selection

The Vehicle Selection array consists of a list of the vehicle configurations that have been studied and the performance capabilities and description of each vehicle. Each vehicle included in Vehicle Selection is represented in the Vehicle Physical Data section of the Data Bank by the physical parameters of the vehicle as given in Table 1. Also stored with the Vehicle Physical Data are complexity factors that relate the complexity of the vehicle subsystems to the complexity of the subsystems that were used to develop the CERs.

C. Program Decisions

The Program Decisions array is a list of the variables that will affect the cost of a program and some representative values or options for each variable. The decision to be made on each variable is not necessarily made by a manager but may be dictated by the Vehicle Selection or some circumstantial condition. The decisions included are both technical and managerial. A representative example of Program Decisions is shown in Figures 3, 4, and 5. Although it is not included, the list of Program Decisions for the Orbiter is the same as the list for the Booster. The Program Decisions array is divided by subject, i.e., Rocket Engine, Jet Engine, Orbiter, and Booster, in an attempt to simplify the problem although there is an interrelationship among the subjects.

To clarify the Program Decisions shown in Figures 3, 4, and 5, some of the terminology used and the interrelationship of the decisions will be discussed.

1. Rocket Engine Decisions. In-house Support is defined as research and development contractor support and related activities located at MSFC that would support the engine development. It is expressed as a percent of the prime contractor cost which is estimated by a CER using the selected thrust as the independent variable. The selection of a static test site would cause the cost of activating that test site to be added to the program cost. The commonality of the Orbiter engine to the Booster engine determines the degree of cost sharing between the Booster and Orbiter. Most other decisions combined with the thrust selected are used to compute the cost of engine development propellants. The Buy/Use Ratio of LH_2 reflects potential loss of propellants from boiloff. Although it was not incorporated because of a lack of data, a relationship between Static Test Sites and propellant requirements that would dictate the cost per pound of propellant could be determined.

2. Jet Engine Decisions. Trades are being made to determine if it would be more economical to design a jet engine that is optimized for the Shuttle or to modify existing engines to use either LH_2 or JP-4 fuel for Shuttle applications. The modification of a jet engine to use LH_2 is obviously more difficult than modifying one to use JP-4 on the Shuttle; but, because of the relative inefficiency of JP-4, the increase in the size of the vehicle may offset the savings in engine development cost.

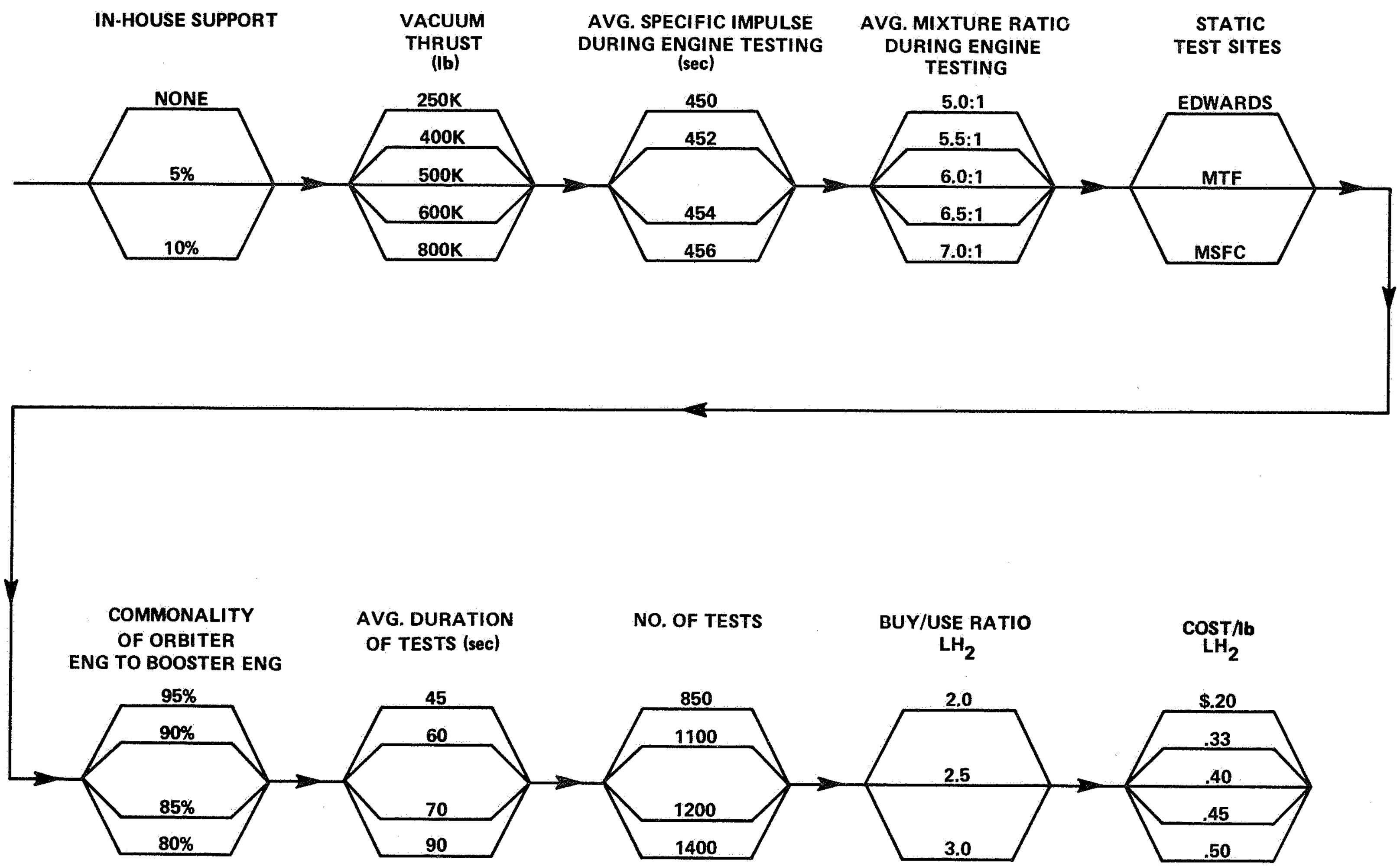

Figure 3. Rocket engine decisions.

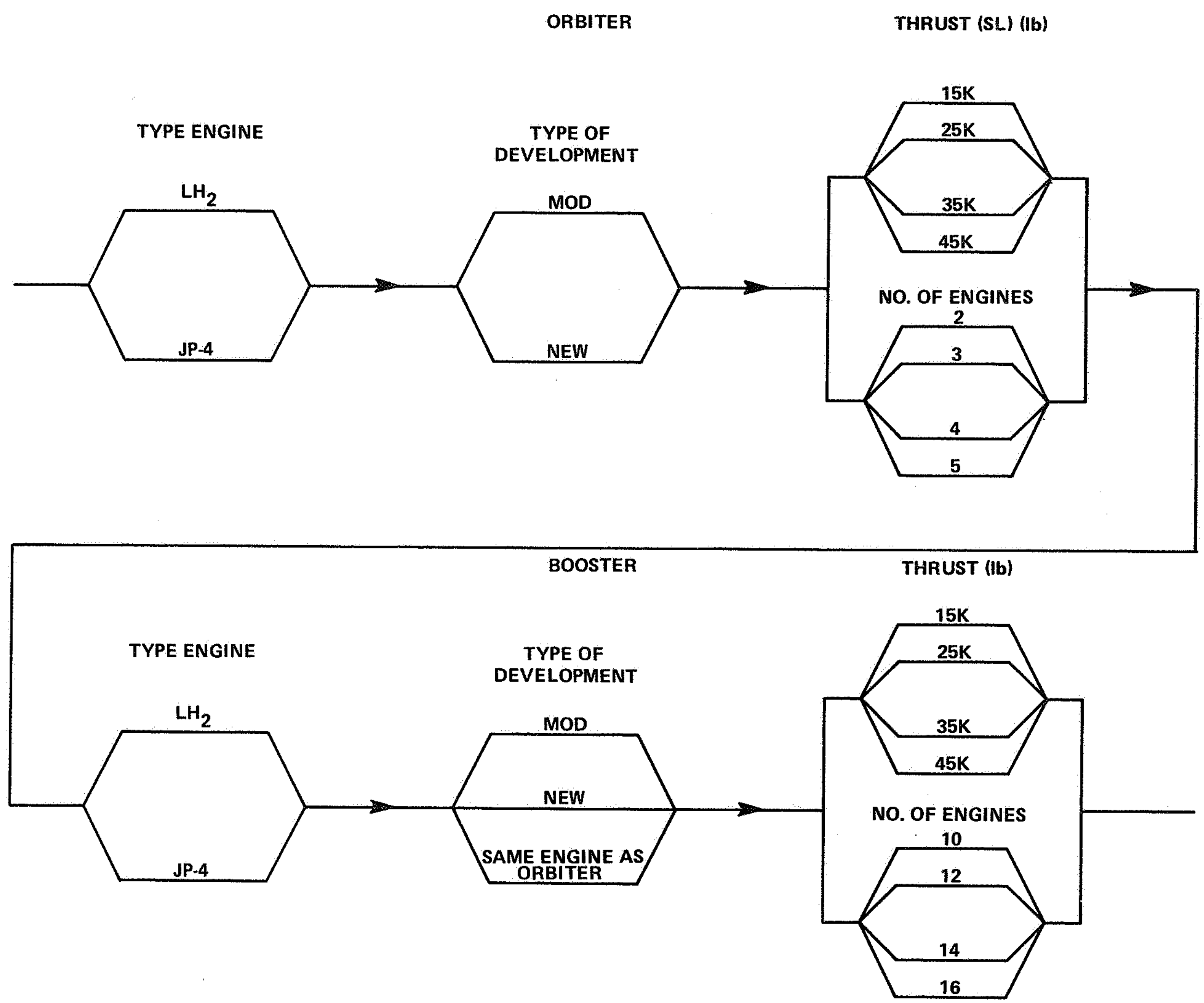

Figure 4. Jet engine decisions.

