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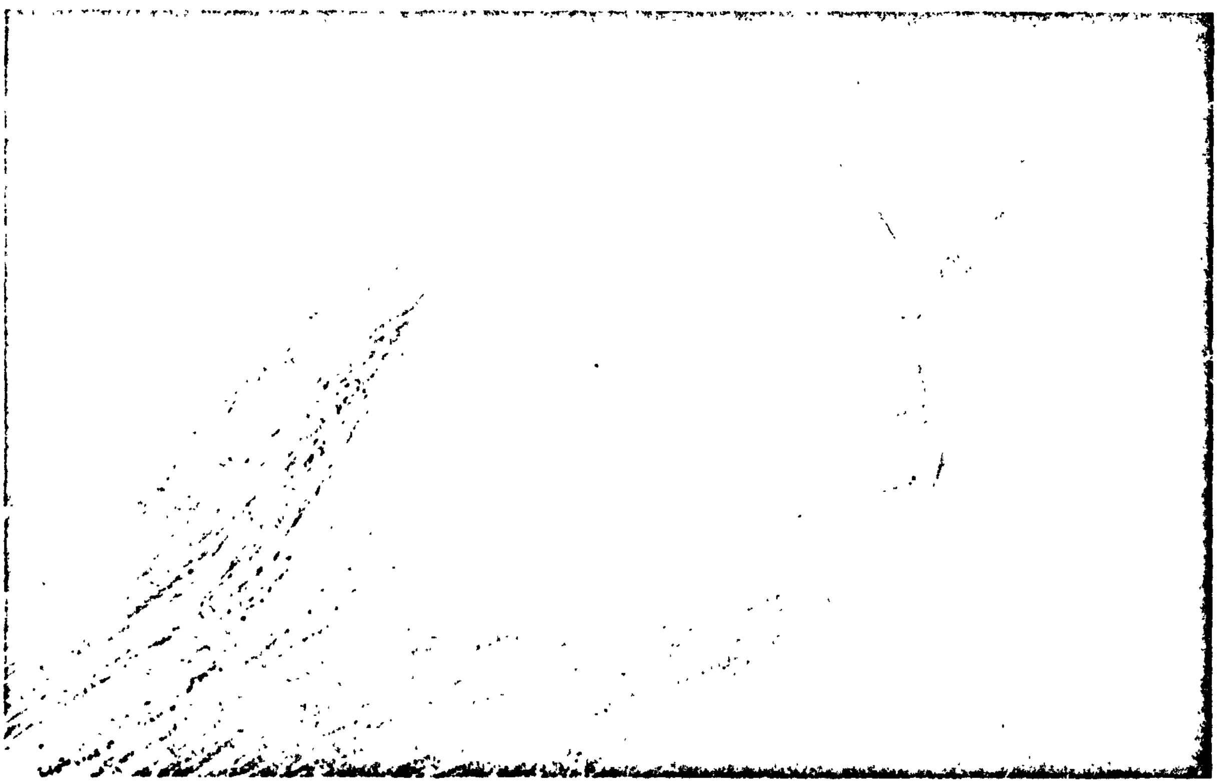
Final Report On Project

Single-stage Earth-orbital Reusable Vehicle

SPACE SHUTTLE FEASIBILITY STUDY

volume 6 — contract NAS8-26341

resources — june 30, 1971



SPACE DIVISION CHRYSLER CORPORATION NEW ORLEANS, LOUISIANA TR-AP-71-4

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Final Report On Project

SINGLE-STAGE EARTH-ORBITAL REUSABLE VEHICLE

SPACE SHUTTLE FEASIBILITY STUDY

volume 6

resources

contract NAS8-26341

june 30, 1971

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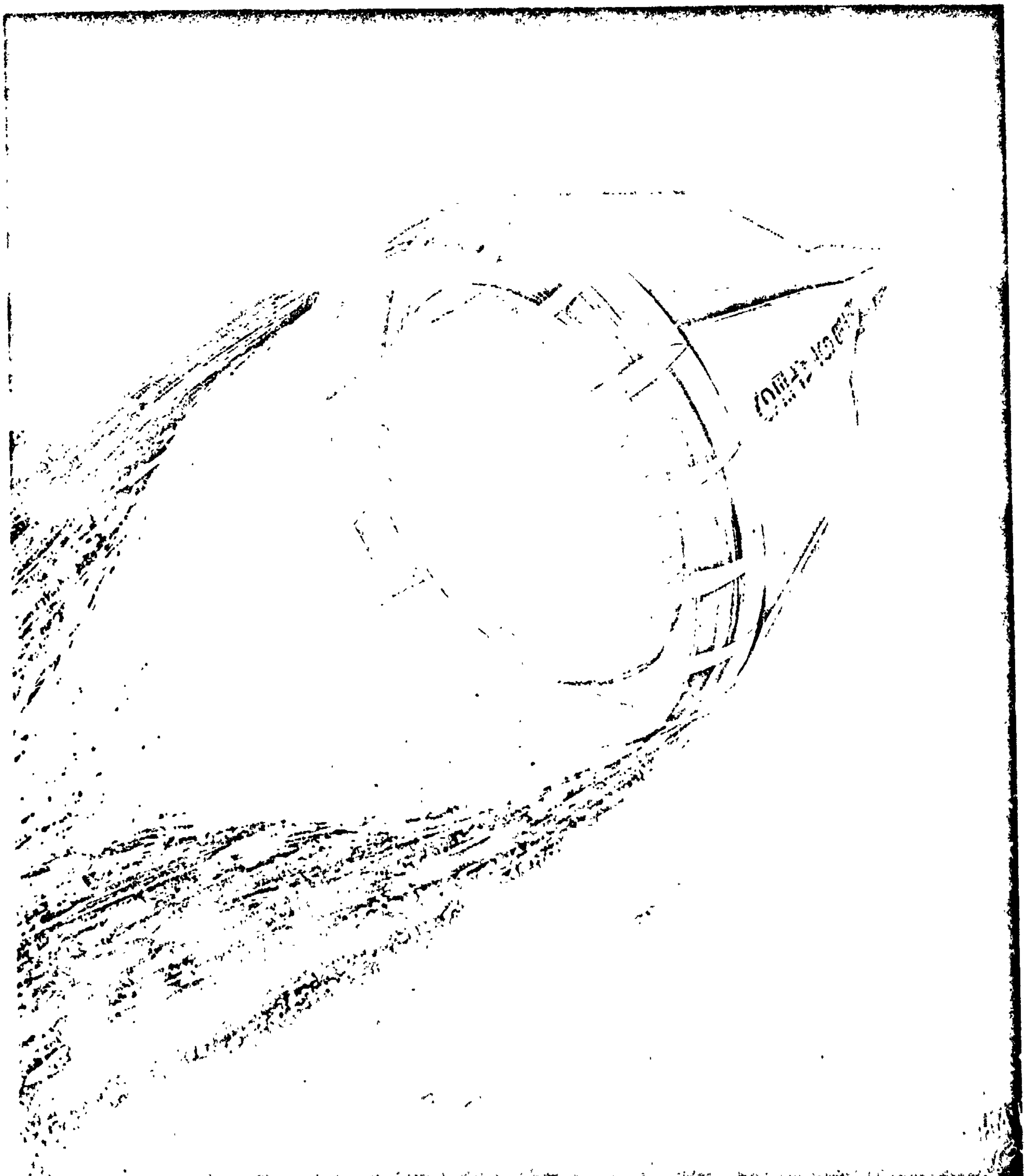

FOREWORD

This volume is one of a 6-volume final report of the Study of a Single-stage Earth-orbital Reusable Vehicle (SERV). The study was conducted by the Chrysler Corporation Space Division (CCSD) for the National Aeronautics and Apace Administration, George C. Marshall Space Flight Center under Contract NAS8-26341. The purpose of the study was to evaluate the potential of SERV as the boost element of a candidate space transportation system. To establish the SERV potential, five key technical areas affecting concept feasibility were identified for examination: engine performance, aerodynamic characteristics, thermal protection, subsystem weights, and the landing method. The results of these analyses are published in a final report consisting of the following six volumes:

Volume 1	Summary
Volume 2	Aerodynamic Model Testing
Volume 3	Concept Evaluation
Volume 4	Vehicle Definition
Volume 5	Operations Definition
Volume 6	Resources

Chrysler gratefully acknowledges the cooperation and support of North American Rockwell Corporation, Rocketdyne Division, who under subcontract assisted in the model test, and analyzed the test results of the uniquely integrated SERV engine-to-structure concept. Rocketdyne also generated parametric engine data and designed the SERV aerospike engine. Chrysler also acknowledges the support and technical assistance received from Detroit Diesel Allison Division of General Motors Corporation who provided parametric engine data for advanced technology direct lift gas turbine engines and the AVCO Systems Division who provided design and cost data for thermal protection systems. In addition, acknowledgement is made to the following NASA and DOD agencies for their cooperation during wind tunnel testing: NASA-Ames, NASA-LaRC, NASA-MSFC, and AF-AEDC.

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of the Chrysler Corporation Space Division, supported by Robert E. Schnurstein of the North American Rockwell Corporation, Rocketdyne Division. The study was conducted under the direction of Robert J. Davies, NASA study manager.

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TABLE OF CONTENTS

Paragraph		Page
	Section 1 - INTRODUCTION	
1.0	General	1-1
	Section 2 - CONFIGURATION DEFINITION	2-1
2.0	General	2-1
2.1	Vehicle Description	2-1
2.2	Typical Mission Profiles	2-3
	Section 3 - COST GROUNDRULES AND ASSUMPTIONS	
3.0	General	3-1
3.1	Program Costs	3-1
3.2	Vehicle Test and Operations	3-2
3.3	Facilities	3-2
3.4	Traffic Models	3-2
3.5	Fleet Requirements	3-5
	Section 4 - PROGRAM REQUIREMENTS	
4.0	General	4-1
4.1	Program Schedule	4-1
	Section 5 - WORK BREAKDOWN STRUCTURE	
5.0	General	5-1
5.1	WBS Format	5-1
5.2	WBS Element Content	5-1
5.2.1	SERV (WBS 101-00-00)	5-1
5.2.1.1	Propulsion (WBS 101-01-00)	5-1
5.2.1.2	Avionics (WBS 101-02-00)	5-5
5.2.1.3	Airframe (WBS 101-03-00)	5-5
5.2.1.4	Power (WBS 101-04-00)	5-6
5.2.1.5	Environmental Control and Life Support (ECLS) (WBS 101-05-00)	5-6
5.2.1.6	Assembly and Checkout (WBS 101-06-00)	5-6
5.2.1.7	System Support (WBS 101-07-00)	5-6
5.2.2	Spacecraft (WBS 102-00-00)	5-7

TABLE OF CONTENTS

Paragraph		Page
5.2.3	Main Engine (WBS 103-00-00)	5-7
5.2.4	Flight Test (WBS 104-00-00)	5-7
5.2.4.1	SERV (WBS 104-01-00).................................	5-7
5.2.4.2	Spacecraft (WBS 104-02-00)...........................	5-8
5.2.4.3	Mated (WBS 104-03-00)	5-8
5.2.4.4	Support (WBS 104-04-00)	5-8
5.2.5	Operations (WBS 105-00-00)	5-8
5.2.6	Management and Integration (WBS 106-00-00)	5-8
5.2.6.1	Systems Engineering and Integration (WBS 106-01-00)..	5-8
5.2.6.2	Program Management (WBS 106-02-00)...................	5-8

Section 6 - COST ESTIMATION METHODS

6.0	General	6-1
6.1	Cost Relationships	6-1
6.1.1	SERV (WBS 101-00-00)	6-1
6.1.1.1	Propulsion (WBS 101-01-00)	6-1
6.1.1.2	Avionics (WBS 101-02-00)	6-2
6.1.1.3	Airframe (WBS 101-03-00)	6-3
6.1.1.4	Power (WBS 101-04-00)	6-6
6.1.1.5	Environmental Control and Life Support (WBS 101-05-00)	6-8
6.1.1.6	Assembly and Checkout (WBS 101-06-00)	6-8
6.1.1.7	System Support (WBS 101-07-00)	6-8
6.1.2	Spacecraft (WBS 102-00-00)	6-10
6.1.3	Main Engine (WBS 103-00-00)..........................	6-10
6.1.4	Flight Test (WBS 104-00-00)	6-10
6.1.4.1	SERV Flight Test (WBS 104-01-00)	6-11
6.1.4.2	Spacecraft (WBS 104-02-00)	6-11
6.1.4.3	SERV Spacecraft Mating (WBS 104-03-00)	6-11
6.1.4.4	Support (WBS 104-04-00)	6-11
6.1.5	Operations (WBS 105-00-00)...........................	6-11
6.1.6	Management and Integration (WBS 106-00-00)	6-12
6.1.6.1	Systems Engineering and Integration (WBS 106-01-00)	6-12
6.1.6.2	Program Management (WBS 106-02-00)	6-12
6.2	Cost Distribution	6-12
6.2.1	Distribution of RDT&E Cost	6-15
6.2.2	Distribution of Investment Cost	6-15
6.2.3	Distribution of Operation Cost	6-15
6.3	Program Cost Model	6-15
6.3.1	Model Description	6-15
6.3.2	Model Operation	6-15

TABLE OF CONTENTS

Paragraph		Page
	Section 7 - COST ANALYSIS RESULTS	
7.0	General	7-1
7.1	Configuration Identification........................	7-1
7.2	Cost Analysis Results	7-1
7.2.1	Program Costs	7-1
7.3	NASA Cost Data Forms	7-2
APPENDICES		
A	Program Cost Model - Flow Diagram	A-1
B	Cost Estimate - Data Form A, Technical Characteristics - Data Form C, Funding Schedule - Data Form D	B-1
C	Detail Facility Cost Analysis	C-1
D	Detail Cost Summary and Total Program Distribution....	D-1

Section 1
INTRODUCTION

1.0 GENERAL

This volume presents the results of a conceptual study of the resource requirements for a Single-stage Earth-orbital vehicle (SERV). All aspects of program cost for the design, manufacture, test, transportation, launch, and facility modification, have been considered for implementing the vehicle concept through Phase C/D; and also, the subsequent 10 years of space shuttle operations, consistent in depth with the requirements of the study plan. This qualification is important because the primary objective of the SERV study was to examine concept feasibility by wind tunnel tests, trade study analyses, and the identification of a recommended configuration through more detailed subsystem analyses.

Prior to the commencement of the resource studies reported herein, a wide range of vehicle trade studies was performed and these are as reported in volume 3. Nine key trade study subtasks were identified: aerodynamic characteristics, aerospike parametric analyses, parametric flight performance, thermal analyses, subsystem concepts, operations concepts; parametric costs; and a vehicle sizing analysis and point design characteristics identification. The program costs for the selected vehicle configuration are documented in this volume of the report and presented in the following manner:

- Section 2 - Configuration Definition
- Section 3 - Guidelines and Assumptions
- Section 4 - Program Requirements
- Section 5 - Work Breakdown Structure
- Section 6 - Cost Estimation Methods
- Section 7 - Cost Analysis Results
- Section 8 - Conclusions and Recommendations

The following is a list of cost category definitions used throughout this volume of this report:

1) Non-recurring Cost (RDT&E). These costs are necessary to develop the pre-production items that are not quantity related but include: developmental engineering and support; test hardware; developmental captive and ground tests; ground support equipment; manufacture of tooling and special test equipment; site activation; trainers and simulators; and facilities.

2) <u>Recurring Cost (Production)</u>. These are defined as those costs associated with producing flight hardware up to and including acceptance of the hardware. Includes all costs associated with: the fabrication, assembly, and checkout of flight hardware; ground test and factory checkout of flight hardware; spares to support airborne hardware during flight operations; maintenance of GSE and spares for GSE; and maintenance of tooling and special test equipment.

3) <u>Recurring Cost (Operations)</u>. These are defined as the costs associated with those activities occurring subsequent to acceptance of the flight hardware. They are further identified as:

   a) <u>Launch Operations</u> - The cost of: receiving the flight hardware; static firings; refurbishment of static test stand; assembly of the vehicle; checkout; prelaunch test and checkout; servicing; launch; and refurbishing the launch pad.

   b) <u>Flight Operations</u> - The cost of: mission control; mission planning; flight crew training; and simulation and aids required for crew training (excluding the cost of those identified as test articles).

   c) <u>Refurbishment Costs</u> - The cost of those activities required to restore a previously flown reusable system to a flight readiness condition.

Section 2

CONFIGURATION DEFINITION

2.0 GENERAL

This section presents baseline features of the SERV configuration that were used in the development of the resource requirements. The final selected configuration differed from the baseline in diameter, weight and performance. However, the differences are not significant and have been accommodated in the resources analyses.

2.1 VEHICLE DESCRIPTION

The SERV configuration is a single-stage-to-orbit vehicle with the capability of transporting passengers and cargo to and from a near earth orbital space station. The prime payload is a 12-man personnel module (PM) in conjunction with 25,000 pounds of cargo. A winged spacecraft is included as an alternate payload.

Overall dimensions of the SERV personnel module configuration, see figure 2.1-1, are 88 feet in diameter by 93 feet in height, with a cargo hold 15 feet in diameter. Four clusters of five engines are buried within the vehicle contour and equally spaced around the vehicle circumference at the thrust ring to provide the thrust for attitude control and deorbit. There are 36 lift jet engines employed to land the vehicle at KSC. These engines are arranged in four banks of nine and attached to the outer cylindrical wall in the engine compartment at the base of the vehicle.

Four landing gear leg assemblies, using a telescoping arrangement enclosed in a cannister, are mounted on the LO_2/LH_2 tank outer cylindrical bulkhead common skirt, and situated between the lift engine banks. Just prior to landing, protective doors are opened and the legs are extended through the reentry bulkhead. A hydraulic shock absorber system built into each landing gear assembly provides a soft landing, with loads well within the capability of the vehicle structure.

The vehicle avionics system is installed in four separate equipment bays, located immediately forward of the LH_2 tank upper bulkhead and equally spaced around the circumference. Supporting power supply systems are mounted in the engine compartment.

Basic dimensions are given in figure 2.1-2 for the two spacecraft under consideration. These two spacecraft were specified for study to evaluate the effect of large and low crossrange reentry vehicles aboard SERV.

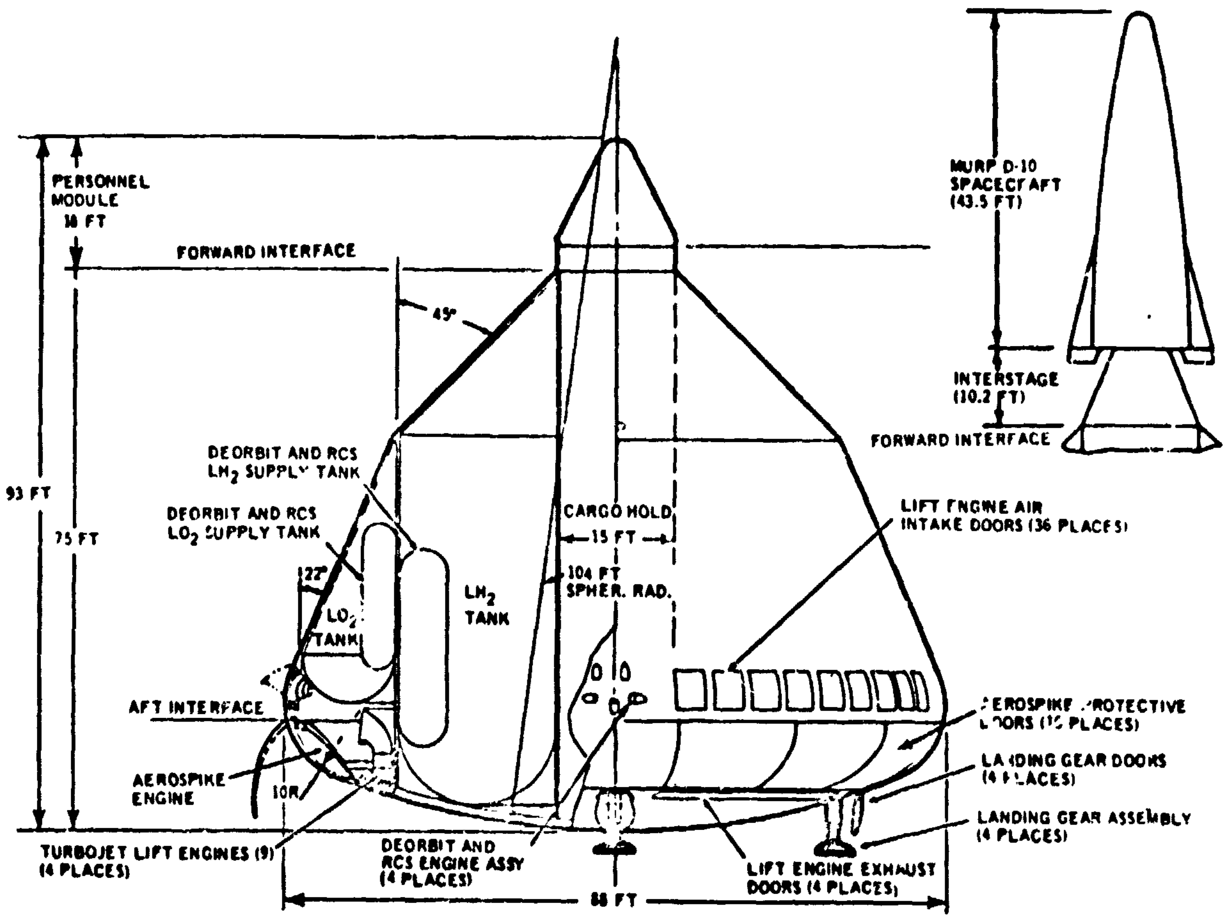


Figure 2.1-1. Vehicle Vertical Profile

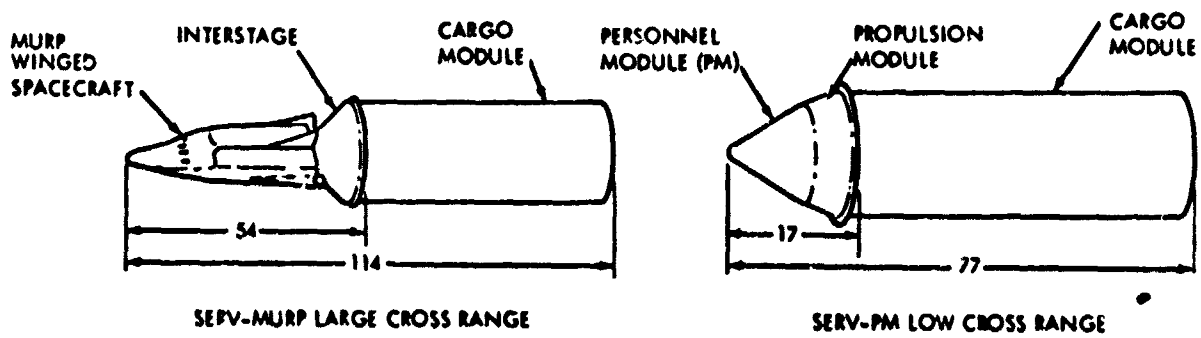


Figure 2.1-2. Spacecraft Configurations

Major dimensions and key SERV configuration features are shown in figure 2.1-1. The standard vehicle has a PM spacecraft that returns to earth on SERV. The alternate MURP spacecraft is also shown. SERV is designed for fully automatic unmanned operation. For this mode of operation a nose cone of the PM external configuration would be installed in lieu of the spacecraft.

Figure 2.1-3 shows the horizontal profile with key dimensions and major configuration features. Locations of the gas turbine lift engines, aerospike protective doors, and landing gear are shown. Note the location of the lift engine fuel supply, diametrically opposite the ballast tanks. Figure 2.1-4 shows the location of one quadrant of the direct-lift gas turbines, air inlet doors, landing gear, and fuel tanks. Figure 2.1-5 shows key features of the engine compartment layout. The gas turbine fuel and transfer tanks, and the electrical power generating and distribution system are located within the engine compartment but are not shown.

2.2 TYPICAL MISSION PROFILES

Figure 2.2-1 shows schematically the recommended mission profiles for the two spacecraft concepts. The profiles apply to the 55-degree inclination, space station cargo delivery, reference mission. For both spacecraft profiles the injection altitude is 50 n mi.

For the SERV-PM profile, both the SERV and PM go into a high altitude (260 n mi) phasing orbit. Terminal rendezvous and docking of the PM and cargo are accomplished using a propulsion system in the PM. Upon mission completion, the PM with its return cargo rejoins SERV. The SERV, plus cargo, and PM, reenters and lands as a unit.

In the SERV-MURP profile, the SERV with its payload establishes a circular orbit at a low altitude (110 n mi). The MURP, plus cargo, proceeds to the space station while the SERV remains in the lower orbit. At mission completion the MURP rejoins SERV and transfers the return cargo. The MURP then separates, reenters, and lands, while the SERV, plus cargo reenters and also lands.

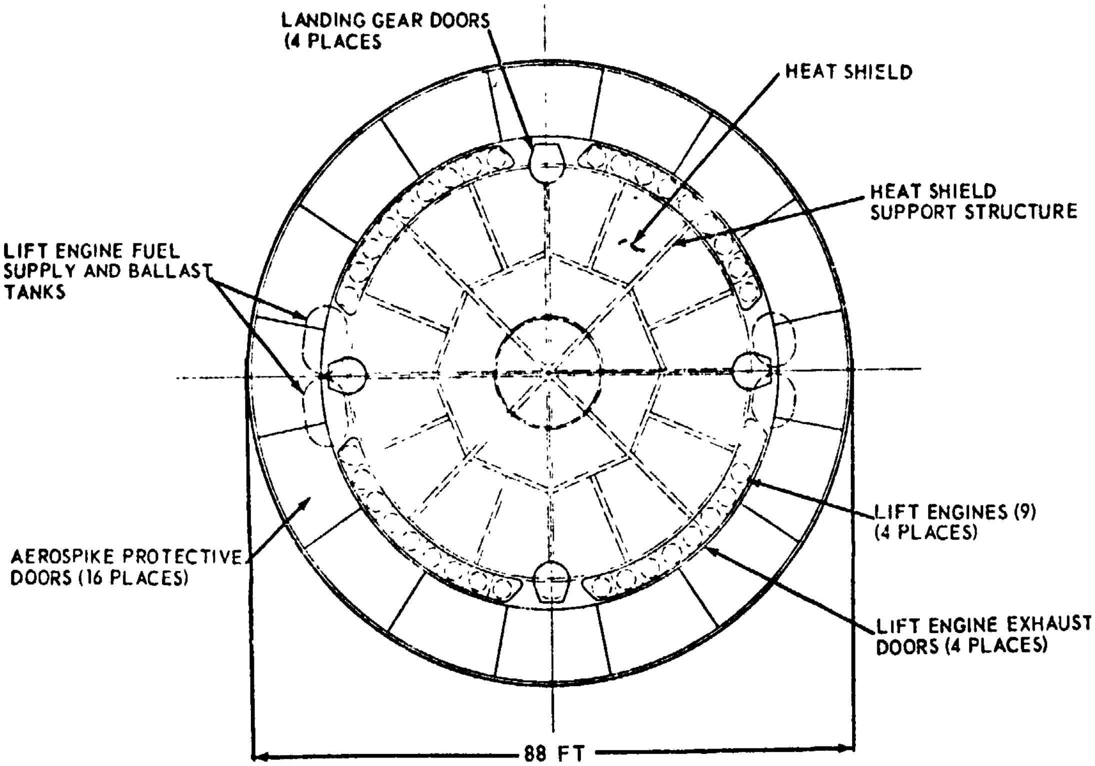


Figure 2.1-3. Vehicle Horizontal Profile

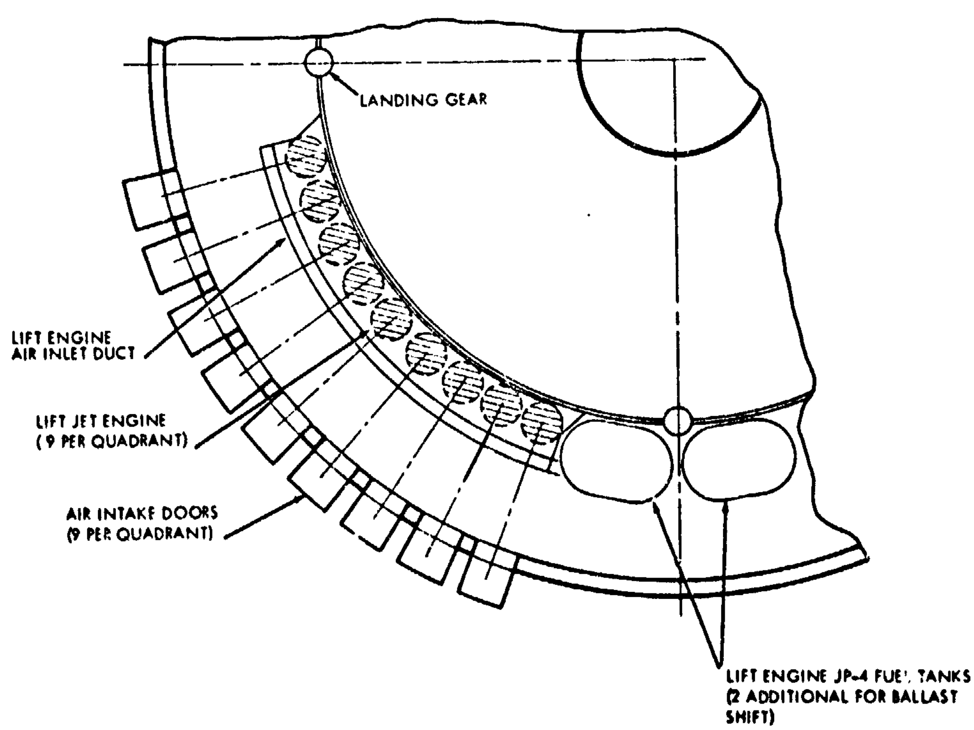


Figure 2.1-4. Turbojet Lift Engine Installation

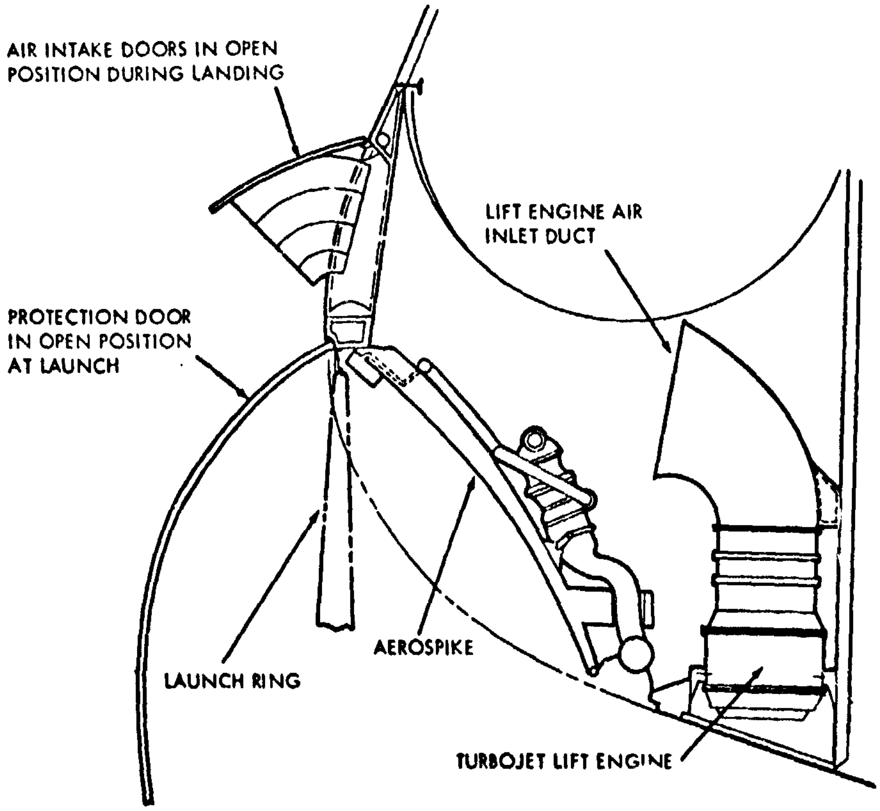
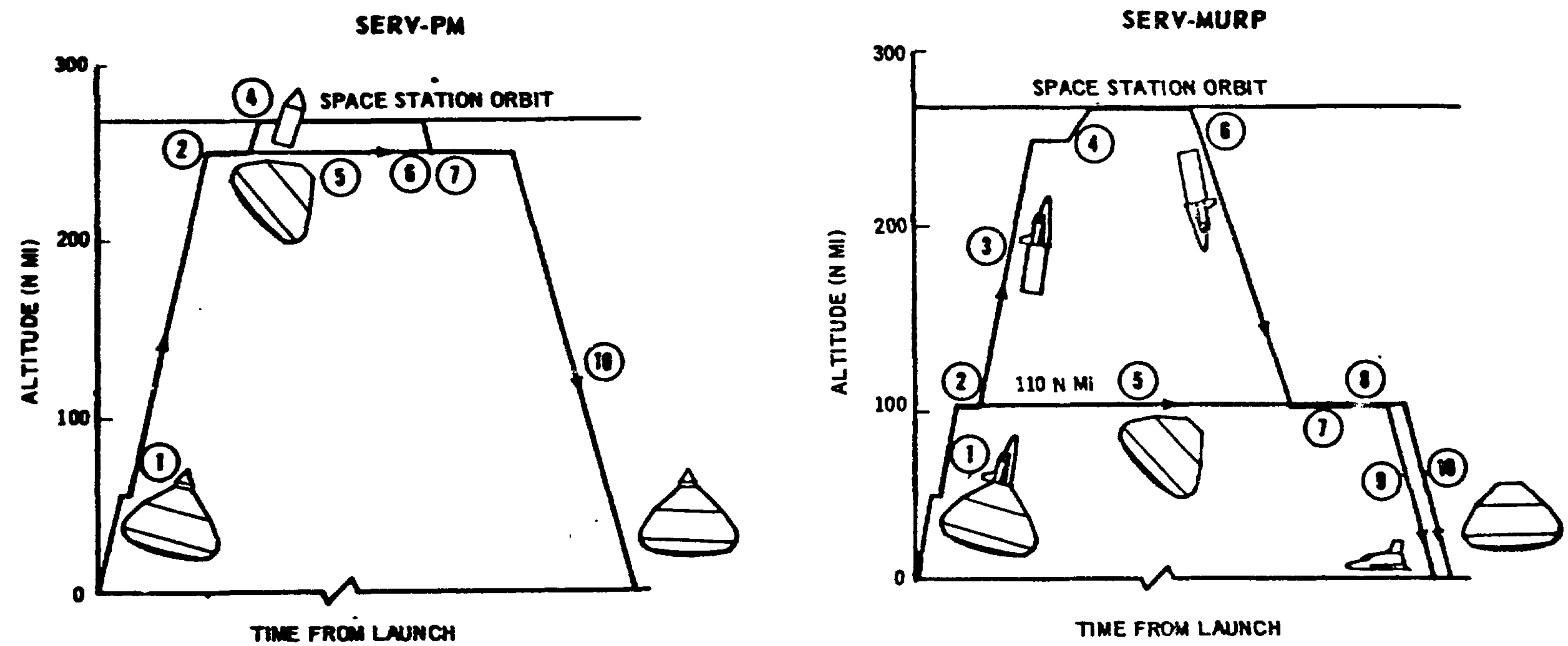


Figure 2.1-5. Engine Compartment Arrangement



1. LAUNCH FROM KSC INTO PERIGEE OF TRANSFER ELLIPSE
2. CIRCULARIZE AT PARKING ORBIT ALTITUDE
3. SEPARATE AND TRANSFER TO 110×260 PHASING ORBIT
4. RENDEZVOUS AND DOCK WITH SPACE STATION AT 270 N MI ORBIT
5. MAINTAIN PARKING ORBIT ALTITUDE
6. SEPARATE, CHANGE PLANE AND TRANSFER TO PHASING ORBIT
7. RENDEZVOUS AND DOCK WITH SERV
8. TRANSFER CARGO AND SEPARATE FROM SERV
9. DEORBIT AND REENTER (MURP)
10. DEORBIT AND REENTER (SERV OR SERV-PM)

Figure 2.2-1. Typical Mission Profile

Section 3
COST GROUNDRULES AND ASSUMPTIONS

3.0 GENERAL

This section contains the basic cost ground rules and assumptions used to cost the SERV shuttle program. Cost ground rules furnished by NASA are incorporated, and assumptions used for vehicle test and operations, facilities, and operation traffic model are discussed.

3.1 PROGRAM COSTS

The groundrules listed below were applied in the determination of the program cost:

1) Costs to be presented in CY-1971 dollars.

2) A 1972 technology base was assumed.

3) Phase C/D starts on January 1, 1972.

4) The primary manufacturing site is baselined at MAF.

5) The primary launch site is baselined at KSC.

6) First manned orbital flight (FMOF) occurs in the last quarter of FY-1978.

7) The baseline operational program extends for 10 years from FMOF.

8) RDT&E funding is concluded 24 months after FMOF.

9) Four traffic models are to be used, consisting of the NASA standard traffic model of 445 operations flights plus three alternatives at 100, 220, and 365 operational flights, respectively.

10) IOC is scheduled for first quarter FY-1980.

11) Costs reported do not include contractor's fee or NASA management costs.

12) Discount costs are based on a 10 percent rate applied to CY-1971 dollars.

13) Investment costs are based on four SERV and three winged spacecraft (identified as MURP) or three PM.

14) Production vehicles to be procured at a rate that minimizes peak funding.

15) Expendable hardware procured in the year in which it is used during the operational phase.

16) A 90 percent learning curve to be used for all SERV hardware except TPS ablative panels. An 85 percent curve to be used for TPS ablative replacement panels.

3.2 VEHICLE TEST AND OPERATIONS

The groundrules listed below are applicable to vehicle test and operations:

1) A structural test vehicle (STV-1) will be used for structural testing of the SERV vehicle.

2) A static fire vehicle (SFC-1) will be used for propellant flow and hot static fire testing.

3) The flight test program will require two flight test vehicles. FTV-1 will be used for Horizontal Flight Testing and FTV-2 for Vertical Flight Testing.

4) All operational launches will occur at equal intervals.

5) Seventy-five percent of all reusable vehicle test and checkout assumed to be accomplished by onboard checkout equipment.

6) Costs shown reflect contractor effort only. Costs for support, such as mission control and range safety are not included.

3.3 FACILITIES

The cost of facilities considered the following guidelines:

1) New facility requirements to be minimized.

2) Manufacture will be at Michoud Assembly Facility (MAF).

3) Existing LC-39 facilities and GSE to be used wherever possible.

4) Launch Complex 39 assumed to be available exclusively for shuttle use.

3.4 TRAFFIC MODELS

At the initiation of the SERV study, NASA established a standard traffic model which built up from 10 to 75 flights per year, accumulating a total of 445 flights for a 10 year baseline operational program. To establish cost sensitivities to launch rate and total program flights, three additional traffic models were defined with peak launch rates of 10, 25 and 50 flights per year. These alternate models resulted in program flight accumulations of 100, 220, and 365 respectively. The launch rate profile of the standard and alternate models are shown in figure 3.4-1.

3.5 FLEET REQUIREMENTS

The requirements for operational fleet vehicles, see table 3.5-1, have been based on the following assumptions:

1) All test vehicles will be converted to an operational status at the conclusion of their test activities with the exception of the structural test vehicle (STV-1).

2) Operational launches occur at equal intervals.

3) Vehicle turnaround time is 2 weeks.

4) Operational spacecraft missions are held constant at 7 days duration each.

5) Vehicle operational life time equals 500 missions.

6) Representative SERV mission duration is 3 days.

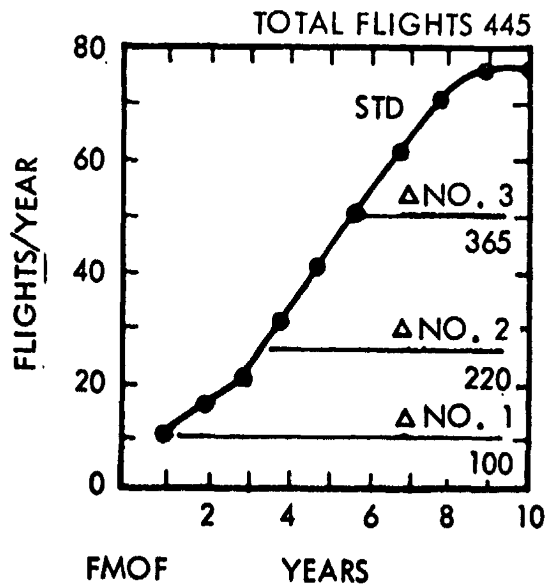


Figure 3.4-1. Traffic Model

Table 3.5-1. SERV Vehicle Requirements

	No. of Vehicles
Test Operations	
Structural Article	0.75
Static Test*	1.0
Flight Test*	2.0
Operational Fleet Requirements	
Total Fleet - 100 flights	2.0
Total Fleet - 220 flights	2.0
Total Fleet - 365 flights	3.0
Total Fleet - 445 flights	4.0

*Static test vehicle STV-1, and first flight test vehicle FTV-1, are converted to operational flight standard. FTV-2 is modified to operational flight status by removal of test instrumentation.

Section 4

PROGRAM REQUIREMENTS

4.0 GENERAL

This section presents a brief description of the program requirements to provide insight to events as depicted in the program schedule.

4.1 PROGRAM SCHEDULE

The program schedule, figure 4.1-1, is a projection of activities for those elements having a major impact on the initiation of the program through to the first manned orbital flight (FMOF). The schedule shows a 12 month phase B study commencing in the last quarter of CY 1971, followed by phases C and D starting at the beginning of CY 1973 with 90 percent engineering release at the end of CY 1974 and 100 percent release 10 months later. Facility modifications are identified at MAF and KSC. Modifications of MAF facilities are scheduled for the start of CY 1973, with the emphasis directed toward the modification, tooling and fixtures for building 420. Modifications of KSC facilities can be delayed a year after the start of MAF modifications.

It is proposed to build one structural test vehicle (STV-1) which will be used for handling and transportation equipment checkout, a mode and frequency test, and a static loads and life cycle test followed by a test to destruction. These tests will be conducted at KSC and take approximately 20 months to complete.

A static fire vehicle (SF-1) will be utilized in the program for propellant load, cold flow and static fire tests. Turbojets and other subsystems will not be installed. The tests, of 15 months duration, will be conducted at KSC and after completion the vehicle will be overhauled, refitted and cycled as a production vehicle.