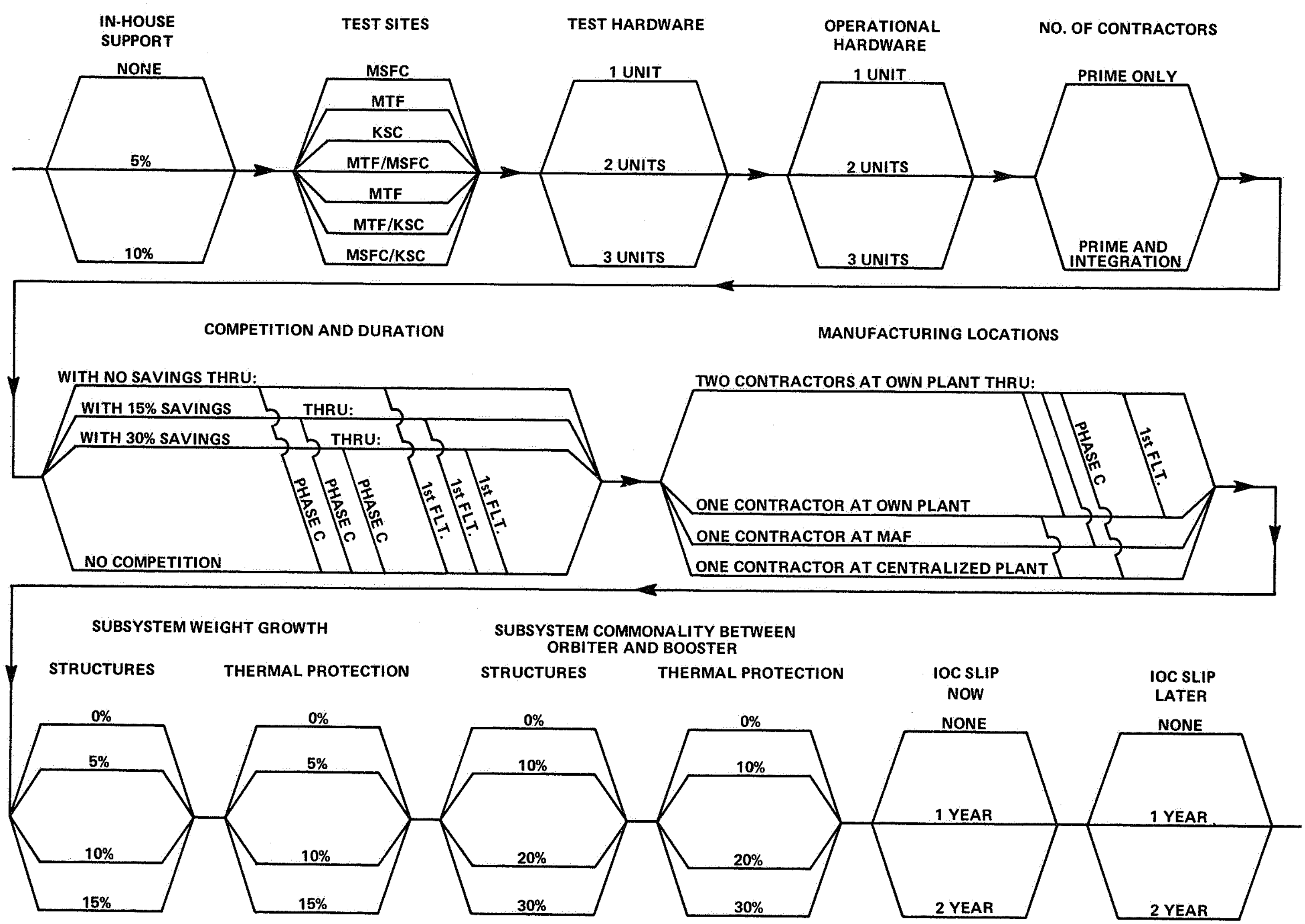

Figure 5. Booster decisions.

3. Booster Decisions. In earlier planning, consideration was being given to having two competing contractors proceed into development, and then terminating one at a predetermined time. One of the reasons for doing this was that the savings in cost after competition ended were assumed to exceed the additional cost of the second contractor. This of course is difficult to express quantitatively and was treated parametrically to evaluate the potential effects of competition on program cost. The Manufacturing Locations decisions add the cost of the facilities at that location to the program cost, and the selection of certain sites causes segments of the program, which were considered to be affected by the manufacturing site, to be multiplied by factors that will increase or decrease the basic estimate. The factors are, at best, an estimate; but a variation of the factors will indicate whether the decision is a cost driver. The subsystem weight growth options were included to determine the effect on cost of subsystem weight growths within the allocated contingency of the selected vehicle.

The IOC Slip Now and IOC Slip Later are decision blocks that are used to determine the effect of a slip of the Initial Operating Capability (IOC) of the Space Shuttle on the funding requirements. The IOC Slip Now indicates the effect on the cost of a slip in IOC that is planned by rephasing the program. The IOC Slip Later is used to determine the effect of a delay in IOC that is caused by program problems. The commonality decisions are used to determine the effect of subsystem similarity between the Orbiter and Booster on the development cost. There are many other decisions to be made on the Shuttle program, but those shown in Figures 3, 4, and 5 are representative of the types to be made.

SECTION IV. COMPUTER PROGRAM

To illustrate the programming technique used in IMPACT, the Program Decisions shown for the jet engine will be used as an example problem. The objective of the program is to compute the jet engine funding requirements for all logical combinations of decisions indicated by the graphical display in Figure 6. To achieve this objective, the development cost must be computed and spread in accordance with a development schedule, and the unit cost will occur as dictated by a delivery schedule. These schedules and the appropriate spreading functions are program inputs.

The Thrust/Number of Engines decision block is called a parallel decision because if the engine thrust is selected, the number of engines is dictated for a given configuration, and vice versa if the number of engines

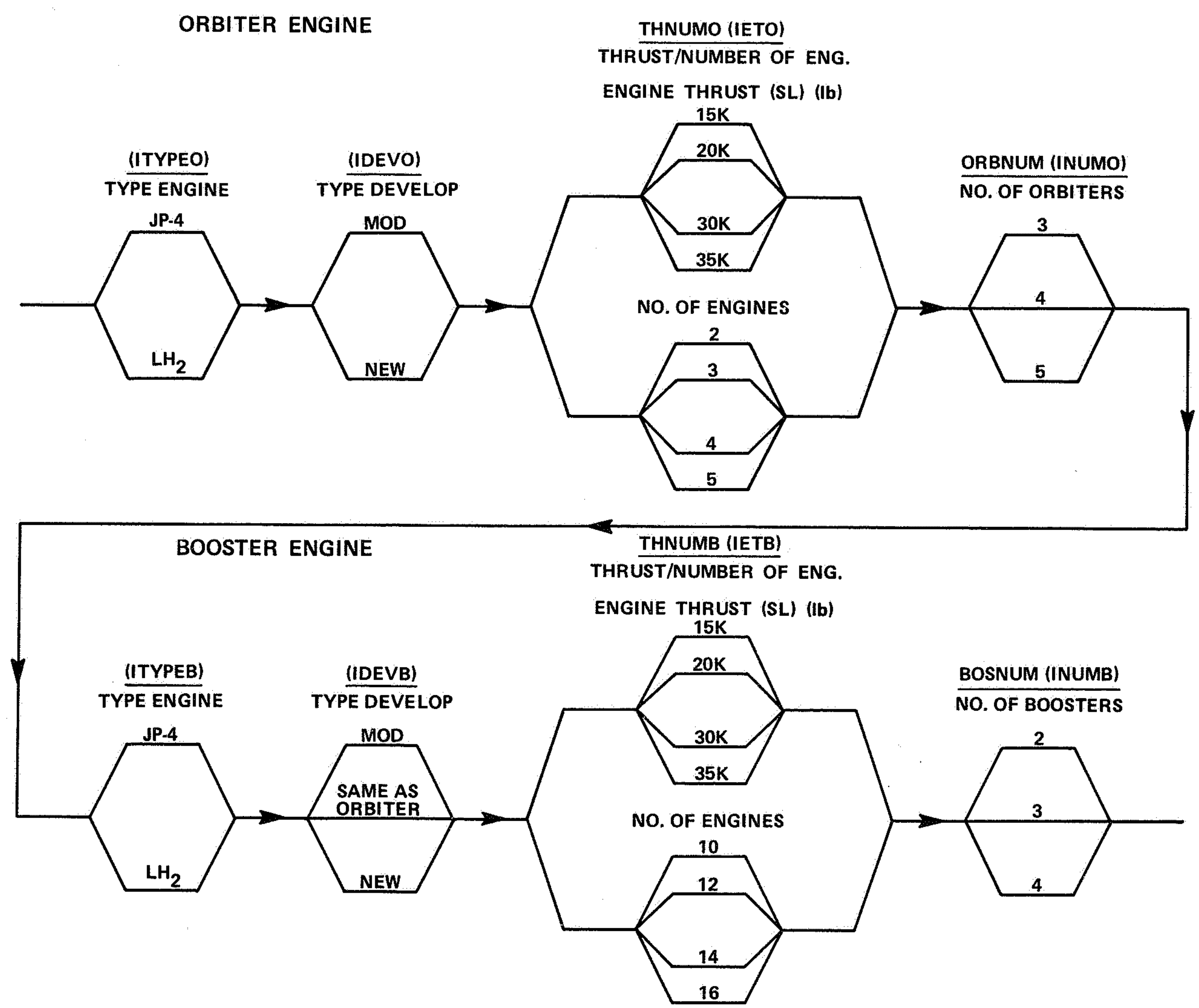

Figure 6. Example of IMPACT programming technique using jet engine decisions.

is selected. Each decision block is given a name for use in the program as shown in Figure 6. Decision blocks that require numerical values to be read into the program for each option are assigned both a variable and a subscript (for example, the Thrust/Number of Engines decision); the other decision blocks are only assigned variable names. Each option is numbered from top to bottom; for example, ITYPEO = 1 indicates a JP-4 engine on the Orbiter. To obtain the cost of a particular jet engine program, the number of the option selected at each decision block is the only input required.

The conditional statements shown below, plus others, have been incorporated into the program:

If	Then	Explanation
ITYPEO = 1	ITYPEB = 1	Not considered feasible to have
ITYPEO = 2	ITYPEB = 2	two types of jet engines on Shuttle.
IDEVO = 2	ITYPEO = 2	If new engine is developed, it will
IDEVB = 3	ITYPEB = 2	be LH_2.

These conditional statements will override the decision selection input data if the data do not agree with the logic in the program. If the conditional statements are not desired, they can be removed from the program. Thus, the program decisions selected will not be changed.

The input sheets for IMPACT, as shown in Table 2, are given to managers to make program decisions. Their decisions are input into the program, calculations inherent to these decisions are made, and the results are analyzed. By using an input format such as this, more participation has been obtained from management than had been experienced in previous cost activities. The advantage of this type of input format over typical cost model inputs is that all alternate approaches are suggested. The program input cards are punched directly from the input sheets; thus, the response time is minimum.

The JP-4 and LH_2 jet engine cost trade involves more than just the cost of the jet engines; however, the sample problem is concerned only with the jet engines. The relative inefficiency of JP-4 compared to LH_2 requires more tankage, etc., which dictates a heavier vehicle. Thus, the total thrust required from the jet engines is greater for a vehicle using JP-4 than for one using LH_2. The thrust levels used in the sample problem are approximate values derived from parametric sizing trades, and are as shown. (The dictionary of variables, which defines the terms used in the program, is presented in Table 3.) THJPO = 67 000, THJPB = 200 000, THLHO = 50 000, and THLHB = 150 000; therefore, more JP-4 engines than LH_2 engines of equal thrust are required.

TABLE 2. IMPACT INPUT, JET ENGINE DECISIONS

	Format (8I5)			
	Case No. 1	Case No. 2	Case No. 3	Name
Orbiter Engine				
Type of Engine (1) JP-4 (2) LH_2	1	2	2	ITYPEO
Type of Development (1) Modification (2) New	1	2	2	IDEVO
Thrust/Number of Engines	1	7	3	IETO
Sea Level Thrust (lb): (1) 15K; (2) 20K; (3) 30K; (4) 35K Number of Engines: (5) 2; (6) 3; (7) 4; (8) 5				
Number of Orbiters (1) 3 (2) 4 (3) 5	3	3	3	INUMO
Booster Engine				
Type of Engine (1) JP-4 (2) LH_2	1	2	2	ITYPEB
Type of Development (1) Modification (2) Same Engine as Orbiter (3) New	2	2	3	IDEVB
Thrust/Number of Engines	1	5	5	IETB
Sea Level Thrust (lb): (1) 15K; (2) 20K; (3) 30K; (4) 35K Number of Engines: (5) 10; (6) 12; (7) 14; (8) 16				
Number of Boosters (1) 2 (2) 3 (3) 4	3	3	3	INUMB

TABLE 3. DICTIONARY OF VARIABLES

BOSNUM(INUMB)	—	Number of Boosters in Program
		INUMB = 1 - 2 Orbiters
		= 2 - 3 Orbiters
		= 3 - 4 Orbiters
DEVBOS	—	Development Cost of Jet Engine for Booster
DEVORB	—	Development Cost of Jet Engine for Orbiter
ENGBOS	—	Number of Engines on Booster
ENGORB	—	Number of Engines on Orbiter
FUBOS	—	First Unit Cost of Jet Engine for Booster
FUORB	—	First Unit Cost of Jet Engine for Orbiter
IDEVB	—	Type of Jet Engine Development for Booster
		1 = Modification
		2 = Same Engine used by Orbiter
		3 = New Development
IDEVO	—	Type of Jet Engine Development for Orbiter
		1 = Modification
		2 = New Development
IFUND	—	Number of Years in Cost Spread
ISTART	—	Year Funding Starts
ITYPEB	—	Type of Jet Engine Selected for Booster
		1 = JP-4 Engine
		2 = LH_2 Engine

TABLE 3. (Concluded)

ITYPEO	—	Type of Jet Engine Selected for Orbiter 1 = JP-4 Engine 2 = LH_2 Engine
ORBNUM(NUMO)	—	Number of Orbiters in Program
RESOCB	—	Recurring Cost of Jet Engines for Booster
RECOSO	—	Recurring Cost of Jet Engines for Orbiter
THBOS	—	Sea Level Thrust of Jet Engines on Booster
THJPB	—	Total Thrust Required from JP-4 Jet Engines on Booster
THJPO	—	Total Thrust Required from JP-4 Jet Engines on Orbiter
THLBH	—	Total Thrust Required from LH_2 Jet Engines on Booster
THLHO	—	Total Thrust Required from LH_2 Jet Engines on Orbiter
THNUMB(IETB)	—	Thrust or Number of Engines Selected IETB $\leqq$ 4 — Size Engine Selected IETB > 4 — Number of Engines Selected
THNUMO(IETO)	—	Thrust or Number of Engines Selected IETO $\leqq$ 4 — Size Engine Selected IETO > 4 — Number of Engines Selected
THORB	—	Sea Level Thrust of Jet Engine on Orbiter
TOTORB	—	Total Cost of Jet Engines for Orbiter

The program listing and the flow chart displaying the program logic are given in Table 4 and Figure 7, respectively. The COMPUTED GO TO statements serve as decisions which are indexed by the input data; thus, the program is directed to the calculations necessary to compute the cost of the jet engines for a particular case. Obviously much of the program is not used on a given set of input, but the potential of costing all the indicated combinations of decisions with a minimum of input has proven to be most valuable.

The factors shown in Table 5 are used to reflect the effect of modifying an existing engine and using that engine on both the Orbiter and Booster. Modifications of these factors are used for other combinations of decisions shown in Figure 6.

The complexity factors relate the complexity of the jet engines of the Shuttle to the complexity of the jet engines used to develop the basic CER. Commonality factors indicate the portion of jet engine development cost that is shared by both the Orbiter and Booster; therefore it is zero if the same engine is not used on both. The off-the-shelf factors reflect the fraction of jet engine development cost that will be paid by other programs; a new engine development would obviously mean that there is no off-the-shelf factor. To compute a development cost factor that represents a combination of all the development factors, the following formula is used:

$$\text{FDEV} = (\text{complexity}) \frac{(2.0 - \text{commonality})}{2} (1.0 - \text{off-the-shelf}) \; .$$

Therefore, the development cost factors for modifying an existing engine to use JP-4 on both the Orbiter and Booster are shown below:

$$\text{FDEV (Orbiter)} = (1.1) \frac{2.0 - 0.9}{2} (1.0 - 0.9) = 0.0605 \; ,$$

and

$$\text{FDEV (Booster)} = (1.0) \frac{2.0 - 0.9}{2} (1.0 - 0.9) = 0.055 \; .$$

These factors multiplied times the basic CER, which uses the selected thrust as the independent variable, will generate the development cost.