The first flight test vehicle (FT-1) will be fitted with turbojets and associated subsystems and used for horizontal and vertical translation flight tests at KSC. An aerospike engine will not be installed in this vehicle. The translation tests are scheduled to take six months and will be completed three months before the completion of checkout of the first orbital flight vehicle. Following satisfactory completion of the horizontal and vertical translation tests, the vehicle will be returned to MAF for recycling as a production vehicle.

The second flight test vehicle (FT-2) will be utilized for orbital flight test and will be delivered to KSC twelve months prior to the first manned orbital flight. Prior to the first manned flight, two unmanned orbital test flights will be accomplished.

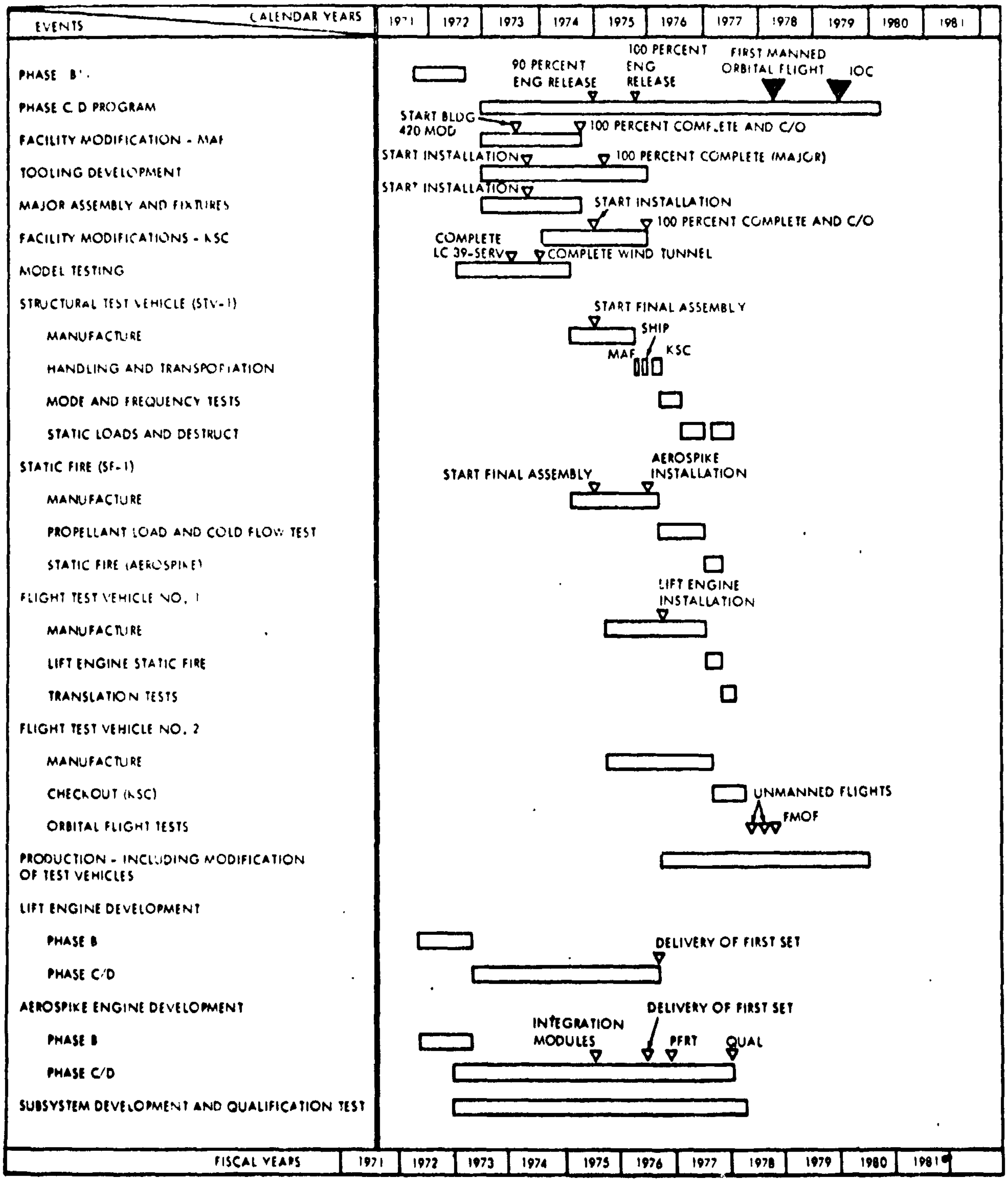


Figure 4.1-1. Program Schedule

Throughout the aforementioned development period, subsystem and component development and qualification tests will be performed at MAF and other government and subcontractor facilities.

The critical path for the schedule is as follows:

1) Complete model tests.

2) Initiate MAF and building 420 modifications.

3) Commence installment of major tooling and fixtures.

4) MAF facility complete and checked out.

5) 90 percent engineering release, start final assembly of structural test vehicle (STV-1) and static fire test vehicle (SF-1) and start facility installations at KSC.

6) 100 percent installation of major tooling at MAF.

7) 100 percent engineering release and shipment of STV-1.

8) Delivery and installation of first aerospike engine modules.

9) Delivery and installation of first direct lift gas turbine engines.

10) Completion of vehicle static loads, static fire, translation tests and completion of subsystem development and qualification tests.

11) Two unmanned orbital flights prior to FMOF.

12) Manned/unmanned flights prior to IOC.

Section 5
WORK BREAKDOWN STRUCTURE

5.0 GENERAL

This section describes the work breakdown structure (WBS) used for assembling cost inputs to a cost analysis of the SERV space shuttle. The elements of the WBS are identified from level 2 through level 5.

5.1 WBS FORMAT

The basic WBS format for levels 2, 3 and 4, is shown in figure 5.1-1. The SERV space shuttle is shown as a level 2 element consisting of six level 3 elements; SERV, Spacecraft, main engines, flight test, operations, and management and integration, respectively. Of these, SERV, flight test, operations, and management and integration, are subdivided to level 4 and, in the case of SERV the subdivision goes down to level 5, see figure 5.1-2. The level 3 spacecraft and main engines elements were not taken to lower levels as, for the purpose of this study, these components were assumed to be GFE. For the purpose of program visibility, the WBS identification number is included with each element shown in figures 5.1-1 and 5.1-2. A compilation of the WBS elements is presented in table 5.1-1; this tabulation is used as the starting point for the cost estimation methods described in section 6.

5.2 WBS ELEMENT CONTENT

A brief description of the content within each level 3 element is presented in the following paragraphs.

5.2.1 SERV (WBS 101-00-00)

The level 3 SERV element consists of seven level 4 elements; 1) propulsion; 2) avionics; 3) airframe; 4) power; 5) environment control and life support; 6) assembly and checkout; and 7) system support.

5.2.1.1 Propulsion (WBS 101-01-00)

This element of cost is developed from the summation of the lower level 5 elements of lift engines and attitude control:

1) Lift Engines. This element includes the design, development and production cost of turbojet lift engines and does not include the testing of complete engine installation or any vehicular activities with SERV.

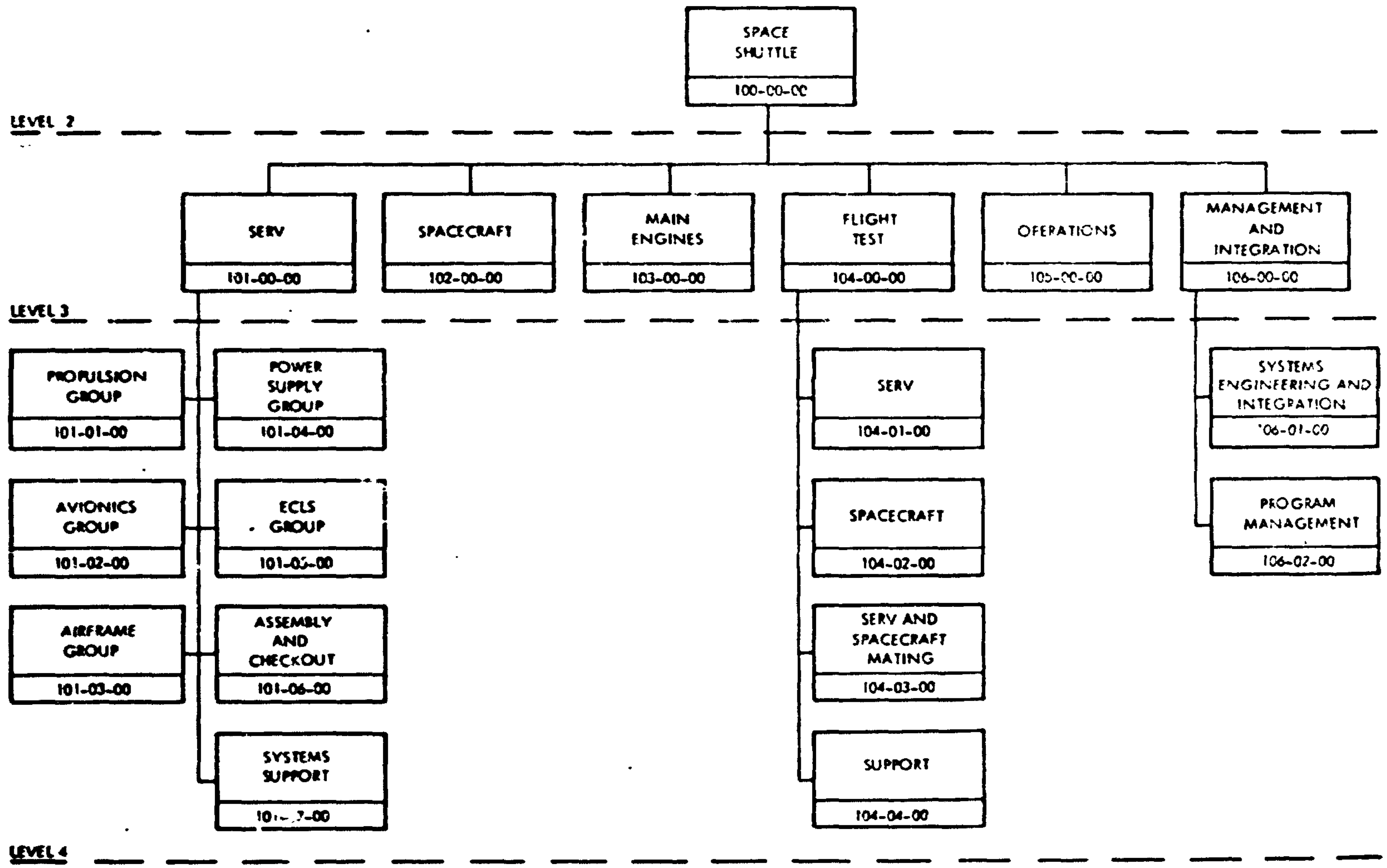


Figure 5.1-1. SERV Space Shuttle WBS Elements

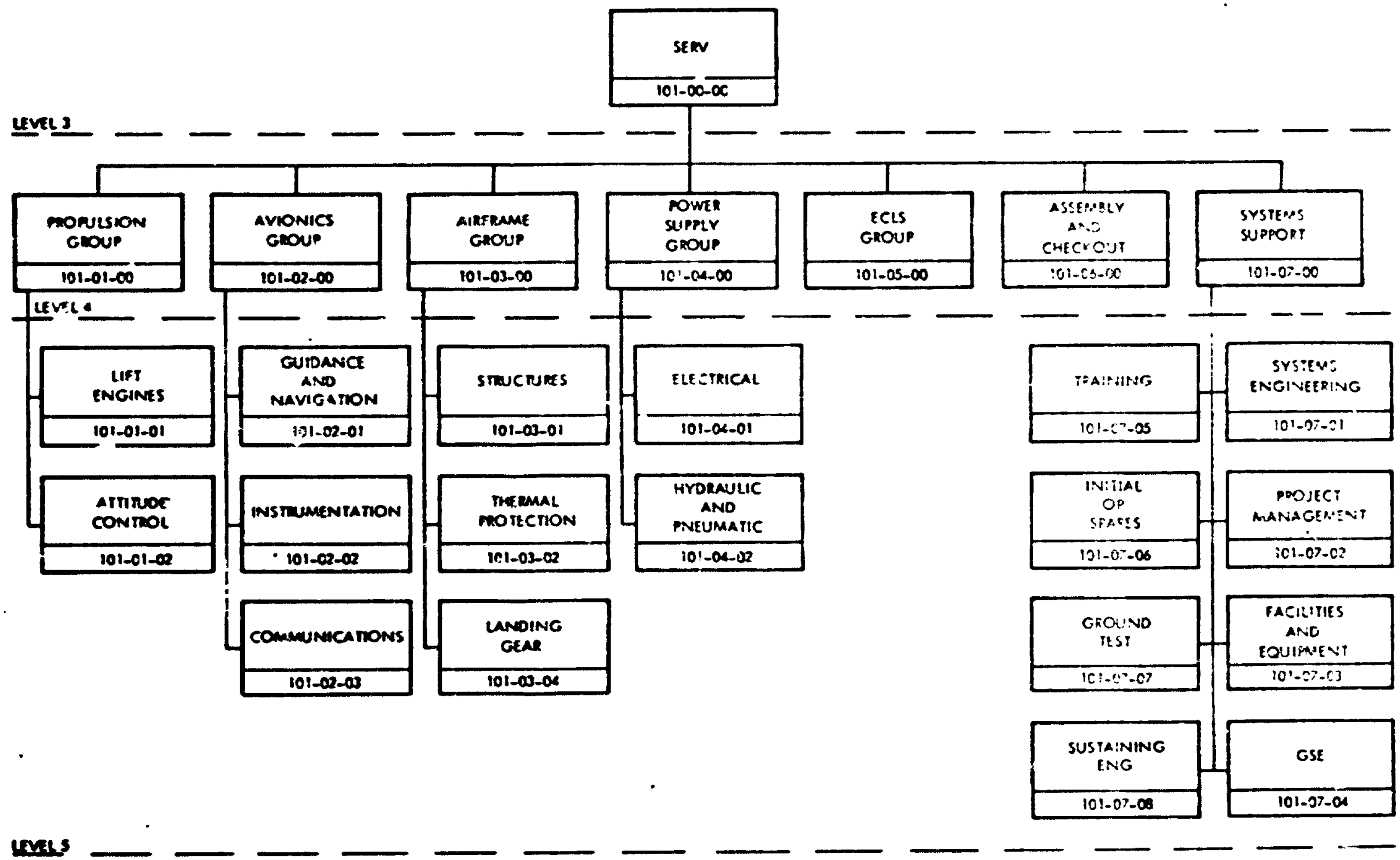


Figure 5.1-2. Breakdown of WBS Elements for SERV

Table 5.1-1. Program Work Breakdown Structure (WBS)

WBS Element Name	Level	WBS Identity No.
SERV Space Shuttle	2	100-00-00
SERV	3	101-00-00
Propulsion	4	101-01-00
Lift Engines	5	101-01-01
Attitude Control	5	101-01-02
Avionics	4	101-02-00
Guidance and Navigation	5	101-02-01
Instrumentation	5	101-02-02
Communications	5	101-02-01
Airframe	4	101-03-00
Structures	5	101-03-01
Thermal Protection	5	101-03-02
Landing Gear	5	101-03-04
Power	4	101-04-00
Electrical Supply and Distribution	5	101-04-01
Hydraulic and Pneumatic	5	101-04-02
ECLS	4	101-05-00
Assembly and Checkout	4	101-06-00
System Support	4	101-07-00
Systems Engineering and Integration	5	101-07-01
Project Management	5	101-07-02
Facilities and Equipment	5	101-07-03
GSE	5	101-07-04
Training	5	101-07-05
Initial Operating Spares	5	101-07-06
Ground Test	5	101-07-07
Sustaining Engineering	5	101-07-08
Spacecraft	3	102-00-00
Main Engine	3	103-00-00
Flight Test	3	104-00-00
SERV	4	104-01-00
Spacecraft	4	104-02-00
Mated	4	104-03-00
Support	4	104-04-00
Operations	3	105-00-00
Management and Integration	3	106-00-00
Systems Engineering and Integration	4	106-01-00
Program Management	4	106-02-00

2) Attitude Control. This element refers to the cost of all activities necessary to design, develop, qualify and produce gaseous LH_2/LO_2 attitude control thrusters. Note: The attitude control thrusters perform the multipurpose function of attitude control, orbit maneuvering, station keeping and deorbit.

5.2.1.2 Avionics (WBS 101-02-00)

This element of cost is developed from the summation of the lower level 5 elements of guidance and navigation, instrumentation, and communications:

1) Guidance and Navigation. This element includes the design, development, and production for all sensors, prime reference, computation, and data processing elements for this function; also, includes cost of central computers, even though they may provide services for other subsystems.

2) Instrumentation. This element includes the design, development and production of all sensors, data conditioning and data evaluation elements.

3) Communications. This element includes the design, development and production cost of all communications elements.

5.2.1.3 Airframe (WBS 101-03-00)

This element of cost is developed from the summation of the lower level 5 elements of structures, thermal protection system and landing gear.

1) Structure. This cost element refers to the cost of designing, developing and manufacturing the SERV structure. Included are all direct and indirect labor costs, materials and subcontract cost related to the engineering design and analysis, procurement, test, and evaluation of components and subsystem in this category. Subsystems included in this category are: integral propellant tanks and bulkheads; load carrying elements; propellant feed, fill, and drain elements; tank insulation; PU subsystem; attitude control propellant tanks and feed system; and landing gear (development cost only).

   Procurement and evaluation of mockups, special test rigs, and other supporting engineering activities are included in this category. Assembly of subelements into major structural elements are also included.

2) Thermal Protection. This element refers to the cost of designing, developing and manufacturing the SERV thermal protection system. Included are all direct and indirect labor costs and material and subcontract cost. Component level test hardware and piece parts costs are included. The principle hardware elements are cover panels, attach structure, insulation, and ablator panels.

3) Landing Gear. This element refers to the cost of manufacturing the SERV landing gear. Included are all direct and indirect labor costs, and material and subcontract costs. Applicable hardware elements are struts and braces, pads, controls and structure.

5.2.1.4 Power (WBS 101-04-00)

This element of cost is developed from the summation of the lower level 5 elements of electrical supply and distribution; and hydraulic and pneumatics.

1) Electrical Supply and Distribution. This element refers to the design, development and production cost of the primary and secondary electrical power supply and distribution elements. Included in the cost are the following applicable hardware elements: fuel cells, fuel cell subsystems, batteries, power conversion equipment, and power distribution equipment.

2) Hydraulic and Pneumatic Power. This element includes all the primary and secondary hydraulic and pneumatic power supply and distribution elements.

5.2.1.5 Environmental Control and Life Support (ECLS) (WBS 101-05-00)

This element refers to the design, development and production of the environmental control and life support subsystem.

5.2.1.6 Assembly and Checkout (WBS 101-06-00)

This element is the cost for all vehicle contractor activities for integrating and assembling vehicle elements and subsystems into an operational vehicle and includes all system calibration and checkout, as well as the necessary acceptance testing.

5.2.1.7 System Support (WBS 101-07-00)

This element of cost is developed from the summation of the lower level 5 elements of systems engineering and integration, project management, facilities and equipment, GSE, training, initial operating spares, ground test and sustaining engineering.

1) Systems Engineering and Integration. This element refers to the cost of vehicle contractor system integration and engineering activities, such as: definition of vehicle and payload interfaces; system trade studies; system effectiveness analysis; and system interface analysis.

2) Project Management. This element includes the effort associated with the prime contractor's centralized direction of effort in the area of program planning, control, and administration.

3) Facilities and Equipment. This element includes the cost for new and modifications to manufacturing, launch, and test facilities. All tooling, sustaining tooling and special test equipment cost are also included in this element.

4) Ground Support Equipment. This element refers to the cost of development engineering, testing and production of all ground-based equipment required to support the launch, recovery, and maintenance phases of the vehicle during flight test operations, and flight operations.

5) Training. This element includes the cost of instruction, audio and visual teaching aids, and parts and accessories required to train ground crew personnel to maintain SERV. Also included is the cost to determine training requirements and planning of training programs and all cost associated with the development, manufacture and maintenance of simulators, trainers, mockups and models.

6) Initial Operating Spares. This element reflects the manufacturing cost of spare parts for the initial spares stock which is required for operations.

7) Ground Test. This element refers to the cost of structural testing (static, hydrostatic, fatigue, dynamic, etc.) as well as propulsion system testing during vehicle hot firing, and a propellant loading system test.

8) Sustaining Engineering. This element includes the cost of engineering effort that is in direct support of manufacturing; involves the coordination of the various manufacturing activities on an interdepartmental basis and with subcontractors and vendors, and also includes continued engineering analyses of test results and other supporting activities.

5.2.2 SPACECRAFT (WBS 102-00-00)

This element includes the design, development and manufacturing cost associated with the complete air frame and installed equipment. Also includes spacecraft and flight test integration effort, ground and flight crew training, training equipment, ground support equipment, ground test and equipment, and propellants and gases, initial spares, and GSE cost.

5.2.3 MAIN ENGINE (WBS 103-00-00)

This element includes the cost associated with the design, development, and production of the main engine developed under a separate contract and supplied as GFE; also includes the cost of engineering and development activities, test hardware and engines, test operations, and propellants consumed by the engine contractor's facility.

5.2.4 FLIGHT TEST (WBS 104-00-00)

The element of cost is developed from the summation of the lower level 4 elements of flight test: SERV, spacecraft, mated and support.

5.2.4.1 SERV (WBS 104-01-00)

This element includes cost associated with the translation and vertical flight tests of SERV and also the cost for flight test hardware.

5.2.4.2 Spacecraft (WBS 104-02-00)

This element includes the cost associated with ground and horizontal flight tests of the winged spacecraft, or ground and drop tests of the PM.

5.2.4.3 Mated (WBS 104-03-00)

This element refers to the cost for flight test integration of SERV to spacecraft.

5.2.4.4 Support (WBS 104-04-00)

This element includes the cost for engineering support from detail planning, support, data acquisition and analysis, reports and material consumed through to flight test activities.

5.2.5 OPERATIONS (WBS 105-00-00)

This level 3 element includes the costs associated with the effort and material necessary to operate the SERV shuttle system and maintain it in an operable condition after initial operational capability has been established. Specifically, this includes maintenance and refurbishment of the SERV and spacecraft after each flight in preparation for the next mission, and maintenance and refurbishment of the GSE and facilities necessary to launch, recover and maintain the vehicles.

5.2.6 MANAGEMENT AND INTEGRATION (WBS 106-00-00)

This element of cost is developed from the summation of the lower level 4 elements of Systems Engineering and Integration, and Program Management.

5.2.6.1 Systems Engineering and Integration (WBS 106-01-00)

This element refers to the cost of the overall integration of development activities. Included is the establishment of engineering design characteristics; determination of criteria for design review; establishment of procedures for testing components, subsystems or vehicle elements; integration of ground and flight test results into the vehicle design; development procedures for vehicle maintenance; and quality planning and administrative engineering.

5.2.6.2 Program Management (WBS 106-02-00)

This element includes the activities within the program management disciplines; data management, configuration management, and program control.

Section 6
COST ESTIMATION METHODS

6.0 GENERAL

This section describes the methods used to estimate the cost of elements identified in the work breakdown structure (WBS), see section 5. Both RDT&E and investment costs are considered. These costs were developed from cost estimating relationships (CER's) and direct estimates. The parametric CER's were generated for hardware elements and development tasks through collection and analysis of cost data from various hardware and study contracts. The prime source of CER's was the "STS Cost Methodology Study", prepared by the Systems Cost Office of Systems Planning Division of the Aerospace Corporation, dated 31 August 1970, and the National Space Booster Study conducted by the Chrysler Corporation Space Division for NASA under Contract NASW-1740. These cost relationships plus cost distribution curves provided by NASA were incorporated in a computerized cost model; the results are presented in section 7. A description of the CER's, direct estimation methods, cost distribution curves, and structure of the cost model is presented in the subsections to follow.

6.1 COST RELATIONSHIPS

A description of the cost relationship used for each element of the WBS, see section 5, is given in paragraph 6.1.1 through 6.1.6. Note that the total investment cost of each WBS element is obtained by multiplying the first unit cost (TFU) of that element by 1.9. Pertinent technical characteristics applicable to this subsection are presented in NASA Data Form C format, appendix B.

The total program cost of the level 2 SERV space shuttle (WBS-100-00-00) is the sum of the RDT&E and investment costs for each of the six level 3 elements identified as SERV, spacecraft, main engines, flight test, operations, and management and integration.

6.1.1 SERV (WBS 101-00-00)

The total cost of the level 3 SERV is the sum of the RDT&E and investment costs for each of the seven level 4 elements identified as propulsion, avionics, airframe, power, environmental control and life support (ECLS), assembly and checkout, and system support.

6.1.1.1 Propulsion (WBS 101-01-00)

This element contains the cost of the direct lift gas turbine engines and the attitude control system. Note that the deorbit propulsion is integrated with the attitude control system.

6.1.1.1.1 Direct Lift Engines (WBS 101-01-01)

Engineering estimates for the lift engine development, and investment costs were obtained from the Detroit Diesel Allison Division of the General Motors Corporation as follows:

- Development Cost - $133 M
- Investment Cost - $0.4M/engine

A 28 million dollar sustaining engineering cost was added to the investment cost estimate, based on a 100-man level for 8 years at an annual cost of 35,000 dollars per man.

6.1.1.1.2 Attitude Control System (WBS 101-01-02)

The development cost of the attitude control system was determined from the following CER:

$$\text{RDT\&E (M\$)} = (\text{Comfac})(2.2)(\text{Vacuum Thrust})^{0.38}$$

The complexity factor (Comfac) for the attitude control system is a function of engine technology, type of engine, and operational mode. For the LO_2/LH_2 advanced, reusable system to be utilized on SERV, a factor of 2.0 was recommended by the Aerospace Corporation. The vacuum thrust for each thruster is 4000 pounds.

The first unit cost (TFU) of the attitude control system is determined from the following expression:

$$\text{TFU (M\$)} = (\text{Number of Thrusters})(0.4)$$

There are twenty thrusters on each SERV.

6.1.1.2 <u>Avionics (WBS 101-02-00)</u>

This element contains the cost of the guidance and navigation, instrumentation and communications.

6.1.1.2.1 Guidance and Navigation (WBS 101-02-01)

The guidance and navigation cost was determined from specialist estimates, and there are two important considerations which influence the development and investment cost estimates:

- The guidance and navigation scheme is state of the art e.g., the platform is used in the Centaur program, the computer is being manufactured for the Viking Program
- NASA is already spending funds on G&N development for the space shuttle.

6.1.1.2.2 Instrumentation (WBS 101-02-02)

The development cost of the instrumentation was determined from the following CER:

$$\text{RDT\&E (M\$)} = (\text{Comfac})(1.5)(\text{weight of system})^{0.7}$$

The Comfac chosen for this system, and the total Avionics system, was 1.0. This is the highest factor recommended by the Aerospace Corporation. The factor is a function of commonality and complexity. No reduction of the complexity factor was taken due to adaptation of the system to the spacecraft.

The weight of the system was obtained from detailed estimates. The weights used are listed on NASA Data form C, appendix B.

The first unit cost was developed from the following expression:

$$\text{TFU (M\$)} = (\text{Comfac})(0.088)(\text{system weight})^{0.7}$$

6.1.1.2.3 Communications (WBS 101-02-03)

The CER's for determining the development and first unit cost for the communications system are as follows with the Comfac and weights obtained as explained in paragraph 6.1.1.2.2:

$$\text{RDT\&E (M\$)} = (\text{Comfac})(1.7)(\text{system weight})^{0.7}$$

$$\text{TFU (M\$)} = (\text{Comfac})(0.042)(\text{system weight})^{0.7}$$

6.1.1.3 <u>Airframe (WBS 101-03-00)</u>

Elements considered under the airframe WBS are structures, thermal protection, and landing gear.

6.1.1.3.1 Structures (WBS 101-03-01)

The RDT&E cost was developed from the following CER:

$$\text{RDT\&E (M\$)} = (\text{Comfac})(3.88)(\text{dry weight})^{0.347}$$

The Comfac is a function of structural development required and complexity of the configuration and materials. The structural Comfac used in the SERV calculations was 1.98.

The dry weight includes the following:

- Primary structure
- Thermal protection on upper and lower frustrums
- Landing gear and support
- Turbojet fuel tanks and lines

- Propellant feed and pressurization

- Aerospike doors

Each of the above are obtained directly from a dry weight summary chart such as table 6.1-1 with the exception of the thermal protection. For this case, the weight used is that associated with the outer honeycomb on the upper and lower frustums and is approximately 46.7 percent of the thermal protection system weight shown in table 6.1-1.

To estimate the structures element investment cost, the first unit cost was determined from the following CER:

$$\text{TFU (M\$)} = (\text{Comfac})(0.00141)(\text{dry weight})^{0.805}$$

The dry weight used in the RDT&E CER was used to estimate TFU. The Comfac for the first unit cost is a function of configuration, propellants, materials and type of construction. The driving parameters of the factor is material and type of construction. The material factor is a function of the percent material by weight used in the fabrication of the vehicle. The SERV vehicle material Comfac was computed as a weighted average based on a percent weight distribution of the following different materials:

- Inconel-718 — 67.1 percent

- Stainless steel Honeycomb — 13.1 percent

- Stainless steel Beams — 9.4 percent

- Miscellaneous — 10.4 percent

The propellants factor is a function of the insulation, pressurization and feed system complexity. for SERV, the Inconel-718 honeycomb requires no insulation inside the LH_2 tanks, and therefore the complexity of the fabrication is reduced.

The Comfac for estimating TFU was determined as follows:

$$\text{Comfac} = (\text{Configuration})(\text{Propellants})(\text{Material/Construction})$$

$$= 1.0 \times 1.5 \times 3.629$$

$$\text{Comfac} = 5.44$$

The material/construction factor was derived from above material percentages as follows:

Fraction		Comfac		
0.094	x	1.3	=	0.122
0.131	x	1.9	=	0.249
0.104	x	1.0	=	0.104
0.671	x	4.7	=	3.154
Material/Construction factor			=	3.629

Table 6.1-1. Dry Weight Summary

Primary Structure	148.297
Thermal Protection System	20,438
Landing Gear and Support	7,711
Actuators for Doors and Covers	4,419
Turbojet Engines	35,775
Turbojet Control	2,574
Turbojet Fuel Tanks and Lines	2,036
Propellant Feed and Pressurization	15,076
GN&C, Power, and Communications	6,681
Aerospike Rocket Engine	83,930
RCS and Deorbit Subsystem	5,573
Aerospike Doors	11,168
Contingency (10%)	34,368
TOTAL DRY WEIGHT (LB)	378,046

6.1.1.3.2 Thermal Protection System (WBS 101-03-02)

The development cost for the SERV thermal protection system (TPS) is determined from the following CER:

$$\text{RDT\&E (M\$)} = 0.2502 \ (\text{TPS weight})^{0.608}$$

The weight of TPS used in this equation is obtained from a weight summary such as table 6.1-1 by taking 53.3 percent of the weight shown for the TPS.

The first unit cost for the thermal protection system was determined from the following CER:

$$\text{TFU (M\$)} = (\text{Comfac})(0.0298)(\text{TPS weight})^{0.610}$$

The Comfac is a function of configuration and material:

$$\text{Comfac} = (\text{Configuration})(\text{Material/Construction})$$

$$= 1.2 \times 1.9$$

$$= 2.28$$

The weight used in this equation is the same weight used to estimate the RDT&E cost.

The investment cost includes only the cost for the initial ablative shields installed on the vehicle during manufacture. The ablative replacement panels cost is included in the operations cost.

6.1.1.3.3 Landing Gear (WBS 101-03-04)

The development cost of the landing gear is included in the development cost of the structures.

The first unit cost of the landing gear is developed using the following CER:

TFU (M$) = 0.003 (TFU Structures)
where "TFU structures" is obtained from paragraph 6.1.1.3.1

6.1.1.4 <u>Power (WBS 101-04-00)</u>

This element contains the cost estimates for electrical power and distribution and hydraulic power.

6.1.1.4.1 Electrical Power and Distribution (WBS 101-04-01)

The development cost for the fuel cell electrical power and distribution was determined from the following CER:

$$\text{RDT\&E (M\$)} = (\text{Comfac})(\text{Fuel cell technology})\ 2.07\ (\text{dry weight per fuel cell})^{0.7} + 0.35\ (\text{weight of distribution system})^{0.7}$$

The Comfac is a function of commonality and complexity of the system. The calculation is as follows:

$$\text{Comfac} = \text{Commonality} \times \text{complexity}$$

$$= 0.65 \times 1.0$$

$$= 0.65$$

A factor of 0.5 was chosen for fuel cell technology because an adaptation from existing technology will be used. The weights used in the equation are obtained from appendix B.

The first unit cost was developed from the following CER:

$$\text{TFU (M\$)} = 0.000191 \text{ (Battery dry weight)} + 0.0124 \text{ (number of fuel cell) (fuel cell dry weight)}^{0.7} + 0.034 \text{ (electrical distribution dry weight)}^{0.7}$$

The data used in this equation are obtained from data form C, appendix B. Note that the dry weight of the electrical distribution system contains the weight of the actuator and mechanism for the doors and covers.

6.1.1.4.2 Hydraulics (WBS 101-04-02)

The development costs for the hydraulic system were developed from the following relationship:

$$\text{RDT\&E (M\$)} = \text{(Comfac)}(0.05)\text{(system dry weight)}^{0.77}$$

The Comfac is a function of commonality and complexity of the system and was calculated as follows:

$$\text{Comfac} = \text{Commonality} \times \text{Complexity}$$

$$= 0.8 \times 1.0$$

$$= 0.8$$

The factors chosen for commonality and complexity were the highest recommended by the Aerospace Corp. The weight of the system, shown in data form C, appendix B, includes the accumulator and associated system for the four landing gears.

The first unit cost is determined from the following CER:

$$\text{TFU (M\$)} = 0.0045 \text{ (system dry weight)}^{0.80}$$

The weight for this equation is the same as that used in the development CER.

6.1.1.5 Environmental Control and Life Support (WBS-101-05-00)

No specific ECLS equipment has been identified for the unmanned SERV configuration. All ECLS equipment is associated with the spacecraft and cargo.

6.1.1.6 Assembly and Checkout (WBS 101-06-00)

Assembly and checkout costs were determined from a CER which reflects the complexity of the vehicle assembly as a function of the first unit costs of the major vehicle subsystems.

TFU (M$) = (0.02)(TFU airframe + TFU main engine + TFU landing gear + TFU propulsion) + (0.10)(TFU avionics + TFU power system)

The TFU cost for each element of the system is obtained by the methods described elsewhere in this section.

6.1.1.7 System Support (WBS 101-07-00)

This element contains systems engineering and integration, project management, facilities and equipment, GSE, training, initial operating spares, ground tests, and sustaining engineering.

6.1.1.7.1 System Engineering and Integration (WBS-101-07-01)

The system engineering and integration elements was determined by specialist estimation.

6.1.1.7.2 Project Management (WBS 101-07-02)

The project management element was determined by specialist estimation.

6 1.1.7.3 Facilities, Tooling and Special Equipment (WBS-101-07-03)

The facilities, tooling and special equipment cost were determined from CCSD specialists cost estimates. These detailed estimates are in appendix C. Sustaining tooling for the investment phase was estimated from the following CER:

$$MS = (0.15)\ (0.199)(\text{dry weight})^{0.593}$$

The dry weight is that used in 6.1.1.3.1 for determining the structure cost.

6.1.1.7.4 GSE (WBS 101-07-04)

The cost of GSE was developed from the following CER:

RDT&E (M$) = 0.02 (airframe RDT&E) + 0.10 (propulsion RDT&E + avionics RDT&E + power RDT&E + main engine RDT&E)

Inputs to the equation are obtained from calculations of system development cost presented elsewhere in this section.

The GSE investment cost is taken as 70 percent of the development cost, or:

$$\text{GSE (M\$)} = 0.70\ (\text{GSE RDT\&E})$$

6.1.1.7.5 Training (WBS 101-07-05)

The development cost for training was determined from the following CER:

$$\text{RDT\&E (M\$)} = 0.15\ (\text{number of personnel to be trained}) + 0.20\ (\text{first unit cost of SERV})$$

The number of personnel to be trained is shown in data form C, appendix B.

6.1.1.7.6 Initial Operating Spares (WBS 101-07-06)

Initial operating spares were costed for the investment phase of the program using the following CER:

$$\text{Total investment cost} = 0.10\ (\text{total SERV hardware cost}) + 0.30\ (\text{TFU structures})$$

The total SERV hardware cost is the cost of two test vehicles plus two flight vehicles. The right hand element in the cost equation is an allowance for a set of spare doors. During refurbishment, the aerospike doors, gas turbine exhaust doors, and landing gear doors will be removed to a separate area for replacement of the ablative protection material. To accomodate this type of refurbishment operation, a spare set of doors is provided.

6.1.1.7.7 Ground Test (WBS 101-07-07)

The development cost associated with ground test of the SERV was determined by the following CER:

$$\text{RDT\&E (M\$)} = 0.05\ (\text{airframe RDT\&E}) + 5\ (\text{number of engines})^{0.26} \times (\text{thrust})^{0.14} + 0.15\ (\text{propellant weight}) \times (\text{number of static tests}) + 1.55 + 0.02\ (\text{wind tunnel test hours})^{0.68} + \text{ground test hardware cost.}$$

The input requirements for this equation are listed in data form C, appendix B. The ground test hardware cost was estimated at \$150M which is the cost for the structural test vehicle. This cost is approximately 0.50 of the SERV first unit cost.

6.1.1.7.8 Sustaining Engineering (WBS 101-07-08)

The sustaining engineering cost for SERV was based on specialist estimates which considered the project manning relationship between the RDT&E and procurement phases. A prime consideration was the duration of the RDT&E phase which extends two years past FMOF. Using this as a base, the sustaining engineering cost during the RDT&E phase was estimated as 0.12 of the total SERV investment cost. Sustaining engineering during the operation phase was estimated at 200 personnel at MAF at 35,000 dollars per man year.

6.1.2 SPACECRAFT (WBS 102-00-00)

Because spacecraft analysis and sizing was specifically excluded from the SERV study, the following spacecraft costs from NASA sponsored studies were used with NASA approval:

- Costs for the MURP D-34 winged spacecraft are shown in data form A, appendix B, and were obtained from a document entitled "Integral Launch & Re-entry Vehicle", reference SP 69-11 dated May 1, 1969, prepared by North American Rockwell Space Division under contract NAS9-9205.

- Costs for the PM spacecraft are shown in data form A, appendix B, and were based on data obtained from a document entitled "Advanced Logistics Spacecraft System", Volume VIII reference Report No. F738 dated October 31, 1967 prepared by McDonnell Astronautics Company under contract NAS9-6801.

6.1.3 MAIN ENGINE (WBS 103-00-00)

The aerospike engine development cost was estimated to be $556M. This was obtained from specialist estimates and data provided by North American Rockwell Rocketdyne Division. A breakdown of the development cost is as follows:

- $500M Development

- $14M Test Facility Modification

- $42M Propellant and Other Fluids

The test facility modification cost is based on information from previous Rocketdyne studies. The $14M is comprised of:

- $75M Capital expenditures and equipment at the Rocketdyne Santa Susanna Flight Laboratory (SSFL) and Nevada Flight Laboratory (NFL).

- $7M To activate two test stands at either Edwards Flight Laboratory (EFL) or the Mississippi Test Facility (MTF)

The first unit cost for the aerospike engine was provided by Rocketdyne. A sustaining engineering cost of $28M was added to this based on eight years of sustaining engineering effort with 100 man level at $35,000 per man year.

6.1.4 FLIGHT TEST (WBS 104-00-00)

Costs for the SERV vehicle flight test program are included in this element. They were developed from a combination of CER's and specialist estimates. The relationships expressing these cost estimates are given in the following paragraphs.

6.1.4.1 SERV Flight Test (WBS 104-01-00)

The SERV flight test development cost was estimated with the following CER:

RDT&E (M$) = 42.5 + 2.84 (number of months in test program)

+0.15 (propellant weight) + 2.0 (TFU of SERV)

6.1.4.2 Spacecraft (WBS 104-02-00)

The spacecraft flight test costs are included in the spacecraft development cost (WBS 102-00-00).

6.1.4.3 SERV Spacecraft Mating (WBS 104-03-00)

The SERV spacecraft mating cost during flight test was estimated from the following CER:

RDT&E (M$) = 0.15 (SERV flight test cost)

6.1.4.4 Support (WBS 104-04-00)

The SERV flight test support cost was developed with the following CER:

RDT&E (M$) = 0.12 (SERV flight test cost)

The data inputs for this equation are in data form C, appendix B.

6.1.5 OPERATIONS (WBS 105-00-00)

Spacecraft operations costs are included in the spacecraft element, paragraph 6.1.2. Operations costs for SERV were subdivided into: ground operations; propellants; flight spares; flight operation; training; facility maintenance; program management; payload integration; and refurbishment of the ablative heatshield.

1) The ground operation costs were obtained through a detailed estimate of the program operational requirements. A subdivision of personnel utilization is contained in volume V of this report.

2) Propellant costs were calculated using vehicle propellant loads, boil-off factors, flights per year, and cost of propellants. Propellant costs used were:

- 32¢ per pound for LH_2
- 2¢ per pound for LO_2
- 2¢ per pound for JP-4 fuel

The cost of gas for purges is included in this element and 130,000 scf of GH_2 was costed for each flight at $44 per 1000 scf.

3) Flight spares were costed using the Aerospace Corporation CER's for spares, which is listed in table 6.1-2.

4) Specialist estimates were used for costing flight operations, training, facility maintenance, program management, and payload integration.

5) Refurbishment of the ablative heatshield contains the cost of the thermal protection panels, attachment hardware and sealing material. The labor cost associated with the refurbishment of the heatshield are included in the operations cost element. The refurbishment costs estimated for this element are based on data provided by the AVCO Corporation. A cost of approximately $90 per square foot was used.

6.1.6 MANAGEMENT AND INTEGRATION (WBS 106-00-00)

This element was estimated by specialist estimates which considered the total program management manning relationships and the timing continuity of the program.

6.1.6.1 Systems Engineering and Integration (WBS 106-01-00)

This element cost was estimated by specialist estimate.

6.1.6.2 Program Management (WBS 106-02-00)

This element cost was estimated by specialist estimate.

6.2 COST DISTRIBUTION

The time phasing of the cost estimates is discussed in this subsection. The idealized cost distributions used in this study were those described in NASA document MSFC-DRD-MF-030. The general expression for the cost distribution curves is given by the following beta function:

$$F(s) = As^2 \left((10+s\ (15-4s)\ s-20)\right) + Bs^3 \left(10 + s\ (6s-15)\right) + (1-(A+B))(5-4s)\ s^4$$

Where s is the fraction of time elapsed and F(s) is the fraction of cost consumed. Since F(s) represents the accumulation of costs, successive intervals must be differenced to obtain the cost estimate. The constants A and B are obtained from the referenced DRD document.

Spreading functions such as these have an important role in program cost estimation. An ideal spread for the program will minimize the funding peaks and also minimize the cost of the program in discount dollars. Utilizing tradeoff data, program schedule requirements, program manpower buildup requirements, and program continuity requirements, a spreading function for each WBS element was developed. Figure 6.2-1 shows the functions used in the study. They are based on the idealized cost distribution factors identified in table 6.2-1.

Table 6.1-2 Spares Factors

Spares Category \ Spares Factor Constants	SURF	NLOHE	URF	SF
Structure - Orbiter and Booster	0.05	100	0.001	0.0015
Thermal Protection System - Orbiter	0.40	50	0.002	0.01
Thermal Protection System - Booster	0.20	50	0.001	0.005
Rocket Engines - Orbiter and Booster	0.33	100	0.0015	0.0048
Airbreathing Engines - Orbiter and Booster	0.25	400	0.001	0.001625
Subsystems - Orbiter and Booster	0.40	100	0.005	0.009

$$\text{Spares Factor } (SF\_) = \left(\frac{SRF}{NLOHE} + URF\right)$$

where SRF = Scheduled Replacement Factor
NLOHE = Number of Launches Between Overhaul
URF = Unscheduled Replacement Factor

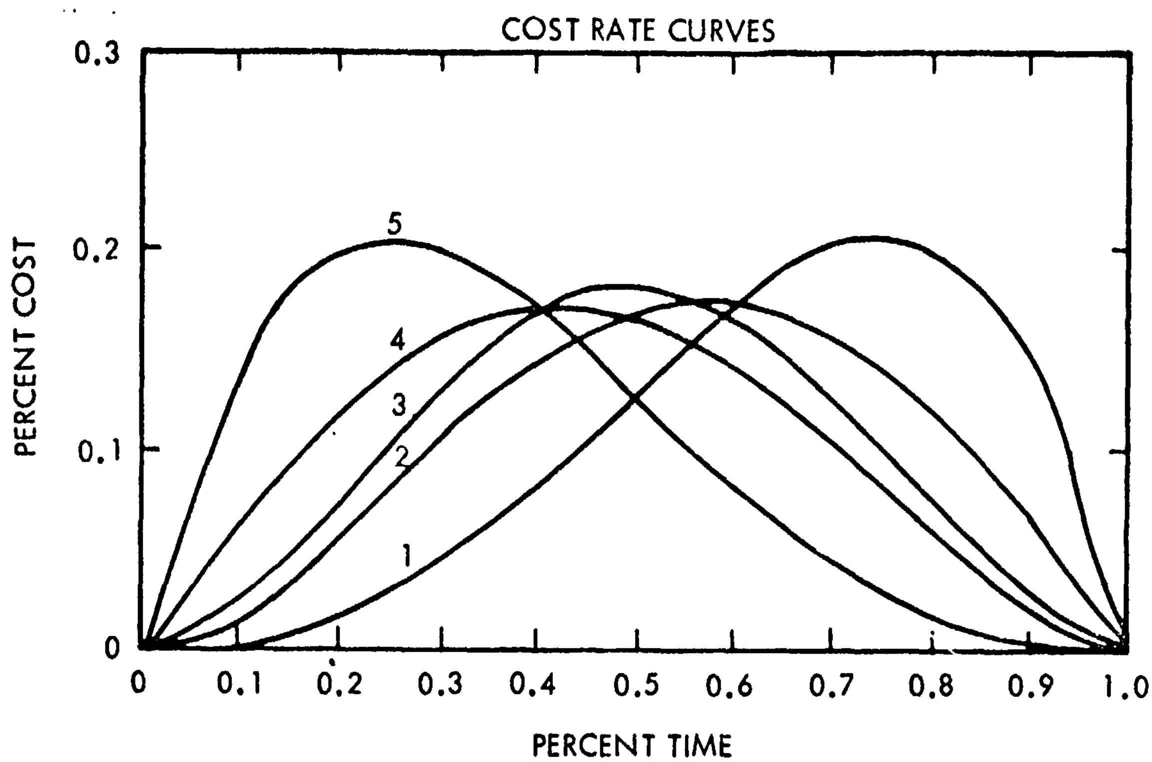


Figure 6.2-1. Idealized Cost Distribution Curves

Table 6.2-1 Idealized Cost Distribution Curves

Curve Type Designation	Curve Distribution	
	Scheduled Time Elapsed (Percent)	Cost Expended (Percent)
No. 1	50	80
No. 2	50	60
No. 3	50	50
No. 4	50	40
No. 5	50	20

6.2.1 DISTRIBUTION OF RDT&E COST

Each element of the RDT&E cost was assigned a beta distribution function. The hardware elements were all assigned beta function No. 3. SERV systems engineering and integration, project management, and ground test were assigned a beta function No. 4. SERV facilities tooling and equipment, GSE, and training utilize a normal distribution, beta function No. 3. All SERV flight test WBS elements were estimated using beta function No. 3. Program management and integration for the SERV, utilized beta function No. 4. The spacecraft development cost were spread utilizing beta function No. 2. This function was also used for the main engine.

6.2.2 DISTRIBUTION OF INVESTMENT COST

Each WBS element with an investment cost was spread utilizing beta function No. 4. All conversion work connected with placing test vehicles into an operational status were also spread utilizing a No. 4 beta function.

6.2.3 DISTRIBUTION OF OPERATION COST

All operations cost were spread by FY quarter based on the mission model launch rate. The costs were distributed equally over the quarter at a constant rate.

6.3 PROGRAM COST MODEL

This subsection describes the cost estimating model used to analyze the SERV Shuttle Program. The model computes cost for RDT&E, production, and operations. Cost model outputs consist of non-recurring and recurring costs for each WBS element, annual program cost distributions, discounted program cost distributions, and cost percentage distributions.

6.3.1 MODEL DESCRIPTION

The program cost model was developed so that parametric analysis of program cost could be effectively performed. These analyses provide the basis for cost-effective system design. The model is designed to accept a hardware -oriented WBS, non-recurring RDT&E costs, recurring production costs, and recurring operations costs. It will provide cost projections in this format over a 20-year period and analyze the data by quarter or by year. Figure 6.3-1 is a generalized flow diagram of the cost model and figure 6.3-2 depicts the estimation flow. A detailed flow diagram of the cost model is contained in appendix A. The program cost model is programmed in COBOL for the UNIVAC 1108 Exec-II System. This model accepts all costs associated with a given project by distributing cost among 100 possible WBS categories.

6.3.2 MODEL OPERATION

Input cost data can be fed into the computer utilizing two techniques: 1) the cost for each WBS item to be used in the analysis can be placed directly into the model; 2) for certain WBS items, the cost estimating relationships (CER) have been developed so that only the vehicle parameter on which the CER of the WBS item is based has to be put into the model, and from this the cost of the WBS item will be calculated.

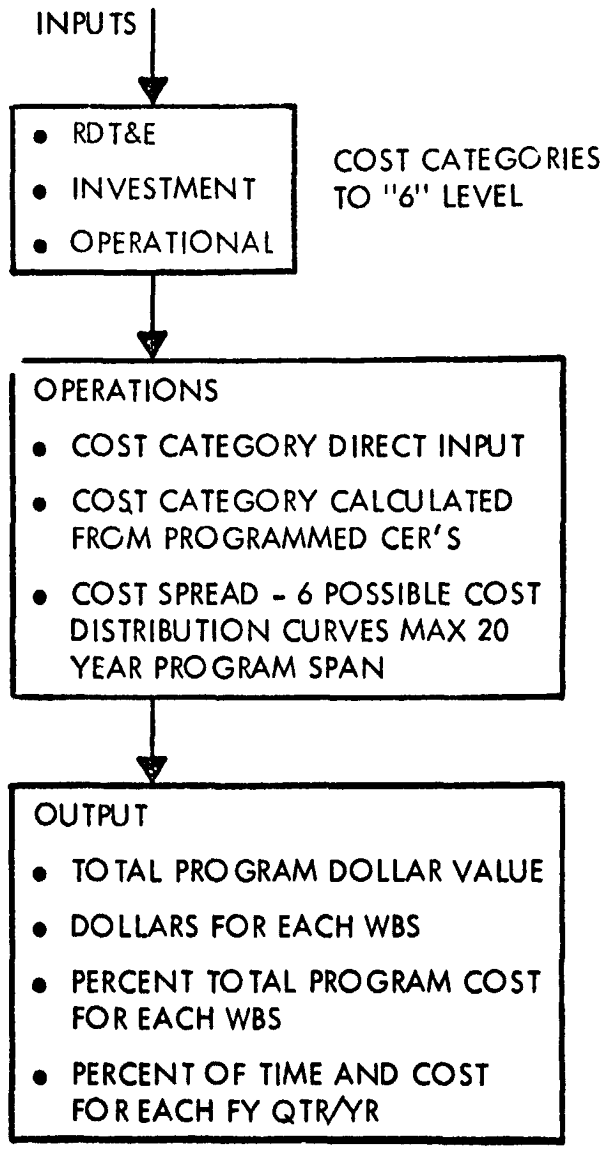


Figure 6.3-1. Generalized Cost Model Flow Diagram

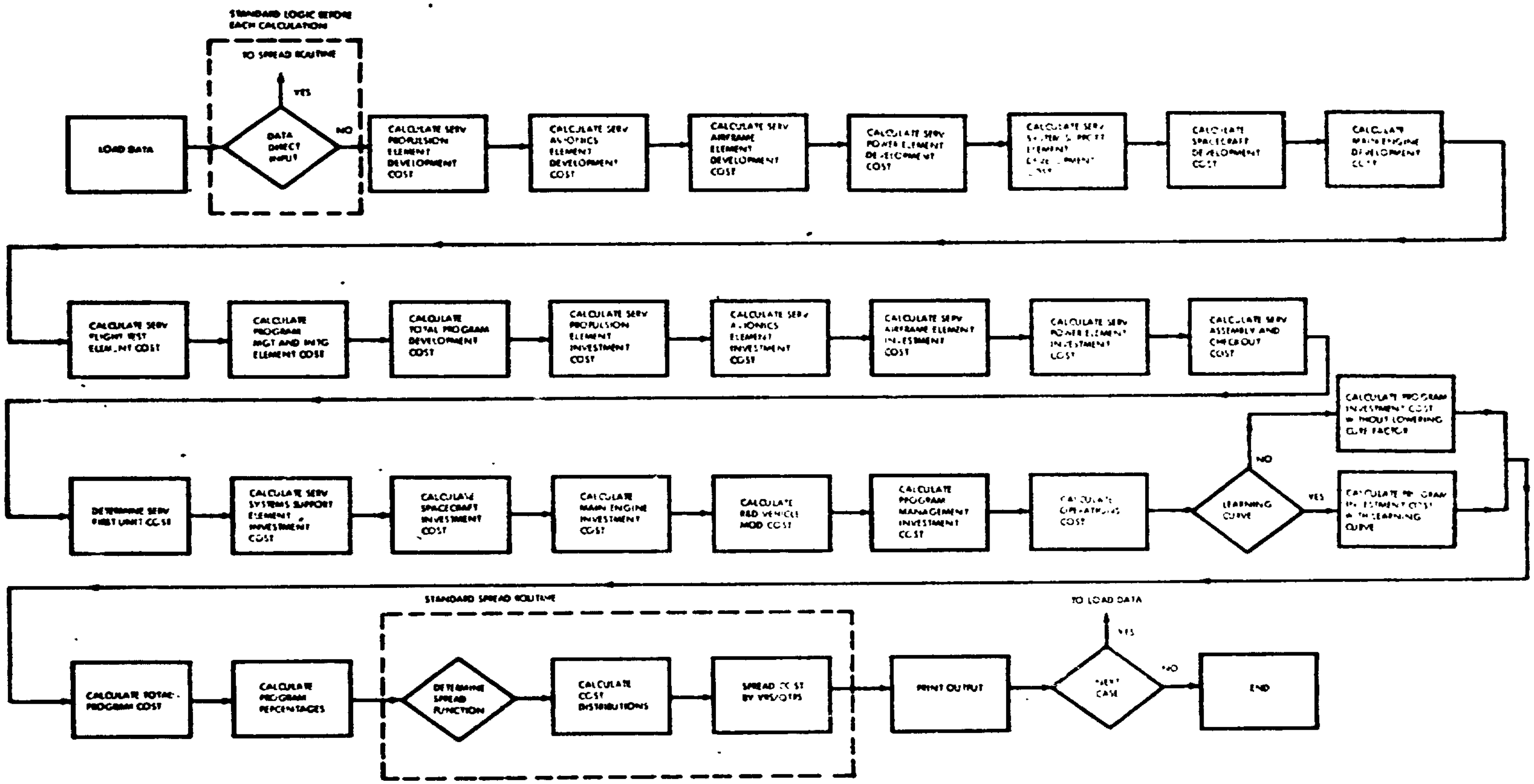


Figure 6.3-2. SERV Cost Model Calculation Flow Diagram

The WBS items in the model are grouped according to the standardized WBS levels so that if the higher level of any group item is input to the model, the lower level WBS items of the same group will be bypassed. As an example WBS-Airframe (level 4) consists of three level 5 elements, namely, structures, thermal protection, and landing gear. Therefore, if WBS-airframe, (level 4) is input, the level 5 items will be bypassed since they are the elements from which the level 4 item-structures is calculated.

The inputs to the model are:

1) Dollar value of WBS item in millions of dollars

2) Parameter value for use in CER for calculating WBS item cost

3) Cost duration in FY quarters or years

4) Cost start in FY quarters of years; both duration and start of cost must be in the same unit, i.e., either FY quarter or years.

5) 'A' beta function coefficient

6) 'B' beta function coefficient

7) Work breakdown structure name

8) Work breakdown structure level

9) Complexity factor

For the initial case, the model requires an input data card for each WBS item of the model. Each succeeding case requires data cards for only those WBS items that have values to be varied.

The output of the model can be in two formats. The first format, figure 6.3-3, is a cost summary listing each WBS item analyzed, its level, dollar value and the percent of time and cost expended in that period. The second format, figure 6.3-4, shows the total program cost in millions of dollars; and this is the final output. The model contains sufficient flexibility to accept CER's as new WBS items are developed.

In summary the model utilizes an idealized cost distribution curve for spreading element cost. The cost of each WBS element is spread utilizing this idealized function to produce a total program funding curve.

COST SUMMARY

WORK BREAKDOWN STRUCTURE NAME	WBS LEVEL	DOLLAR VALUE	PERCENT OF TOTAL PROGRAM
PROPULSION	4	$ 242.02	03.76
LIFT ENGINES	5	$ 133.00	02.07
ATTITUDE CONTROL	5	$ 109.02	01.69
AVIONICS	4	$ 217.85	03.38
GUIDANCE + NAV.	5	$ 77.37	01.20
INSTRUMENTATION	5	$ 95.22	01.48
COMMUNICATIONS	5	$ 45.26	00.70
AIRFRAME	4	$ 631.04	09.80
STRUCTURES	5	$ 555.21	08.62
TPS	5	$ 75.83	01.18
POWER	4	$ 181.48	02.82
ELECTRICAL P&R	5	$ 165.47	02.57
HYD-PNEU SYSTEM	5	$ 16.01	00.25
SYSTEMS SUPPORT	4	$ 973.97	15.13
SYSTEM ENG. + IVT	5	$ 154.28	02.40
PROJECT MGT.	5	$ 171.69	02.67
FACILITIES-EQUIP.	5	$ 188.20	02.92
GSE	5	$ 131.35	02.04
TRAINING	5	$ 71.99	01.12
GROUND TEST	5	$ 256.46	03.98
MAIN ENGINE	3	$ 556.00	08.64
FLIGHT TEST	3	$ 850.12	13.21
SERV FLIGHT TEST	4	$ 669.40	10.40
MATED	4	$ 100.40	01.56

Figure 6.3-3. Cost Summary Format

TOTAL PRO. COST DISTRIBUTION

FISCAL YEAR	DOLLAR VALUE	PERCENT OF TIME	PERCENT OF COST	DISCOUNT DOLLARS
01	$ 184.83	06.25	02.87	$ 168.07
02	$ 457.31	12.50	07.10	$ 377.94
03	$ 614.54	18.75	09.55	$ 461.71
04	$ 644.07	25.00	10.00	$ 439.91
05	$ 715.17	31.25	11.11	$ 444.06
06	$ 864.30	37.50	13.43	$ 487.87
07	$ 807.87	43.75	12.55	$ 414.56
08	$ 575.24	50.00	08.94	$ 268.35
09	$ 307.02	56.25	04.77	$ 130.21
10	$ 119.30	62.50	01.85	$ 46.00
11	$ 140.40	68.75	02.18	$ 49.21
12	$ 163.90	75.00	02.55	$ 52.22
13	$ 188.00	81.25	02.92	$ 54.46
14	$ 208.90	87.50	03.24	$ 55.01
15	$ 223.40	93.75	03.47	$ 53.48
16	$ 223.40	00.00	03.47	$ 48.62

TOTAL PROGRAM COST $ 6437.71 TOTAL PROGRAM COST DIS DOL $ 3551.68

CASE NO.	DUTE START	DOTE DURATION	DOTE A	DOTE B	INVEST A	INVEST B	INVEST ST.	INVEST DUR.
01	01	09	0.96	0.04	0.00	0.68	05	05

Figure 6.3-4. Total Program Cost Distribution Format

Section 7
COST ANALYSIS RESULTS

7.0 GENERAL

This section presents the final SERV configuration characteristics, and results of the cost analysis.

7.1 CONFIGURATION IDENTIFICATION

The final SERV configuration is presented in figure 7.1-1. The chief characteristics are shown in figure 7.1-2 and the dry weight breadkown is presented in table 7.1-1.

7.2 COST ANALYSIS RESULTS

Costs of the configuration identified in subsection 7.1 were analyzed and a cost summary and total program cost distribution is presented in appendix D.

7.2.1 PROGRAM COSTS

The cost for each WBS element is shown in figure 7.2-1 and 7.2-2. These figures illustrate the cost associated with each WBS element for both development and investment. It is important to note that investment cost totals include the cost for modification of three test vehicles, STV-1 and the two flight test vehicles, into operational vehicles.

The SERV first unit costs are shown on table 7.2-1. Investment costs for the SERV program are estimated from the SERV first unit cost utilizing a 95 percent learning curve.

Table 7.2-2 illustrates the cost per year for operational cost by operations element. Operations costs shown on this chart reflect a 60 percent unmanned flight ratio for the mission model, which reduces the program operating cost. The cost per flight is shown in table 7.2-3. This cost includes the cost of amortization which is based on a 500-flight life vehicle.

Table 7.2-4 shows the effect of launch rate on operations cost. A mission model of 100, 220, 365 and 445 was used and the associated costs for a ten year program are presented.

SERV program cost distributions are shown on figure 7.2-3 and 7.2-4. Figure 7.2-3 illustrates SERV Shuttle Program cumulative costs for the SERV only, SERV-PM and SERV-MURP. The cumulative cost curves also show program cost in discount dollars. The program cost in discount dollars was based on a 10 percent discount rate in accordance with Bureau of the Budget circular No. A-94, dated June 26, 1969, subject: "Discount Rates and Procedures to be used in Evaluating Deferred Costs and Benefits". SERV Shuttle Program cost distribution is shown on figure 7.2-4. Peak funding for the program options are also presented.

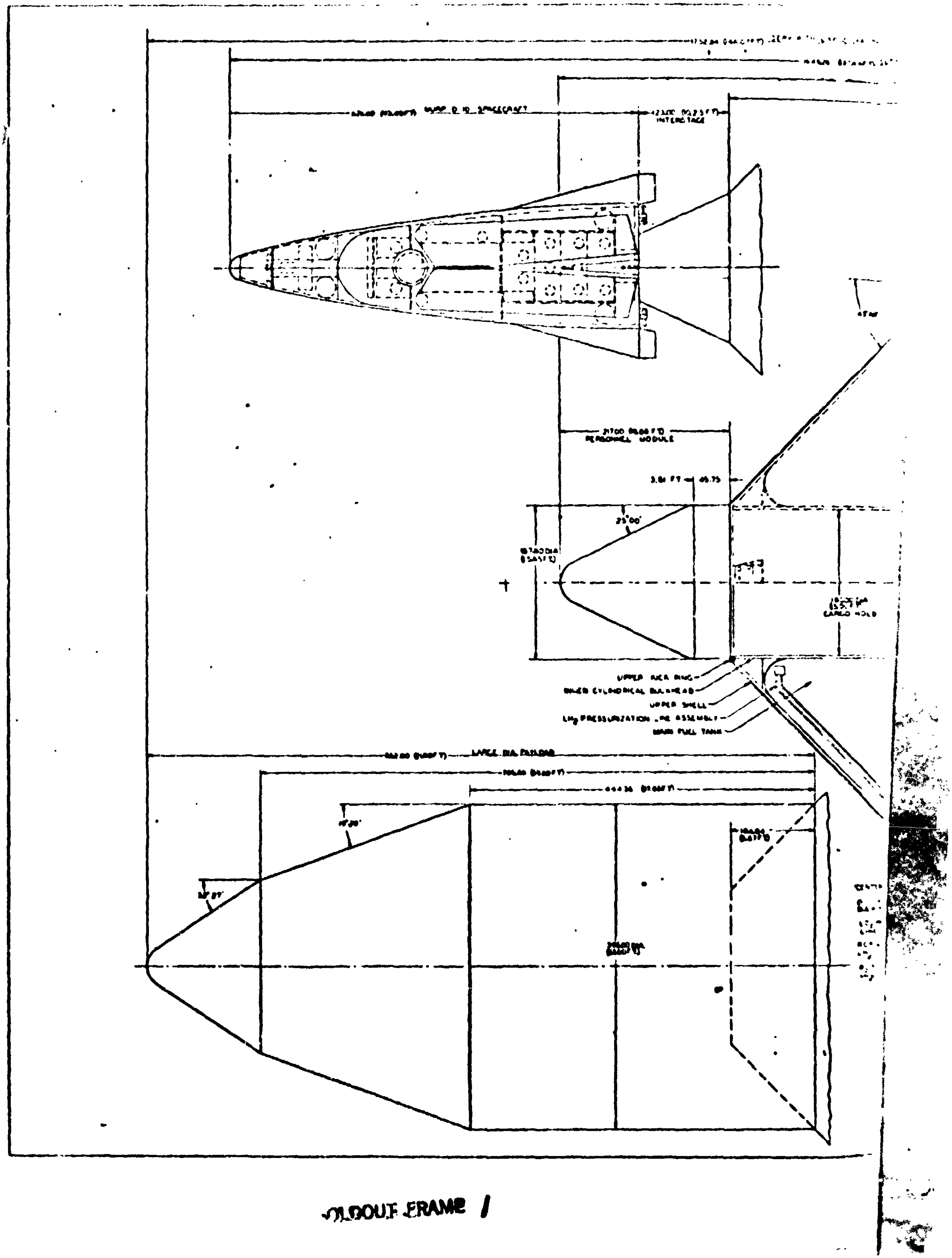
A typical breakdown of the SERV Shuttle Program cost is presented in figure 7.2-5; high cost areas are presented in table 7.2-5. The table identifies the high cost areas by WBS element, percentage of total program cost, and the cost drivers of the WBS element; all other elements have lower percentage costs. Note that the five RDT&E high cost areas identified account for 28.06 percent of the program cost and this represents 48.3 percent of the total RDT&E cost (see figure 7.2-5). Restated, five areas account for approximately 48 percent of the program RDT&E cost.

7.3 NASA COST DATA FORMS

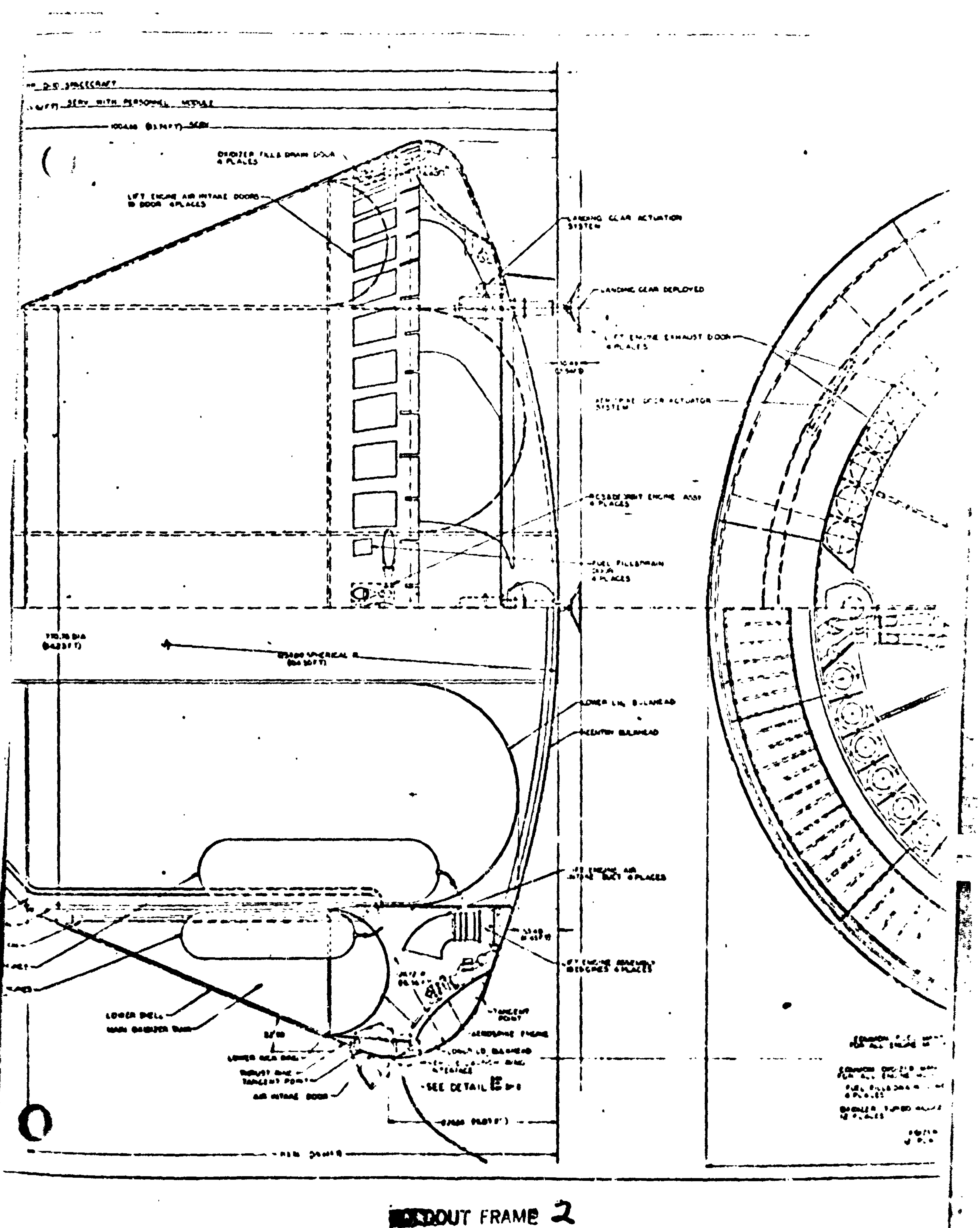
NASA cost estimate forms 'A', 'C' and 'D' are presented in appendix B. Separate sets of Forms 'A; and 'D' are included for non-recurring (DDT&E), recurring (Production) and recurring (Operations) costs. The forms display total cost and distribution by fiscal year for the SERV Shuttle Program.

Table 7.1-1 DRY WEIGHT BREAKDOWN

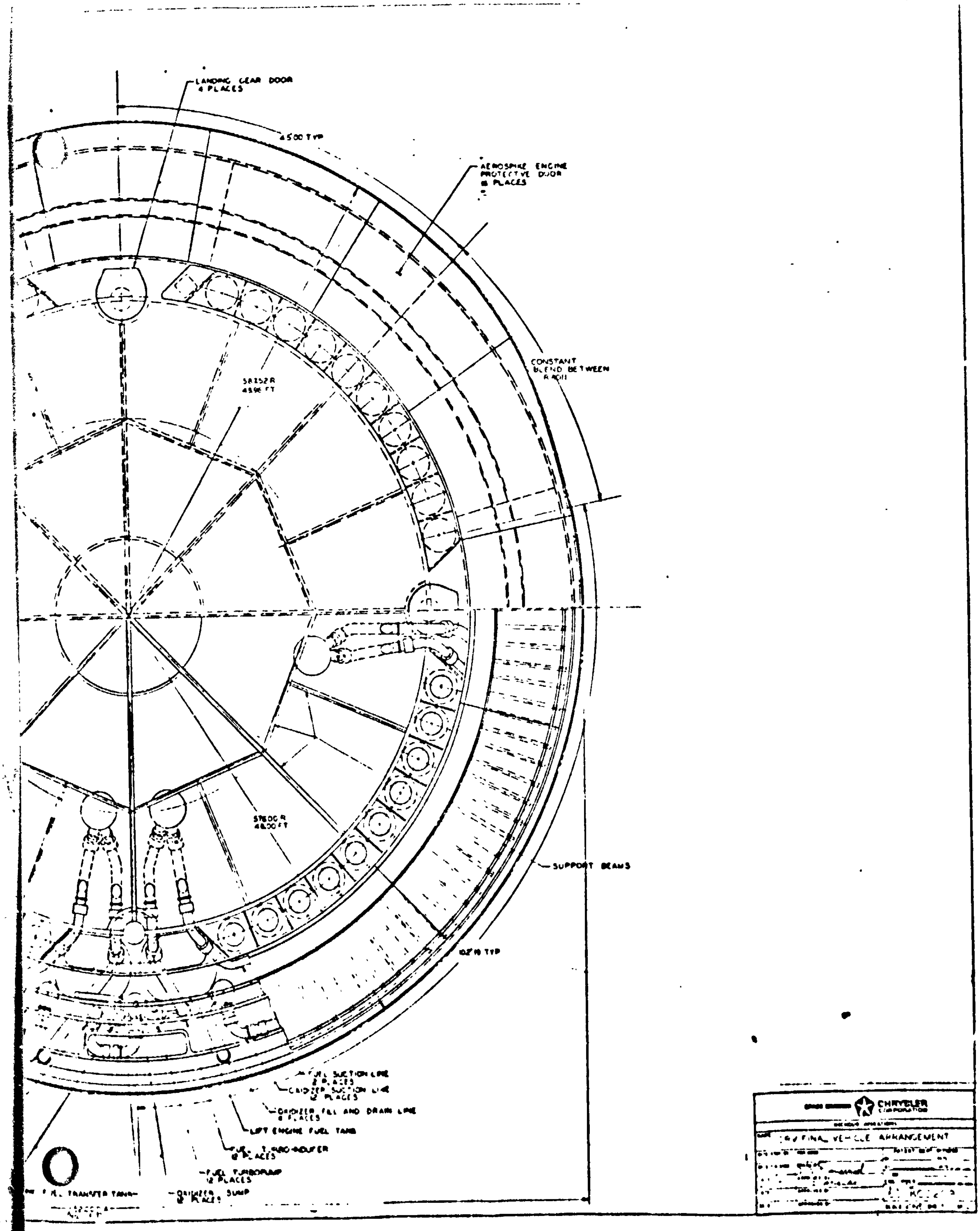
Primary Structure	200,018
Thermal Protection	24,695
Landing Gear	11,631
Actuators for Doors	5,405
Turbojet Engines	48,845
Turbojet Controls	3,146
Turbojet Tanks, Lines	2,490
Propellant Feed, Press.	17,348
Avionics and Power	6,681
Aerospike Engine	110,804
Auxiliary Propulsion	6,071
Aerospike Doors	12,183
Contingency (10%)	44,932
Total Dry Weight	494,249
GLOW	6,053,400



FOLDOUT FRAME 1



[redacted]OUT FRAME 2



FOLDOUT FRAME 3

Figure 7.1-1. Final Vehicle Arrangement

ITEM	SPACECRAFT/PROFILE DESCRIPTION	
	PM (260 x 55)	MURP (110 x 55)
PAYLOAD WEIGHT (LB)	50,900	88,900
CARGO WEIGHT TO 270 x 55 (LB)	25,000	27,300
LIFTOFF THRUST (LB)	7,454,000	7,454,000
GLOW (LB)	6,046,000	6,049,000
VEHICLE DRY WEIGHT (LB)	494,249	
• PRIMARY STRUCTURE	200,018	
• AEROSPIKE ENGINE	110,804	
• TURBOJET ENGINES	48,845	
• THERMAL PROTECTION	24,695	
• ALL OTHER SUBSYSTEMS	64,955	
• CONTINGENCY (10%)	44,932	

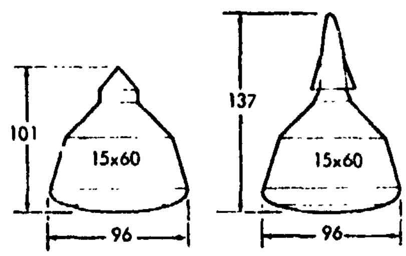


Figure 7.1-2. Final Vehicle Selection

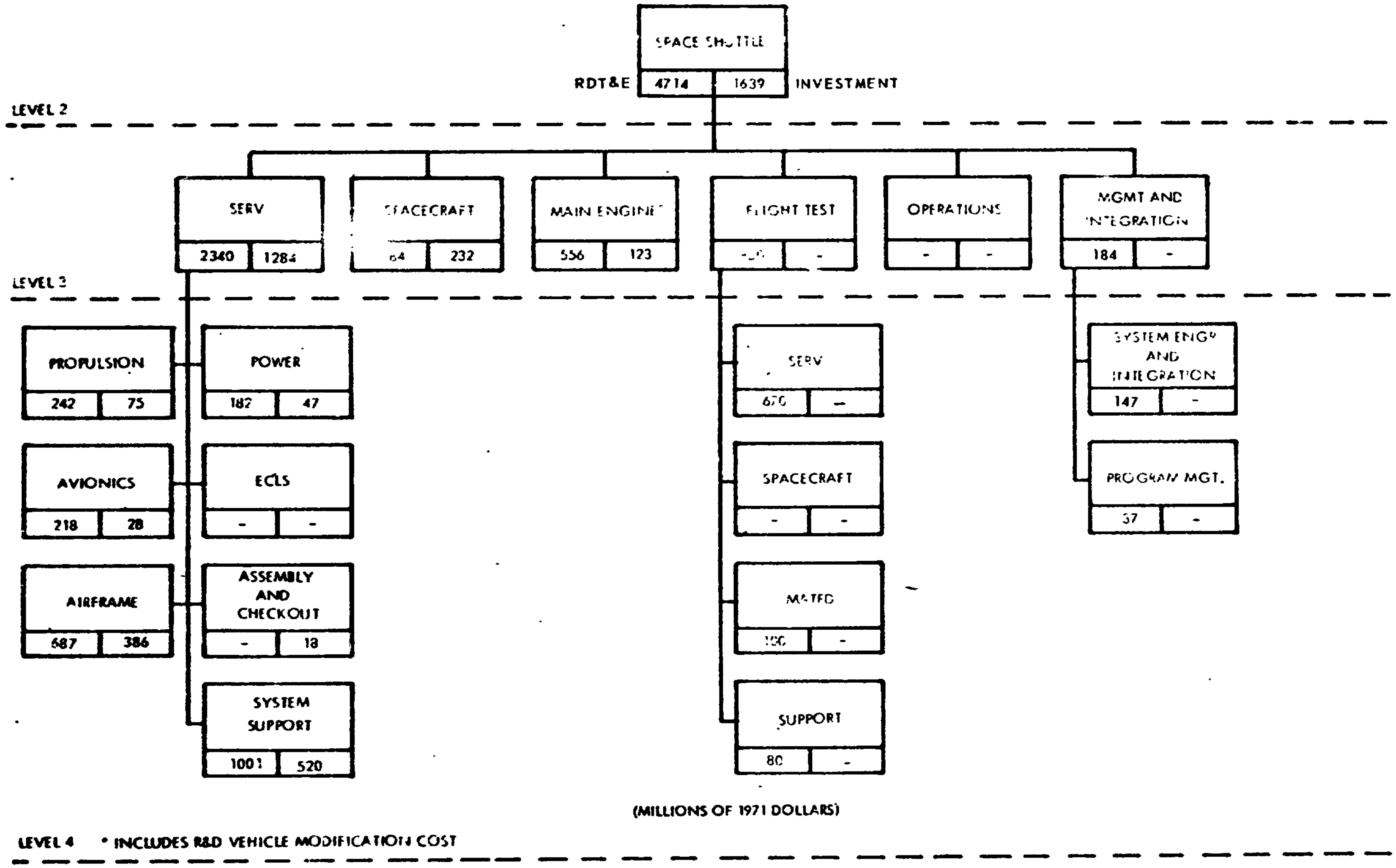


Figure 7.2-1. Program Nonrecurring Cost Breakdown

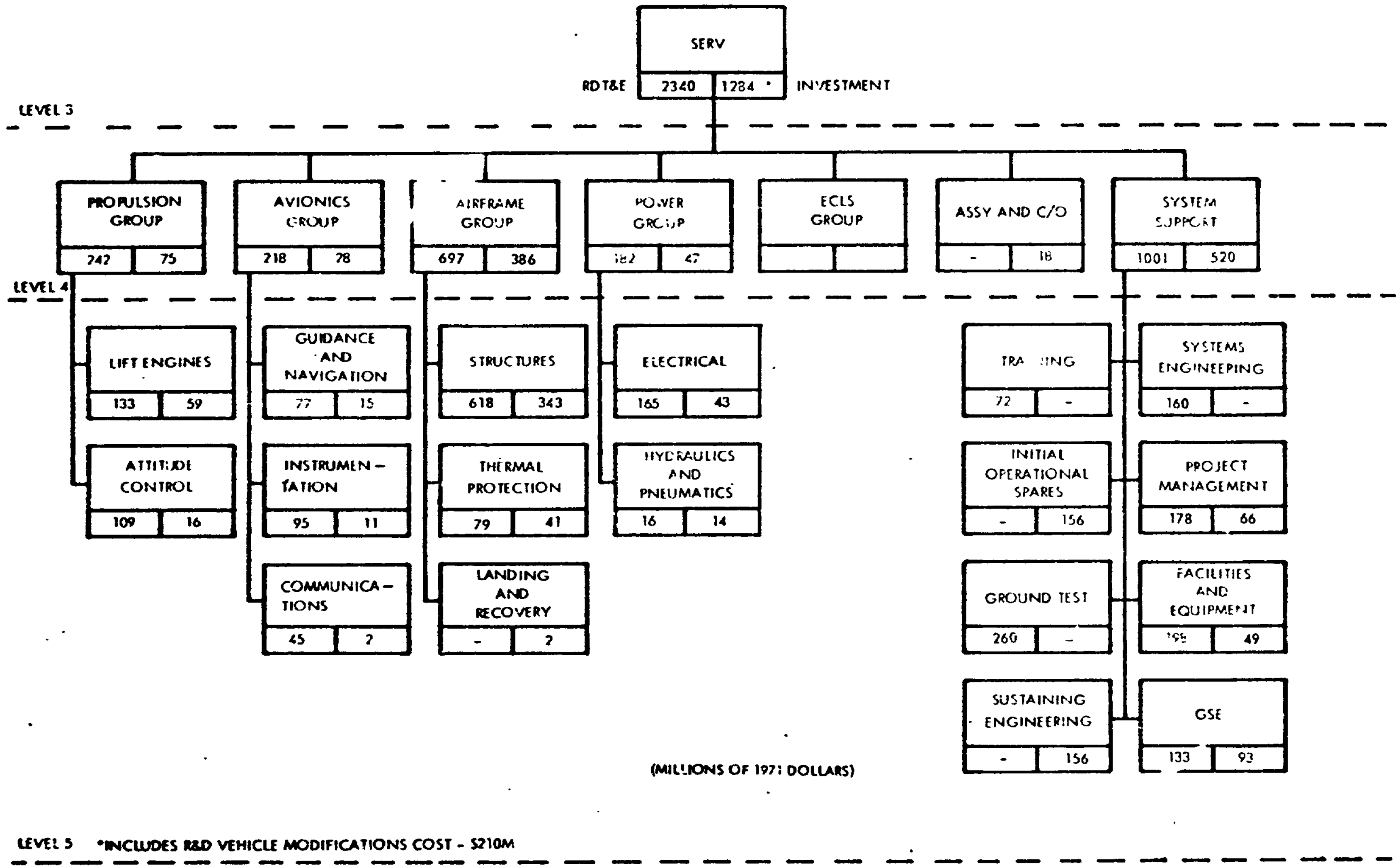


Figure 7.2-2. SERV Nonrecurring Cost Breakdown

Table 7.2-1. SERV First Unit Cost

WBS ITEM		TOTALS
• PROPULSION		
- AEROSPIKE ENGINE	60.0	
- LIFT ENGINES	29.5	
- ATTITUDE CONTROL	8.5	
		98.0
• AVIONICS		
- GUIDANCE AND NAVIGATION	8.0	
- INSTRUMENTATION	5.6	
- COMMUNICATIONS	1.4	
		14.8
• AIRFRAME		
- STRUCTURES AND TPS	202.0	
- LANDING	1.0	
		203.0
• POWER		
- ELECTRICAL	22.7	
- HYDRAULIC AND PNEUMATIC	2.1	
		24.8
• ASSEMBLY AND CHECKOUT		9.5
• FIRST UNIT COST TOTAL		350.1

(MILLIONS OF 1971 DOLLARS)