The first unit complexity factor is the only factor used to affect the basic unit cost derived from the CER. It is based on manufacturing and production complexity of the Shuttle engines relative to the historical engine used

TABLE 4. PROGRAM LISTING

```
ΔASSIGN S=MT0,SI=CR,B0=MT1,L0=LP.
ΔREWIND MT1.
Δ FORTRAN B0, L0.
             DIMENSION DNAME[2, 9,5]
             DIMENSION COSENG[2,10],FUND[2,10,10],FR[10],SUBTOT[10,10],ENGTOT[1
            X0],IFUND[2,6],A[10,10],B[10,10],ISTART[2,6]
             DIMENSION ANAME[6, 8],               CNAME[1,10]
             DIMENSION THNUMO[8],ORBNUM[3],THNUMB[8],BOSNUM[3]
             DO 71 N=1,6
       71    READ 18,[ANAME[N,NX],NX=1,8 ]
       18    FORMAT[ 8A5]
             READ 67,[CNAME[1,NZ],NZ=1,10]
       67    FORMAT[10A8]
             DO 307 N=1,2
             DO 307 NX=2,10
      307    READ 309, [DNAME[N,NX,NY],NY=1,4]
      309    FORMAT[4A5]
             READ 1,THNUMO
             READ 1,ORBNUM
             READ 1,THNUMB
             READ 1,BOSNUM
             READ 1,THJPO,THJPB,THLHO,THLHB
             READ 2,ITYPEO,IDEVO,IETO,INUMO,ITYPEB,IDEVB,IETB,INUMB
     1       FORMAT[8F9.2]
     2       FORMAT[8I5]
             READ 286, [[ISTART[M,N],N=1,6],M=1,2]
             READ 286, [[IFUND[M,N],N=1,6],M=1,2]
    286      FORMAT [12I4]
             READ 259, [[A[M,N],N=1,6],M=1,2]
             READ 259, [[B[M,N],N=1,6],M=1,2]
    259      FORMAT [6F10.2]
             GO TO [3,4],IDEVO
       4     ITYPEO=2
       3     IF[IETO-4]5,5,6
       5     THORB=THNUMO[IETO]
             IF[ITYPEO-1]7,7,8
       7     ENGORB=THJPO/THORB
             GO TO 9
       8     ENGORB=THLHO/THORB
       9     INUM=ENGORB
             IF[ENGORB-INUM]10,10,11
      11     ENGORB=INUM+1
             GO TO 10
       6     ENGORB=THNUMO[IETO]
             IF[ITYPEO-1]12,12,13
      12     THORB=THJPO/ENGORB
             GO TO 10
      13     THORB=THLHO/ENGORB
      10     GO TO [14,15],IDEVO
      14     GO TO [16,17],ITYPEO
      16     DEVORB=.110*[218500.*[THORB]**.726]
             GO TO 21
      17     DEVORB=.39*[218500.*[THORB]**.726]
```

```
           GO TO 21
      15   GO TO [19,20],ITYPEO
      19   DEVORB=1.1*[218500.*[THORB]**.726]
           GO TO 21
      20   DEVORB=1.3*[218500.*[THORB]**.726]
      21   FUORB=1.1*[50000.+119*[THORB]**.901]
           RECOSO=FUORB*ENGORB
           TOTORB=DEVORB+RECOSO
           ITYPEB=ITYPEO
           GO TO [31,23,31],IDEVB
      23   DEVORB=.55*DEVORB
           IF[ITYPEB-1]51,51,52
      51   DEVBOS=.91*DEVORB
           GO TO 53
      52   DEVBOS=.925*DEVORB
      53   THBOS=THORB
           FUBOS=.91*FUORB
           GO TO [24,25],ITYPEB
      24   ENGBOS=THJPB/THBOS
           GO TO 36
      25   ENGBOS=THLHB/THBOS
           GO TO 36
      31   IF[IETB-4]32,32,33
      32   THBOS=THNUMB[IETB]
           GO TO [34,35],ITYPEB
      34   ENGBOS=THJPB/THBOS
           GO TO 36
      35   ENGBOS=THLHB/THBOS
      36   INUM=ENGBOS
           IF[ENGBOS-INUM]40,40,61
      61   ENGBOS=INUM+1
           GO TO 40
      33   ENGBOS=THNUMB[IETB]
           GO TO [37,38],ITYPEB
      37   THBOS=THJPB/ENGBOS
           GO TO 40
      38   THBOS=THLHB/ENGBOS
      40   IF[IDEVB-2]41,50,42
      41   IF[ITYPEB-1]43,43,44
      43   DEVBOS=.10*[218500.*[THBOS]**.726]
           GO TO 50
      44   DEVBOS=.36*[218500. *[THBOS]**.726]
           GO TO 50
      42   IF[ITYPEB-1] 131,131,132
     131   DEVBOS=1.0*[218500.*[THBOS]**.726]
           GO TO 50
     132   DEVBOS=1.2*[218500.*[THBOS]**.726]
      50   FUBOS=50000. + 119.*[THBOS]**.901
           RECOSB=FUBOS*ENGBOS
           DEVORB=DEVORB/ 10.**6
           DEVBOS=DEVBOS/ 10.**6
           RECOSO=RECOSO/ 10.**6
           RECOSB=RECOSB/ 10.**6
           FUORB=FUORB/10.**6
```

TABLE 4. (Continued)

```
        FUBOS=FUBOS/ 10.**6
        DO 256 M=1,2
        DO 256 N=1,10
  256   COSENG[M,N]=0.0
        COSENG[1,1]=DEVORB
        LIMORB=ORBNUM[INUMO]
        DO 257 N=1,LIMORB
        M=N+1
  257   COSENG[1,M]=RECOSO
        COSENG[2,1]=DEVBOS
        LIMBOS=BOSNUM[INUMB]
        DO 258, N=1,LIMBOS
        M=N+1
  258   COSENG[2,M]=RECOSB
        DO 260, K=1,2
        DO 260, L=1,10
        DO 260, M=1,10
  260   FUND[K,L,M]=0.0
        DO 261, K=1,2
        DO 261, L=1,6
        DO 262, M=1,10
  262   FR[M]=0.0
        TR=0.0
        S=1.0/IFUND[K,L]
        T=0.0
        NI=IFUND[K,L]
        DO 263, N=1,NI
        T=T+S
        FX=[A[K,L]*T**2]*[10.+T*[[15.-4.*T]*T-20.]]+B[K,L]*T**3*[10.+T*[
       $6.*T-15.]]+[1.-[A[K,L]+B[K,L]]]*T**4*[5.-4.*T]
        M=ISTART[K,L]+N-1.
        FR[M]=FX-TR
  263   TR=TR+FR[M]
        ISTOP=ISTART[K,L]+IFUND[K,L]-1.
        NI=ISTART[K,L]
        DO 264, M=NI,ISTOP
  264   FUND[K,L,M]=COSENG[K,L]*FR[M]
  261   CONTINUE
        DO 265,K=1,2
        DO 265, M=1,10
        SUBTOT[K,M]=0.0
        DO 266, L=2,6
  266   SUBTOT[K,M]=SUBTOT[K,M]+FUND[K,L,M]
  265   CONTINUE
        DO 267,K=1,2
        DO 267, M=1,10
        FUND[K,7,M]=.10*SUBTOT[K,M]
        FUND[K,8,M]=.20*SUBTOT[K,M]
  267   FUND[K,9,M]=.08*[SUBTOT[K,M]+FUND[K,7,M]+FUND[K,8,M]]
        DO 268, K=1,2
        DO 268, L=1,9
        DO 268, M=1,10
  268   FUND[K,10,M]=FUND[K,10,M]+FUND[K,L,M]
        DO 269 K=1,2
```

```
      DO 269 L=1,10
  269 COSENG[K,L]=0.0
      DO 270 K=1,2
      DO 270 L=1,10
      DO 270 M=1,10
  270 COSENG[K,L]=COSENG[K,L]+FUND[K,L,M]
      DO 271, M=1,10
 271  ENGTOT[M]=0.0
      DO 272, M=1,10
 272  ENGTOT[M]=FUND[1,10,M]+FUND[2,10,M]
      TOTENG=0.0
      DO 273, N=1,10
  273 TOTENG=TOTENG+ENGTOT[N]
      PRINT 62
   62 FORMAT[1H1,56X,19HJET ENGINE DECISION]
      PRINT 63
   63 FORMAT[ /48X,7HORBITER,17X,7HBOOSTER]
      IF[ITYPEO-1]111,111,112
  111 GO TO [113,114],ITYPEB
  113 PRINT 101
 101  FORMAT[12H TYPE ENGINE,39X,4HJP-4, 20X,4HJP-4]
      GO TO 124
  114 PRINT 102
  102 FORMAT[12H TYPE ENGINE,39X,4HJP-4,20X,4H LH2]
      GO TO 124
  112 GO TO [115,116],ITYPEB
  115 PRINT 103
  103 FORMAT[12H TYPE ENGINE,40X,3HLH2,20X,4HJP-4]
      GO TO 124
  116 PRINT 104
  104 FORMAT[12H TYPE ENGINE,40X,3HLH2,21X,3HLH2]
  124 IF[IDEVO-1]117,117,118
  117 GO TO [119,120,121],IDEVB
  119 PRINT 105
  105 FORMAT[17H TYPE DEVELOPMENT,35X,3HMOD,21X,3HMOD]
      GO TO 126
  120 PRINT 106
  106 FORMAT[17H TYPE DEVELOPMENT,35X,3HMOD, 9X,15HSAME ENG AS ORB]
      GO TO 126
  121 PRINT 107
  107 FORMAT[17H TYPE DEVELOPMENT,35X,3HMOD,21X,3HNEW]
      GO TO 126
  118 GO TO [122,123,125],IDEVB
  122 PRINT 108
  108 FORMAT[17H TYPE DEVELOPMENT,35X,3HNEW,21X,3HMOD]
      GO TO 126
  123 PRINT 109
  109 FORMAT[17H TYPE DEVELOPMENT,35X,3HNEW, 9X,15HSAME ENG AS ORB]
      GO TO 126
  125 PRINT 110
  110 FORMAT[17H TYPE DEVELOPMENT,35X,3HNEW,21X,3HNEW]
  126 CONTINUE
      PRINT 57,[ANAME[1,NX],NX=1,8],THORB,THBOS
      PRINT 64,[ANAME[2,NX],NX=1,8],ENGORB,ENGBOS
```

```
          PRINT 57,[ANAME[3,NX],NX=1,8],ORBNUM[INUMO],BOSNUM[INUMB]
          PRINT 60,[CNAME[1,NZ],NZ=1,10]
          PRINT 54,[ANAME[4,NX],NX=1,8 ],DEVORB,DEVBOS
          PRINT 54,[ANAME[5,NX],NX=1,8 ],FUORB,FUBOS
          PRINT 54,[ANAME[6,NX],NX=1,8],RECOSO,RECOSB
     54   FORMAT[8A5,F15.2,F24.2]
     57   FORMAT[8A5,F15,F24]
     60   FORMAT[/10A8/]
     64   FORMAT[8A5,F15.1,F24.1]
          PRINT 201
  201     FORMAT[ /  50X,31HJET ENGINE FUNDING REQUIREMENTS   ]
          PRINT 228
    228   FORMAT[56X,19HMILLIONS OF DOLLARS/ ]
          DO 301 N=1,2
          IF[N-1]305,305,306
     305 PRINT 202
     202 FORMAT[58X,14HORBITER ENGINE//]
          GO TO 308
     306 PRINT 203
     203 FORMAT[/58X,14HBOOSTER ENGINE//]
     308 PRINT 310
     310 FORMAT[12HFISCAL YEARS,13X,4H1972,5X,4H1973,5X,4H1974,5X,4H1975,5X
        X,4H1976,5X,4H1977,5X,4H1978,5X,4H1979,5X,4H1980,5X,4H1981,4X,5HTOT
        XAL,/ ]
          IF[N-1]311,311,312
     311 PRINT 204,[FUND[1,1,M],M=1,10],COSENG[1,1]
          GO TO 313
     312 PRINT 204,[FUND[2,1,M],M=1,10],COSENG[2,1]
  204     FORMAT[18HENGINE DEVELOPMENT ,2X,11F9.2]
     313 PRINT 205
  205     FORMAT[18HINVESTMENT ENGINES]
          DO 301 NX=2,10
     301 PRINT 302,[DNAME[N,NX,NY],NY=1,4],[FUND[N,NX,M],M=1,10],COSENG[N,N
        1X]
     302 FORMAT[4A5,11F9.2]
          PRINT 250,[ENGTOT[M],M=1,10],TOTENG
  250     FORMAT [//16HTOTAL JET ENGINE,4X,11F9.2]
          END
```

PROGRAM ALLOCATION

00024	DNAME	00310	COSENG	00360	FUND	01200	FR
01224	SUBTOT	01534	ENGTOT	01560	IFUND	01574	A
02104	B	02414	ISTART	02430	ANAME	02570	CNAME
02614	THNUMO	02634	ORBNUM	02642	THNUMB	02662	BOSNUM
02670	N	02671	NX	02672	NZ	02673	NY
02674	ITYPEO	02675	IDEVO	02676	IETO	02677	INUMO
02700	ITYPEB	02701	IDEVB	02702	IETB	02703	INUMB
02704	M	02705	INUM	02706	LIMORB	02707	LIMBOS
02710	K	02711	L	02712	NI	02713	ISTOP
02714	THJPO	02716	THJPB	02720	THLHO	02722	THLHB
02724	THORB	02726	ENGORB	02730	DEVORB	02732	FUORB
02734	RECOSO	02736	TOTORB	02740	DEVBOS	02742	THBOS

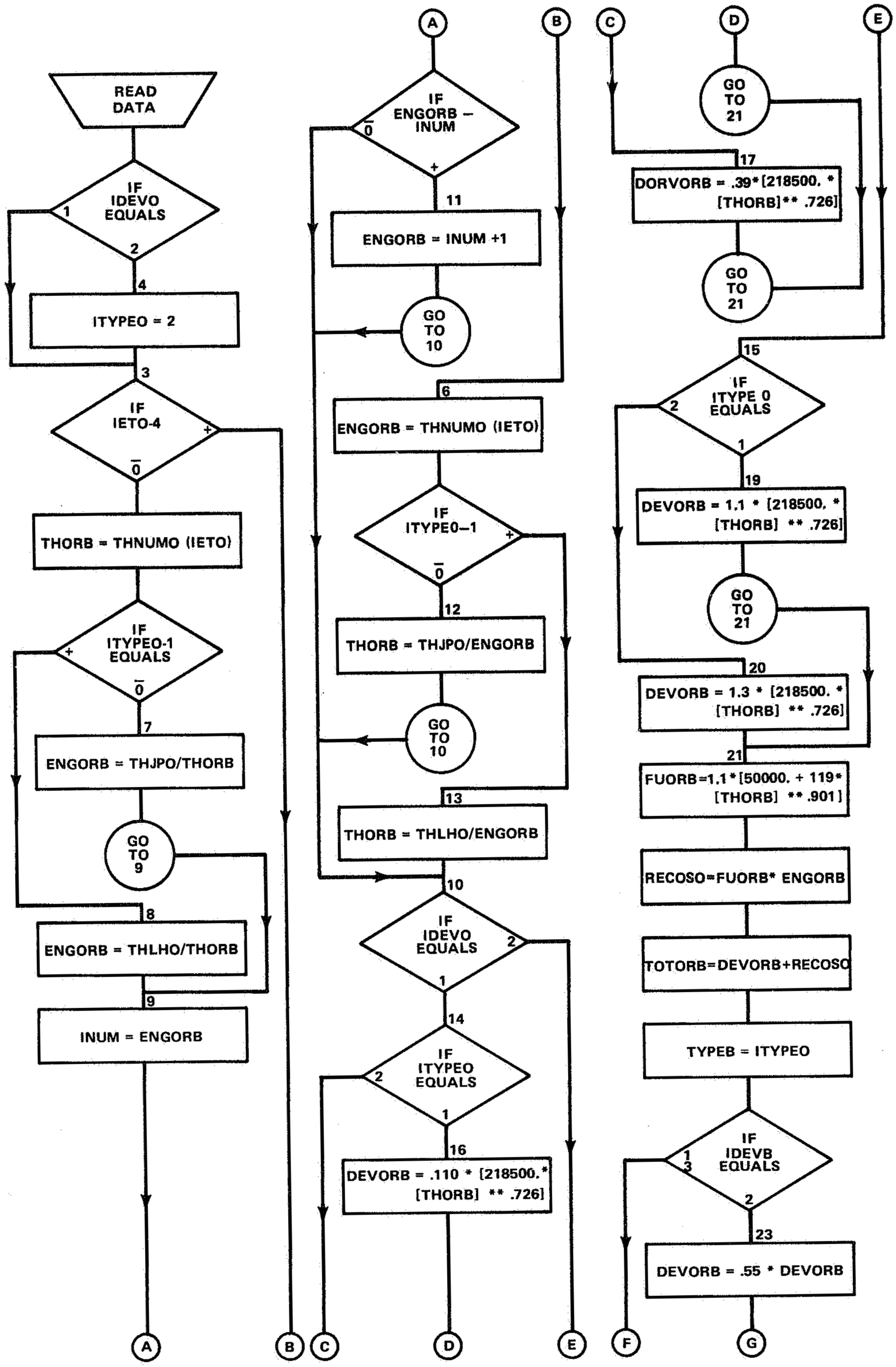

Figure 7. Flow chart.