Table 7.2-2. Operating Cost Per Year

YEAR	1	2	3	4	5	6	7	8	9	10	
MANNED/UNMANNED	4 6	6 9	8 12	12 18	16 24	20 30	24 36	28 42	30 45	39 45	TOTAL
PM											
Operations	21.2	21.2	21.2	24.1	24.1	28.4	31.2	31.2	31.2	31.2	265.2
Propellants	4.2	6.3	8.4	12.6	16.8	21.0	25.2	29.4	31.5	31.5	186.9
Flight Spares	8.0	12.0	15.9	23.7	31.8	39.8	47.7	55.7	59.7	59.7	353.8
Flight Operations	2.2	3.3	4.4	6.6	8.8	11.0	13.2	15.4	16.5	16.5	97.9
Training	5.0	5.0	5.0	5.4	5.4	6.1	6.5	6.5	6.5	6.5	57.9
Facility Maintenance	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	200.0
Program Management	2.6	3.0	3.6	4.8	5.8	7.2	8.5	9.3	9.7	9.7	64.2
Payload Integration	4.0	6.0	8.0	12.0	16.0	20.0	24.0	28.0	30.0	30.0	178.0
Ablative Refurbishment	8.8	13.3	17.6	26.4	35.2	44.0	52.8	61.6	66.1	66.1	391.9
Overhaul									4.0	4.0	8.0
TOTAL	76.0	90.1	104.1	135.6	163.9	197.5	229.1	257.1	275.2	275.2	1803.9
MURP											
Operations	21.8	21.8	21.8	24.7	24.7	29.1	31.9	31.9	31.9	31.9	271.5
Propellants	4.2	6.3	8.4	12.6	16.8	21.0	25.2	29.4	31.5	31.5	186.9
Flight Spares	7.5	13.6	18.0	26.9	36.1	45.1	54.1	63.1	67.7	67.7	399.8
Flight Operations	2.6	3.9	5.2	7.8	10.4	13.0	15.6	18.2	19.5	19.5	115.7
Training	5.0	5.0	5.0	5.4	5.4	6.1	6.5	6.5	6.5	6.5	57.9
Facility Maintenance	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	20.0	200.0
Program Management	2.6	3.0	3.6	4.8	5.8	7.2	8.5	9.3	9.7	9.7	64.2
Payload Integration	4.0	6.0	8.0	12.0	16.0	20.0	24.0	28.0	30.0	30.0	178.0
Ablative Refurbishment	8.8	13.3	17.6	26.4	35.2	44.0	52.8	61.6	66.1	66.1	391.9
Overhaul									4.0	4.0	8.0
TOTAL	76.5	92.9	107.6	140.6	170.4	205.5	238.6	268.0	286.9	286.9	1873.9

(MILLIONS OF 1971 DOLLARS)

Table 7.2-3. Typical Cost Per Flight

TYPICAL COST PER FLIGHT (445 FLIGHT PROGRAM)	SERV-MURP	SERV-PM
Operations	4.21	4.05
Fleet Amortization	0.86	0.83
Total ($M/FLT)	5.07	4.88

Table 7.2-4. Effect of Launch Rate on Operations Cost

NUMBER OF LAUNCHES IN LAST YEAR	TOTAL LAUNCHES IN TEN YEAR PROGRAM	TOTAL COST FOR 10 YEAR PROGRAM		TOTAL OPERATIONS COST PER FLIGHT	
		SERV-MURP	SERV-PM	SERV-MURP	SERV-PM
10	100	765.0	760.0	7.65	7.60
25	220	1147.8	1111.6	5.21	5.05
50	365	1615.5	1557.2	4.43	4.27
75	445	1873.9	1803.9	4.21	4.05

(MILLIONS OF 1971 DOLLARS)

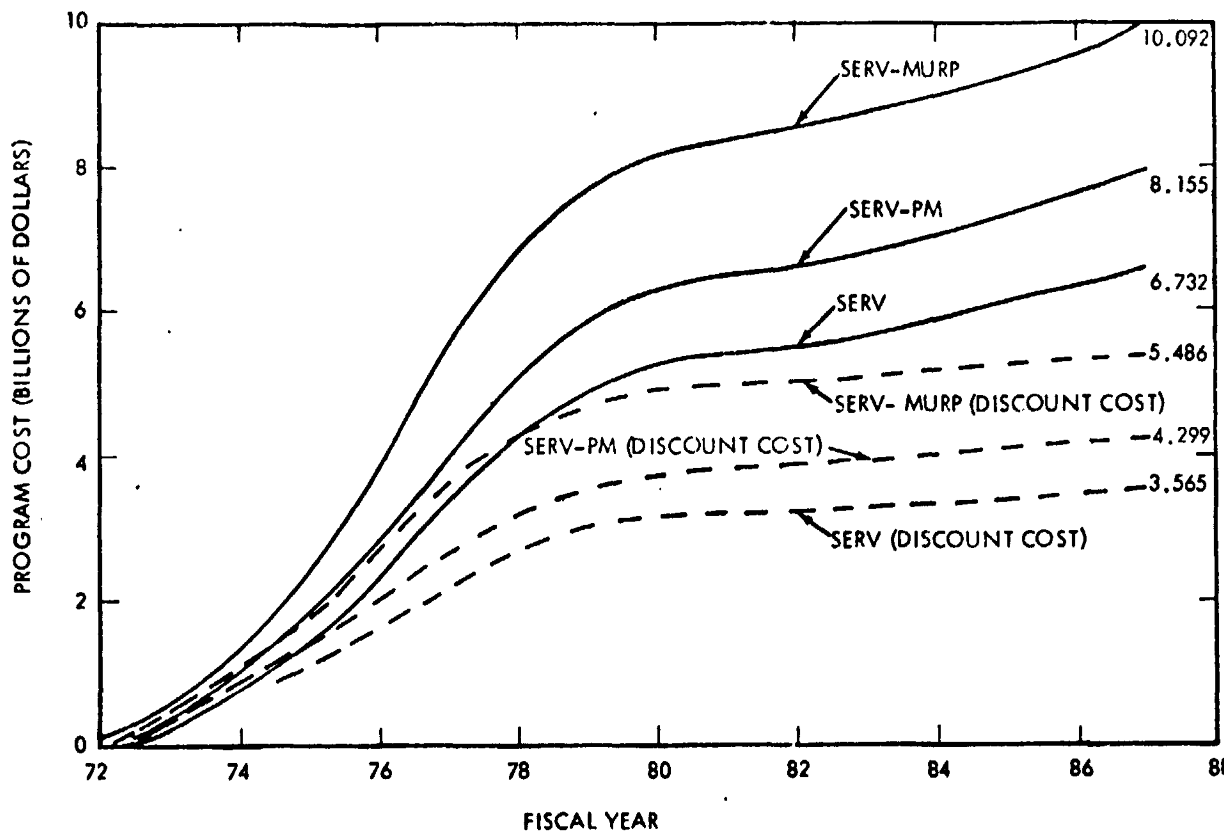
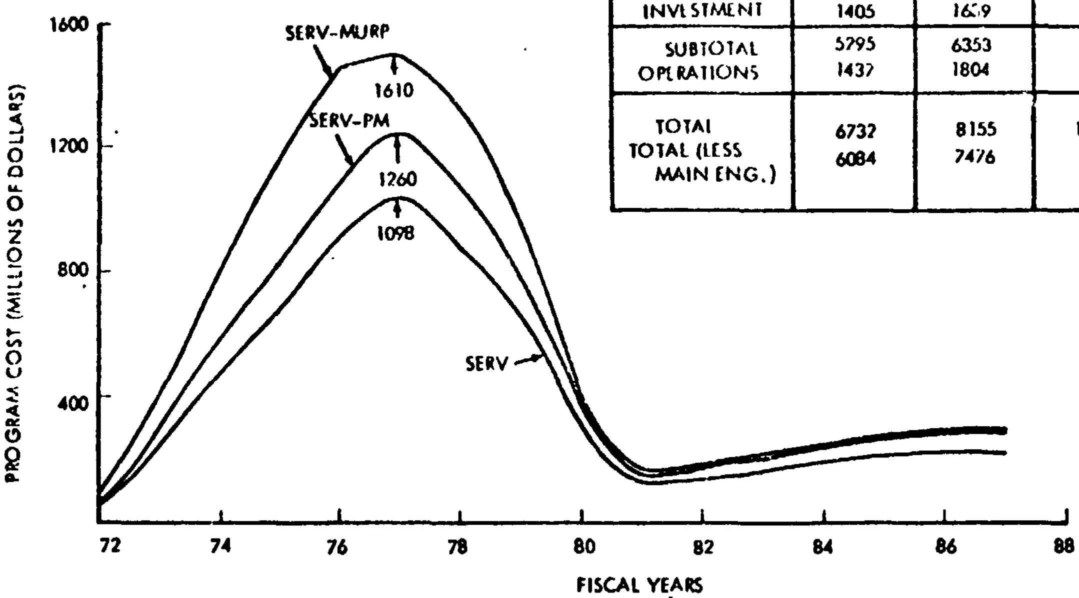


Figure 7.2-3. SERV Shuttle Program Cumulative Cost



PROGRAM COST SUMMARY (10^6 $)			
CONFIGURATION	SERV	SERV-PM	SERV-MURP
RDT&E	3890	4714	6530
INVESTMENT	1405	1639	1689
SUBTOTAL	5295	6353	8219
OPERATIONS	1437	1804	1873
TOTAL	6732	8155	10092
TOTAL (LESS MAIN ENG.)	6084	7476	9413

Figure 7.2-4. Program Cost Distributions

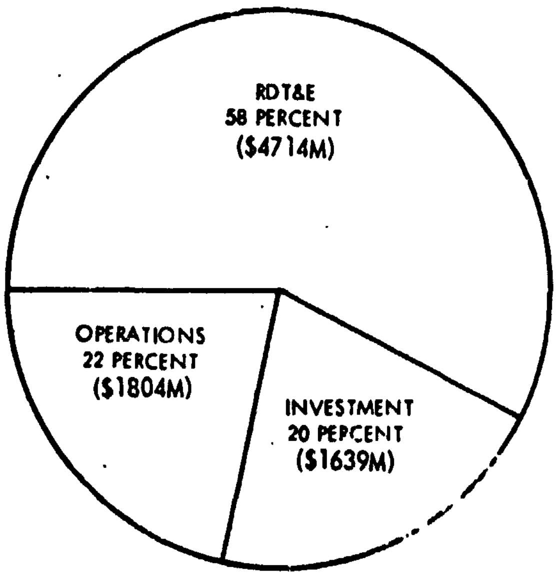


Figure 7.2-5. Typical Breakdown of SERV Shuttle Program Cost

Table 7.2-5. SERV Shuttle Program High Cost Areas

AREA	PERCENTAGE TOTAL PROGRAM COST	COST DRIVERS
SERV Flight Test - RDT&E	8.21	Months in Flight Test Program, Number of Test Flights, Test Hardware.
Structures - RDT&E	7.58	Development of Sandwich Fabrication, EBW Welding and Non-Destructive Testing Techniques.
Main Engines - RDT&E	6.82	Engine Thrust, Chamber Pressure, Specific Impulse.
Structures - Investment	4.20	Fabrication of Sandwich.
Ground Test - RDT&E	3.19	Structural Testing, Hot Firing, Wind Tunnel Testing.
Program System Eng - RDT&E	2.26	Engineering Support to Integration and Development Activities

APPENDIX A

PROGRAM COST MODEL--FLOW DIAGRAM

1.1

OPEN-FILES

OPEN INPUT PARAM

OPEN OUTPUT REPORT

MOVE 1 TO SUB1

1.2

MS

MOVE 0 TO INTERVAL (SUB1)

IF SUB1 = 80 — MOVE 1 TO SUB1

GO TO PREPARE

OTHERWISE

```
2.1                                                     PAGE

ADD 1 TO SUB1

GO TO WS

1.2

2.1

PREPARE
MOVE 0 TO DOL-VAL (SUB1) PARA-VAL
(SUB1) CO-OUR (SUB1) CO-ST (SUB1) A
(SUB1) B (SUB1) AB-LEVEL (SUB1)
CHECK (SUB1)

MOVE 0 TO AB-COMFAC (SUB1)

MOVE SPACE TO AB-NAME (SUB1)

IF SUB1 = 100  ..................  MOVE 1 TO SUB1
```

OTHERWISE

ADD 1 TO SUB1

GO TO PREPARE

2.1

3.1

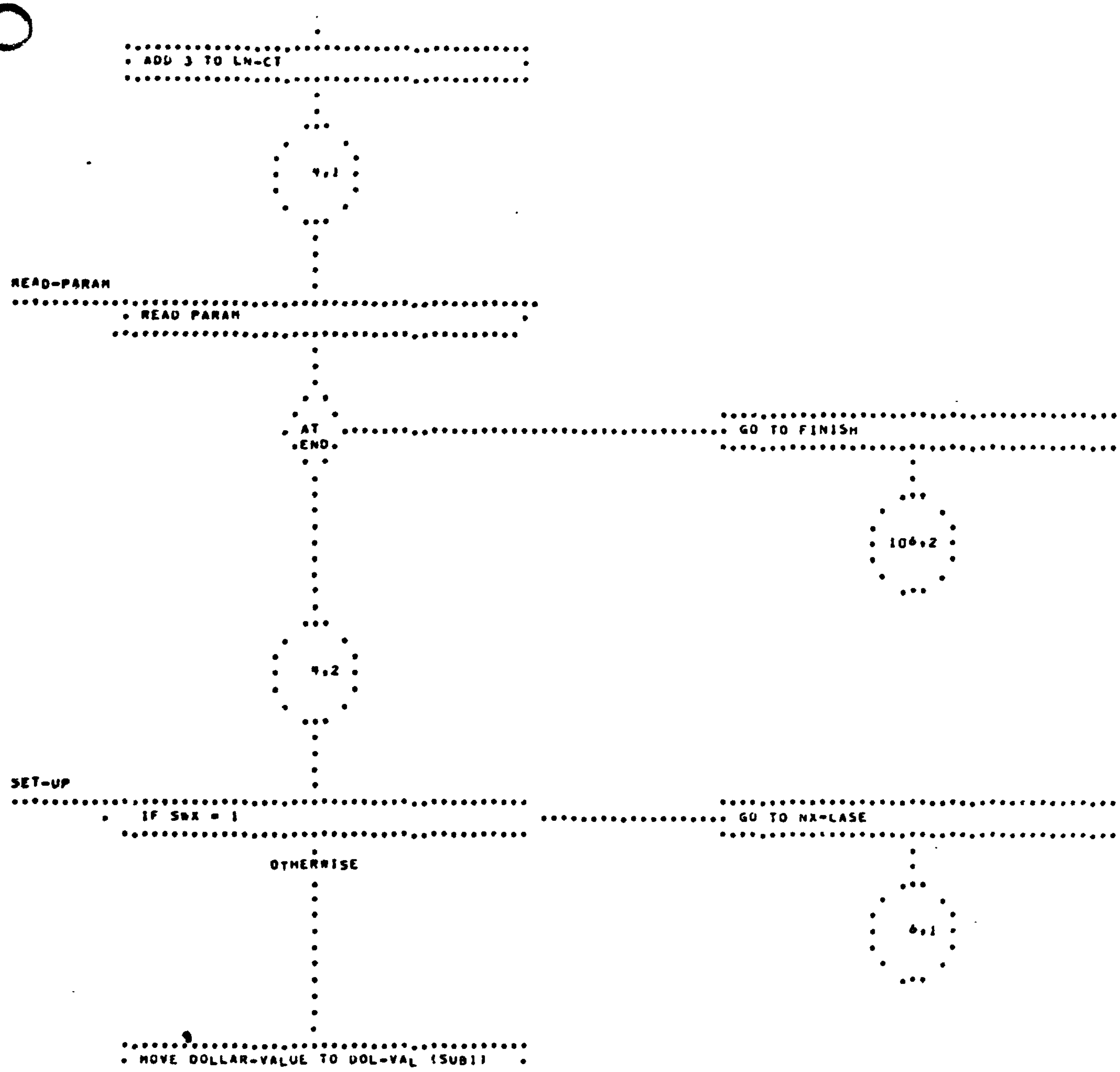
WRITE-HDRS

WRITE REPT FROM SUMMARY-HD AFTER ADVANCING PAGE

WRITE REPT FROM SUMMARY-HD1 AFTER ADVANCING 2 LINES

GO TO WRITE-HDRS

3.1


ADD 3 TO LN-CT
4.1
READ-PARAM
READ PARAM
AT END
GO TO FINISH
106.2
4.2
SET-UP
IF SWX = 1
GO TO NX-LASE
OTHERWISE
6.1
MOVE DOLLAR-VALUE TO DOL-VAL (SUB1)

IF DOL-VAL (SUB1) = 0 — GO TO SET-UP1

5,1

OTHERWISE

MOVE 1 TO CHECK (SUB1)

5,1

SET-UP1

MOVE PARAMETER-VA TO PARA-VAL (SUB1)

MOVE COST-DUR TO CO-DUR (SUB1)

MOVE COST-START TO CO-ST (SUB1)

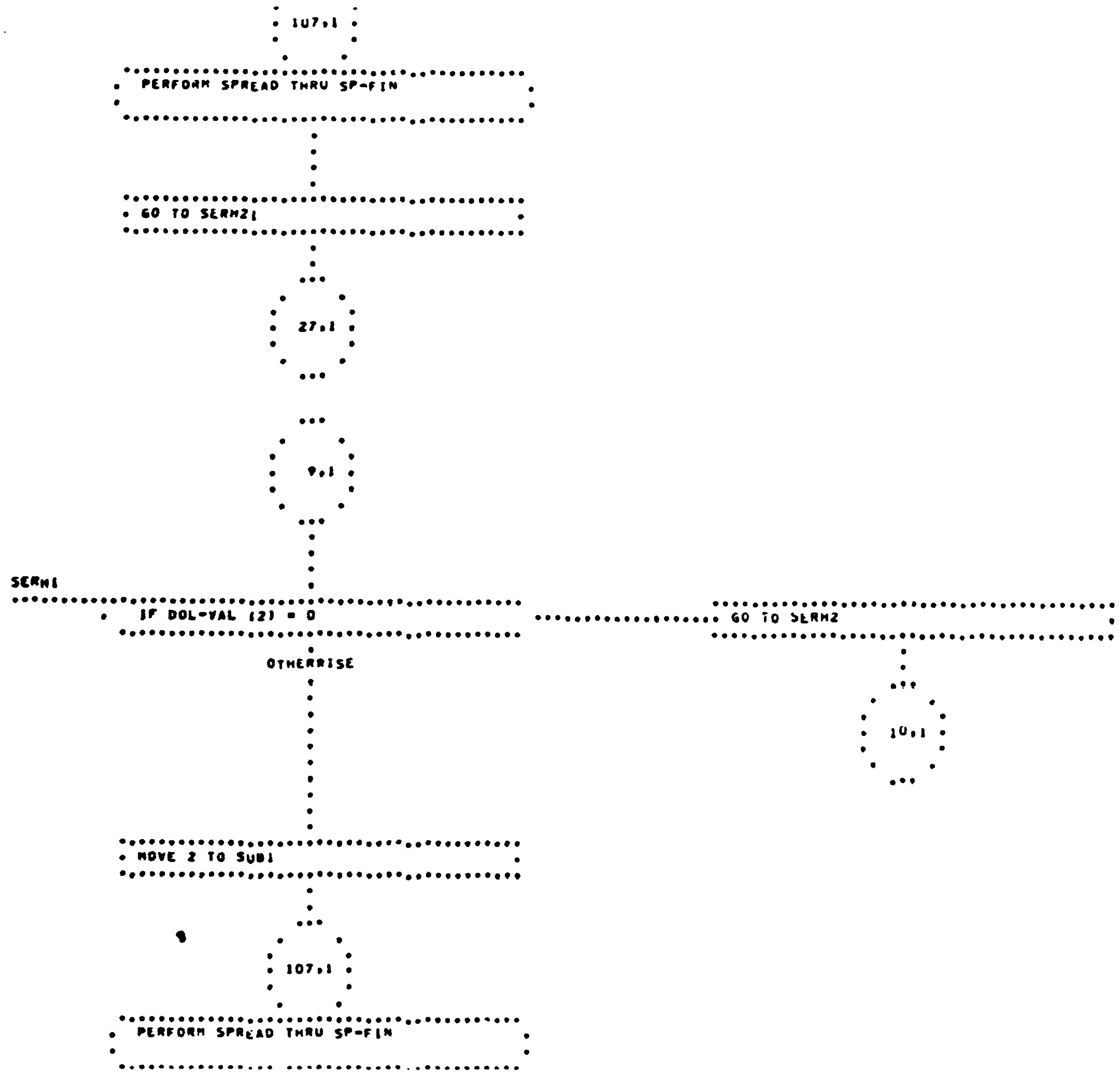
MOVE A-COEFF TO A (SUB1)

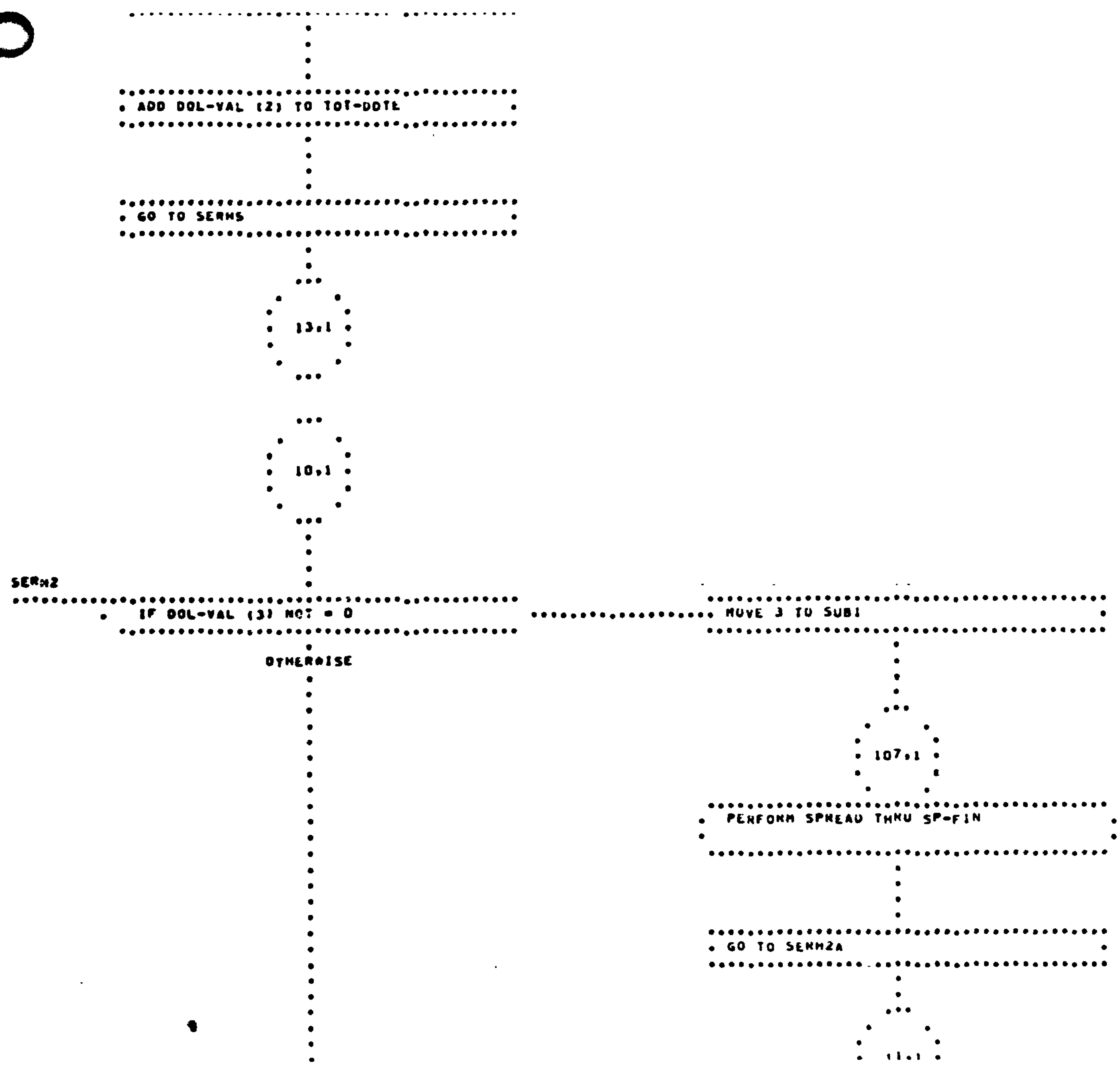
MOVE B-COEFF TO [illegible] (SUB1)

```
MOVE WB-NMEX TO WB-NAME (SUB1)

MOVE WB-LVX TO WB-LEVEL(SUB1)

MOVE WB-CF TO WB-CONFAC (SUB1)

IF SUB1 = 100 ............ GO TO DATA-COMP
                                 (8.1)
OTHERWISE

ADD 1 TO SUB1

GO TO READ-PARAM

(4.1)

(6.1)
```

```
NX-CASE
IF WB-NX > 100  ............  GO TO DATA-COMP
                                    B,1
OTHERWISE
MOVE WB-NX TO SUBI
MOVE DOLLAR-VALUE TO DOL-VAL (SUBI)
MOVE PARAMETER-VA TO PARA-VAL (SUBI)
MOVE COST-DUR TO CO-DUR (SUBI)
MOVE COST-START TO CO-ST (SUBI)
MOVE A-COEFF TO A (SUBI)
MOVE B-COEFF TO B (SUBI)
```

```
MOVE #B-CF TO #B-COMFAC (SUB1)

GO TO READ-PARAM

9.1

8.1

DATA-COMP
MOVE 1 TO SWX

MOVE 1 TO SUB1

IF DOL-VAL (1) = 0 ........ GO TO SERM1
                                  9.1
OTHERWISE
```


107.1
PERFORM SPREAD THRU SP-FIN
GO TO SERM2.
27.1
9.1
SERM1
IF DOL-VAL (2) = 0
GO TO SERM2
10.1
OTHERWISE
MOVE 2 TO SUB1
107.1
PERFORM SPREAD THRU SP-FIN


ADD DOL-VAL (2) TO TOT-DDTE
GO TO SERNS
13.1
10.1
SERN2
IF DOL-VAL (3) NOT = 0
OTHERWISE
MOVE 3 TO SUBI
107.1
PERFORM SPREAD THRU SP-FIN
GO TO SERN2A
11.1

11.1

SERM2A

IF DOL-VAL (9) NOT = 0

MOVE 9 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

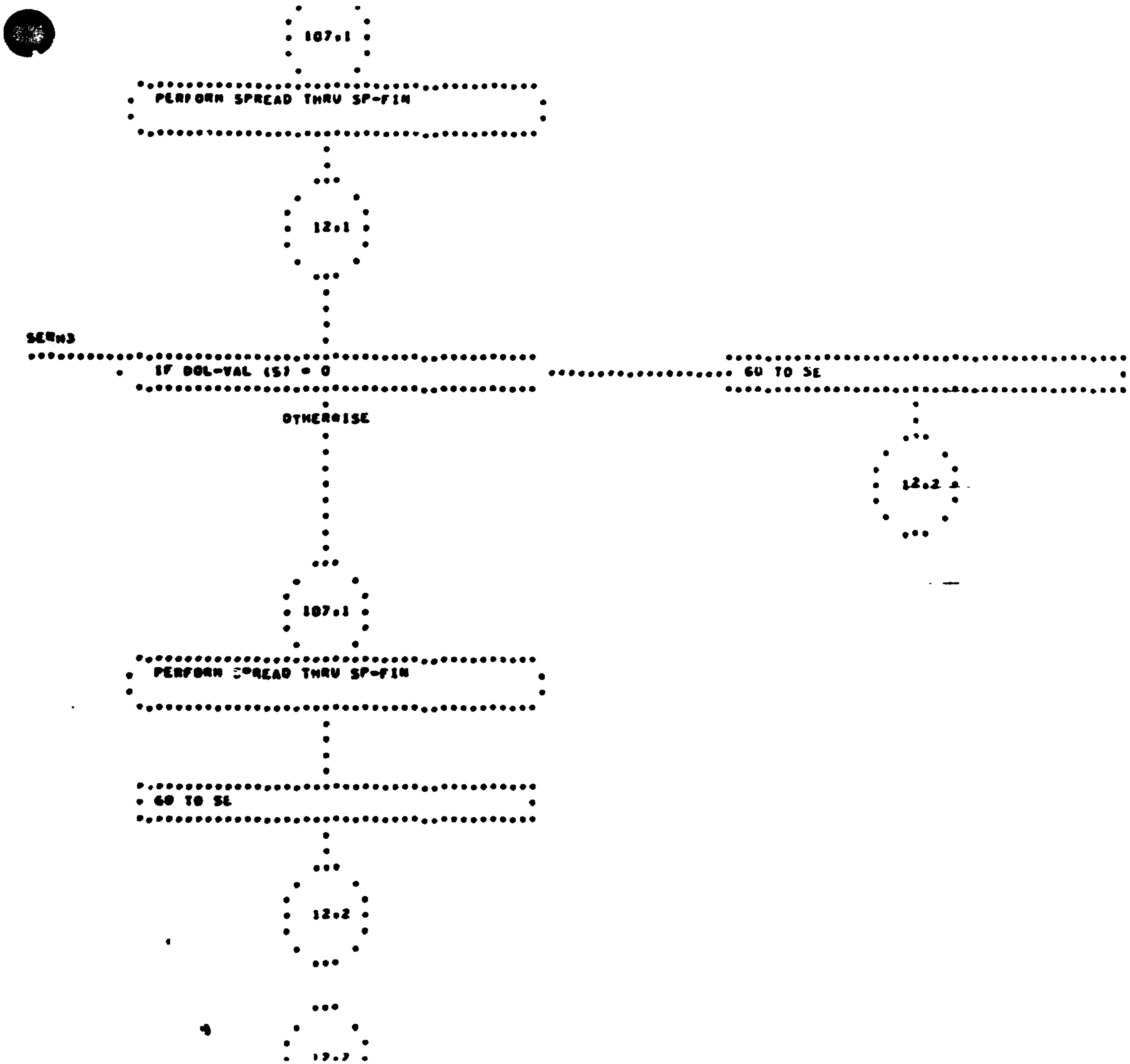
GO TO SERM3

12.1

OTHERWISE

COMPUTE DOL-VAL (9) = BB-CONFAC (9)
* (2.2 * PARA-VAL (9) ** .38)

MOVE 9 TO SUB1


107.1
PERFORM SPREAD THRU SP-FIN
12.1
SERN3
IF DOL-VAL (S) = 0
GO TO SE
12.2
OTHERWISE
107.1
PERFORM SPREAD THRU SP-FIN
GO TO SE
12.2

```
SE
ADD DOL-VAL (3) DOL-VAL (4) DOL-VAL
(5) GIVING DOL-VAL (2)

ADD DOL-VAL (2) TO TOT-DDTE

13.1

SERNS
IF DOL-VAL (6) = 0 ............ GO TO SERN6
                                      19.1
OTHERWISE

MOVE 6 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN
```

```
ADD DOL-VAL (6) TO TOT-DOTL

GO TO SERN10

17.2

19.1

SERN6
IF DOL-VAL (7) NOT = 0  ......  MOVE 7 TO SUB1
                                      107.1
                                PERFORM SPREAD THRU SP-FIN
                                GO TO SERN7
                                      19.1
OTHERWISE
```

```
COMPUTE DOL-VAL (7) = OB-CONFAC (7)
* 73

MOVE 7 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

15.1

SERN7
IF DOL-VAL (8) NOT = 0          MOVE 8 TO SUB1
OTHERWISE
                                107.1
                                PERFORM SPREAD THRU SP-FIN
                                GO TO SERN8
```

16.1

COMPUTE DOL-VAL (8) = MD-CONFAC (8) * (1.5 * PARA-VAL (8) ** .7)

MOVE 8 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

16.1

SEGNB

IF DOL-VAL (9) NOT = 0

MOVE 9 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

GO TO SEGNB

OTHERWISE

```
17.1

COMPUTE DOL-VAL (7) = RS-COMPAC (9)
* (1.7 * PARA-VAL (9) ** .7)

MOVE 9 TO SUBI

107.1

PERFORM SPREAD THRU SP-FIN

17.1

SENMP
ADD DOL-VAL (7) DOL-VAL (8) DOL-VAL
(9) GIVING DOL-VAL (10)

ADD DOL-VAL (6) TO TOT-DOTE

17.2
```

```
SERN10

IF DOL-VAL (ID) = 0          GO TO SERN11
                                 18,1
OTHERWISE

MOVE ID TO SUB1

   107,1

PERFORM SPREAD THRU SP-FIN

ADD DOL-VAL (ID) TO TOT-DOTE

GO TO SERN16

   23,1

   18,1
```

```
SERM11
IF DOL-VAL (II) NOT = 0      MOVE II TO SUB1
OTHERWISE                    107.1
                             PERFORM SPREAD THRU SP-FIN
                             GO TO SERM12
                             20.1

COMPUTE DOL-VAL (II) = YB-CONFAC
(II) * (3.88 * PARA-VAL (II) **
.397)

MOVE II TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN
```

```
20.1

SENM12
IF DOL-VAL (12) NOT = 0          MOVE 12 TO SUB1
                                  107.1
                                  PERFORM SPREAD THRU SP-FIN
                                  GO TO SENM13
                                  21.1
OTHERWISE

COMPUTE DOL-VAL (12) = BB-CONFAC
(12) * (.2502 * PARA-VAL (12) **
.608 ) + 0.1 * PARA-VAL (94) ** .608

MOVE 12 TO SUB1
```

```
107,1
PERFORM SPREAD THRU SP-FIN
21,1
SERM13
IF DOL-VAL (13) = 0 ........ GO TO SERM14
                                 21,2
OTHERWISE
MOVE 13 TO SUB1
107,1
PERFORM SPREAD THRU SP-FIN
21,2
SERM14
IF DOL-VAL (14) = 0 ........ GO TO SERM15
```

OTHERWISE

22.1

MOVE 14 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

GO TO SERMIS

22.1

22.1

SERMIS

ADD DOL-VAL (11) DOL-VAL (12)
DOL-VAL (13) DOL-VAL (14) GIVING
DOL-VAL (10)

```
ADD DOL-VAL (10) TO TOT-DDTE

(23.1)

SERH16
IF DOL-VAL (15) = 0 .................. GO TO SERH17
                                            (29.1)
OTHERWISE

MOVE 15 TO SUB1

(107.1)

PERFORM SPREAD THRU SP-FIN

ADD DOL-VAL (15) TO TOT-DDTE

GO TO SERH20

(24.2)
```

29.1

SERH17

IF DOL-VAL (16) NOT = 0

MOVE 16 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

GO TO SERH16

25.1

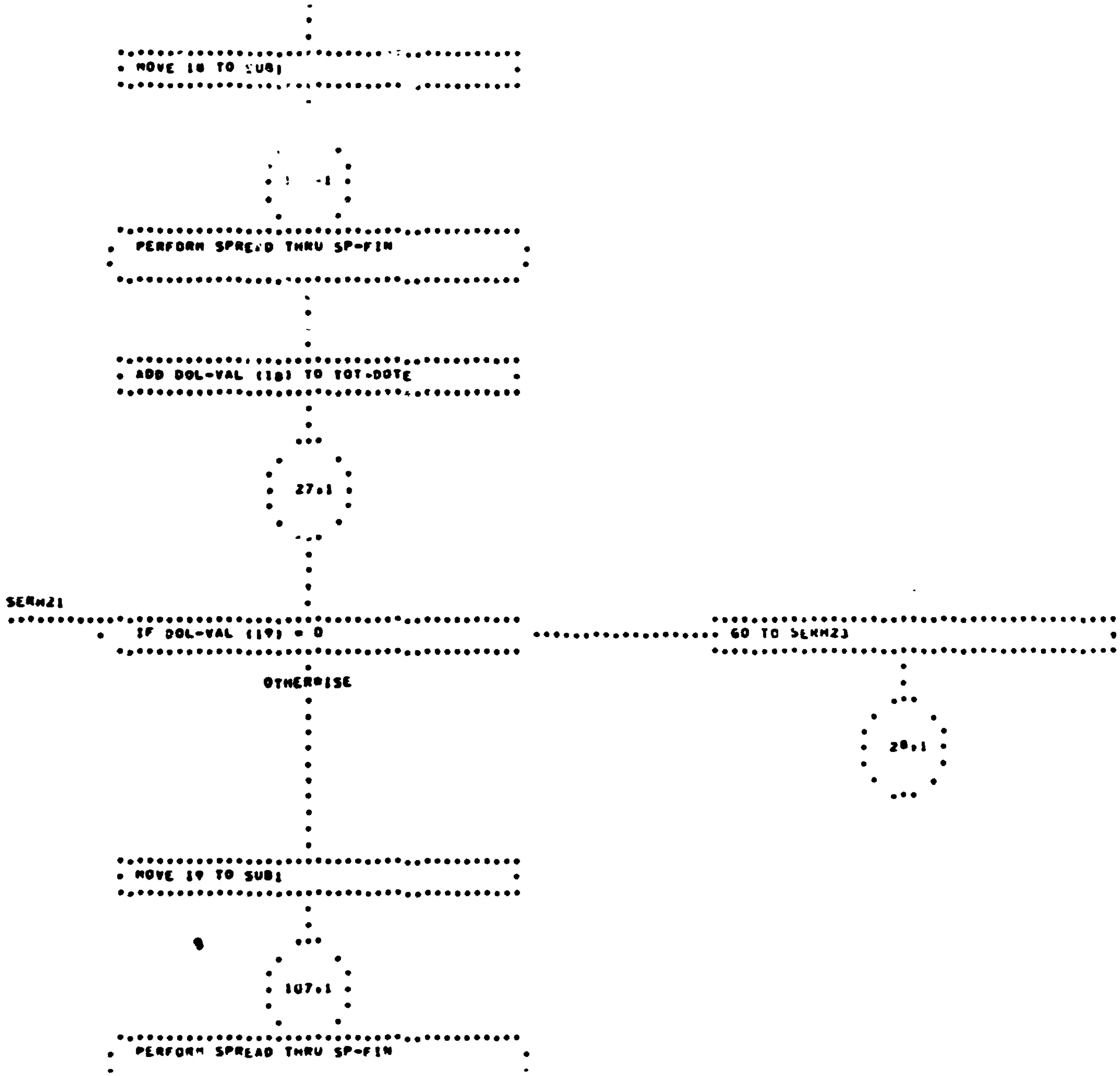
OTHERWISE

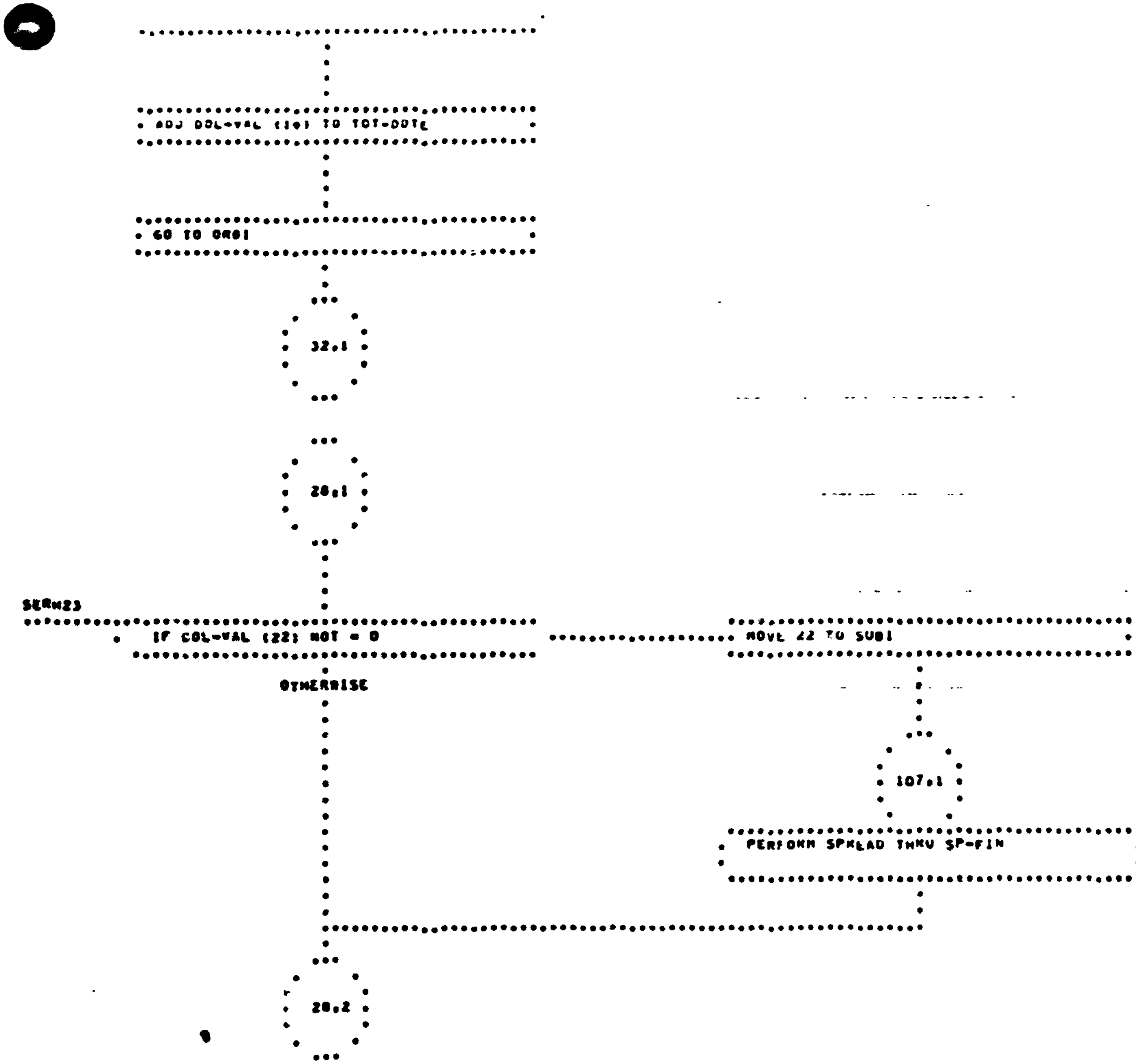
COMPUTE DOL-VAL (16) = BB-CONFAC
(16) * (.35 * PARA-VAL (16) ** .70 +
1.035 * PARA-VAL (15) ** .70)

MOVE 16 TO SUB1

```
107.1
PERFORM SPREAD THRU SP-FIN
25.1
SERMI0
IF UOL-VAL (17) NOT = 0 ........ MOVE 17 TO SUB1
                                 107.1
                                 PERFORM SPREAD THRU SP-FIN
                                 GO TO SERMIV
                                 26.1
OTHERWISE
COMPUTE UOL-VAL (17) = BB-CONFAC
(17) * 1.05 * PARA-VAL (17) ** .77)
```

```
    MOVE 17 TO SUB;

        107.1

    PERFORM SPREAD THRU SP-FIN

        26.1

SERH19
    ADD DOL-VAL (16) DOL-VAL (17) GIVING
    DOL-VAL (15)

    ADD DOL-VAL (15) TO TOT-DOTE

        26.2

SERH20
    IF DOL-VAL (18) = 0  ..................  GO TO SERH21;

        OTHERWISE                                   27.1
```


MOVE 18 TO SUB1
PERFORM SPREAD THRU SP-FIN
ADD DOL-VAL (18) TO TOT-DOTE
27.1
SEKM21
IF DOL-VAL (19) = 0
GO TO SEKM23
28.1
OTHERWISE
MOVE 19 TO SUB1
107.1
PERFORM SPREAD THRU SP-FIN


ADD COL-VAL (10) TO TOT-DOTE
GO TO ORB1
32.1
28.1
SERN23
IF COL-VAL (22) NOT = 0
MOVE 22 TO SUB1
OTHERWISE
107.1
PERFORM SPREAD THRU SP-FIN
28.2

SERM25

IF DOL-VAL (23) NOT = 0

MOVE 23 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

GO TO SERM26

30.1

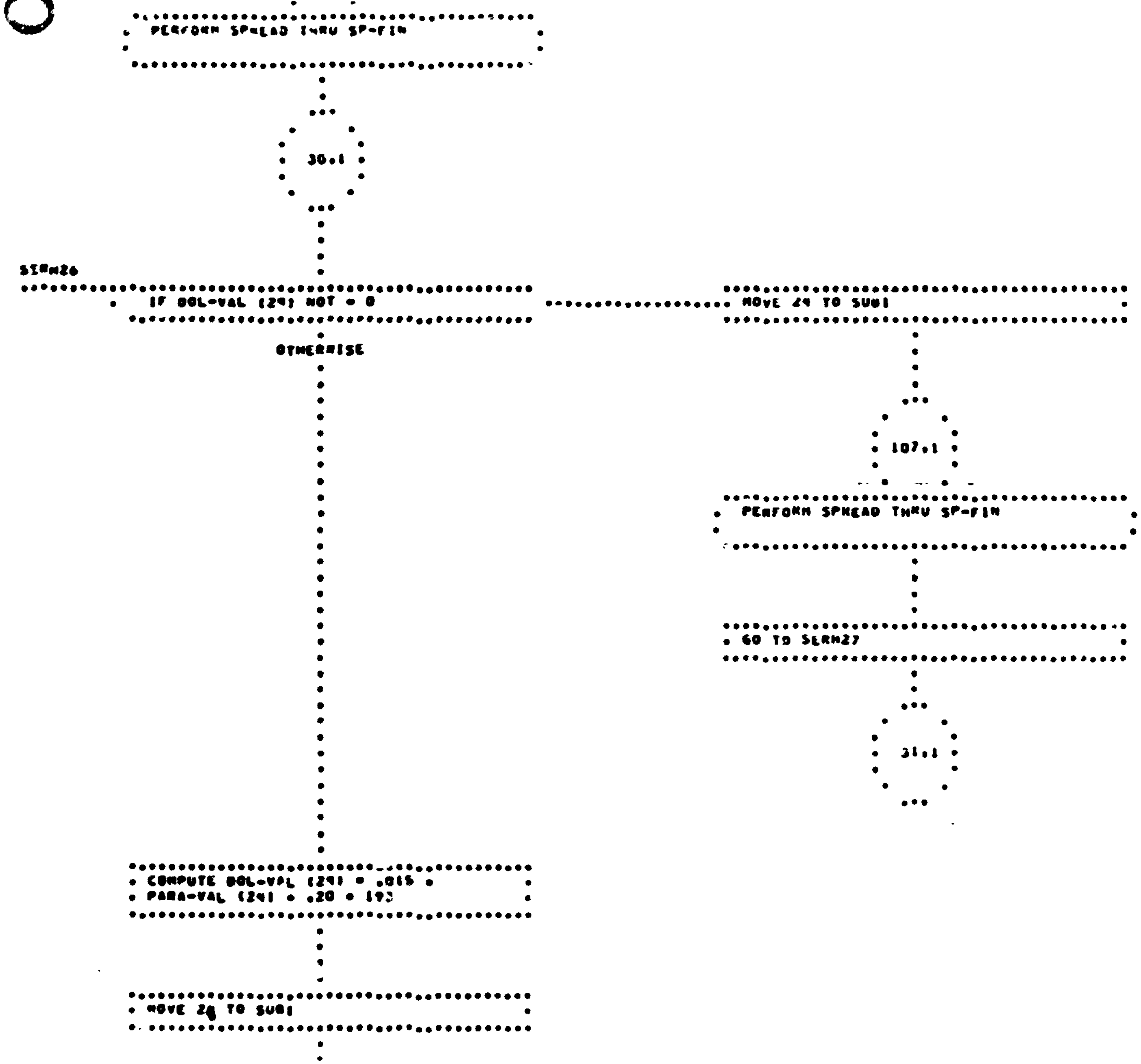
OTHERWISE

ADD DOL-VAL (6) DOL-VAL (2) DOL-VAL (15) GIVING XX1

COMPUTE DOL-VAL (23) = .02 * DOL-VAL (10) + .10 * XX1

MOVE 23 TO SUB1

107.1


PERFORM SPREAD THRU SP-FIN
30.1
SERM26
IF DOL-VAL (29) NOT = 0
OTHERWISE
MOVE 29 TO SUB1
107.1
PERFORM SPREAD THRU SP-FIN
GO TO SERM27
31.1
COMPUTE DOL-VAL (29) = .015 *
PARA-VAL (29) * .20 * 193
MOVE 29 TO SUB1

```
197.1

PERFORM SPREAD THRU SP-FIN

31.1

SERN27
IF DOL-VAL (25) NOT = 0  ......  MOVE 25 TO SUB1

                                  197.1

                                  PERFORM SPREAD THRU SP-FIN

                                  GO TO UNB1

                                  32.1
OTHERWISE

COMPUTE DOL-VAL (25) = .05 * DOL-VAL
(10) * (CU - 5 * (12 ** .26 * 4.000
** .14) * .15 * 4 * 2U * 1.65 *
PARA-VAL (25) ** .66 * .02
```

MOVE 25 TO SUB;

107.1

PERFORM SPREAD THRU SP-FIN

32.1

ORB;

IF DOL-VAL (26) = 0 → GO TO ME;

34.2

OTHERWISE

MOVE 26 TO SUB;

107.1

PERFORM SPREAD THRU SP-FIN

```
32.2

ME1
IF DOL-VAL (27) = 0 ............ GO TO SP1
                                   33.1
OTHERWISE

MOVE 27 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

GO TO SP

34.1

33.1
```

```
SP1
  COMPUTE DOL-VAL (27) = BB-CONFAC
  (27) * (2.2 * PANA-VAL (27) ** .38)

  MOVE 27 TO SUB1

  107.1

  PERFORM SPREAD THRU SP-FIN

  34.1

SP
  IF DOL-VAL (28) = 0  ..........  GO TO FLG1
                                   35.1
  OTHERWISE

  MOVE 28 TO SUB1

  107.1

  PERFORM SPREAD THRU SP-FIN
```

GO TO MGT2

39,2

35,1

FLG1

IF DOL-VAL (29) NOT = 0

OTHERWISE

MOVE 29 TO SUB1

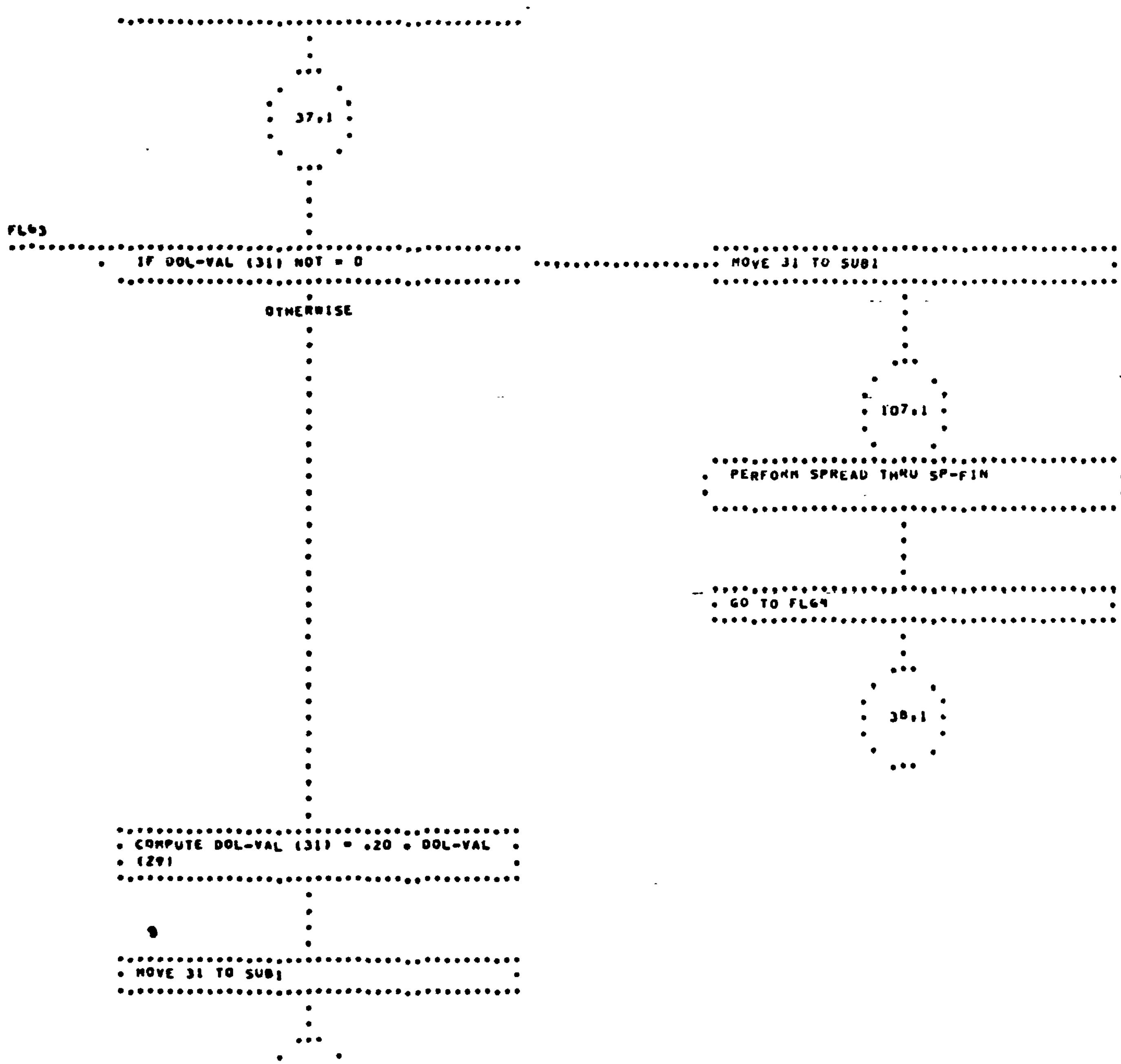
107,1

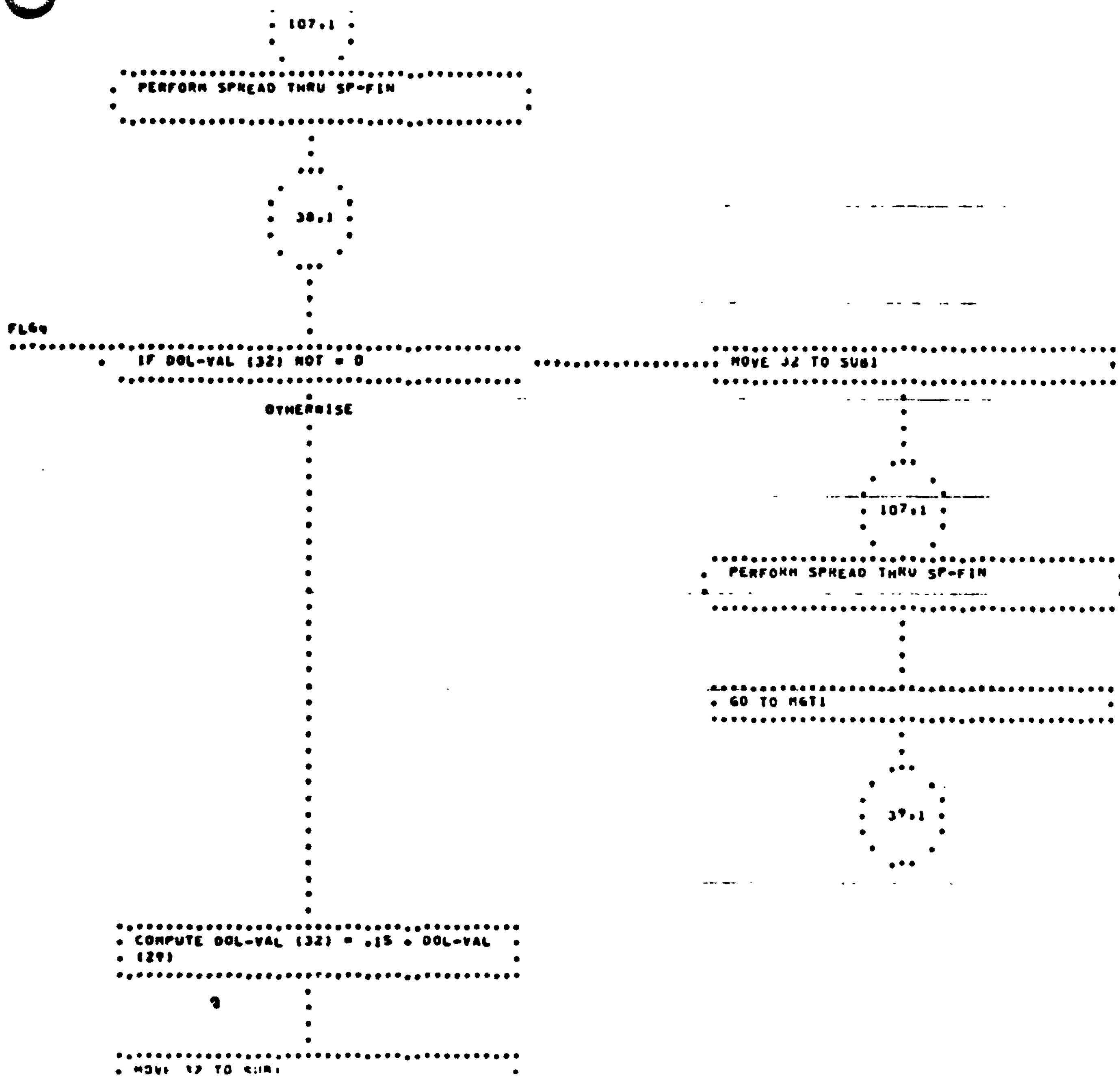
PERFORM SPREAD THRU SP-FIN

GO TO FLG2

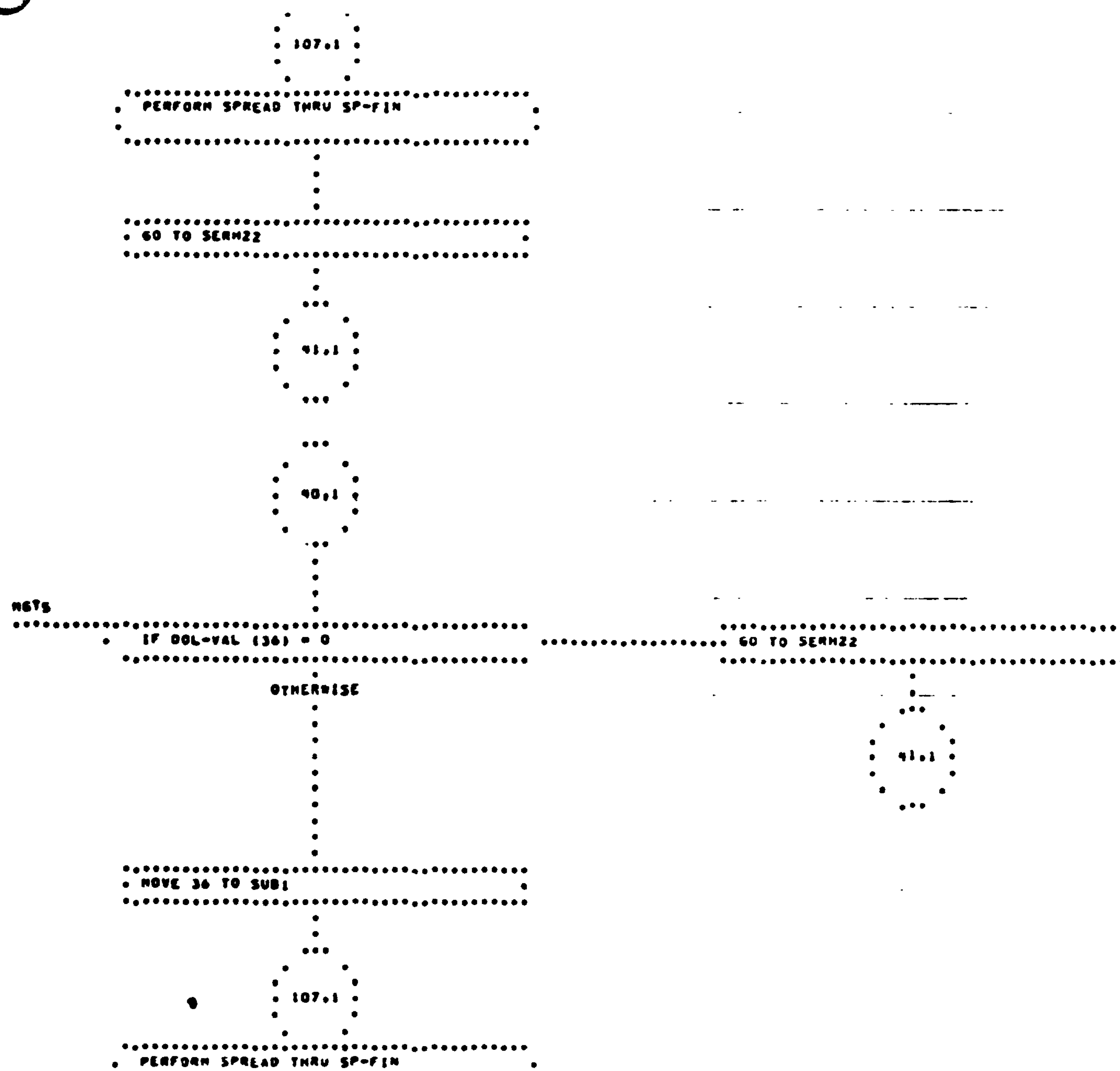
36,1

```
COMPUTE DOL-VAL (29) = 42.5 + 2.89 *
9 + .15 * 9.5 + PARA-VAL (29) *
335.28

MOVE 29 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

36.1

FLG2
IF DOL-VAL (30) = 0                GO TO FLG3

                                   37.1
OTHERWISE

MOVE 30 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN
```


37.1
FL63
IF DOL-VAL (31) NOT = 0
OTHERWISE
MOVE 31 TO SUB1
107.1
PERFORM SPREAD THRU SP-FIN
GO TO FL64
38.1
COMPUTE DOL-VAL (31) = .20 * DOL-VAL (29)
MOVE 31 TO SUB1


107.1
PERFORM SPREAD THRU SP-FIN
38.1
FL64
IF DOL-VAL (32) NOT = 0
MOVE 32 TO SUB1
107.1
PERFORM SPREAD THRU SP-FIN
GO TO MGT1
39.1
OTHERWISE
COMPUTE DOL-VAL (32) = .15 * DOL-VAL (29)
MOVE 32 TO SUB1

```
107.1

PERFORM SPREAD THRU SP-FIN

39.1

MGT1
ADD DOL-VAL (29) DOL-VAL (30)
DOL-VAL (31) DOL-VAL (32) GIVING
DOL-VAL (28)

39.2

MGT2
IF DOL-VAL (33) = 0 ........ GO TO MGT5
                                40.1
OTHERWISE

MOVE 33 TO SUB1
```


107.1
PERFORM SPREAD THRU SP-FIN
GO TO SERM22
41.1
40.1
MGTS
IF DOL-VAL (36) = 0
GO TO SERM22
41.1
OTHERWISE
MOVE 36 TO SUB1
107.1
PERFORM SPREAD THRU SP-FIN

```
41.1

SERH22
IF DOL-VAL (20) NOT = 0 ........ MOVE 20 TO SUB1
OTHERWISE
                                   107.1
                                   PERFORM SPREAD THRU SP-FIN
                                   GO TO SERH24
                                   42.1

MOVE 0 TO ZZ1

ADD DOL-VAL (10) DOL-VAL (34)
DOL-VAL (24) DOL-VAL (28) DOL-VAL
(25) GIVING ZZ1
```

```
ADD DOL-VAL (2) DOL-VAL (27)
PARA-VAL (20) DOL-VAL (23) PARA-VAL
(19) GIVING XX2

COMPUTE DOL-VAL (20) = .05 * XX1 +
.02 * XX2 + .04 * DOL-VAL (10) + .02
* (DOL-VAL (2) + DOL-VAL (27))

MOVE 0 TO XX1 XX2

MOVE 20 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

92.1

SEMW24
IF DOL-VAL (21) NOT = 0          MOVE 21 TO SUB1
OTHERWISE                              107.1
```

```
PERFORM SPREAD THRU SP-FIN

GO TO URB2

43.1
```

```
ADD DOL-VAL (10) DOL-VAL (34)
DOL-VAL (24) DOL-VAL (28) DOL-VAL
(25) DOL-VAL (23) PARA-VAL (20)
DOL-VAL (20) GIVING Z1

COMPUTE DOL-VAL (21) = .08 * Z1

MOVE Z1 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

43.1
```

```
D402
ADD DOL-VAL (20) DOL-VAL (21)
DOL-VAL (22) DOL-VAL (23) DOL-VAL
(24) DOL-VAL (25) GIVING DOL-VAL
(19)

ADD DOL-VAL (19) TO TOT-DDTE

ADD DOL-VAL (26) DOL-VAL (27)
TOT-DDTE GIVING TOT-PRO-DDTE

99,1

NGT3
IF DOL-VAL (34) NOT = 0          MOVE 34 TO SUB1
OTHERWISE
                                 107,1
                                 PERFORM SPREAD THRU SP-FIN
                                 GO TO NGT4
                                 95,1
```

```
COMPUTE DOL-VAL (34) = .09 *
TOT-PRO-DDTE

MOVE 34 TO SUBI

107.1

PERFORM SPREAD THRU SP-FIN

95.1

MGT4
IF DOL-VAL (35) NOT = C ........ MOVE 35 TO SUBI
OTHERWISE
                                  107.1
                                  PERFORM SPREAD THRU SP-FIN
                                  GO TO MGT6
```

46,1

COMPUTE DOL-VAL (35) = .01 *
TOT-PRO-DDTE

MOVE 35 TO SUB1

107,1

PERFORM SPREAD THRU SP-FIN

46,1

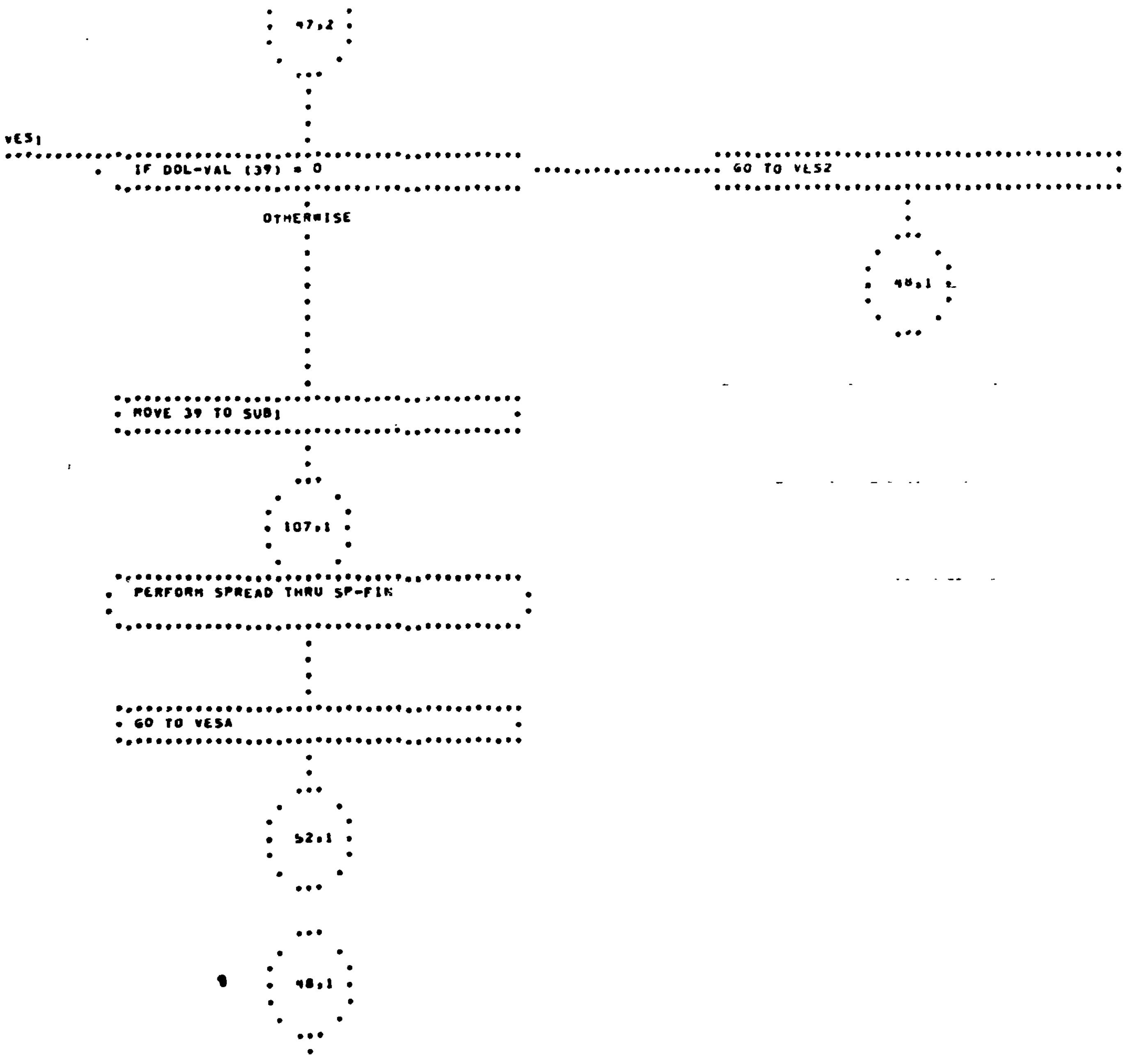
MGT6

ADD DOL-VAL (34) DOL-VAL (35)
DOL-VAL (36) GIVING DOL-VAL (33)

46,2

DDTE1

```
. ADD TOT-PRO-DUTE DOL-VAL (28)
. DOL-VAL (33) GIVING DOL-VAL (37)

        47.1

YES
        IF DOL-VAL (38) = 0  ..........  GO TO YES1

        OTHERWISE                            47.2

. MOVE 38 TO SUB1

        107.1

. PERFORM SPREAD THRU SP-FIN

. GO TO OYES1

        78.3
```

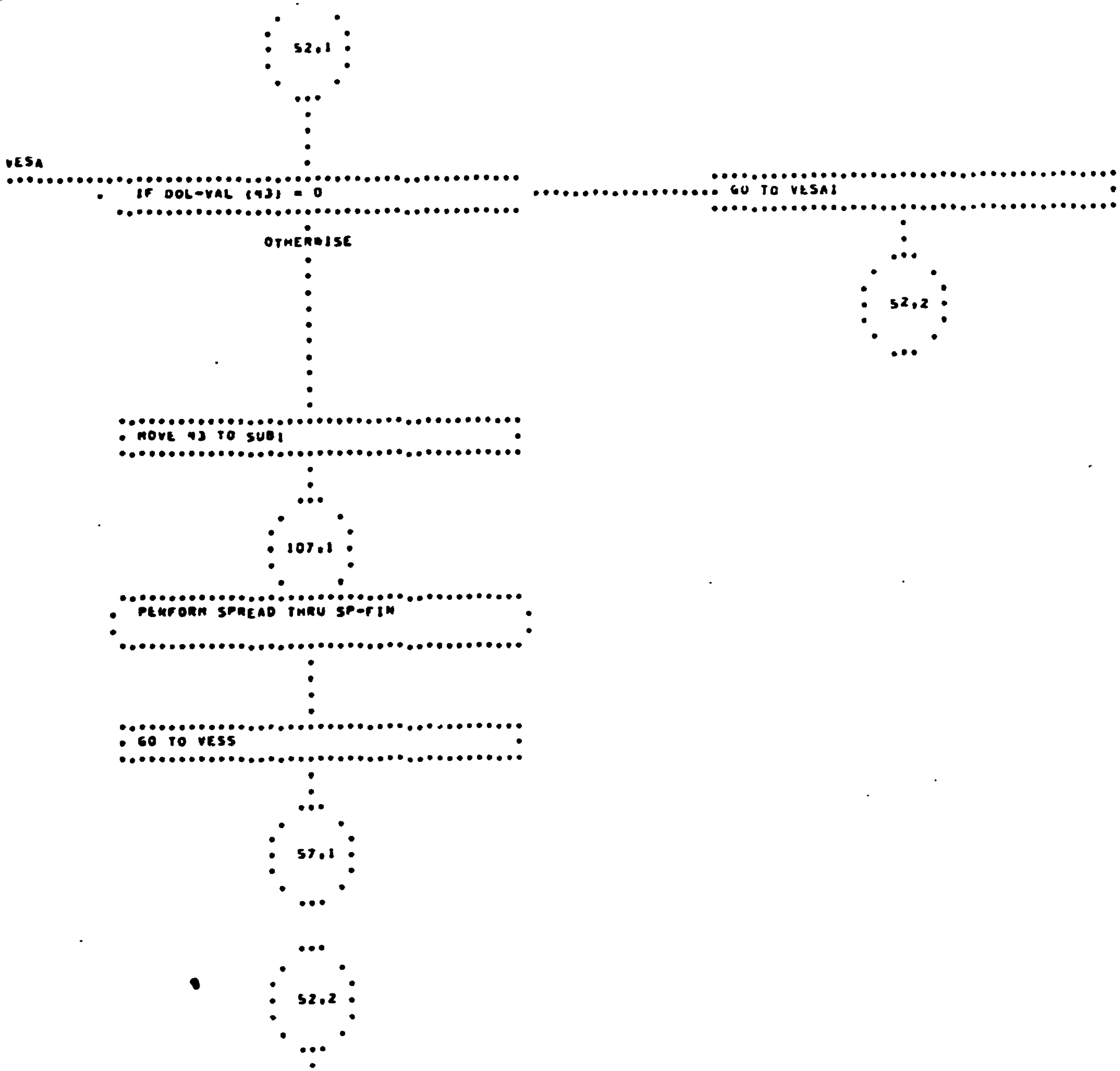

47.2
VES1
IF DOL-VAL (39) = 0
GO TO VES2
48.1
OTHERWISE
MOVE 39 TO SUB1
107.1
PERFORM SPREAD THRU SP-FIN
GO TO VESA
52.1
48.1

```
VES2
   IF DOL-VAL (40) = 0  ..........  GO TO VES3
                                        (49.1)
   OTHERWISE
   MOVE 40 TO SUB1
   (107.1)
   PERFORM SPREAD THRU SP-FIN
   ADD 14.4 TO FST-UNT
   (49.1)

VES3
   IF DOL-VAL (41) NOT = 0  ......  MOVE 41 TO SUB1
                                        (107.1)
   OTHERWISE
```

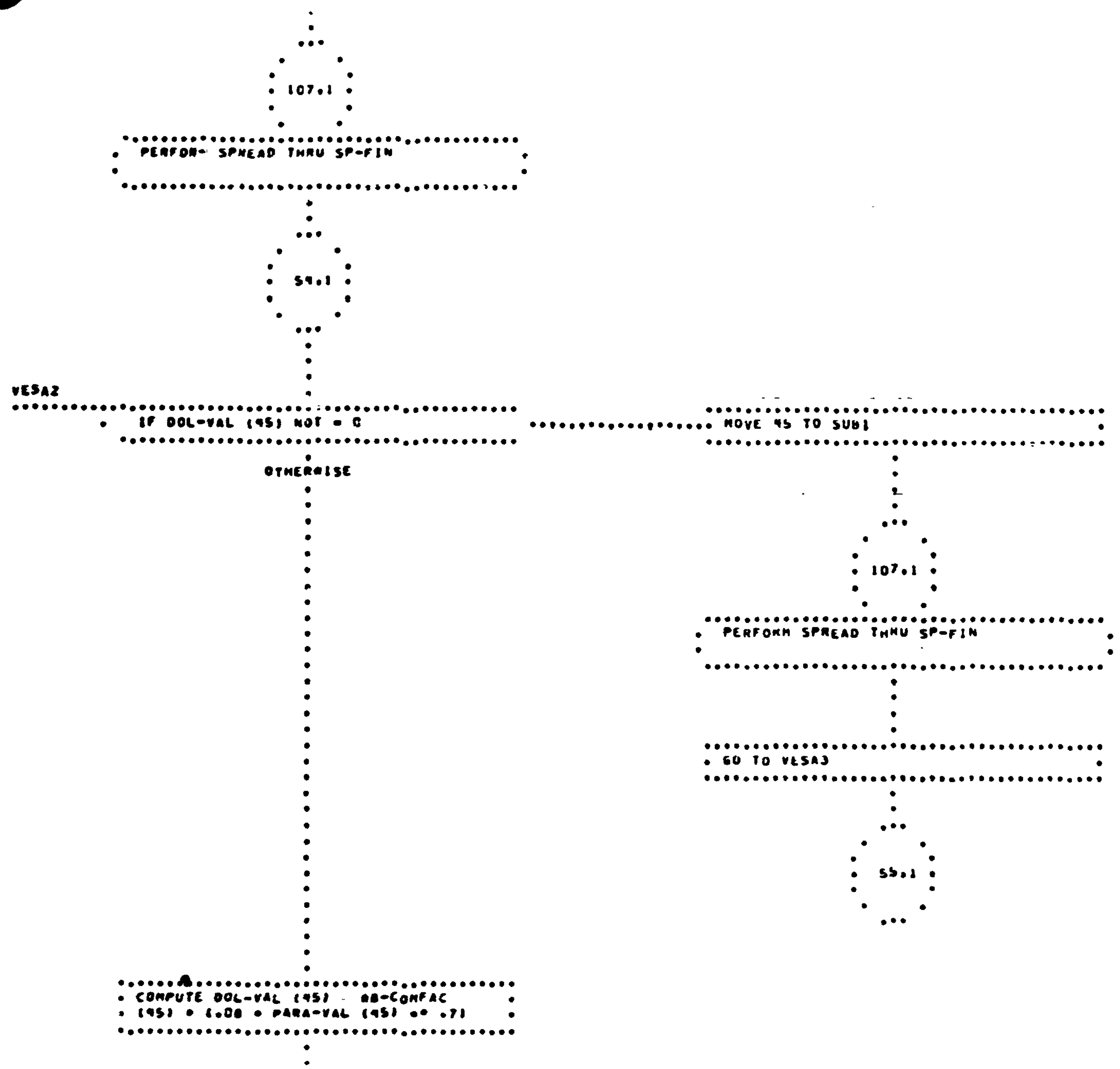
```
COMPUTE DOL-VAL (91) = WB-CONFAC
(91) * 20 * .9

ADD DOL-VAL (91) TO FST-UNT

COMPUTE DOL-VAL (91) = LN-CURVE *
DOL-VAL (91)

MOVE 91 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

50.1
```

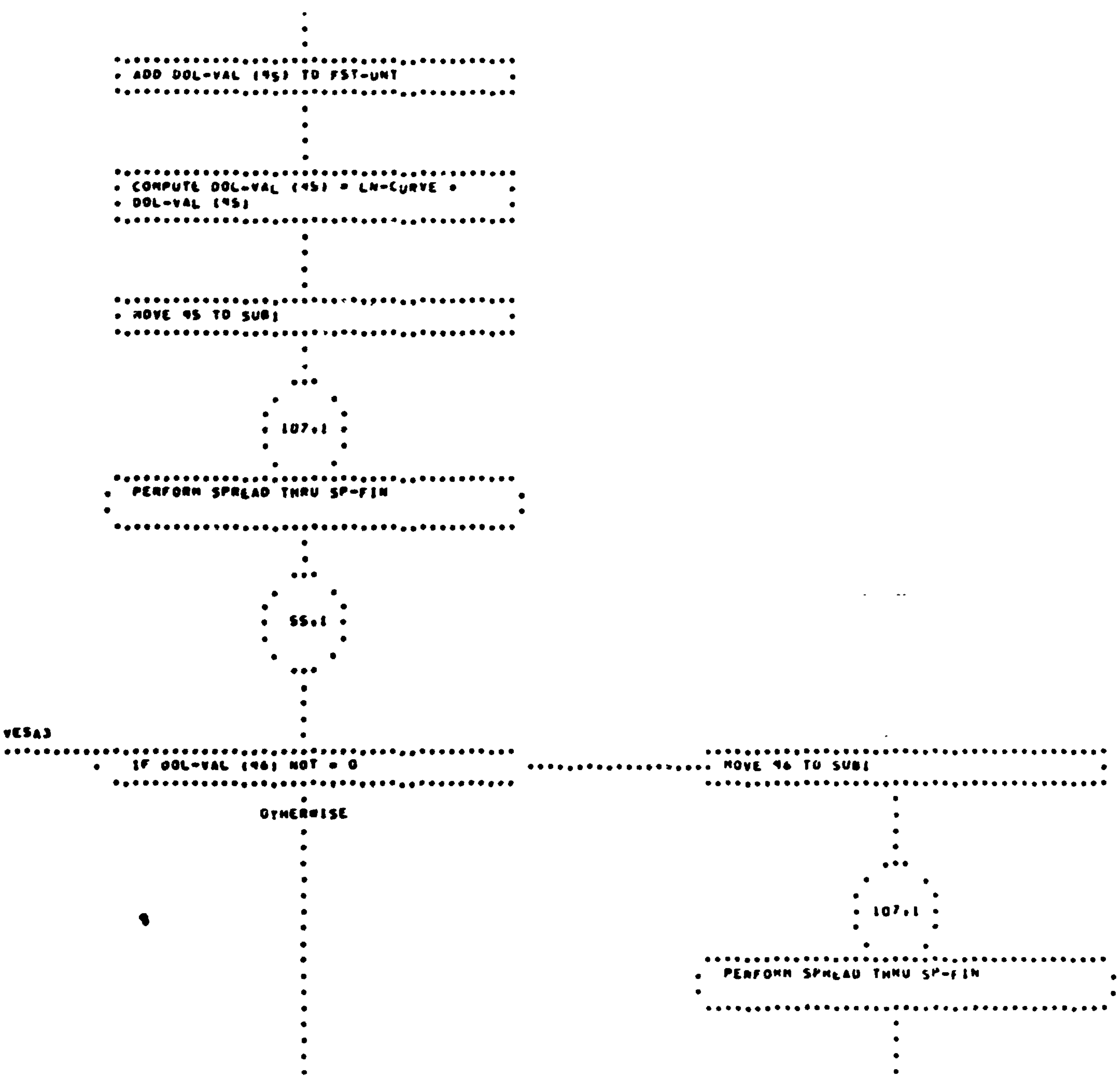
```
PERFORM SPREAD THRU SP-FIN

GO TO VES9

50.1
```

```
YES=
   IF DOL-VAL (92) = 0  ..........  GO TO VE
                                      51,1
   OTHERWISE
   107,1
   PERFORM SPREAD THRU SP-FIN
   GO TO VE
   51,1
   51,1
VE
   ADD DOL-VAL (90) DOL-VAL (91)
   DOL-VAL (92) GIVING DOL-VAL (39)
```


52.1
VESA
IF DOL-VAL (43) = 0
GO TO VESA1
52.2
OTHERWISE
MOVE 43 TO SUB1
107.1
PERFORM SPREAD THRU SP-FIN
GO TO VESS
57.1
52.2

```
VESA1
    IF DOL-VAL (99) NOT = 0  ...........  MOVE 99 TO SUB1
                                               |
    OTHERWISE                               (107.1)
        |                                      |
        |                           PERFORM SPREAD THRU SP-FIN
        |                                      |
        |                              GO TO VESA2
        |                                      |
        |                                   (59.1)
        |
    COMPUTE DOL-VAL (99) = BB-CONFAC
    (99) * 7.6
        |
    ADD DOL-VAL (99) TO FST-UNT
        |
    COMPUTE DOL-VAL (99) = LN-CURVE *
    DOL-VAL (99)
        |
    MOVE 99 TO SUB1
```


107.1
PERFORM SPREAD THRU SP-FIN
59.1
VESA2
IF DOL-VAL (45) NOT = 0
OTHERWISE
MOVE 45 TO SUB1
107.1
PERFORM SPREAD THRU SP-FIN
GO TO VESA3
55.1
COMPUTE DOL-VAL (45) = BB-CONFAC
(45) * (.08 * PARA-VAL (45) ** .7)


ADD DOL-VAL (95) TO FST-UNT
COMPUTE DOL-VAL (95) = LN-CURVE *
DOL-VAL (95)
MOVE 95 TO SUB1
107.1
PERFORM SPREAD THRU SP-FIN
55.1
YESA3
IF DOL-VAL (96) NOT = 0
OTHERWISE
MOVE 96 TO SUB1
107.1
PERFORM SPREAD THRU SP-FIN

```
COMPUTE DOL-VAL (96) = BB-CONFAC
(96) * (1.09 * PARA-VAL (96) ** .7)

ADD DOL-VAL (96) TO FST-UNT

COMPUTE DOL-VAL (96) = LN-CURVE *
DOL-VAL (96)

MOVE 96 TO SUB1

107..

PERFORM SPREAD THRU SP-FIN

56.1

VESA4
```

```
GO TO VESA4

56.1
```

PAGE 57

ADD DOL-VAL (44) DOL-VAL (45)
DOL-VAL (46) GIVING DOL-VAL (43)