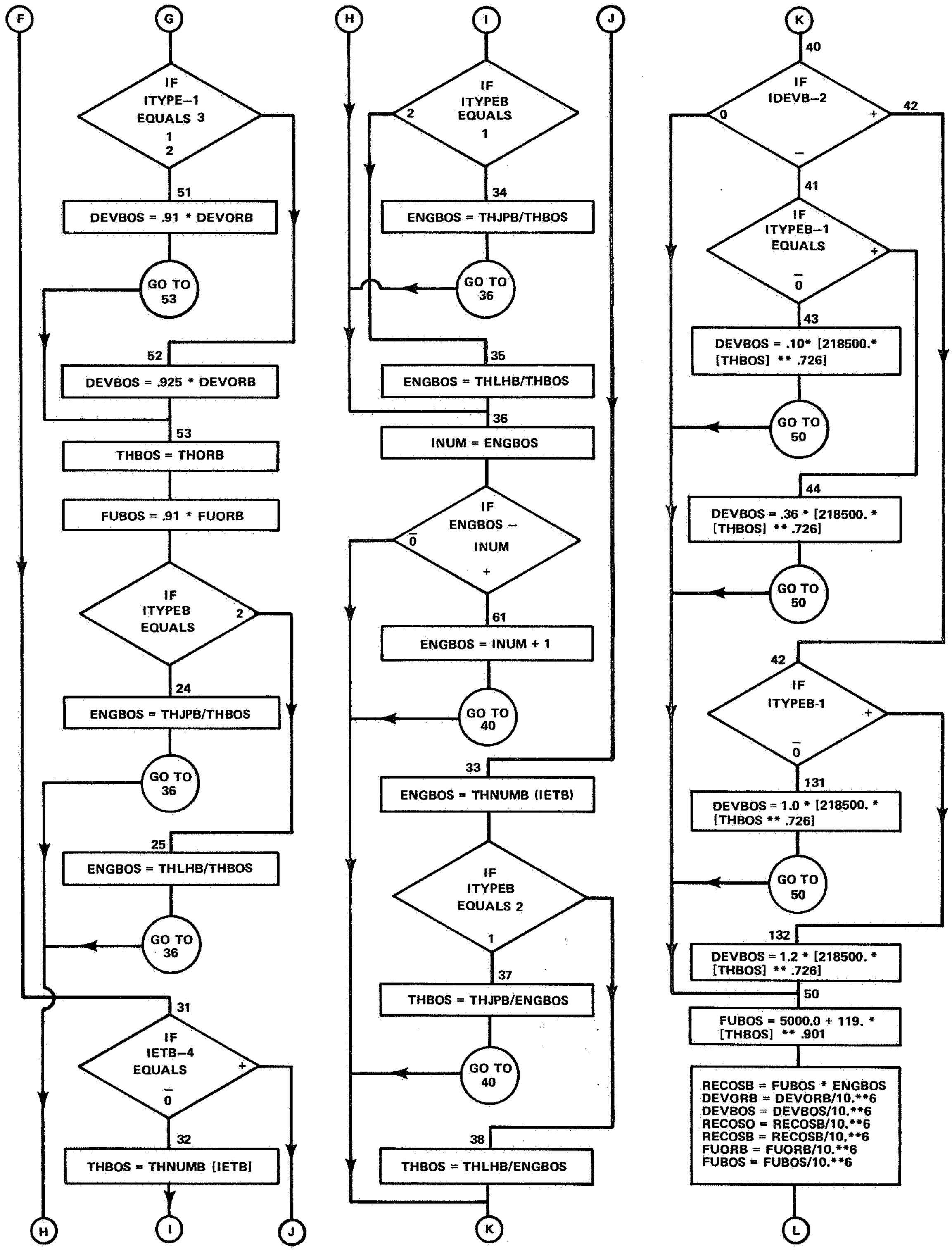

Figure 7. Flow chart (Continued).

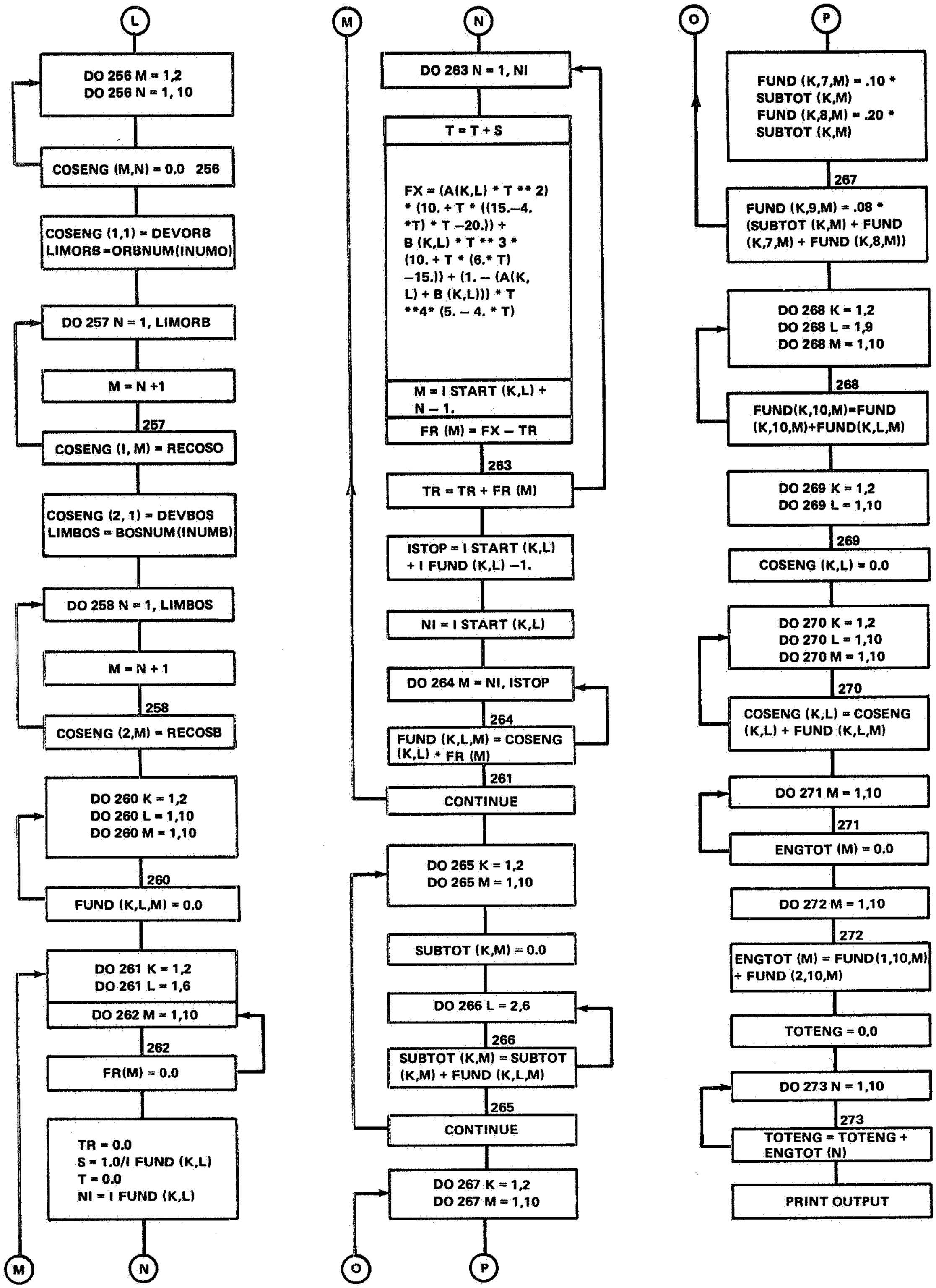

Figure 7. Flow chart (Concluded).

TABLE 5. JET ENGINE COMPLEXITY, COMMONALITY, AND OFF-THE-SHELF FACTORS

Development of Factors	Type of Engine	
Complexity	JP-4	LH_2
Orbiter	1.1	1.3
Booster	1.0	1.2
Commonality	0.9	0.9
Off-the-Shelf	0.9	0.7
First Unit Factors		
Complexity		
Orbiter	1.1	1.1
Booster	1.0	1.0

to develop the CER. The first unit complexity factor times the first unit cost CER using the appropriate thrust provides the first unit cost.

The program decisions shown in the three cases in Table 2 are used for the sample problem. These cases have been selected to demonstrate the capabilities of the system and to indicate the impact of certain decisions on jet engine costs.

A jet engine development schedule and delivery schedules of the engines for each vehicle as shown in Figure 8, along with cost spreading functions for each of these elements, are inputs to the program. The development cost of the engine is spread by a 60 percent cost/50 percent time spreading function, and the engine cost of each vehicle is distributed by a 50 percent cost/50 percent time function.

Other jet engine program costs that are functions of the cost of the delivered engines are Initial Spares, Engineering Support, and Contractor Program Management.

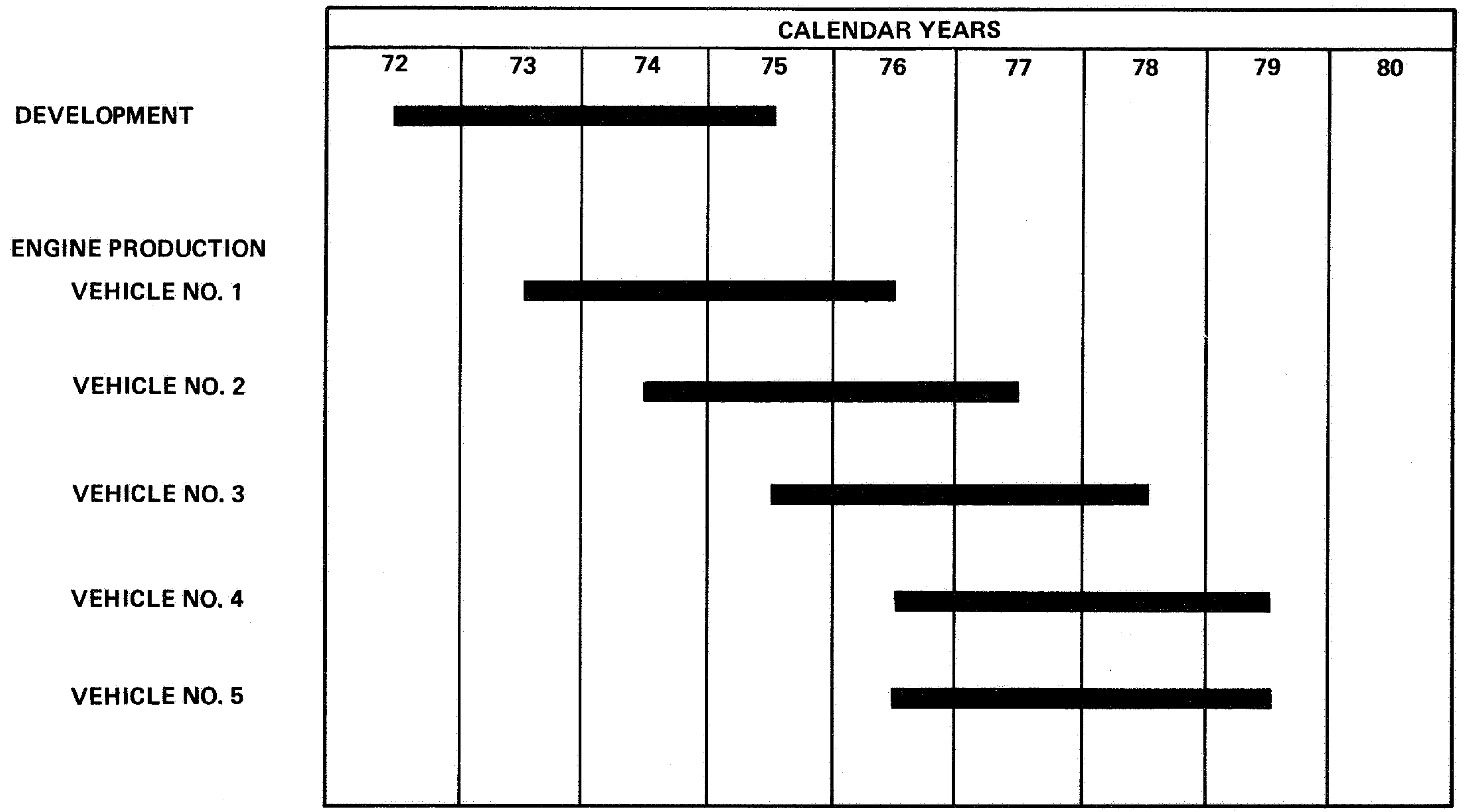

Figure 8. Jet engine development/production schedule.

Initial Spares include the manufacturing cost of spare parts for the initial spares stock that is required for operations.

Engineering Support includes the cost of engineering effort that is in direct support of manufacturing. It involves the coordination of the various manufacturing activities on an interdepartmental basis and with subcontractors and vendors. It also includes continued engineering analysis of test results and other supporting activities.

Contractor Program Management refers to the costs associated with the prime contractor's centralized direction of effort in the areas of program planning, control, and administration. Therefore, the funding requirements of the example problems shown in Tables 6, 7, and 8 are functions of the program decisions in Table 2, the schedule shown in Figure 8, and the selected spreading functions.

The results of Case 1 in Figure 2 reflect the funding requirements for modifying an existing engine and using it on both the Orbiter and Booster. It is assumed that if one engine is selected to be used on both the Orbiter and Booster, the Orbiter, because of performance reasons, will select that engine. Therefore the type and thrust of the engine on the Booster is dictated by the decision made on the Orbiter if the engine is common to both. Although the decisions made on the Booster engine are compatible with those made on the Orbiter engine, the conditional statements in the program would have forced all decisions that would have been necessary to reflect the decision that the same engine is being used on the Orbiter and Booster.

Table 7 shows the funding requirements of the decisions made in Case 2 of Table 2. For this case, it is assumed that the number of jet engines for the Orbiter is dictated by the configuration. Therefore the costs in Table 7 are for developing a new LH_2 engine for the Orbiter and using it on the Booster. Because of the conditional statements in the program, the IETB value is recomputed in the program.

The costs of the decisions in Case 3 are shown in Table 8. These costs represent the effect on funding requirements of developing a new LH_2 engine for the Orbiter and another for the Booster.

The example problems are obviously for only one segment of a total program, but they do illustrate the effect of decisions on program cost. When different options of the total program are costed, the differences in cost of the options can be pronounced as the examples shown.

The decisions made for each case are recorded with the cost, which helps keep the cost from being used out of context.

TABLE 6. JET ENGINE FUNDING REQUIREMENTS (CASE 1)

JET ENGINE DECISION

	ORBITER	BOOSTER
TYPE ENGINE	JP-4	JP-4
TYPE DEVELOPMENT	MOD	SAME ENG AS ORB
ENGINE THRUST(SL)	15000.	15000.
NO. OF ENGINES	5.0	14.0
NO. OF STAGES WITH JET ENGINES	5.	4.

MILLIONS OF DOLLARS

	ORBITER	BOOSTER
DEVELOPMENT COST	14.22	12.94
ENGINE FIRST UNIT COST	.81	.74
ENGINE COST PER STAGE	4.06	10.35

JET ENGINE FUNDING REQUIREMENTS
MILLIONS OF DOLLARS

ORBITER ENGINE

FISCAL YEARS	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	TOTAL
ENGINE DEVELOPMENT	.00	4.48	7.50	2.24	.00	.00	.00	.00	.00	.00	14.22
INVESTMENT ENGINES											
VEHICLE NO. 1	.00	.00	.85	2.36	.85	.00	.00	.00	.00	.00	4.06
VEHICLE NO. 2	.00	.00	.00	.85	2.36	.85	.00	.00	.00	.00	4.06
VEHICLE NO. 3	.00	.00	.00	.00	.85	2.36	.85	.00	.00	.00	4.06
VEHICLE NO. 4	.00	.00	.00	.00	.00	.85	2.36	.85	.00	.00	4.06
VEHICLE NO. 5	.00	.00	.00	.00	.00	.85	2.36	.85	.00	.00	4.06
INITIAL SPARES	.00	.00	.09	.32	.41	.49	.56	.17	.00	.00	2.03
ENGINEERING SUPPORT	.00	.00	.17	.64	.81	.98	1.11	.34	.00	.00	4.06
CONTRACTOR PROG MGT	.00	.00	.09	.33	.42	.51	.58	.18	.00	.00	2.11
TOTAL	.00	4.48	8.70	6.74	5.71	6.90	7.82	2.40	.00	.00	42.76

BOOSTER ENGINE

FISCAL YEARS	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	TOTAL
ENGINE DEVELOPMENT	.00	4.08	6.83	2.03	.00	.00	.00	.00	.00	.00	12.94
INVESTMENT ENGINES											
VEHICLE NO. 1	.00	.00	2.17	6.00	2.17	.00	.00	.00	.00	.00	10.35
VEHICLE NO. 2	.00	.00	.00	2.17	6.00	2.17	.00	.00	.00	.00	10.35
VEHICLE NO. 3	.00	.00	.00	.00	2.17	6.00	2.17	.00	.00	.00	10.35
VEHICLE NO. 4	.00	.00	.00	.00	.00	2.17	6.00	2.17	.00	.00	10.35
VEHICLE NO. 5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
INITIAL SPARES	.00	.00	.22	.82	1.03	1.03	.82	.22	.00	.00	4.14
ENGINEERING SUPPORT	.00	.00	.43	1.63	2.07	2.07	1.63	.43	.00	.00	8.28
CONTRACTOR PROG MGT	.00	.00	.23	.85	1.08	1.08	.85	.23	.00	.00	4.30
TOTAL	.00	4.08	9.88	13.51	14.53	14.53	11.48	3.05	.00	.00	71.05

	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	TOTAL
TOTAL JET ENGINE	.00	8.56	18.58	20.26	20.23	21.43	19.30	5.44	.00	.00	113.80

TABLE 7. JET ENGINE FUNDING REQUIREMENTS (CASE 2)

JET ENGINE DECISION

	ORBITER	BOOSTER
TYPE ENGINE	LH2	LH2
TYPE DEVELOPMENT	NEW	SAME ENG AS ORB
ENGINE THRUST(SL)	12500.	12500.
NO. OF ENGINES	4.0	12.0
NO. OF STAGES WITH JET ENGINES	5.	4.