57.1

VEDS
IF DOL-VAL (47) = 0 .... GO TO VESS1

58.1

OTHERWISE

MOVE 47 TO SUB1

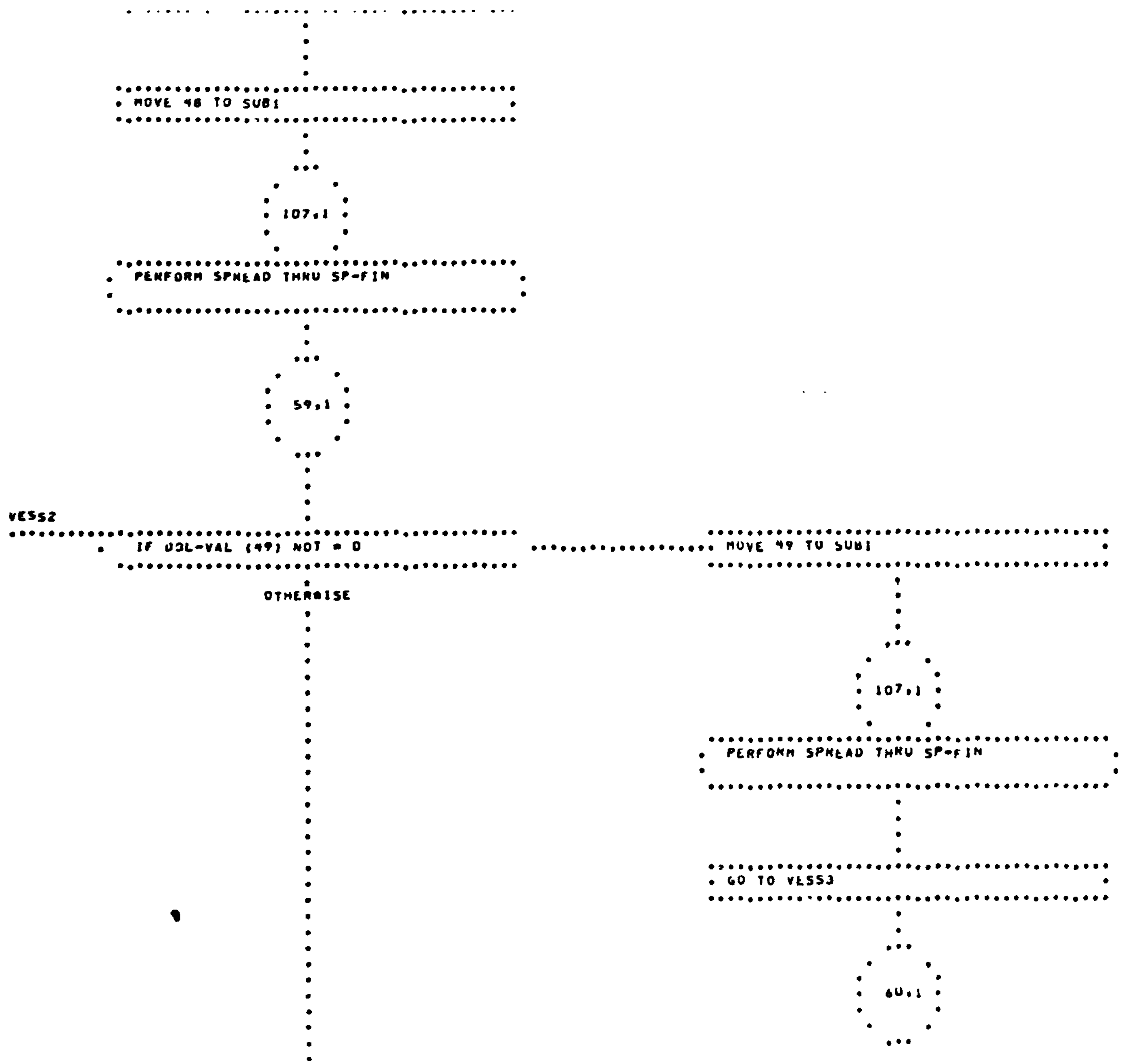
107.1

PERFORM SPREAD THRU SP-FIN

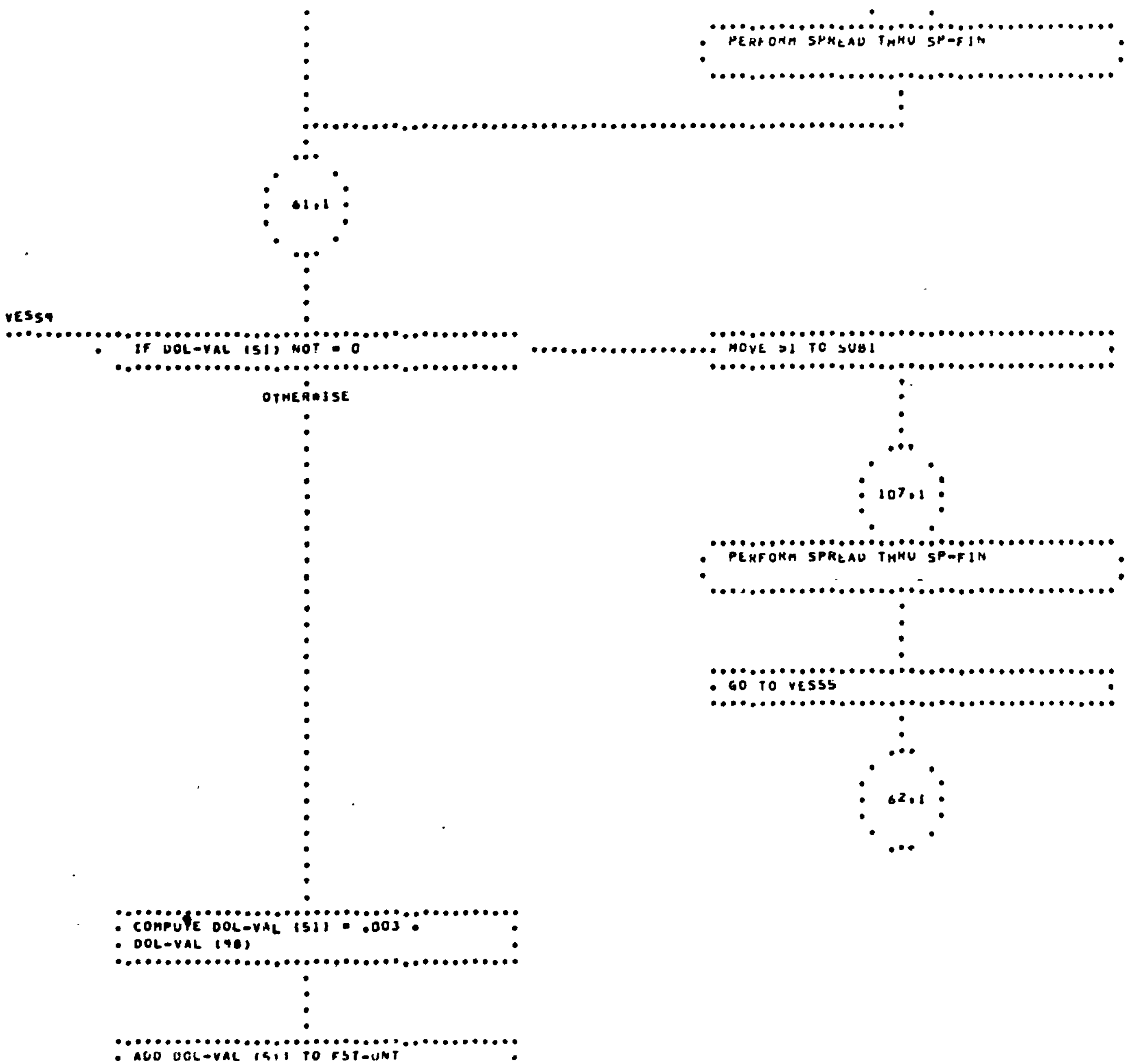
GO TO VLSP

62.2

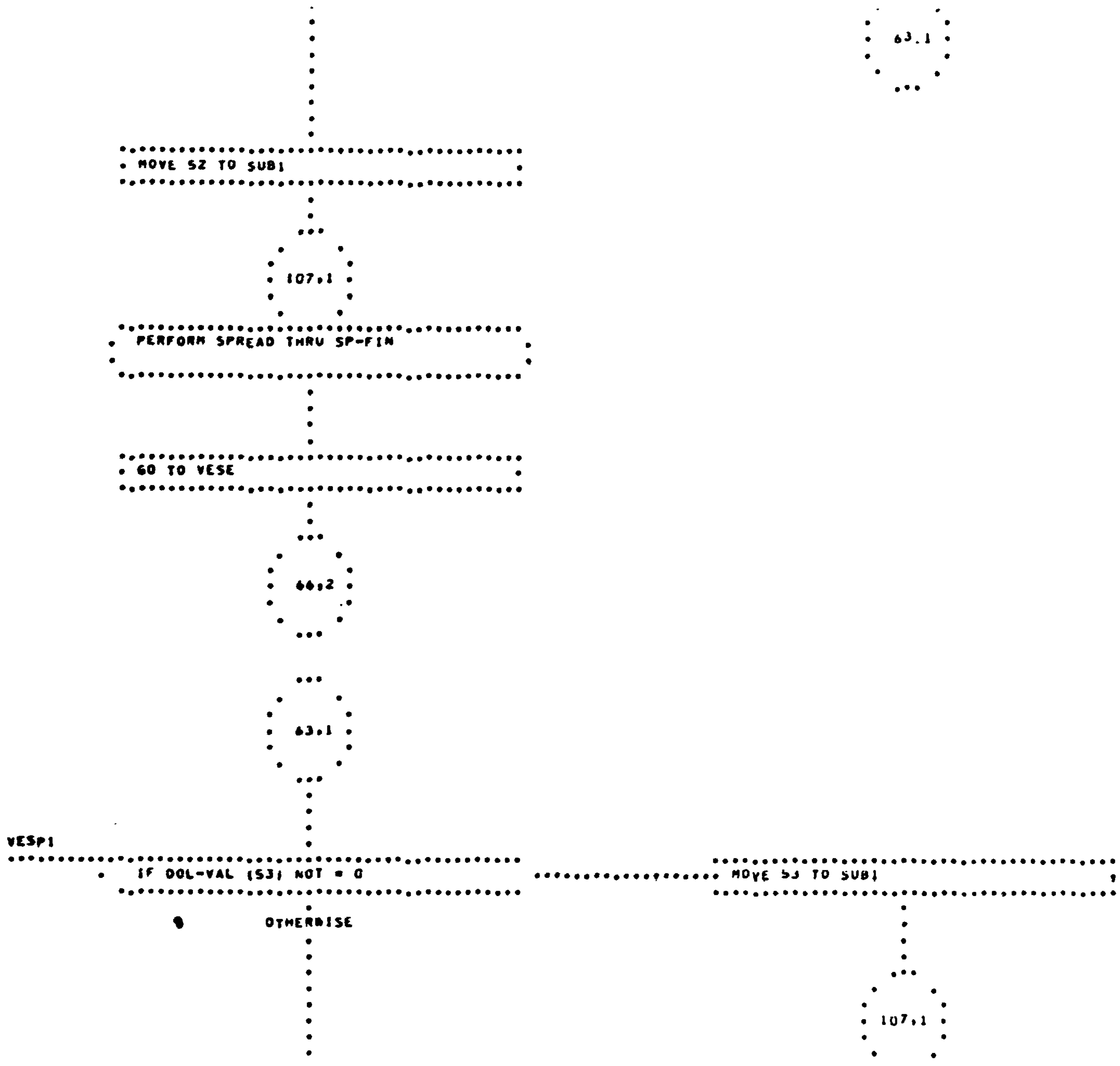
```
58.1

VESS1
IF DOL-VAL (96) NOT = 0 .................. MOVE 96 TO SUB1
OTHERWISE
                                            107.1
                                            PERFORM SPREAD THRU SP-FIN
                                            GO TO VESS2
                                            59.1

COMPUTE DOL-VAL (96) = 88-CONFAC
(96) * 1.00(4) * PARS-VAL (96) **
.805)

ADD DOL-VAL (96) TO FST-UNT

COMPUTE DOL-VAL (96) = LN-CURVE *
DOL-VAL (96)
```


MOVE 48 TO SUB1
107.1
PERFORM SPREAD THRU SP-FIN
59.1
VESS2
IF DOL-VAL (49) NOT = 0
OTHERWISE
MOVE 49 TO SUB1
107.1
PERFORM SPREAD THRU SP-FIN
GO TO VESS3
60.1

```
COMPUTE DOL-VAL (49) = AB-COMFAC
(49) * (.03 * PARA-VAL (49) ** .61)
* .015 * PARA-VAL (50) ** .61

ADD DOL-VAL (49) TO FST-UNT

COMPUTE DOL-VAL (49) = LN-CURVE *
DOL-VAL (49)

MOVE 49 TO SUB1

107,1

PERFORM SPREAD THRU SP-FIN

60,1

VESS3
IF DOL-VAL (50) NOT = 0 .......... MOVE 50 TO SUB1 → 107,1
OTHERWISE
```


PERFORM SPREAD THRU SP-FIN
61.1
VESS4
IF DOL-VAL (S1) NOT = 0
MOVE S1 TO SUB1
OTHERWISE
107.1
PERFORM SPREAD THRU SP-FIN
GO TO VESS5
62.1
COMPUTE DOL-VAL (S1) = .003 *
DOL-VAL (98)
ADD DOL-VAL (S1) TO FST-UNT

```
COMPUTE DOL-VAL (51) = LN-CURVE *
DOL-VAL (51)

MOVE 51 TO SUB1

107,1

PERFORM SPREAD THRU SP-FIN

62,1

VESSS
ADD DOL-VAL (48) DOL-VAL (49)
DOL-VAL (50) DOL-VAL (51) GIVING
DOL-VAL (47)

62,2

VESP
IF DOL-VAL (52) = 0          GO TO VESP1
OTHERWISE
```


63.1
MOVE S2 TO SUB1
107.1
PERFORM SPREAD THRU SP-FIN
GO TO VESE
66.2
63.1
VESP1
IF DOL-VAL (S3) NOT = 0
OTHERWISE
MOVE S3 TO SUB1
107.1

```
PERFORM SPREAD THRU SP-FIN

GO TO YESP2

64.1
```

```
COMPUTE DOL-VAL (S3) = BB-CONFAC
(S3) * (.00019 * PARA-VAL (S3) +
.0334 * PARA-VAL (S2) ** .7 + .00496
* 810 ** .7)

ADD DOL-VAL (S3) TO FST-UNT

COMPUTE DOL-VAL (S3) = LN-CURVE *
DOL-VAL (S3)

MOVE S3 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN
```

64.1

VESP2

IF DOL-VAL (S4) NOT = 0

MOVE S4 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

GO TO VESP3

66.1

OTHERWISE

COMPUTE DOL-VAL (S4) = BB-COMFAC (S4) * (.0045 * PARA-VAL (S4) ** .80)

ADD DOL-VAL (S4) TO FST-UNT

COMPUTE DOL-VAL (S4) = LN-CURVE * DOL-VAL (S4)

MOVE 54 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

66.1

VESP3

ADD DOL-VAL (55) DOL-VAL (54) GIVING DOL-VAL (52)

66.2

VESE

IF DOL-VAL (55) = 0

GO TO VESA

67.1

OTHERWISE

MOVE 55 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

67.1

VESX

IF DOL-VAL (S6) = 0 .... GO TO VESXA

67.2

OTHERWISE

MOVE S6 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

67.2

L39A

IF DOL-VAL (66) NOT = 0

MOVE 66 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

GO TO VESAA

69.1

OTHERWISE

COMPUTE DOL-VAL (66) = 5 * 12

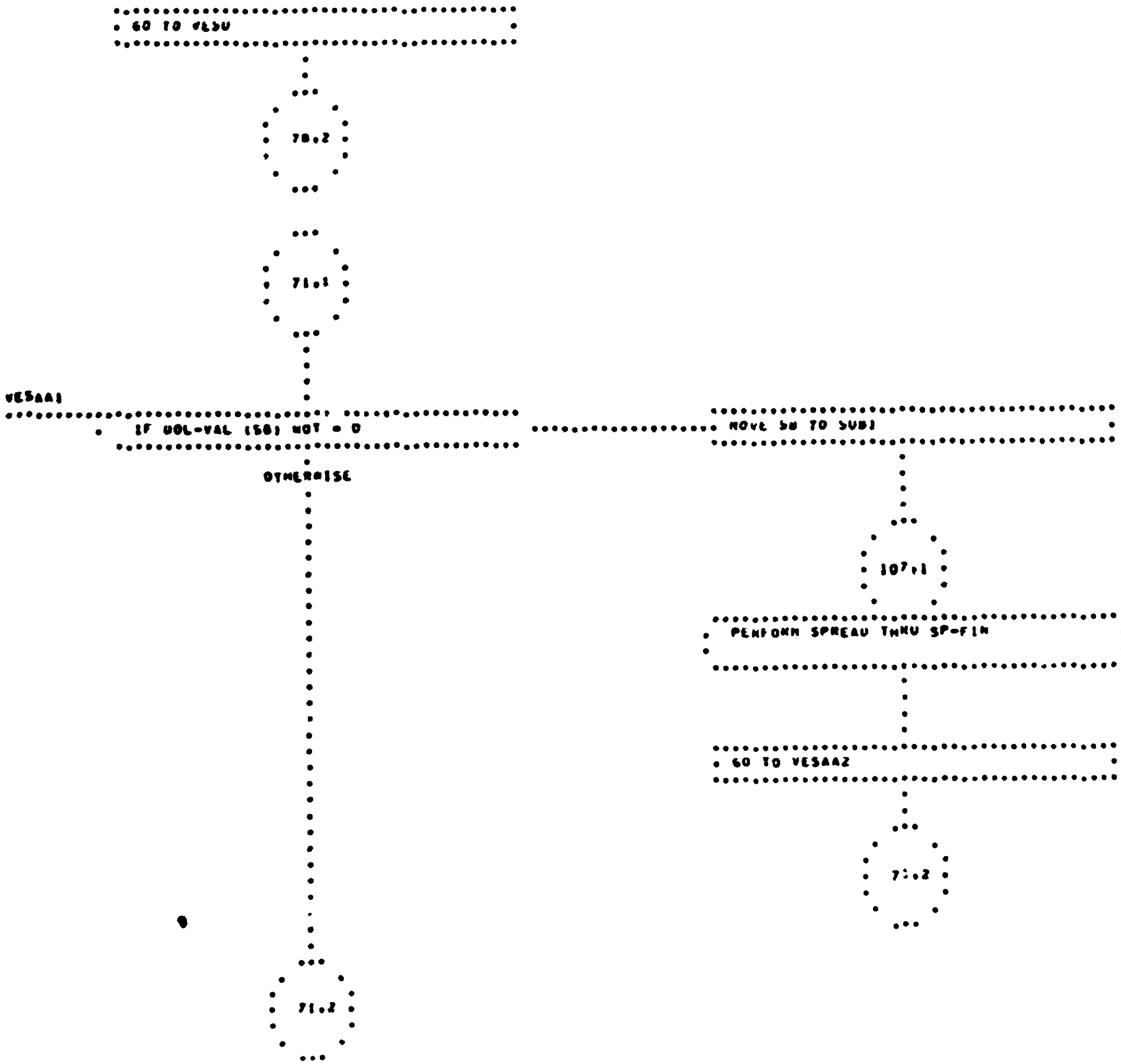
ADD DOL-VAL (66) TO FST-UNT

COMPUTE DOL-VAL (66) = 5 * 36

MOVE 86 TO SUB1

```
               107.1

PERFORM SPREAD THRU SP-FIN

               69.1

VESAA
COMPUTE DOL-VAL (56) = .02 *
(DOL-VAL (47) + DOL-VAL (39) +
DOL-VAL (66)) + .10 * (DOL-VAL (43)
+ DOL-VAL (52))

MOVE 56 TO SUB1

               107.1

PERFORM SPREAD THRU SP-FIN

MOVE 0 TO XXI

DIVIDE LN-CURVE INTO DOL-VAL (56)
GIVING XXI ROUNDED
```

```
ADD XX1 TO TST-UNT

MOVE 0 TO XX1

70.1

VESAX
ADD DOL-VAL (39) DOL-VAL (43)
DOL-VAL (47) DOL-VAL (52) DOL-VAL
(55) DOL-VAL (56) DOL-VAL (66)
GIVING TOT-SERV-MOD

IF DOL-VAL (57) = 0 ............ GO TO VESAA1
                                      71.1
OTHERWISE

MOVE 57 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN
```


GO TO VESU
78.2
71.1
VESAA1
IF UOL-VAL (SB) NOT = 0
OTHERWISE
MOVE SB TO SUB1
107.1
PERFORM SPREAD THRU SP-FIN
GO TO VESAA2
71.2
71.2

VESAA2

IF VOL-VAL (SV) NOT = 0

MOVE SV TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

GO TO VESAA3

73.1

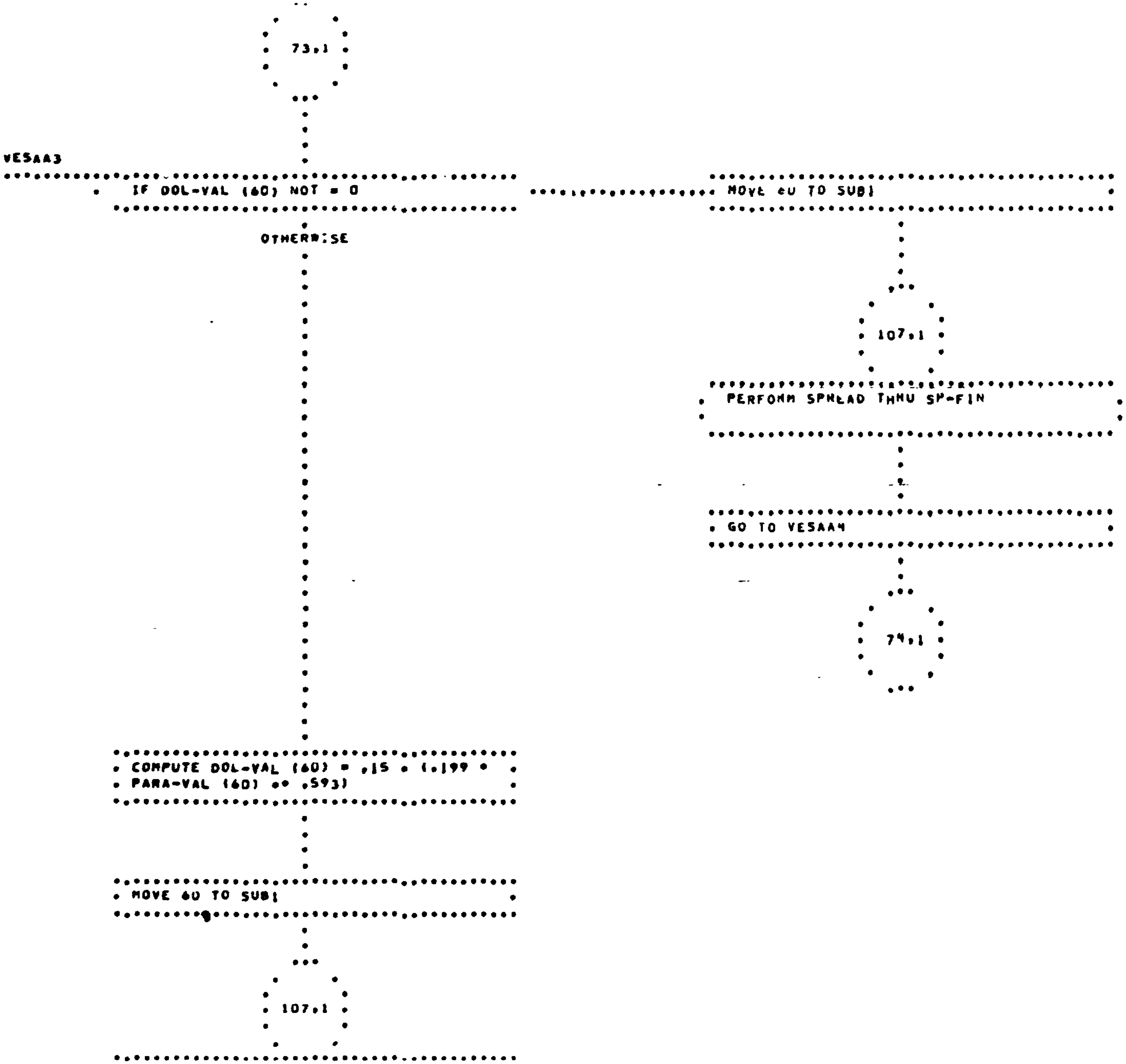
OTHERWISE

COMPUTE VOL-VAL (SV) = .08 *
TOT-SERV-MOD

MOVE SV TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN


73.1
VESAA3
IF DOL-VAL (6D) NOT = 0
OTHERWISE
MOVE 6U TO SUB1
107.1
PERFORM SPREAD THRU SP-FIN
GO TO VESAA4
74.1
COMPUTE DOL-VAL (6D) = .15 * (.199 *
PARA-VAL (6D) ** .593)
MOVE 6U TO SUB1
107.1

PERFORM SPREAD THRU SP-FIN

74.1

VESAA9

IF DOL-VAL (61) NOT = 0

MOVE 61 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

GO TO VESAAS

75.1

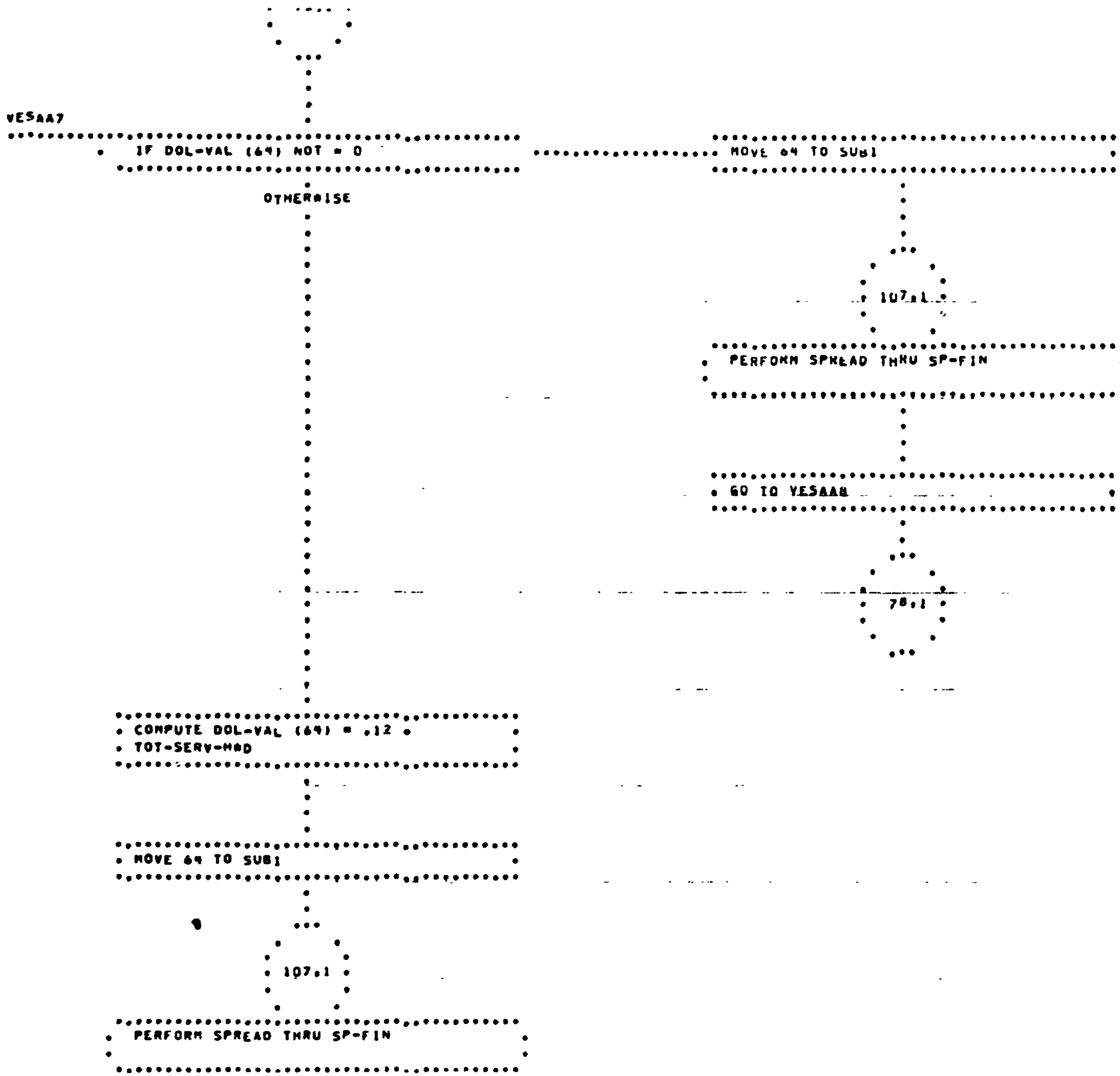
OTHERWISE

COMPUTE DOL-VAL (61) = .70 * DOL-VAL (23)

MOVE 61 TO SUB1

```
107,1

PERFORM SPREAD THRU SP-FIN

75,1

VESAAS
IF DOL-VAL (62) NOT = 0          MOVE 62 TO SUB1
OTHERWISE
                                 107,1

                                 PERFORM SPREAD THRU SP-FIN

                                 GO TO VESAA6

                                 75,2

75,2
```

```
VESAA6
. IF DOL-VAL (63) NOT = 0 .................. MOVE 63 TO SUB1
                                              107,1
                                              PERFORM SPREAD THRU SP-FIN
                                              GO TO VESAA7
                                              76,1
  OTHERWISE
  COMPUTE DOL-VAL (63) = .10 *
  TOT-SERV-MRD
  MOVE 63 TO SUB1
  107,1
  PERFORM SPREAD THRU SP-FIN
  76,1
```


VESAA7
IF DOL-VAL (64) NOT = 0
OTHERWISE
MOVE 64 TO SUB1
107.1
PERFORM SPREAD THRU SP-FIN
GO TO VESAA8
78.1
COMPUTE DOL-VAL (64) = .12 *
TOT-SERV-MHD
MOVE 64 TO SUB1
107.1
PERFORM SPREAD THRU SP-FIN

78,1

VESAAB

ADD DOL-VAL (58) DOL-VAL (59) DOL-VAL (60) DOL-VAL (61) DOL-VAL (62) DOL-VAL (63) DOL-VAL (64) GIVING DOL-VAL (57)

COMPUTE DOL-VAL (78) = .60 * FST-UNT

MOVE 78 TO SUB1

107,1

PERFORM SPREAD THRU SP-FIN

78,2

VESU

ADD DOL-VAL (57) DOL-VAL (78) TOT-SBRV-HRD GIVING DOL-VAL (38)

78,3

OVES1

IF DOL-VAL (65) = 0 → GO TO VESG → 79,1

OTHERWISE

MOVE 65 TO SUB;

107,1

PERFORM SPREAD THRU SP-FIN

79,1

VESG

IF DOL-VAL (67) = 0 → GO TO VESG1 → 80,1

OTHERWISE

MOVE 67 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

GO TO VES62

81.1

80.1

VES61

IF DOL-VAL (68) NOT = 0

MOVE 68 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

OTHERWISE

```
                                                   ....................
                                                   . GO TO VES62      .
                                                   ....................
                                                            :
                                                          81,1

                      81,1
                       :
VES62                  :
.............................................
            . MOVE DOL-VAL (68) TO DOL-VAL (67) .
            .....................................
                       :
            .....................................
            . ADD DOL-VAL (65) DOL-VAL (38)     .
            . DOL-VAL (67) GIVING DOL-VAL (69)  .
            .....................................
                       :
                      81,2
                       :
OPS                    :
.............................................     ....................
          . IF BB-LEVEL (70) = 9            ........ GO TO OPS6       .
            .....................................     ....................
                   OTHERWISE                               :
                       :                                 82,1
                       :
            .....................................     ....................
          . IF DOL-VAL (70) = 0             ........ GO TO OPS1       .
            .....................................     ....................
```

84.1

OTHERWISE

MOVE 70 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

GO TO OPS3

85.1

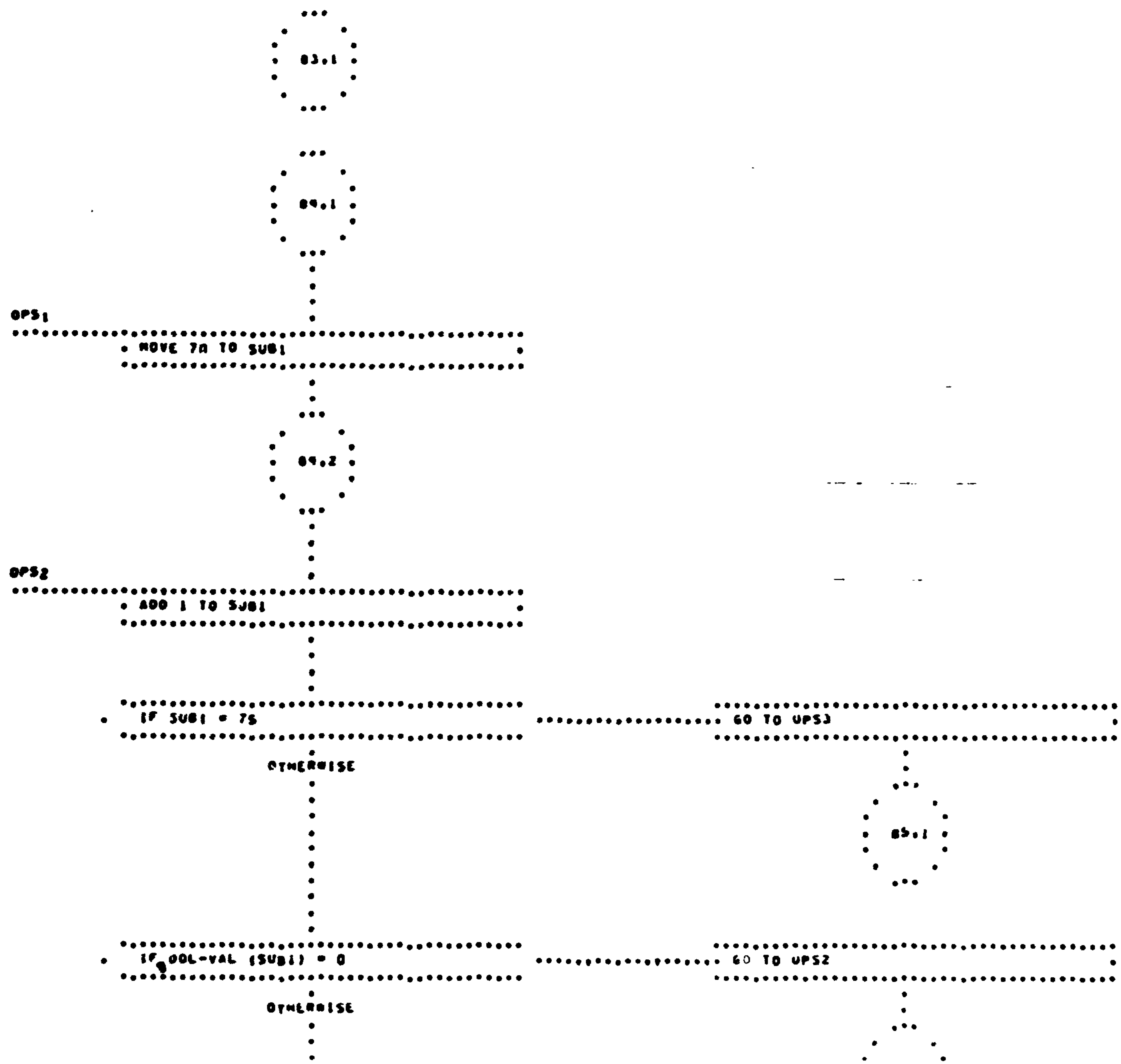
82.1

OPS6

MOVE 1 TO SUB5

MOVE 84 TO SUB1

```
                  83.1

OPS57
      IF SUBS = 11   ............   GO TO OPS55

                                       87.1
        OTHERWISE

                 107.1

      PERFORM SPREAD THRU SP-FIN

      ADD DOL-VAL (SUB1) TO DOL-VAL (70)

      ADD 1 TO SUB1

      ADD 1 TO SUBS

      GO TO OPS57
```


83.1
84.1
OPS1
MOVE 7A TO SUB1
84.2
OPS2
ADD 1 TO SUB1
IF SUB1 = 75
GO TO OPS3
OTHERWISE
85.1
IF DOL-VAL (SUB1) = 0
GO TO OPS2
OTHERWISE

89.2

107.1

PERFORM SPREAD THRU SP-FIN

ADD DOL-VAL (SUB1) TO DOL-VAL (70)

GO TO OPS2

89.2

85.1

OPS3

IF DOL-VAL (76) NOT = 0

MOVE 76 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

OTHERWISE

GO TO UPS9

86.1

COMPUTE DOL-VAL (76) = .01 *
PARA-VAL (76)

MOVE 76 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

86.1

UPS9

IF DOL-VAL (77) = 0 — GO TO UPS5

87.1

OTHERWISE

```
MOVE 77 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

87.1

OPSS
ADD DOL-VAL (76) DOL-VAL (77) GIVING
DOL-VAL (75)

ADD DOL-VAL (75) DOL-VAL (70) GIVING
DOL-VAL (79)

MOVE FST-UNT TO DOL-VAL (95)

87.2

FEL
```

IF AB-LEVEL (81) = 0 → GO TO FEE3

89.1

OTHERWISE

ADD DOL-VAL (37) TO DOL-VAL (81)

SUBTRACT DOL-VAL (4) DOL-VAL (6)
DOL-VAL (10) DOL-VAL (15) DOL-VAL
(27) FROM DOL-VAL (81)

COMPUTE DOL-VAL (81) = .10 * DOL-VAL
(81)

MOVE 81 TO SUB1

107.1

PERFORM SPREAD THRU SP-FIN

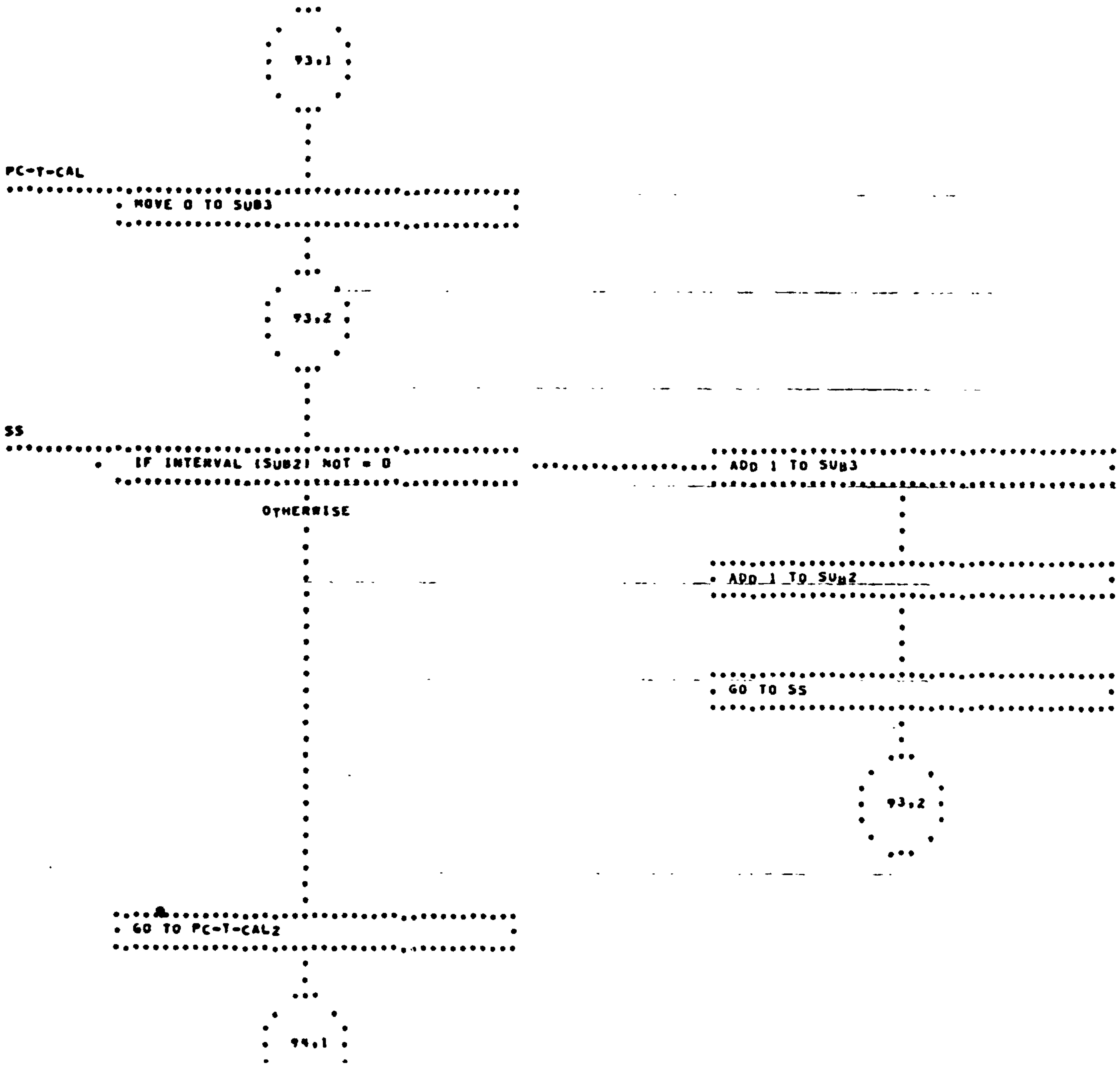
ADD DOL-VAL (69) TO DOL-VAL (82)

```
SUBTRACT DOL-VAL (39) DOL-VAL (43)
DOL-VAL (47) DOL-VAL (52) DOL-VAL
(66) FROM DOL-VAL (82)

COMPUTE DOL-VAL (82) = .10 * DOL-VAL
(82)

MOVE 82 TO SUB1

107,1

PERFORM SPREAD THRU SP-FIN

COMPUTE DOL-VAL (83) = .10 * DOL-VAL
(79)

MOVE 83 TO SUB1

107,1

PERFORM SPREAD THRU SP-FIN

89,1
```

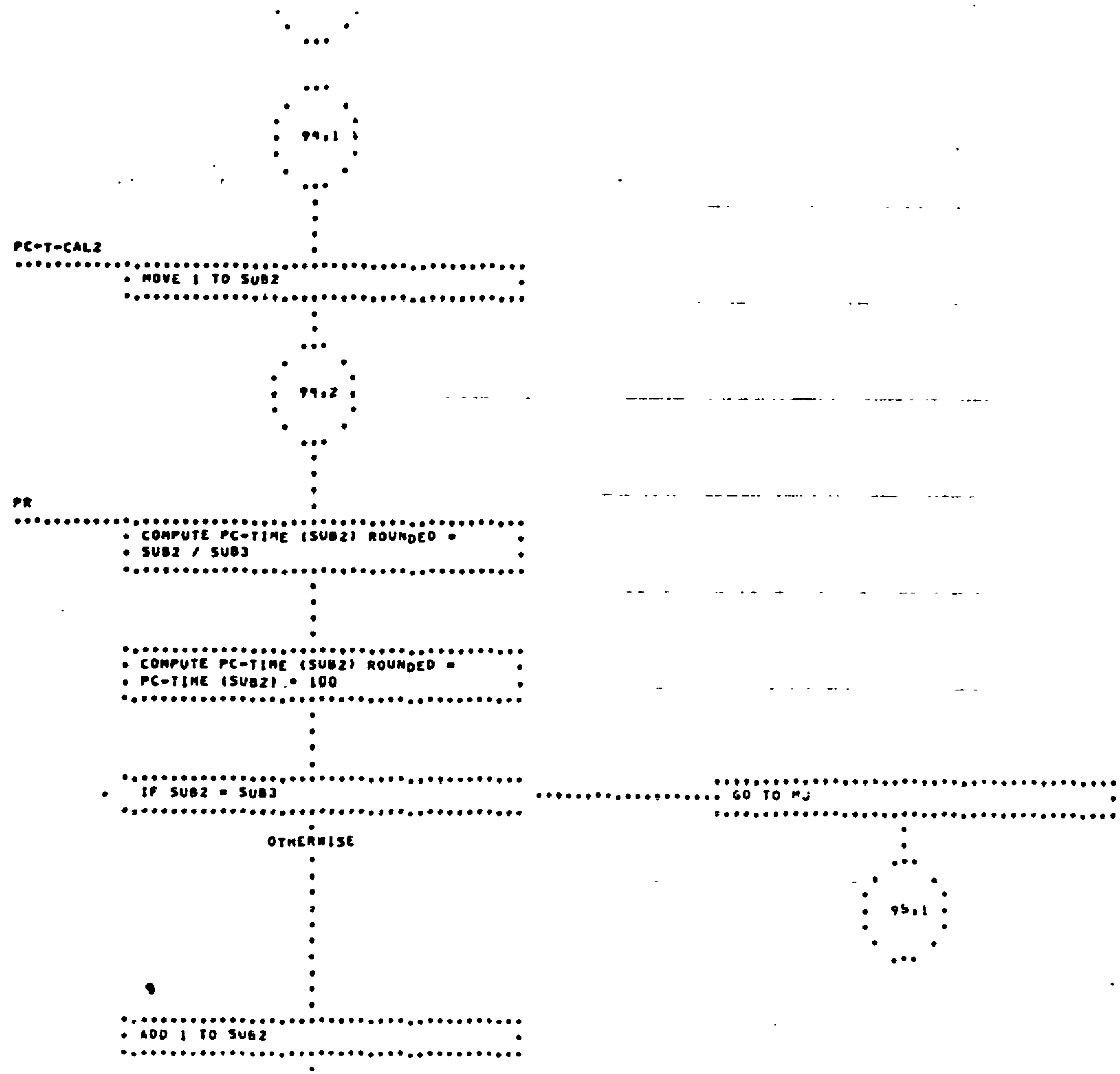
```
FEE3
     MOVE 1 TO SUB1

        90.1

PC-C1
     COMPUTE PC-TOT-PROG (SUB1) ROUNDED =
     DOL-VAL (SUB1) / TOTAL-PRO

     COMPUTE PC-TOT-PROG (SUB1) ROUNDED =
     PC-TOT-PROG (SUB1) * 100

     IF SUB1 = 100 .................. GO TO PC-COMPT
          OTHERWISE                        91.1

     ADD 1 TO SUB1

     GO TO PC-C1
```

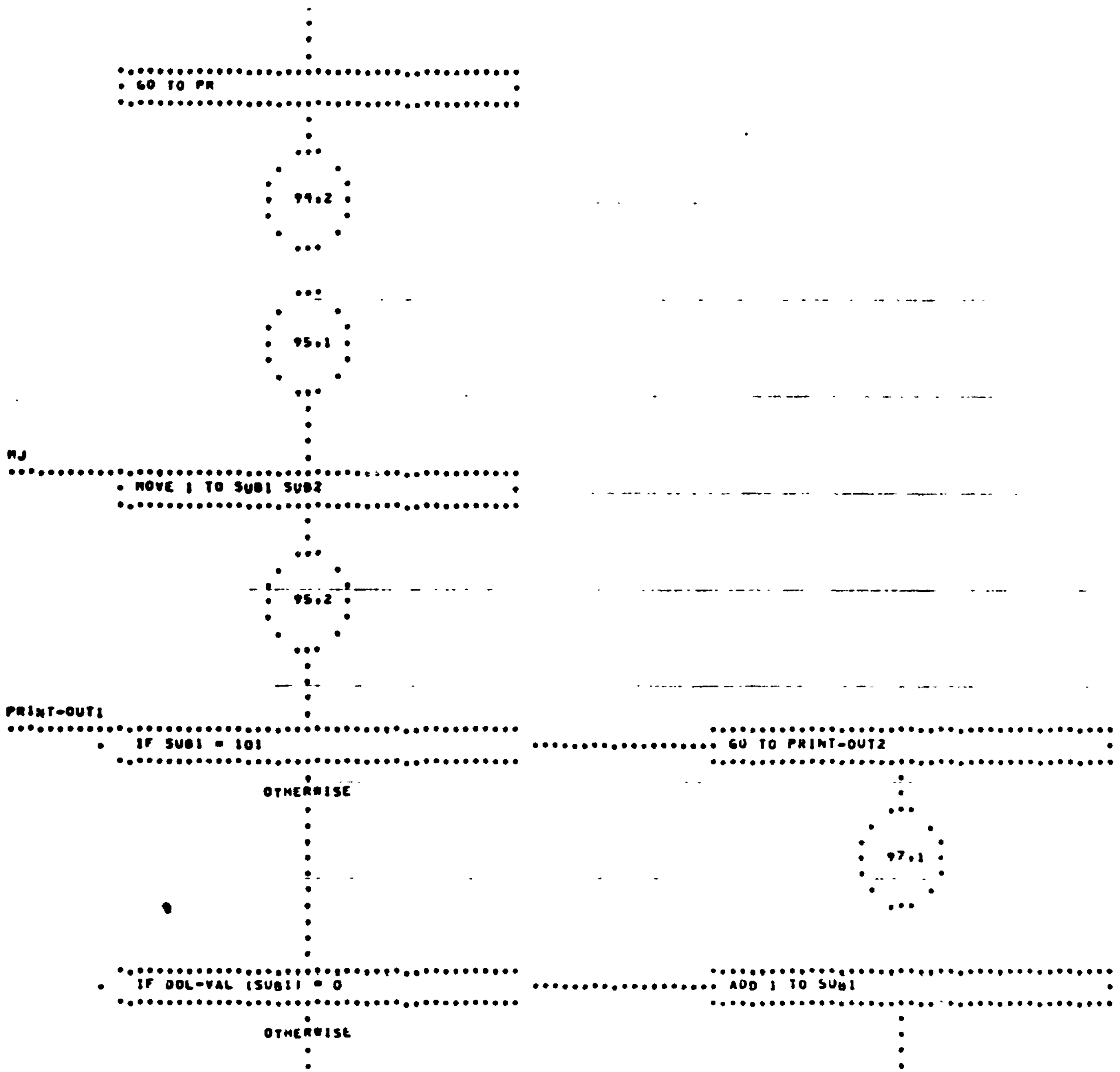
```
        90.1

        91.1

PC-COMPT
    MOVE 1 TO SUB1

    MOVE 1 TO SUB2

        91.2

PC-COST
    COMPUTE PC-INT-COST (SUB1) ROUNDED =
    INTERVAL (SUB1) / TOTAL-PRO

    COMPUTE PC-INT-COST (SUB1) ROUNDED =
    PC-INT-COST (SUB1) * 100

    IF SUB1 > 20  ..........  GO TO PR1
        OTHERWISE                  92.1
```

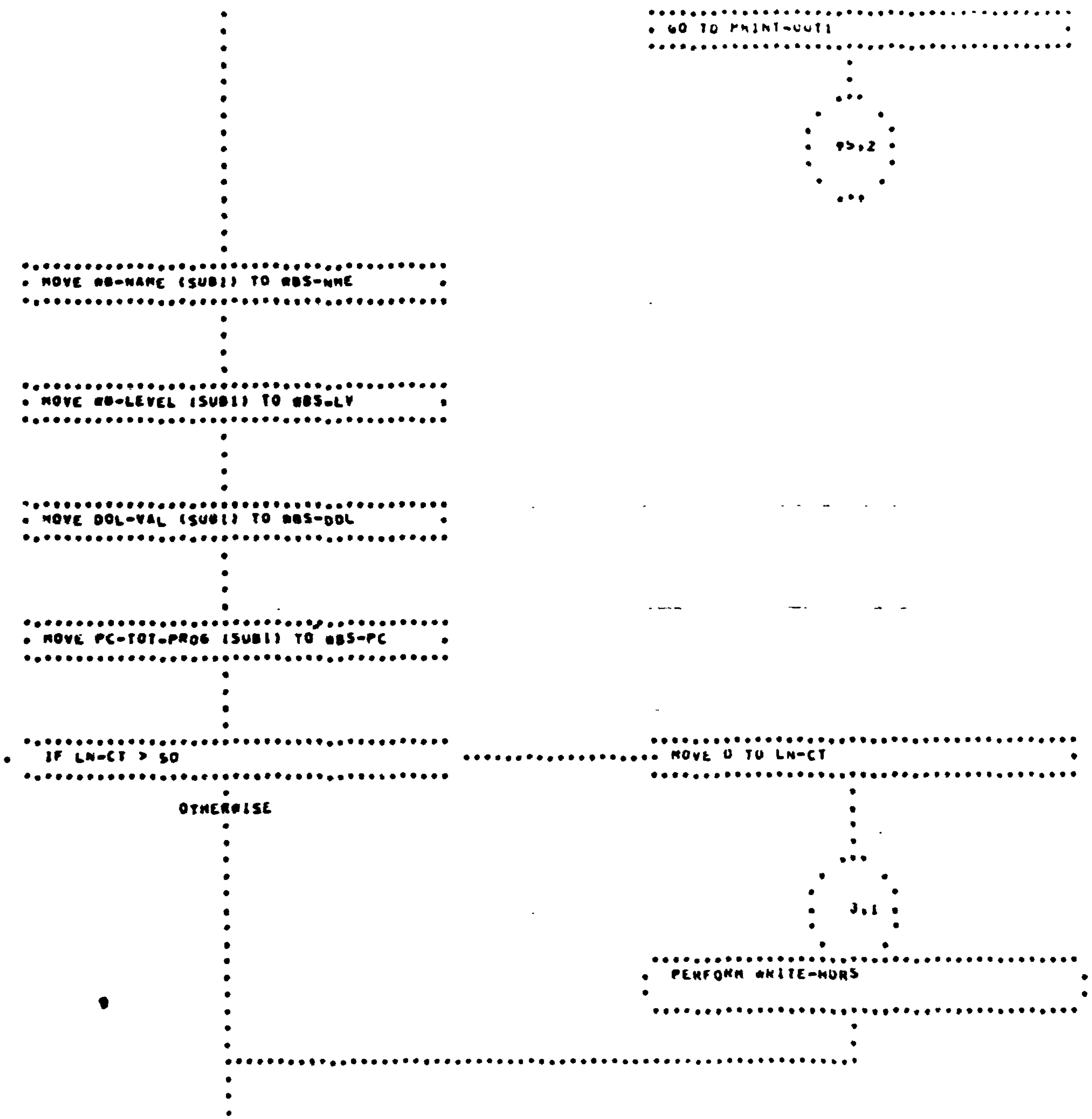
```
COMPUTE DIS-DOL (SUB1) ROUNDED =
PRE-VL (SUB1) * INTERVAL (SUB1)

ADD DIS-DOL (SUB1) TO TOT-DIS-DOL

92.1

PR1
IF SUB1 = 80  ................  GO TO PC-T-CAL
                                    93.1
OTHERWISE

ADD 1 TO SUB1

GO TO PC-COST

91.2
```

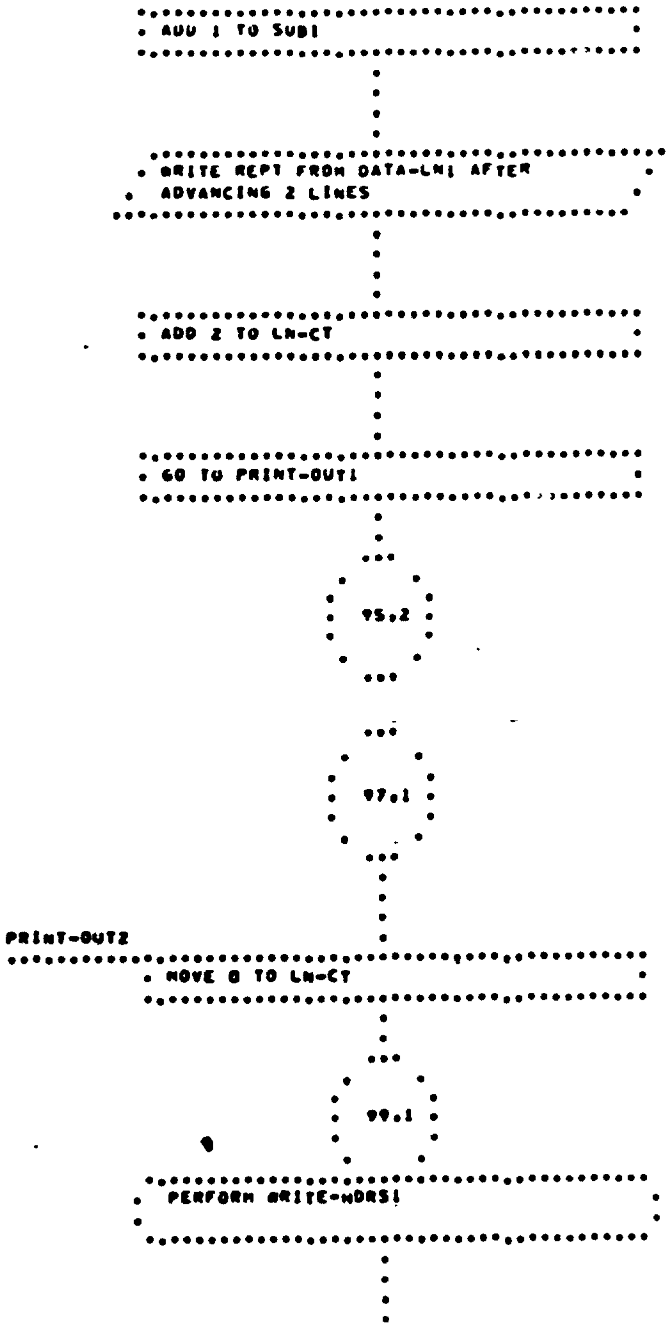

93.1
PC-T-CAL
MOVE 0 TO SUB3
93.2
SS
IF INTERVAL (SUB2) NOT = 0
OTHERWISE
ADD 1 TO SUB3
ADD 1 TO SUB2
GO TO SS
93.2
GO TO PC-T-CAL2
94.1

PAGE

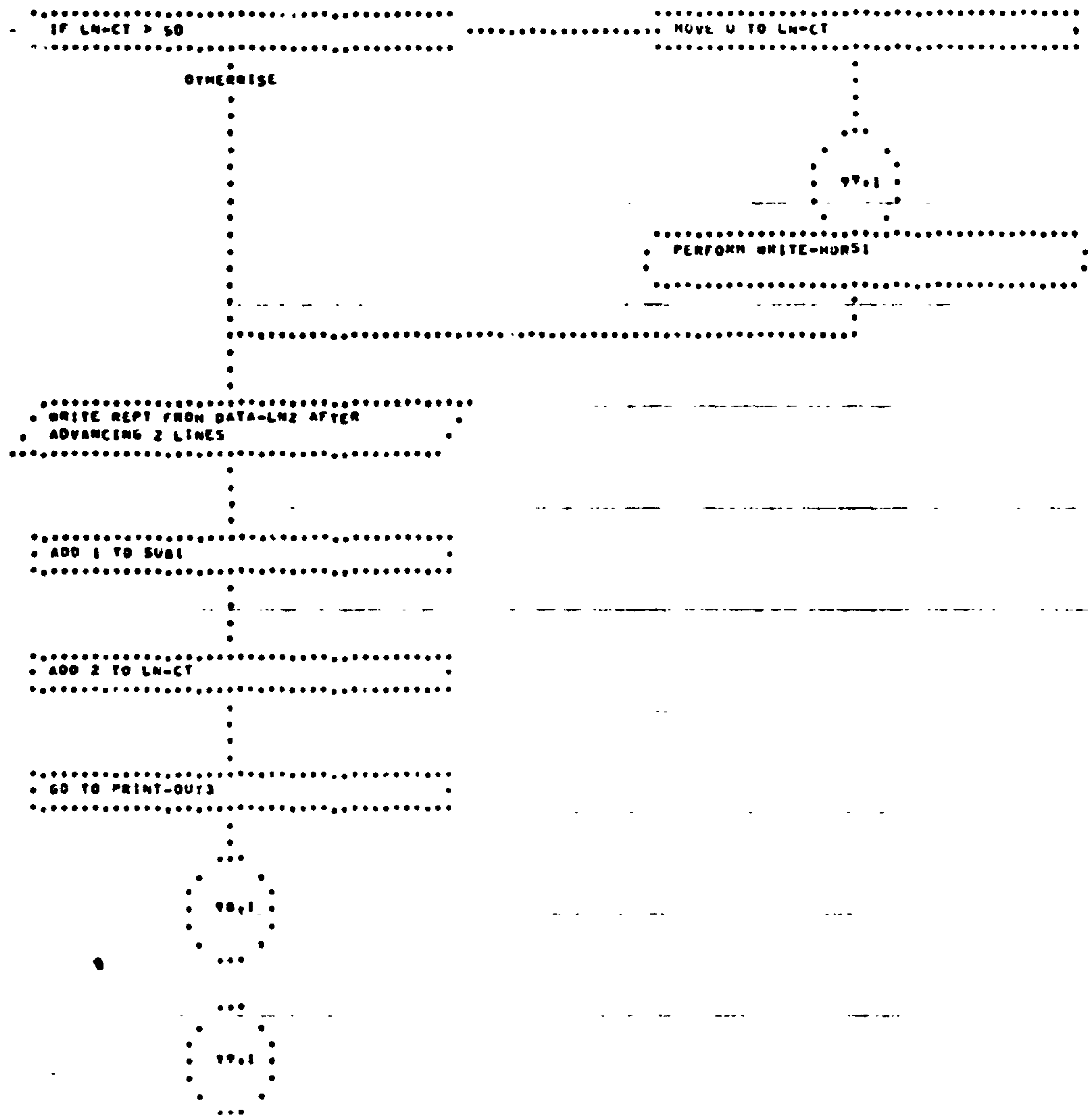

99.1
PC-T-CAL2
MOVE 1 TO SUB2
99.2
PR
COMPUTE PC-TIME (SUB2) ROUNDED =
SUB2 / SUB3
COMPUTE PC-TIME (SUB2) ROUNDED =
PC-TIME (SUB2) * 100
IF SUB2 = SUB3
GO TO MJ
95.1
OTHERWISE
ADD 1 TO SUB2


GO TO PR
99.2
95.1
MJ
MOVE 1 TO SUB1 SUB2
95.2
PRINT-OUT1
IF SUB1 = 101
GO TO PRINT-OUT2
OTHERWISE
97.1
IF DOL-VAL (SUB1) = 0
ADD 1 TO SUB1
OTHERWISE


GO TO PRINT-OUT1
95,2
MOVE WB-NAME (SUB1) TO WBS-NME
MOVE WB-LEVEL (SUB1) TO WBS-LV
MOVE DOL-VAL (SUB1) TO WBS-DOL
MOVE PC-TOT-PROG (SUB1) TO WBS-PC
IF LN-CT > 50
MOVE 0 TO LN-CT
3,1
PERFORM WRITE-HDRS
OTHERWISE


ADD 1 TO SUB1
WRITE REPT FROM DATA-LN1 AFTER ADVANCING 2 LINES
ADD 2 TO LN-CT
GO TO PRINT-OUT1
95.2
97.1
PRINT-OUT2
MOVE 0 TO LN-CT
99.1
PERFORM WRITE-HDRS1

```
        MOVE 1 TO SUB1
              |
            98.1
              |
PRINT-OUT3
        IF SUB1 > SUB3  ..................  GO TO PR-COMP
              |                                   |
          OTHERWISE                             100.1
              |
        MOVE SUB1 TO FY
              |
        MOVE INTERVAL (SUB1) TO DDV
              |
        MOVE PC-TIME (SUB1) TO PC-T
              |
        MOVE PC-INT-COST (SUB1) TO PC-C
              |
        MOVE DIS-DOL (SUB1) TO DOSL
              |
```


IF LN-CT > 50
MOVE 0 TO LN-CT
OTHERWISE
99.1
PERFORM WRITE-HDRS1
WRITE REPT FROM DATA-LN2 AFTER
ADVANCING 2 LINES
ADD 1 TO SUB1
ADD 2 TO LN-CT
GO TO PRINT-OUT3
98.1
99.1

```
WRITE-HDRS1
    WRITE RLPT FROM DIST-HD1 AFTER
    ADVANCING PAGE

    WRITE RLPT FROM DIST-HD2 AFTER
    ADVANCING 2 LINES

    MOVE 0 TO LN-CT

    ADD 3 TO LN-CT

    100:1

PR-COMP
    MOVE [illegible]-DIS-DOL TO DIS-DOLX

    MOVE TOTAL-PRO TO DOL-X

    WRITE RLPT FROM DATA-LN3 AFTER
    ADVANCING 2 LINES
```

```
MOVE CASE TO CASEX

MOVE CO-ST (3) TO DDTE-ST

MOVE CO-DUR (3) TO DDTE-D

MOVE A (3) TO DDTE-A

MOVE B (3) TO DDTE-B

MOVE A (40) TO INVE-A

MOVE B (40) TO INVE-B

MOVE CO-ST (40) TO IN-ST

MOVE CO-DUR (40) TO IN-DUR

WRITE REPT FROM DIST-HD3 AFTER
ADVANCING 3 LINES
```

```
WRITE REPT FROM DATA-LNS AFTER
ADVANCING 1 LINES

ADD 1 TO CASE

MOVE 1 TO SUB1 SUB2 SUB3

MOVE 0 TO TOT-DDTE TOT-PRO-DDTE
TOT-SERV-HWD TOTAL-PRO

MOVE 0 TO TOT-DIS-DOL FST-UNI LN-CT

102.1

ZR
MOVE 0 TO INTERVAL (SUB1)

IF SUB1 = 80 ..................  MOVE 1 TO SUB1
        OTHERWISE                  GO TO AN
```

103,1

ADD 1 TO SUB1

GO TO ZR

102,1

103,1

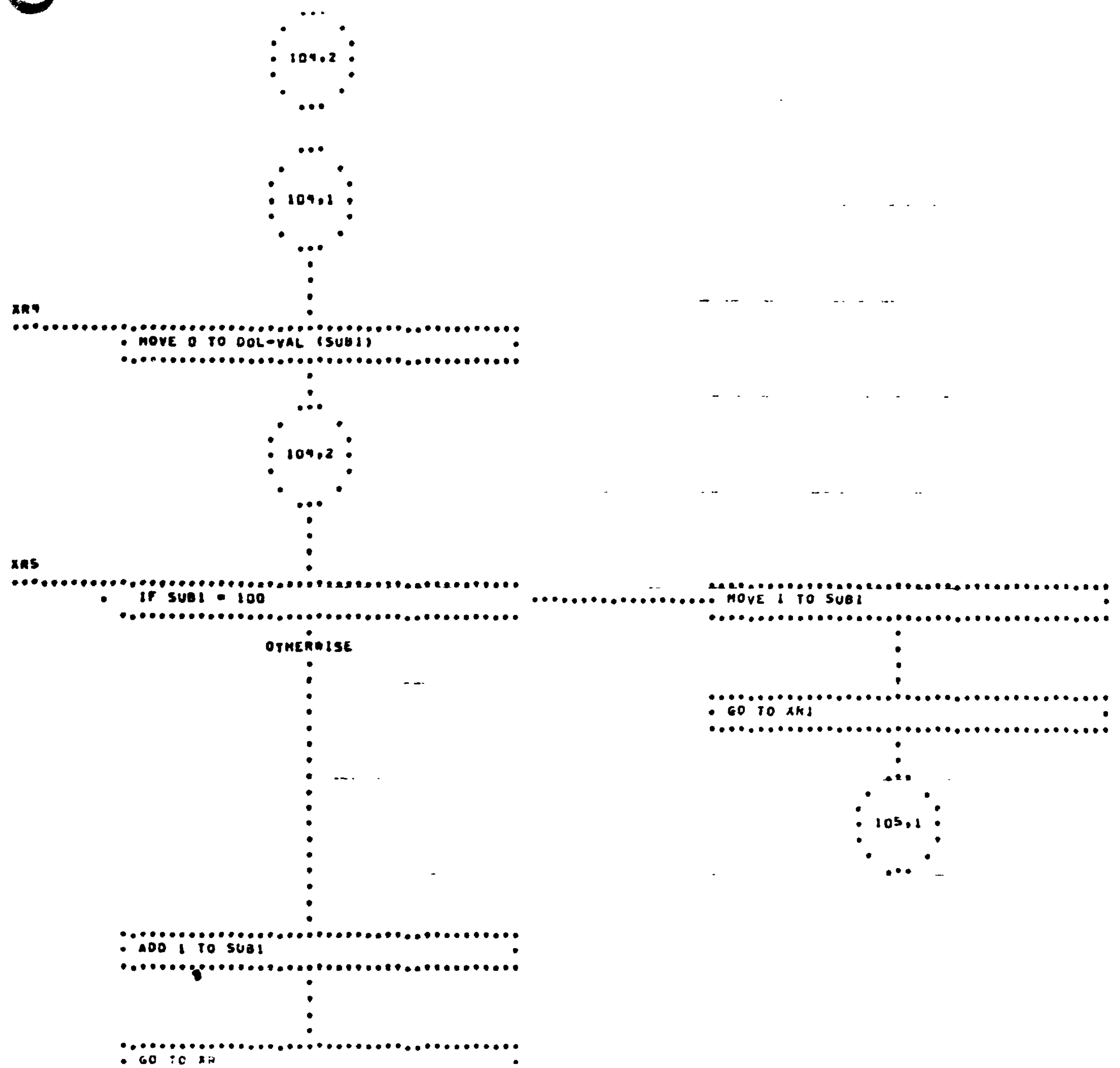
XR

IF CHECK (SUB1) = 0 GO TO XR4

104,1

OTHERWISE

GO TO XR5


104.2
104.1
XR9
MOVE 0 TO DOL-VAL (SUB1)
104.2
XR5
IF SUB1 = 100
MOVE 1 TO SUB1
GO TO XR1
105.1
OTHERWISE
ADD 1 TO SUB1
GO TO XR

103.1

105.1

XR1

IF NB-LEVEL (1) = 9 .... GO TO XR2

105.2

OTHERWISE

GO TO XR3

106.1

105.2

XR2

IF SUB4 = NB-LEVEL (2) .... GO TO XR3

```
                                     106.1

OTHERWISE

MOVE LN-CURX (SUB4) TO LN-CURVE

ADD 1 TO SUB4

106.1

3.1

XR3
PERFORM WRITE-HDRS

GO TO READ-PARAM

4.1

106.2
```

```
FINISH
        CLOSE PARAM

        CLOSE REPORT

        STOP RUN

        107.1

SPREAD
        IF DOL-VAL (SUB1) = 0  ........  GO TO SP-FIN
                                           111.1
        OTHERWISE

        MOVE 1 TO SUB3

        DIVIDE CO-OUR (SUB1) INTO SUB3
        GIVING F ROUNDED
```

```
MOVE CO-ST (SUB1) TO SUB2

108.1

SP-CON
IF A (SUB1) = 1 ................ MOVE 1 TO FRA2
                                 GO TO SR
                                 109.1
OTHERWISE

ADD F TO S

COMPUTE X1 ROUNDED = (15 - 4 * S) *
S

COMPUTE X2 ROUNDED = S * (X1 - 20)

COMPUTE X3 ROUNDED = (A (SUB1) * S
** 2 * (10 - X2)
```

```
COMPUTE X4 ROUNDED = S * (6 * S -
15)

COMPUTE X5 ROUNDED = (B (SUB1) * S
** 3) * (10 - X4)

COMPUTE X6 ROUNDED = 1 - (A (SUB1) +
B (SUB1))

COMPUTE X7 ROUNDED = S - (4 * S)

COMPUTE X8 ROUNDED = (X6 * S ** 4) *
X7

ADD X3 X5 X6 GIVING FRA ROUNDED

SUBTRACT FRA1 FROM FRA GIVING FRA2
ROUNDED

MOVE FRA TO FRA1

109.1
```

```
SM
    MULTIPLY FRA2 BY DOL-VAL (SUB1)
    GIVING DOL-INT ROUNDED

    ADD DOL-INT TO INTERVAL (SUB2)

    IF SUB3 = CO-DUR (SUB1) ............ GO TO SP-FINI
                                             110.1
    OTHERWISE

    ADD 1 TO SUB2

    ADD 1 TO SUB3

    GO TO SP-CON

       108.1
```

```
                  110.1

SP-FIN1
          MOVE 1 TO SUB3

          ADD DOL-VAL (SUB1) TO TOTAL-PRO

          MOVE 0 TO FRA1 FRA2 S

                  111.1

SP-FIN
          EXIT
```

APPENDIX B

- COST ESTIMATE DATA FORM A
- TECHNICAL CHARACTERISTICS DATA FORM C
- FUNDING SCHEDULE DATA FORM D

APPENDIX B

COST ESTIMATE DATA FORM A

DATE 5/7/71
PAGE 1 OF 5

X NON-RECURRING (DDT&E)
___ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)
($ IN MILLIONS)

a WBS IDENT. NUMBER	b WBS ITEM NAME	c WBS ITEM COST	d NUMBER OF UNITS	e REFER. UNIT	f LEARN. INDEX	g T_d	h T_s	i SPREAD FUNC.	j MILESTONE DATE
101-00-00	SERV								
101-01-00	Propulsion								
101-01-01	Lift Engines	$ 133				99	78	2	
101-01-02	Attitude Control	109				99	78	3	
101-02-00	AVIONICS								
101-02-01	Guidance & Navigation	77				99	78	3	
101-02-02	Instrumentation	95				99	78	3	
101-02-03	Communication	45				99	78	3	
101-03-00	AIRFRAME	Conf. A							
101-03-01	Structures	618				99	78	3	
101-03-02	Thermal Protection	79				99	78	3	
101-03-04	Landing & Gear	-				99	78	3	
101-04-00	POWER								
101-04-01	Electrical Supply & Distribution	165				99	78	3	
101-04-02	Hydraulic and Pneumatics	16				99	78	3	
101-05-00	ECLS	-							

APPENDIX B

COST ESTIMATE DATA FORM A

DATE 5/7
PAGE 2 OF 5

X NON-RECURRING (DDT&E)
___ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)
($ IN MILLIONS)

WBS IDENT. NUMBER a	WBS ITEM NAME b	WBS ITEM COST c	NUMBER OF UNITS d	REFER. UNIT e	LEARN. INDEX f	T_d g	T_s h	SPREAD FUNC. i	MILESTONE DATE j
101-07-00	SYSTEM SUPPORT								
101-07-01	Systems Eng. & Intg.	$ 160				88	78	4	
101-07-02	Project Mgt.	178				99	78	4	
101-07-03	Facilities & Equipment	198				16	63	3	
101-07-04	GSE	133				99	78	3	
101-07-05	Training	72				16	30	3	
101-07-07	Ground Test	260				16	66	4	
102-00-00	SPACECRAFT								
	-Warp	2515				99	78	3	
	- Personnel Module	784				99	78	3	
103-00-00	MAIN ENGINE	556				99	78	2	
104-00-00	FLIGHT TEST								
104-01-00	SERV	670				16	42	3	
104-02-00	Spacecraft								
104-03-00	Mated	100				12	30	3	
104-04-00	Support	80				12	30	3	
106-00-00	MGMT AND INTEGRATION								
106-01-00	Systems Intg.	147				99	78	4	

APPENDIX B

COST ESTIMATE DATA FORM A

DATE 5/7/71

____ NON-RECURRING (DDT&E)
X ____ RECURRING (PRODUCTION)
____ RECURRING (OPERATIONS)
($ IN MILLIONS)

WBS IDENT. NUMBER a	WBS ITEM NAME b	WBS ITEM COST c	NUMBER OF UNITS d	REFER. UNIT e	LEARN. INDEX f	T_c g	T_s h	SPREAD FUNC. i	MILESTONE DATE
101-00-00	SERV								
101-01-00	PROPULSION								
101-01-01	Lift Engines	$ 59	72		95%				
101-01-02	Attitude Control	16	2 sets		95%			4	
101-02-00	AVIONICS								
101-02-01	Guidance and Navigation	15	2		95%			4	
101-02-02	Instrumentation	11	2		95%			4	
101-02-03	Communications	2	2		95%			4	
101-03-00	AIR FRAME								
101-03-01	Structures	343	2		95%			4	
101-03-02	Thermal Protection	41	2		95%			4	
101-03-04	Landing Gear								
101-04-00	POWER								
101-04-01	Electrical Supply & Distribution	43	2		95%			4	
101-04-02	Hydraulics & Pneumatics	4	2		95%			4	
101-05-00	ECLS								
101-06-00	Assembly and Checkout	18	2		95%			4	

MF-030

APPENDIX B

COST ESTIMATE DATA FORM A

DATE [illegible]

PAGE 4 of 5

___ NON-RECURRING (DDT&E)
X RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)
($ IN MILLIONS)

a WBS IDENT. NUMBER	b WBS ITEM NAME	c WBS ITEM COST	d NUMBER OF UNITS	e REFER. UNIT	f LEARN. INDEX	g T_d	h T_s	i SPREAD FUNC.	j MILESTONE DATE
101-07-00	<u>SYSTEM SUPPORT</u>								
101-07-02	Project Management	5						4	
101-07-03	Facilities & Equipment	49						4	
101-07-04	GSE	93						4	
101-07-06	Initial Operating Spares	156						4	
101-07-08	Sustaining Engineering	156						4	
102-00-00	<u>SPACECRAFT</u>								
	-Murp	232	3					4	
	-Personnel Module	282	3					4	
103-00-00	<u>MAIN ENGINES</u>	123	2 sets					4	

APPENDIX B

COST ESTIMATE DATA FORM A

DATE 5/7/71

PAGE 5 OF 5

___ NON-RECURRING (DDT&E)

___ RECURRING (PRODUCTION)

X RECURRING (OPERATIONS)

($ IN MILLIONS)

a WBS IDENT. NUMBER	b WBS ITEM NAME	c WBS ITEM COST	d NUMBER OF UNITS	e REFER. UNIT	f LEARN. INDEX	g T_d	h T_s	i SPREAD FUNC.	j MILESTONE DATE
105-00-00	OPERATIONS					120			
	SERV	$ 1437							
	SERV-PM	1804							
	SERV-MURP	1873							

MF-030

APPENDIX B

TECHNICAL CHARACTERISTICS DATA FORM C

DATE 5 1
PAGE 1 of 3

WBS IDENTIFICATION NUMBER (1)	WBS IDENTIFICATION (2)	QUANTITY OR VALUE (3)	UNITS OF MEASURE (4)	CHARACTERISTICS (5)	NOTES (6)
101-00-00	<u>SERV</u>				
101-01-00	<u>Propulsion</u>				
101-01-01	Lift Engines				
101-01-02	Attitude Controls	4,000	lbs	Vacuum Thrust	Lift Engine's Cost obtained from Allison
		20		Number of Engines in System	
101-02-00	<u>Avionics</u>				
101-02-01	Guidance & Navigation	454	lbs	Weight of System	
101-02-02	Instrumentations	346	lbs	Weight of System	
101-02-03	Communications	100	lbs	Weight of System	
101-03-00	<u>Airframe</u>				
101-03-01	Structures	262,087	lbs	Structural System Weight	Structural Material Percent Weight Distribution SS-Beam 9.4% -Hyc 13.1 Misc. 10.4
101-03-02	Thermal Protection	11,532	lbs	Wt of TPS Panels	INCO 718 67.1
		9,300	ft^2	Area of ablative heat Shield	Upper shell Hyc TPS
		3,760	ft	Linear length of RTD Seal	Included in structure
		8,675	--	Number of plugs	
101-04-00	<u>Power</u>	340	lbs	Wt of Batteries	
101-04-01	Electrical Supply & Distribution	8,000	lbs	Wt of Distribution	
		400	lbs	Wt of fuel cells	

IR-030

APPENDIX B

TECHNICAL CHARACTERISTICS DATA FORM C

(1) WBS IDENTIFICATION NUMBER	(2) WBS IDENTIFICATION	(3) QUANTITY OR VALUE	(4) UNITS OF MEASURE	(5) CHARACTERISTICS	(6) NOTES
101-04-02	Hydraulics & Pneu.	2,000	lbs	Weight of System	
101-05-00	ECLS				
101-06-00	Assembly and Checkout				
101-07-00	System Support				
101-07-01	Systems Engineering				
101-07-C2	Project Mgt.				
101-07-03	Facilities & Equipment	262,087	lbs.	Weight of Structure System.	
101-07-05	Training	800	personnel	Number of Personnel to be trained	
101-07-06	Initial Operating Spares	TFU	$	First Unit cost of each system.	
101-07-07	Ground Test	10,000	hrs	hours of wind tunnel testing	
		5		Number of full duration static test firings.	
		667	$	Development Cost of Airframe system	
		12		Number of primary Rocket Engines	
		450,000	lbs	Vacuum thrust engines	

APPENDIX B

TECHNICAL CHARACTERISTICS DATA FORM C

DATE 5/[illegible]
PAGE 3 OF 3

WBS IDENTIFICATION (1) NUMBER	WBS IDENTIFICATION (2)	QUANTITY OR (3) VALUE	UNITS OF (4) MEASURE	CHARACTERISTICS (5)	NOTES (6)
101-07-03	Sustaining Engineering	100		personnel	100 man force considered for main engine, lift engine, and spacecraft 200 man force for SERV project sustaining Eng.
102-00-00	<u>Spacecraft</u>				
103-00-00	<u>Main Engine</u>				Cost obtained from Rocketdyne
104-00-00	<u>Flight Test</u>				
104-01-00	SERV	2	-	Number of Flight Test	
		9	-	Length of Flight Test Program	
104-02-00	Spacecraft	TFU	-	First Unit Cost	
104-03-00	Mated	850	$	SERV Flight Test Cost	
104-04-00	Support	850	$	SERV Flight Test Cost	
105-00-00	<u>Operations</u>				
106-00-00	<u>Management & Integration</u>	4714	$	Total Program Development Cost	

MF-030

[redacted] [redacted]

APPENDIX B

FUNDING SCHEDULE DATA FORM D

DATE 5/6/71
PAGE 1 OF 2

X NON-RECURRING (DDT&E)
___ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)
($ IN MILLIONS)

PROJECT WBS ITEMS	FY 72	FY 73	FY 74	FY 75	FY 76	FY 77	FY 78
101-00-00 SERV	30.46	175.56	382.05	485.38	447.12	363.81	270.79
102-00-00 SPACECRAFT - PM	9.02	50.88	104.59	146.45	161.97	146.45	104.66
103-00-00 MAIN ENGINE	21.80	61.99	91.46	105.53	102.86	84.90	56.77
104-00-00 FLIGHT TEST				69.28	303.33	370.27	107.23
106-00-00 MANAGEMENT & INTEGRATION	1.28	7.62	16.93	26.09	32.74	35.09	32.06

APPENDIX B

FUNDING SCHEDULE DATA [illegible]

DATE 5/6/71
PAGE 2 OF 2

X NON-RECURRING (DDT&E)
___ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)
($ IN MILLIONS)

PROJECT WBS ITEMS	FY 79	FY 80	FY__	FY__	FY__	FY__	FY__
101-00-00 SERV	151.04	32.43					
102-00-00 SPACECRAFT - PM	50.88	9.09					
103-00-00 MAIN ENGINE	26.19	4.50					
104-00-00 FLIGHT TEST							
[illegible]6-00-00 MANAGEMENT & INTEGRATION	23.24	8.88					

MF-030

APPENDIX B

FUNDING SCHEDULE DATA FORM D

DATE 5/6/71
PAGE 1 OF 2

X NON-RECURRING (DDT&E)
___ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)
($ IN MILLIONS)

PROJECT WBS ITEMS	FY 72	FY 73	FY 74	FY 75	FY 76	FY 77	FY 78
101-00-00 SERV	30.46	175.56	382.05	485.38	447.12	363.81	270.79
102-00-00 SPACECRAFT - MURP	28.92	163.22	335.50	469.80	519.80	469.80	335.75
103-00-00 MAIN ENGINES	21.80	61.99	91.46	105.53	102.86	84.90	56.77
104-00-00 FLIGHT TEST				69.28	303.33	370.27	107.23
106-00-00 MANAGEMENT & INTEGRATION	1.87	11.20	24.90	38.36	48.15	51.60	47.16

MF-030

APPENDIX B

FUNDING SCHEDULE DATA FORM D

DATE 5/6/77
PAGE 2 OF 2

X NON-RECURRING (DDT&E)
___ RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)
($ IN MILLIONS)

PROJECT WBS ITEMS	FY 79	FY 80	FY___	FY___	FY___	FY___	FY___
101-00-00 SERV	151.04	32.43					
102-00-00 SPACECRAFT - M	153.22	29.17					
103-00-00 MAIN ENGINES	26.19	4.50					
104-00-00 FLIGHT TEST							
106-00-00 MANAGEMENT & INTEGRATION	47.16	34.17					