MILLIONS OF DOLLARS

	ORBITER	BOOSTER
DEVELOPMENT COST	147.27	136.22
ENGINE FIRST UNIT COST	.70	.63
ENGINE COST PER STAGE	2.79	7.62

JET ENGINE FUNDING REQUIREMENTS
MILLIONS OF DOLLARS

ORBITER ENGINE

FISCAL YEARS	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	TOTAL
ENGINE DEVELOPMENT	.00	46.42	77.70	23.15	.00	.00	.00	.00	.00	.00	147.27
INVESTMENT ENGINES											
VEHICLE NO. 1	.00	.00	.59	1.62	.59	.00	.00	.00	.00	.00	2.79
VEHICLE NO. 2	.00	.00	.00	.59	1.62	.59	.00	.00	.00	.00	2.79
VEHICLE NO. 3	.00	.00	.00	.00	.59	1.62	.59	.00	.00	.00	2.79
VEHICLE NO. 4	.00	.00	.00	.00	.00	.59	1.62	.59	.00	.00	2.79
VEHICLE NO. 5	.00	.00	.00	.00	.00	.59	1.62	.59	.00	.00	2.79
INITIAL SPARES	.00	.00	.06	.22	.28	.34	.38	.12	.00	.00	1.40
ENGINEERING SUPPORT	.00	.00	.12	.44	.56	.68	.77	.23	.00	.00	2.79
CONTRACTOR PROG MGT	.00	.00	.06	.23	.29	.35	.40	.12	.00	.00	1.45
TOTAL	.00	46.42	78.52	26.25	3.92	4.74	5.37	1.65	.00	.00	166.87

BOOSTER ENGINE

FISCAL YEARS	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	TOTAL
ENGINE DEVELOPMENT	.00	42.94	71.87	21.41	.00	.00	.00	.00	.00	.00	136.22
INVESTMENT ENGINES											
VEHICLE NO. 1	.00	.00	1.60	4.42	1.60	.00	.00	.00	.00	.00	7.62
VEHICLE NO. 2	.00	.00	.00	1.60	4.42	1.60	.00	.00	.00	.00	7.62
VEHICLE NO. 3	.00	.00	.00	.00	1.60	4.42	1.60	.00	.00	.00	7.62
VEHICLE NO. 4	.00	.00	.00	.00	.00	1.60	4.42	1.60	.00	.00	7.62
VEHICLE NO. 5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
INITIAL SPARES	.00	.00	.16	.60	.76	.76	.60	.16	.00	.00	3.05
ENGINEERING SUPPORT	.00	.00	.32	1.20	1.52	1.52	1.20	.32	.00	.00	6.09
CONTRACTOR PROG MGT	.00	.00	.17	.63	.79	.79	.63	.17	.00	.00	3.17
TOTAL	.00	42.94	74.11	29.86	10.69	10.69	8.45	2.24	.00	.00	178.99
TOTAL JET ENGINE	.00	89.36	152.63	56.11	14.61	15.43	13.82	3.89	.00	.00	345.86

TABLE 8. JET ENGINE FUNDING REQUIREMENTS (CASE 3)

JET ENGINE DECISION

	ORBITER	BOOSTER
TYPE ENGINE	LH2	LH2
TYPE DEVELOPMENT	NEW	NEW
ENGINE THRUST(SL)	12500.	15000.
NO. OF ENGINES	4.0	10.0
NO. OF STAGES WITH JET ENGINES	5.	4.

MILLIONS OF DOLLARS

DEVELOPMENT COST	267.76	282.15
ENGINE FIRST UNIT COST	.70	.74
ENGINE COST PER STAGE	2.79	7.39

JET ENGINE FUNDING REQUIREMENTS
MILLIONS OF DOLLARS

ORBITER ENGINE

FISCAL YEARS	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	TOTAL
ENGINE DEVELOPMENT	.00	84.41	141.26	42.09	.00	.00	.00	.00	.00	.00	267.76
INVESTMENT ENGINES											
VEHICLE NO. 1	.00	.00	.59	1.62	.59	.00	.00	.00	.00	.00	2.79
VEHICLE NO. 2	.00	.00	.00	.59	1.62	.59	.00	.00	.00	.00	2.79
VEHICLE NO. 3	.00	.00	.00	.00	.59	1.62	.59	.00	.00	.00	2.79
VEHICLE NO. 4	.00	.00	.00	.00	.00	.59	1.62	.59	.00	.00	2.79
VEHICLE NO. 5	.00	.00	.00	.00	.00	.59	1.62	.59	.00	.00	2.79
INITIAL SPARES	.00	.00	.06	.22	.28	.34	.38	.12	.00	.00	1.40
ENGINEERING SUPPORT	.00	.00	.12	.44	.56	.68	.77	.23	.00	.00	2.79
CONTRACTOR PROG MGT	.00	.00	.06	.23	.29	.35	.40	.12	.00	.00	1.45
TOTAL	.00	84.41	142.09	45.19	3.92	4.74	5.37	1.65	.00	.00	287.37

BOOSTER ENGINE

FISCAL YEARS	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	TOTAL
ENGINE DEVELOPMENT	.00	88.94	148.85	44.35	.00	.00	.00	.00	.00	.00	282.15
INVESTMENT ENGINES											
VEHICLE NO. 1	.00	.00	1.55	4.29	1.55	.00	.00	.00	.00	.00	7.39
VEHICLE NO. 2	.00	.00	.00	1.55	4.29	1.55	.00	.00	.00	.00	7.39
VEHICLE NO. 3	.00	.00	.00	.00	1.55	4.29	1.55	.00	.00	.00	7.39
VEHICLE NO. 4	.00	.00	.00	.00	.00	1.55	4.29	1.55	.00	.00	7.39
VEHICLE NO. 5	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00	.00
INITIAL SPARES	.00	.00	.16	.58	.74	.74	.58	.16	.00	.00	2.96
ENGINEERING SUPPORT	.00	.00	.31	1.17	1.48	1.48	1.17	.31	.00	.00	5.91
CONTRACTOR PROG MGT	.00	.00	.16	.61	.77	.77	.61	.16	.00	.00	3.07
TOTAL	.00	88.94	151.03	52.55	10.38	10.38	8.20	2.18	.00	.00	323.65
TOTAL JET ENGINE	.00	173.35	293.12	97.74	14.30	15.12	13.57	3.82	.00	.00	611.01

SECTION V. CONCLUSIONS

IMPACT is simple and straightforward, yet it provides insight into and analysis of a total program. Even with low confidence input data, it provides trends and rankings for cost trades and indicates the cost drivers. The relationship of input data to output data is very efficient since the output possibilities are almost infinite with a minimum amount of input. It can be applied to simple or complex programs and even on combinations of programs.

Further applications of IMPACT would be to assign a probability distribution and a "worth" or "goodness" rating to the options on each decision. Thus, the estimated cost of the most probable program and the cost of the "best" program could be derived. The capability for estimating the cost, "worth," and probability of any combination of decisions would then be available, thus providing data for cost effectiveness trades. Because of the many possible combinations of decisions, the probability of any one set of decisions would be small, but the relative probability of several alternatives could be meaningful.

As the space programs are further defined, other required decisions will be identified and some decisions will be made. The IMPACT system being used for the program can be kept updated by adding recently identified decisions to the system, determining the interrelationships with the remaining decisions, and removing other options when a decision is made. Low confidence input data, which may have been used, can often be replaced with new data as they become available, thus adding validity to the system. As additional programs are put into IMPACT format, the composite of these programs would form the basis for performing cost analysis of NASA long-range integrated planning. In this application, the impact of one program upon another in the total NASA plan could be identified and studied.

In conclusion, IMPACT has proven to be a valuable tool in Space Shuttle costing and has demonstrated a potential for additional applications in other areas. Its merits warrant continued use and expansion of this cost/decision management system.

APPROVAL

TM X-64620

INTEGRATED MULTI-PATH PROGRAM ANALYSIS AND COST TECHNIQUE (IMPACT)

By O'Keefe Sullivan

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This document has also been reviewed and approved for technical accuracy.

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