MF-030

APPENDIX B

FUNDING SCHEDULE DATA FORM D

DATE 5/6/71

___ NON-RECURRING (DDT&E)
X RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)
($ IN MILLIONS)

PROJECT WBS ITEMS	FY 76	FY 77	FY 78	FY 79	FY 80	FY 81	FY 82
101-00-00 SERV	40.68	198.37	385.62	510.89	200.80	10.50	10.50
102-00-00 SPACECRAFT - PM	8.49	41.25	66.93	62.14	28.69	3.50	3.50
103-00-00 MAIN ENGINES	3.95	19.18	31.12	28.89	15.21	3.50	3.50

MF-030

APPENDIX B

FUNDING SCHEDULE DATA FORM D

DATE 5/6/7_
PAGE 2 OF _

____ NON-RECURRING (DDT&E)
__X__ RECURRING (PRODUCTION)
____ RECURRING (OPERATIONS)
($ IN MILLIONS)

PROJECT WBS ITEMS	FY 83	FY 84	FY 85	FY 86	FY 87	FY___	FY___
101-00-00 SERV	10.50	10.50	10.50	10.50	10.50		
102-00-00 SPACECRAFT - PM	3.50	3.50	3.50	3.50	3.50		
103-00-00 MAIN ENGINES	3.50	3.50	3.50	3.50	3.50		

MF-030

APPENDIX B

FUNDING SCHEDULE DATA FORM D

DATE 5/6/71
PAGE 1 OF 2

___ NON-RECURRING (DDT&E)
X RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)
($ IN MILLIONS)

PROJECT WBS ITEMS	FY 76	FY 77	FY 78	FY 79	FY 80	FY 81	FY 82
101-00-00 SERV	40.68	198.37	385.62	510.89	200.80	10.50	10.50
102-00-00 SPACECRAFT - MURP	10.57	51.36	83.34	77.37	34.87	3.50	3.50
103-00-00 MAIN ENGINES	3.95	19.18	31.12	28.89	15.21	3.50	3.50

MF-030

APPENDIX B

FUNDING SCHEDULE DATA FORM B

DATE 5/6/71
PAGE 2 OF ___

___ NON-RECURRING (DDT&E)
X RECURRING (PRODUCTION)
___ RECURRING (OPERATIONS)
($ IN MILLIONS)

PROJECT WBS ITEMS	FY 83	FY 84	FY 85	FY 86	FY 87	FY___	FY___
101-00-00 SERV	10.50	10.50	10.5[illegible]	10.50	10.50		
102-00-00 MURP	3.50	3.50	3.50	3.50	3.50		
103-00-00 MAIN ENGINES	3.50	3.50	3.50	3.50	3.50		

MF-030

APPENDIX B

FUNDING SCHEDULE DATA FORM D

DATE 5/6/71
PAGE 1 OF 2

___ NON-RECURRING (DDT&E)
___ RECURRING (PRODUCTION)
X RECURRING (OPERATIONS)
($ IN MILLIONS)

PROJECT WBS ITEMS	FY 78	FY 79	FY 80	FY 81	FY 82	FY 83	FY 84
105-00-00 **OPERATIONS**							
SERV (Only)	58.2	71.2	82.6	107.8	130.9	156.4	182.5
SERV-PM	76.0	90.1	104.1	135.6	163.9	197.5	229.1
SERV-MURP	76.5	92.9	107.6	140.6	170.4	205.5	238.6

MF-030

APPENDIX B

FUNDING SCHEDULE DATA FORM B

DATE 5/[illegible]
PAGE 2 OF [illegible]

___ NON-RECURRING (DDT&E)
___ RECURRING (PRODUCTION)
_X_ RECURRING (OPERATIONS)
($ IN MILLIONS)

PROJECT WBS ITEMS	FY 85	FY 86	FY 87	FY___	FY___	FY___	FY___
105-00-00 OPERATIONS							
SERV (only)	205.4	220.9	220.9				
SERV - PM	257.1	275.2	275.2				
SERV - MURP	268.0	286.9	286.9				

MT-030

APPENDIX C

DETAIL FACILITY COST ANALYSIS

APPENDIX C

DETAIL FACILITY COST ANALYSIS

This Appendix contains the working papers which were generated in the estimation of facility costs. The following working papers are presented:

A. MAF Tooling Cost Summary

B. MAF Tooling Costs

C. Minor Facilities Cost for System, Subsystem, and Component Test Program

D. MAF Facility Cost

E. KSC Facility Modification Cost

A. MAF TOOLING COST SUMMARY

A-1. MAF Tooling Costs Summary

Basic Tooling Cost	36,524,000
Facility	21,141,600
Special Equipment	3,516,000
Handling Equipment	1,459,700
Total	62,641,700

NOTE: For detailed breakdown of costs see working paper B and volume V, appendix A

B. MAF TOOLING COSTS

B-1. MAF Tooling Costs

Operation Name	Operation No.	COST				
		Tooling	Special Equipment	Handling Equipment	Facilities	Total
Thrust Ring	50	1,840,000	65,000	32,000	75,000	2,012,000
Support Beam	100	70,000	15,000	21,000	40,000	146,000
Lift Engine Thrust Ring Structure	150	75,000		6,000		81,000
Lift Engine Modification	165	22,000		49,000		71,000
Lift Engine Thrust Ring Fit-up	170	44,000	5,000			49,000
Inner Cylindrical Bulkhead-Lower Ring	205	85,000		17,000		102,000
Inner Cylindrical Bulkhead-Attach Ring	210	85,000				85,000
Inner Cylindrical Bulkhead-Upper Ring	215	85,000				85,000
Inner Cylindrical Bulkhead-Lower Section	220	60,000		30,000		110,000

Sheet 1 of 10

B-1. MAF Tooling Costs (continued)

Operation Name	Operation No.	COST				
		Tooling	Special Equipment	Handling Equipment	Facilities	Total
Inner Cylindrical Bulkhead-Middle Section	240	80,000				80,000
Inner Cylindrical Wall	250	190,000	60,000	43,000	5,000	298,000
Landing Gear Structure	290	65,000		23,000		88,000
Main Structural Assembly Station	300	1,750,000			170,000	1,920,000
Outer Cylindrical Bulkhead-Upper Ring	303	110,000		10,000		120,000
Outer Cylindrical Bulkhead-Attach Rings	305	110,000				110,000
Outer Cylindrical Bulkhead-Lower Ring	307	110,000				110,000
Outer Cylindrical Bulkhead-Upper Section	330	75,000		38,000	15,000	128,000

Sheet 2 of 10

B-1. MAF Tooling Costs (continued)

Operation Name	Operation No.	COST				
		Tooling	Special Equipment	Handling Equipment	Facilities	Total
Inner Cylindrical Bulkhead-Middle Section	240	80,000				80,000
Inner Cylindrical Wall	250	190,000	60,000	43,000	5,000	298,000
Landing Gear Structure	290	65,000		23,000		88,000
Main Structural Assembly Station	300	1,750,000			170,000	1,920,000
Outer Cylindrical Bulkhead-Upper Ring	303	110,000		10,000		120,000
Outer Cylindrical Bulkhead-Attach Rings	305	110,000				110,000
Outer Cylindrical Bulkhead-Lower Ring	307	110,000				110,000
Outer Cylindrical Bulkhead-Upper Section	330	75,000		38,000	15,000	128,000

Sheet 3 of 10

B-1. MAF Tooling Costs (continued)

Operation Name	Operation No.	COST				
		Tooling	Special Equipment	Handling Equipment	Facilities	Total
LH_2 Baffle Assembly	300-50	445,000		38,000	165,000	648,000
Install LH_2 Anti-Slosh Baffles		110,000			50,000	160,000
Lower LO_2 Bulkhead	700	520,000		40,000	138,000	698,000
Mating Lower LO_2 Bulkhead-Thrust Ring	800	475,000		25,000	35,000	535,000
Lower Kick Ring Assembly	820	260,000	23,000	22,000	65,000	370,000
Mating Lower Kick Ring-Thrust Ring	1000	280,000			90,000	370,000
Lower Shell, Lower Ring	915	205,000		12,000		217,000
Lower Shell, Transition Ring	917	205,000				205,000
Lower Shell, Lower Section	920	140,000		38,000	90,000	268,000
Lower Shell, Upper Ring	925	205,000				205,000

Sheet 4 of 10

B-1. MAF Tooling Costs (continued)

Operation Name	Operation No.	COST				
		Tooling	Special Equipment	Handling Equipment	Facilities	Total
Lower Shell-Upper Section	930	140,000			90,000	230,000
Lower Shell Assembly	950	1,120,000			840,000	1,960,000
FAB Thermal Protection System	960	60,000	15,000	20,000	175,000	270,000
LO_2 Anti-Slosh Baffles	300-60	350,000				350,000
Mating Lower Shell	1000	340,000		4,000	95,000	439,000
Install LO_2 Anti-Slosh Baffles	300-60	90,000		10,000	55,000	155,000
Center Kick Ring	1100	185,000		20,000		205,000
Mating Center Kick Ring	1400	60,000				60,000
Upper Shell-Lower Ring	1203	90,000		33,000		123,000
Upper Shell-Upper Ring	1209	125,000				125,000

Sheet 5 of 10

B-1. MAF Tooling Costs (continued)

Operation Name	Operation No.	COST				
		Tooling	Special Equipment	Handling Equipment	Facilities	Total
Upper Shell-Lower Section	920	140,000		43,000	60,000	243,000
Upper Shell Assemb	1250	135,000			55,000	190,000
FAB Thermal Protection System	1260	90,000				90,000
Final Stuffing Propellant Tank Interiors	300-70	350,000		15,000		365,000
Install Deorbit and RCS Tankage	300-72			15,000		15,000
Install Pressurization System	300-70			30,000		30,000
Upper Kick Ring	1395	85,000		25,000		110,000
Mating Upper Shell	1400	290,000			55,000	345,000
Install Upper Kick Ring	1400	160,000				160,000
Cleaning Leak Test and Hydro-pneumatic Test	1600				2,500,000	2,500,000

Sheet 6 of 10

B-1. MAF Tooling Costs (continued)

Operation Name	Operation No.	COST				
		Tooling	Special Equipment	Handling Equipment	Facilities	Total
Installation of Propellant Lines	2000	125,000		10,000		135,000
Aerospike Engine Modification and Checkout	2000	165,000		130,000	185,000	480,000
Aerospike Engine Installation	2000	300,000	10,000	4,000	125,000	439,000
Install Aerospike Engine Protection Doors	2000	175,000		15,000		190,000
Fabricate Reentry Bulkhead Panels	1900	90,000				90,000
Install Reentry Bulkhead Panels	2000	225,000		20,000	45,000	290,000
Install Lending Gear Doors	2000	40,000		10,000	30,000	80,000
Install Lift Engine Doors	2000	40,000		10,000		50,000
Install Actuation Systems for Doors and Landing Gears (Power Sources and Connections)	2000	90,000				90,000

Sheet 7 of 10

B-1. MAF Tooling Costs (continued)

Operation Name	Operation No.	COST				
		Tooling	Special Equipment	Handling Equipment	Facilities	Total
Instrument Module Buildup and Check-out	1920	15,000	20,000			35,000
Instrumentation and Control Components	2000				90,000	90,000
Install Instrument Modules	2000	5,000		15,000		20,000
Install Onboard Computer	2000	2,000		20,000		22,000
Install Distributors	2000	5,000		10,000		15,000
Install Deorbit Engines	4000	40,000		35,000		75,000
Install RCS Engines	4000	30,000		10,000		40,000
Install Sensors and Remove Instruments	3000	22,000				22,000
Install Gyros and Accelerometers	2000	2,500				2,500
Stuff Instrument Compartment	2000	125,000				125,000

Sheet 8 of 10

B-1. MAF Tooling Costs (continued)

Operation Name	Operation No.	COST				
		Tooling	Special Equipment	Handling Equipment	Facilities	Total
Interconnection Operation	3000			10,000	31,000	41,000
Install Instrumentation and Control Tubing	2000	120,000				120,000
Install Distribution System	2000	77,000				77,000
Install Instrumentation and Control Cabling	2000	125,000				125,000
Install Computer Interfaces	2000	35,000			20,000	55,000
Checkout	5000	38,000		15,000	12,000,000	12,053,000
Weight and CG Radial CG	5500		70,000	30,000		100,000
Preparation for Ship	6000				80,000	80,000
Hydraulic Test Area		130,000				130,000

Sheet 9 of 10

B-1. MAF Tooling Costs (continued)

Operation Name	Operation No.	COST				
		Tooling	Special Equipment	Handling Equipment	Facilities	Total
Machine Major Assemblies and Subassembly Components		30,000		4,000		34,000
Mock-up		630,000				630,000
Fabricate Electrical Harnesses, Black Boxes, and P. C. Boards		190,000	27,000			217,000
Pneumatic Test		35,000		5,000		40,000
Tube Fabrication and Clean		100,000		500		100,500
Valve Buildup, Test and Refurbishment		130,000				130,000
Fabricate Subassembly Components				15,000		15,000
Surface Treat		10,000		10,000		20,000
Hydrostatic Test				15,000		15,000

Sheet 10 of 10

C. MINOR FACILITIES COST FOR SYSTEM, SUBSYSTEM AND COMPONENT TEST PROGRAM

C-1. Minor Facilities Cost

for

System, Subsystem and Component Test Program

System	Cost
Cryogenics	$ 200,000
Pneumatics	75,000
Hydraulics	50,000
Shock	30,000
Electronics	200,000
Structures	200,000
Total	$ 755,000

D. MAF FACILITY COST

D-1. MAF Facility Cost

1) Plant Modification - Building 420 - Stage Test	
o Modification of building 420, stage test, by addition of 4 stations including all foundations with 130 foot clear height in one station and 90 feet in the 3 remaining stations; also environmentally controlled and separate power and chilled water capability	19,404,000
o Furnish and install 90-foot rotary table - Station No. 1	Part of tooling installation
o Furnish and install 150-ton gantry crane - Station No. 1	312,000
o Furnish and install pneumastatic, pneumatic, hydrostatic, and clean facility - Station No. 2	2,500,000
o Furnish and install weight and CG test equipment (horizontal) - Station No. 4	100,000
2) Plant Modification - Building 103	
o Install three 90-foot rotary tables in the subassembly areas	Part of tooling installation
o Enclosure for rotary table	580,000
o Various crane modifications	500,000
3) Plant Modification - VAB Building	
o Install one 60-foot rotary table	Part of tooling installation
4) Tooling, Facilities and Special Equipment - All Buildings	
o Install new tooling and special equipment	4,950,000
o Procure and install new facility items	4,495,000
o Relocate existing facility equipment within the MAF	750,000
o Re-install relocated facility equipment	445,000
o Various foundations	800,000
o Modification of existing platforms and acquisition of new platforms	1,760,000
5) Roadways and Transportation	
o Provide access roads to and from building 420 and from building 420 to dock area	1,175,000
Total All Costs	$37,479,950

E. KSC FACILITY MODIFICATION COST

E-1. KSC Facility Modification Cost

VEHICLE MURP/SERV			STATIC TEST MOD	
ITEM	DESIGN	MATERIAL	CONSTRUCTION LABOR	TOTAL
Flame Deflector Mods				
Redesign for Load Pattern)				168,840
Redesign for Water Cooled)				
Construction (Deflector)				1,125,600
Site Work/Foundation				100,000
Design and Engineering 15%				210,000
Sub Total				1,610,000
Intermediate Deflect - 2 Required				
Surface Plate at $60,000				120,000
Struc. Truss Work at $60,000				120,000
Wheel Assemblies at $40,000				80,000
Anchoring System at $50,000				100,000
Design and Engineering 15%				63,000
Sub Total				483,000
Water System				
Pumps and Diesels (20 units at $267,000)				5,340,000
Pump Buildings/Facilities				1,040,000
Storage Tanks				382,000
Water Mains and Lines				580,000
Site Work/Utilities				134,000
Design and Engineering 15%				1,121,000
Sub Total				8,597,000
GRAND TOTAL				$10,690,000

E-2. KSC Facility Modification Cost

VEHICLE MURP/SERV		LAUNCH PAD MODS		
ITEM	DESIGN	MATERIAL	CONSTRUCTION LABOR	TOTAL
New 850,000 gal. tank adjacent to existing tank (LH_2) - Site Preparation and Foundation		100,000		
New 850,000 gal. V. J. Tank		2,500,000		
Hex and Transfer Plumbing		150,000		
Electrical		50,000		
Sub Total				2,800,000
Design 4,000 hours	50,000			2,850,000
Conversion of RP-1 to JP-4 (Pump and Plumbing Conversion)				20,000
Total - Propellant Mods			Total (Excludes LUT Plumbing)	2,870,000
		Round to $3.0M x 2 Pads		6,000,000
Flame Deflector Modification	500,000	x 2 Pads		1,000,000
GRAND TOTAL				7,000,000

E-3. KSC Facility Modification Cost

VEHICLE MURP/SERV	LUT MODS			
ITEM	DESIGN	MATERIAL	CONSTRUCTION LABOR	TOTAL
Removal of Mech/Elec. Equip - 120 ft up				500,000
Removal of Struc. Steel - 120 ft up				1,500,000
Structural Steel LUT Base - Mod				3,500,000
Flame Deflector Segments				200,000
LUT-to-Crawler Interface				250,000
Relocate Hammerhead Crane				100,000
Umbilical Arms (2 arms plus Access Arm)				500,000
Elevator-Machinery-1 room Relocate, Emergency Egress				500,000
TSM-Electrical				250,000
TSM-Propellant Servicing				250,000
Propellant - MURP				
LO_2-Line Mod U.T. to Vehicle				100,000
LH_2-Line Mod U.T. to Vehicle				100,000
Pneumatics, GN_2, GHe				600,000
ECS				500,000
Electrical				750,000
Holddown Arm System				500,000
Water Quench				300,000
Qual., Test, TSM's, S.A.'s and AAA				250,000
Sub Total				10,650,000
Refurbishment and Spares				400,000
Supervision/Management - 5%				660,000
Design - 12%				1,320,000
Total				13,030,000
Activation, Integration and Checkout				1,970,000
GRAND TOTAL (Each)				15,000,000

E-4. KSC Facility Modification Cost

VEHICLE MURP/SERV			SUMMARY - VAB	
ITEM	DESIGN	MATERIAL	CONSTRUCTION LABOR	TOTAL
High Bay's, Rounded				6,000,000
Low Bay's, Rounded				1,000,000
Mechanical Checkout Equipment				3,055,000
Electrical Checkout Equipment				2,570,000
Grand Total				12,625,000
Round To				13,000,000

E-5. KSC Facility Modification Cost

VEHICLE MURP/SERV			VAB, HIGH BAY	
ITEM	DESIGN @ $10.25/hr	MATERIAL ($)	CONSTRUCTION LABOR @ $15.00/hr	TOTAL
Remove existing platforms			1,200-hrs	72,000
SERV Access Platform (Fabricate @ $12.50/hr, Install @ $15/hr)	12,000-hrs	65,000	(Fab. 10,000-hrs (Instl. 16,000-hrs	
Platform Services (Pneumatics, Power, Water) - Including Labor		60,000		
Two 20-Ton Hoists (Installed) for Platform Adjustment		40,000		
				653,000
MURP Access Platform (Fabricate @ $12.50/hr, Install @ $15/hr)	9,000-hrs	45,000	(Fab. 9,000-hrs (Instl. 13,000-hrs	
Services (Pneumatics, Power, Water)		50,000		
Two 15-Ton Hoists for Platform Adjustment (Installed)		34,000		
				528,750
Total for One High Bay				1,253,750
Four Bays - GRAND TOTAL				5,015,000

E-6. KSC Facility Modification Cost

VEHICLE MURP/SERV			VAB, LOW BAY	
ITEM	DESIGN ($)	MATERIAL ($)	CONSTRUCTION LABOR ($)	TOTAL ($)
Remove SII and SIVB Access Equipment				
3-days x 20-men x 8-hrs x 6-sets				
@ $10/hr			30,000	
Equipment Rental - Crane and Low Boy			20,000	
			Sub Total	50,000
MURP Access Equipment	25,000	72,000		
		6-stands @		
		12,000 ea		
Services - Pneumatics		20,000		
Electrical		60,000		
Special Equipment		75,000		
Storage and Monitoring		50,000		
	Sub Total	302,000	Sub Total	302,000
Cargo Module	50,000			
Access stands 15,000 x 4 stands		60,000		
Services - Pneumatic		20,000		
Electrical		20,000		
Special Equipment		50,000		
Storage and Monitoring		40,000		
	Sub Total	240,000	Sub Total	240,000
Low Bay Door Mod (Widen from 55 ft to				
90 ft)	25,000			
Remove Existing Structure		15-tons @$300/ton	50,000	
			2400-hrs @ $15/hr	
New Door Structure		4,500	36,000	
New 90 ft Door		50,000	20,000	
Control Equipment		10,000		
			Sub Total	195,500
GRAND TOTAL				787,500

(Sheet 1 of 2)

E-7. KSC Facility Modification Cost

VEHICLE MURP/SERV	VAB CHECKOUT EQUIPMENT			
ITEM	DESIGN	MATERIAL	CONSTRUCTION LABOR	TOTAL ($)
Mechanical Checkout Equipment				3,055,000
Pneumatic				
Pressure Switch Modules				412,000
Transducer Modules				412,000
Universal Pressure Test Modules				300,000
Carry-On Equipment				162,000
Fuel Systems				
Leak Test Modules				185,000
Control Systems Modules				210,000
Carry-On Equipment				102,000
Oxidizer System				
Leak Test Modules				185,000
Control Systems Modules				210,000
Carry-On Equipment				102,000
Hydraulic Systems				
Cycle/Re-Service Modules				225,000
Miscellanecus				
Fuel Control Checkout Cells				330,000
Lift Engine Removal Instl. Equipment				125,000
Boost Engine Module R&R Equip.				125,000
Mechanical Sub-Total				3,055,000

(Sheet 2 of 2)

E-7. KSC Facility Modification Cost (continued)

VEHICLE MURP/SERV			VAB CHECKOUT EQUIPMENT	
ITEM	DESIGN	MATERIAL	CONSTRUCTION LABOR	TOTAL ($)
Electrical Checkout Equipment				2,370,000
Electrical Ordnance				70,000
Propellants				200,000
Networks Communications				110,000
Environmental Control				130,000
Sequencing				90,000
Power				
Batteries				160,000
Solid State Power Supplies				170,000
Power Distribution				130,000
Guid/Nav/Ctl				
Stabilization and Control				390,000
Guidance				200,000
Attitude Control				200,000
EDS				150,000
Checkout Computer				
Vehicle Interface				130,000
Instrumentation				
Measuring				130,000
Telemetry				150,000
RF				160,000
Electrical Sub-Total				2,570,000
Checkout Equipment Total				5,625,000

E-8. KSC Facility Modification

VEHICLE SERV/MURP	LCC MODS			
ITEM	DESIGN ($)	MATERIAL ($)	CONSTRUCTION LABOR ($)	TOTAL ($)
Assume 100 New Patchboard Changes and 100 New Console Panels (Monitor of Instrumentation Only). Requirements too indefinite to List				
Per Firing Room	5,000-hrs			
100 New Patchboards	50,000	50,000		
100 New Panels @ $10,000 ea		1,000,000		
Remove Sat V Equipment			150,000	
Propellant System Mods	5,000-hrs			
a) PTCR Changes	50,000		50,000	
b) Tanking Computer Changes		100,000		
Elect. Design and Integration 25-men x 1/3-yr x 2000-hrs @ $10/hr			168,000	
Sub Total - (Per LCC Room)				1,618,000
TOTAL x 3				4,854,000
Contingencies				1,146,000
GRAND TOTAL				6,000,000

E-9. KSC Facility Modification Cost

VEHICLE MURP/SERV	SERV LANDING PADS			
ITEM	**DESIGN**	**MATERIAL ($)**	**CONSTRUCTION LABOR ($)**	**TOTAL ($)**
SERV Pad - One Landing Pad				
121,500-yds. Reinforced Concrete @ $15/yd, Poured		1,822,500		
84,000-yds. Crushed Rock @ $4/yd Installed		336,000		
Sand Flotation and Rolling			30,000	2,188,500
GSE				
1000-ft H.P. 3 inch Carbon Steel tubing @ $10/ft. Installed		10,000		
2000-ft 4 inch Water Pipe @ $4/ft Installed		8,000		
One Pneumatics Panel and Enclosure		10,000		
Power Cables and Outlets		8,000		
Hydrogen Vent Disposal		20,000		
	Sub Total	56,000		56,000
TOTAL - ONE SERV PAD				2,244,500
Two Pads				4,489,000
Design @ 6%				270,000
Roadways				241,000
GRAND TOTAL -				5,000,000

APPENDIX D

DETAIL COST SUMMARY

AND TOTAL PROGRAM COST DISTRIBUTION

Personnel Module

COST SUMMARY

WORK BREAKDOWN STRUCTURE NME	WBS LEVEL	DOLLAR VALUE	PERCENT OF TOTAL PROGRAM
PROPULSION	4	$ 242.02	02.97
LIFT ENGINES	5	$ 133.00	01.63
ATTITUDE CONTROL	5	$ 109.02	01.34
AVIONICS	4	$ 217.85	02.67
GUIDANCE + NAV.	5	$ 77.37	00.95
INSTRUMENTATION	5	$ 95.22	01.17
COMMUNICATIONS	5	$ 45.26	00.56
AIRFRAME	4	$ 696.57	08.54
STRUCTURES	5	$ 618.37	07.58
TPS	5	$ 78.20	00.96
POWER	4	$ 181.48	02.23
ELECTRICAL PWR	5	$ 165.47	02.03
HYD-PNEU SYSTEM	5	$ 16.01	00.20
SYSTEMS SUPPORT	4	$ 1000.75	12.27
SYSTEM ENG. + IVT	5	$ 160.37	01.97
PROJECT MGT.	5	$ 177.79	02.18
FACILITIES-EQUIP.	5	$ 198.20	02.43
GSE	5	$ 132.66	01.63
TRAINING	5	$ 71.99	00.88
GROUND TEST	5	$ 259.74	03.19
SPACECRAFT	3	$ 784.00	09.62
MAIN ENGINE	3	$ 556.00	06.82
FLIGHT TEST	3	$ 850.12	10.43
SERV FLIGHT TEST	4	$ 669.40	08.21

COST SUMMARY

WORK BREAKDOWN STRUCTURE NAME	WBS LEVEL	DOLLAR VALUE	PERCENT OF TOTAL PROGRAM
MATED	4	$ 100.40	01.23
SUPPORT	4	$ 80.32	00.99
MGT. + INTG. RDT+E	3	$ 183.92	02.26
SYS ENG PROGRAM	4	$ 147.14	01.80
PROGRAM MGT	4	$ 36.78	00.45
TOTAL COST RDT+E	2	$ 4712.71	57.80
SERV PROJECT INVST	3	$ 1294.11	15.87
PROPULSION	4	$ 47.50	00.58
LIFT ENGINES	5	$ 31.41	00.39
ATTITUDE CONTROL	5	$ 16.09	00.20
AVIONICS	4	$ 28.11	00.34
GUIDANCE + NAVG	5	$ 15.29	00.19
INSTRUMENTATION	5	$ 10.60	00.13
COMMUNICATIONS	5	$ 2.22	00.03
AIRFRAME	4	$ 385.70	04.73
STRUCTURES	5	$ 342.68	04.20
TPS	5	$ 41.09	00.50
LANDING SYSTEM	5	$ 1.93	00.02
POWER	4	$ 47.00	00.58
ELECTRICAL	5	$ 43.05	00.53
HYD-PNEU SYSTEM	5	$ 3.95	00.05
ASSEMBLY-CHECKOUT	4	$ 18.07	00.22
SYSTEMS SUPPORT	4	$ 462.87	05.68
SERV PROJECT MGT	5	$ 65.69	00.81

Personne.

WORK BREAKDOWN STRUCTURE LINE	WBS LEVEL	DOLLAR VALUE	PERCENT OF TOTAL PROGRAM
FACILITIES + EQUIP	5	$ 48.76	00.60
GSE	5	$ 92.86	01.14
INITIAL OPS SPARES	5	$ 156.02	01.91
SUSTAINING ENG.	5	$ 99.54	01.22
SPACECRAFT	3	$ 204.00	02.50
MAIN ENGINE	3	$ 94.85	01.16
TOTAL SERV PRO. INV	2	$ 1498.11	18.37
OPERATIONS	9	$ 1802.30	22.11
LIFT ENG PROJ.MGT	5	$ 3.50	00.04
MN ENG PROJ MGT	5	$ 3.50	00.04
S/C PROJ MGT	5	$ 3.50	00.04
SERV SUS ENGR	5	$ 7.00	00.09
R+D VEHICLE MODS	3	$ 210.01	02.58
OPERATIONS YR 1		$ 76.00	00.93
YR 2		$ 90.10	01.11
YR 3		$ 104.10	01.28
YR 4		$ 135.60	01.66
YR 5		$ 163.90	02.01
YR 6		$ 196.50	02.41
YR 7		$ 229.10	02.81
YR 8		$ 256.60	03.15
YR 9		$ 275.20	03.38
YR10		$ 275.20	03.38
FIRST UNIT COST SLRV		$ 350.02	04.29

Personnel Module

TOTAL PRO. COST DISTRIBUTION

FISCAL YEAR	DOLLAR VALUE	PERCENT OF TIME	PERCENT OF COST	DISCOUNT DOLLARS
01	$ 62.56	06.25	00.77	$ 56.87
02	$ 296.05	12.50	03.63	$ 244.67
03	$ 595.03	18.75	07.30	$ 447.05
04	$ 807.43	25.00	09.90	$ 551.49
05	$ 1023.70	31.25	12.56	$ 635.64
06	$ 1260.56	37.50	15.46	$ 711.55
07	$ 1203.60	43.75	14.76	$ 617.64
08	$ 845.87	50.00	10.37	$ 394.60
09	$ 403.70	56.25	04.95	$ 171.21
10	$ 153.10	62.50	01.88	$ 59.03
11	$ 181.40	68.75	02.22	$ 63.58
12	$ 214.00	75.00	02.62	$ 68.19
13	$ 246.60	81.25	03.02	$ 71.43
14	$ 274.10	87.50	03.36	$ 72.18
15	$ 292.70	93.75	03.59	$ 70.07
16	$ 292.70	00.00	03.59	$ 63.70

TOTAL PROGRAM COST $ 8153.12 TOTAL PROGRAM COST DIS DOL $ 4298.90

CASE NO.	DOTE START	DOTE DURATION	DDTE A	DDTE B	INVEST A	INVEST B	INVEST ST.	INVEST DUR.
02	01	09	0.32	0.68	0.00	0.68	05	05

MURP

COST SUMMARY

WORK BREAKDOWN STRUCTURE NAME	WBS LEVEL	DOLLAR VALUE	PERCENT OF TOTAL PROGRAM
PROPULSION	4	$ 242.02	02.40
LIFT ENGINES	5	$ 133.00	01.32
ATTITUDE CONTROL	5	$ 109.02	01.08
AVIONICS	4	$ 217.85	02.16
GUIDANCE + NAV.	5	$ 77.37	00.77
INSTRUMENTATION	5	$ 95.22	00.94
COMMUNICATIONS	5	$ 45.26	00.45
AIRFRAME	4	$ 606.57	06.00
STRUCTURES	5	$ 618.37	06.13
TPS	5	$ 78.20	00.77
POWER	4	$ 181.48	01.80
ELECTRICAL PWR	5	$ 165.47	01.64
HYD-PNEU SYSTEM	5	$ 16.01	00.16
SYSTEMS SUPPORT	4	$ 1000.75	09.92
SYSTEM ENG. + IVT	5	$ 160.37	01.59
PROJECT MGT.	5	$ 177.70	01.76
FACILITIES-EQUIP.	5	$ 198.20	01.96
GSE	5	$ 132.66	01.31
TRAINING	5	$ 71.99	00.71
GROUND TEST	5	$ 259.78	02.57
SPACECRAFT	3	$ 2515.00	24.92
MAIN ENGINE	3	$ 556.00	05.51
FLIGHT TEST	3	$ 850.12	08.42
SERV FLIGHT TEST	4	$ 669.40	06.63

MURP

COST SUMMARY

WORK BREAKDOWN STRUCTURE NME	WBS LEVEL	DOLLAR VALUE	PERCENT OF TOTAL PROGRAM
MATED	4	$ 100.40	00.99
SUPPORT	4	$ 80.32	00.80
MGT. + INTG. RDT+E	3	$ 270.47	02.68
SYS ENG PROGRAM	4	$ 216.38	02.14
PROGRAM MGT	4	$ 54.09	00.54
TOTAL COST RDT+E	2	$ 6530.26	64.71
SERV PROJECT INVST	3	$ 1294.11	12.82
PROPULSION	4	$ 47.50	00.47
LIFT ENGINES	5	$ 31.41	00.31
ATTITUDE CONTROL	5	$ 16.09	00.16
AVIONICS	4	$ 28.11	00.28
GUIDANCE + NAVG	5	$ 15.29	00.15
INSTRUMENTATION	5	$ 10.60	00.11
COMMUNICATIONS	5	$ 2.22	00.02
AIRFRAME	4	$ 385.70	03.82
STRUCTURES	5	$ 342.68	03.40
TPS	5	$ 41.09	00.41
LANDING SYSTEM	5	$ 1.93	00.02
POWER	4	$ 47.00	00.47
ELECTRICAL	5	$ 43.05	00.43
HYD-PNEU SYSTEM	5	$ 3.95	00.04
ASSEMBLY + CHECKOUT	4	$ 18.07	00.18
SYSTEMS SUPPORT	4	$ 462.87	04.59
SERV PROJECT MGT	5	$ 65.69	00.65

MURP

COST SUMMARY

WORK BREAKDOWN STRUCTURE NAME	WBS LEVEL	DOLLAR VALUE	PERCENT OF TOTAL PROGRAM
FACILITIES + EQUIP	5	$ 88.76	00.88
GSC	5	$ 92.86	00.92
INITIAL OPS SPARES	5	$ 156.02	01.55
SUSTAINING ENG.	5	$ 99.54	00.99
SPACECRAFT	3	$ 254.00	02.52
MAIN ENGINE	3	$ 94.85	00.94
TOTAL SERV PRO. INV	2	$ 1548.11	15.34
OPERATIONS	4	$ 1872.90	18.56
LIFT ENG PROJ.MGT	5	$ 3.50	00.03
MN ENG PROJ MGT	5	$ 3.50	00.03
S/C PROJ MGT	5	$ 3.50	00.03
SERV SUS ENGR	5	$ 7.00	00.07
R+D VEHICLE MOCS	3	$ 210.01	02.08
OPERATIONS YR 1		$ 76.50	00.76
YR 2		$ 92.90	00.92
YR 3		$ 107.60	01.07
YR 4		$ 140.60	01.39
YR 5		$ 170.40	01.69
YR 6		$ 204.50	02.03
YR 7		$ 238.60	02.36
YR 8		$ 268.00	02.66
YR 9		$ 286.90	02.84
YR10		$ 286.90	02.84
FIRST UNIT COST SERV		$ 350.02	03.47

MCRP

TOTAL PRO. COST DISTRIBUTION

FISCAL YEAR	DOLLAR VALUE	PERCENT OF TIME	PERCENT OF COST	DISCOUNT DOLLARS
01	$ 83.05	06.25	00.82	$ 75.50
02	$ 411.37	12.50	04.08	$ 340.47
03	$ 833.91	18.75	08.26	$ 626.53
04	$ 1143.05	25.00	11.33	$ 780.72
05	$ 1398.82	31.25	13.86	$ 868.56
06	$ 1610.53	37.50	15.96	$ 909.10
07	$ 1466.69	43.75	14.53	$ 752.64
08	$ 987.17	50.00	09.78	$ 460.52
09	$ 437.64	56.25	04.34	$ 185.60
10	$ 158.10	62.50	01.57	$ 60.95
11	$ 187.90	68.75	01.86	$ 65.86
12	$ 222.00	75.00	02.20	$ 70.74
13	$ 256.10	81.25	02.54	$ 74.18
14	$ 285.50	87.50	02.83	$ 75.18
15	$ 304.40	93.75	03.02	$ 72.87
16	$ 304.40	00.00	03.02	$ 66.25

TOTAL PROGRAM COST $10091.27 TOTAL PROGRAM COST DIS DOL $ 5485.67

CASE NO.	DOTE START	DOTE DURATION	DOTE A	DOTE B	INVEST A	INVEST B	INVEST ST.	INVEST DUR.
03	01	09	0.32	0.68	0.00	0.68	05	05

SERV Only

COST SUMMARY

WORK BREAKDOWN STRUCTURE NME	WBS LEVEL	DOLLAR VALUE	PERCENT OF TOTAL PROGRAM
PROPULSION	4	$ 242.02	03.58
LIFT ENGINES	5	$ 133.00	01.97
ATTITUDE CONTROL	5	$ 109.02	01.61
AVIONICS	4	$ 217.85	03.22
GUIDANCE + NAV.	5	$ 77.37	01.14
INSTRUMENTATION	5	$ 95.22	01.41
COMMUNICATIONS	5	$ 45.26	00.67
AIRFRAME	4	$ 696.57	10.30
STRUCTURES	5	$ 618.37	09.15
TPS	5	$ 78.20	01.16
POWER	4	$ 181.46	02.68
ELECTRICAL PWR	5	$ 165.47	02.45
HYD-PNEU SYSTEM	5	$ 16.01	00.24
SYSTEMS SUPPORT	4	$ 1000.75	14.80
SYSTEM ENG. + IVT	5	$ 160.37	02.37
PROJECT MGT.	5	$ 177.79	02.63
FACILITIES-EGUIP.	5	$ 198.20	02.93
GSE	5	$ 132.66	01.96
TRAINING	5	$ 71.99	01.06
GROUND TEST	5	$ 259.74	03.84
MAIN ENGINE	3	$ 556.00	08.22
FLIGHT TEST	3	$ 850.12	12.57
SERV FLIGHT T-ST	4	$ 669.40	09.90
MATED	4	$ 100.40	01.49

SERV Only

COST SUMMARY

WORK BREAKDOWN STRUCTURE NAME	WBS LEVEL	DOLLAR VALUE	PERCENT OF TOTAL PROGRAM
SUPPORT	4	$ 80.32	01.19
MGT. + INTG. RDT+E	3	$ 144.72	02.14
SYS ENG PROGRAM	4	$ 115.78	01.71
PROGRAM MGT	4	$ 28.94	00.43
TOTAL COST RDT+E	2	$ 3889.51	57.53
SERV PROJECT INVST	3	$ 1294.11	19.14
PROPULSION	4	$ 47.50	00.70
LIFT ENGINES	5	$ 31.41	00.46
ATTITUDE CONTROL	5	$ 16.09	00.24
AVIONICS	4	$ 28.11	00.42
GUIDANCE + NAVG	5	$ 15.29	00.23
INSTRUMENTATION	5	$ 10.60	00.16
COMMUNICATIONS	5	$ 2.22	00.03
AIRFRAME	4	$ 385.70	05.71
STRUCTURES	5	$ 342.68	05.07
TPS	5	$ 41.09	00.61
LANDING SYSTEM	5	$ 1.93	00.03
POWER	4	$ 47.00	00.70
ELECTRICAL	5	$ 43.05	00.64
HYD-PNEU SYSTEM	5	$ 3.95	00.06
ASSEMBLY-CHECKOUT	4	$ 18.07	00.27
SYSTEMS SUPPORT	4	$ 462.87	06.85
SERV PROJECT MGT	5	$ 65.69	00.97
FACILITIES + EQUIP	5	$ 48.76	00.72

SERV Only

COST SUMMARY

WORK BREAKDOWN STRUCTURE NME	WBS LEVEL	DOLLAR VALUE	PERCENT OF TOTAL PROGRAM
GSE	5	$ 92.86	01.37
INITIAL OPS SPARES	5	$ 156.02	02.31
SUSTAINING ENG.	5	$ 99.54	01.47
MAIN ENGINE	3	$ 94.85	01.40
TOTAL SERV PRO. INV	2	$ 1294.11	19.14
OPERATIONS	9	$ 1436.80	21.25
LIFT ENG PROJ.MGT	5	$ 3.50	00.05
MN ENG PROJ MGT	5	$ 3.50	00.05
S/C PROJ MGT	5	$ 3.50	00.05
SERV SUS ENGR	5	$ 7.00	00.10
R+D VEHICLE MODS	3	$ 210.01	03.11
OPERATIONS YR 1		$ 58.20	00.86
YR 2		$ 71.20	01.05
YR 3		$ 82.60	01.22
YR 4		$ 107.80	01.59
YR 5		$ 130.90	01.94
YR 6		$ 156.40	02.31
YR 7		$ 182.50	02.70
YR 8		$ 205.40	03.04
YR 9		$ 220.90	03.27
YR10		$ 220.90	03.27
FIRST UNIT COST SERV		$ 350.02	05.18

SERV Only

TOTAL PRO. COST DISTRIBUTION

FISCAL YEAR	DOLL ? VALUE	PERCENT OF TIME	PERCENT OF COST	DISCOUNT DOLLARS
01	$ 53.27	06.25	00.79	$ 48.43
02	$ 243.54	12.50	03.60	$ 201.27
03	$ 486.83	18.75	07.20	$ 365.76
04	$ 655.42	25.00	09.69	$ 447.66
05	$ 846.26	31.25	12.52	$ 525.46
06	$ 1065.38	37.50	15.76	$ 601.38
07	$ 1007.38	43.75	14.90	$ 516.95
08	$ 708.99	50.00	10.49	$ 330.75
09	$ 346.02	56.25	05.12	$ 146.75
10	$ 125.30	62.50	01.85	$ 48.31
11	$ 148.40	68.75	02.20	$ 52.01
12	$ 173.90	75.00	02.57	$ 55.41
13	$ 200.00	81.25	02.96	$ 57.93
14	$ 222.90	87.50	03.30	$ 58.70
15	$ 238.40	93.75	03.53	$ 57.07
16	$ 238.40	00.00	03.53	$ 51.88

TOTAL PROGRAM COST $ 6760.42 TOTAL PROGRAM COST DIS DOL $ 3565.72

CASE NO.	DDTE START	DDTE DURATION	DDTE A	DDTE B	INVEST A	INVEST B	INVEST ST.	INVEST DUR.
04	01	09	0.32	0.68	0.00	0.68	05	05