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NASA TECHNICAL MEMORANDUM

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OPTIMUM REPAIR LEVEL ANALYSIS (ORLA) FOR THE SPACE TRANSPORTATION SYSTEM (STS)

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TECHNICAL MEMORANDUM

OPTIMUM REPAIR LEVEL ANALYSIS (ORLA) FOR THE SPACE TRANSPORTATION SYSTEM (STS)

I. INTRODUCTION

Planning the operational phase of hardware systems should include the determination of the most cost-effective level of repair for reparable hardware and the location for the repair. Such a requirement was formally imposed upon all projects of the Space Shuttle Program by the Level II program definition and requirements document, JSC 07700, Volume XII, Integrated Logistics Requirements, which states: "An Optimum Repair Level Analysis (ORLA) shall be accomplished to recommend repair levels for line replaceable units (LRU), assemblies, and sub-assemblies which will accrue minimum total support costs within operational and technical constraints over the system design life."

Ideally, the analysis should be by methods which are logical, repeatable, rapid, and flexible enough to provide for future reassessments as program data accumulates. Air Force Manual AFLCM/AFSCM 800-4, Optimum Repair Level Analysis (ORLA) presents a method which embodies many of these desirable properties and includes equations for comparison of selected costs to completion for assumed repair alternates. Applications of this method, however, must be tailored to individual program peculiarities.

This memorandum presents an adaptation of the Air Force ORLA method to a Space Shuttle Scenario. The Air Force designation and abbreviation style for cost equations have been retained. Those equations having the identical definitions as applied by the Air Force retain identical abbreviations; however, their constants may have been changed to fit the Space Shuttle Scenario. The "vendor repair" cost buildup and many cost equations and methods were originated to suit requirements of this scenario which are not addressed by the Air Force publication. As with the Air Force ORLA, only those costs which discriminate between repair alternates are considered.

II. TOTAL ORLA PROCEDURE

Hardware repair policies should be based upon all available and pertinent information. This ORLA cost comparison process will assist in the identification of candidate items for cost effective repair at Kennedy Space Center (KSC) on the basis (and within the limits) of its programmed equations. The management body responsible for ORLA decisions should always use the cost comparisons available from this (or other formal computation programs) in conjunction with any pertinent cost, programmatic, or other information not included in the cost equations. The analyst must thoroughly understand the basis for all mechanized computations in order to assist in relating the outputs to these other pertinent data. Figure 1 illustrates the overall process.

Conversely, the cost equations should be as nearly representative of the project under consideration as feasible to minimize the need for additional cost adjustments. The scenario and equations which follow were designed for this purpose.

III. ORLA SCENARIO

A. Maintenance Designations

1. Customary Nomenclature. The customary scenario consists of an option to discard failed hardware and three maintenance options: organizational, intermediate, and depot (Fig. 2).

The "organizational" level includes those scheduled and unscheduled preventive and corrective actions required for direct support of turnaround flow. To the extent that this activity is common to all ensuing alternate hardware repair actions, associated costs do not provide cost discrimination.

"Intermediate" and "depot" levels are normally assumed to be at different locations with higher requirements for personnel skills, training, documentation, etc., for the depot level. The basic US Air Force ORLA equations for these modes differ only in their constants.

The "discard" option trades the costs associated with replacing an item against the costs of repair options.

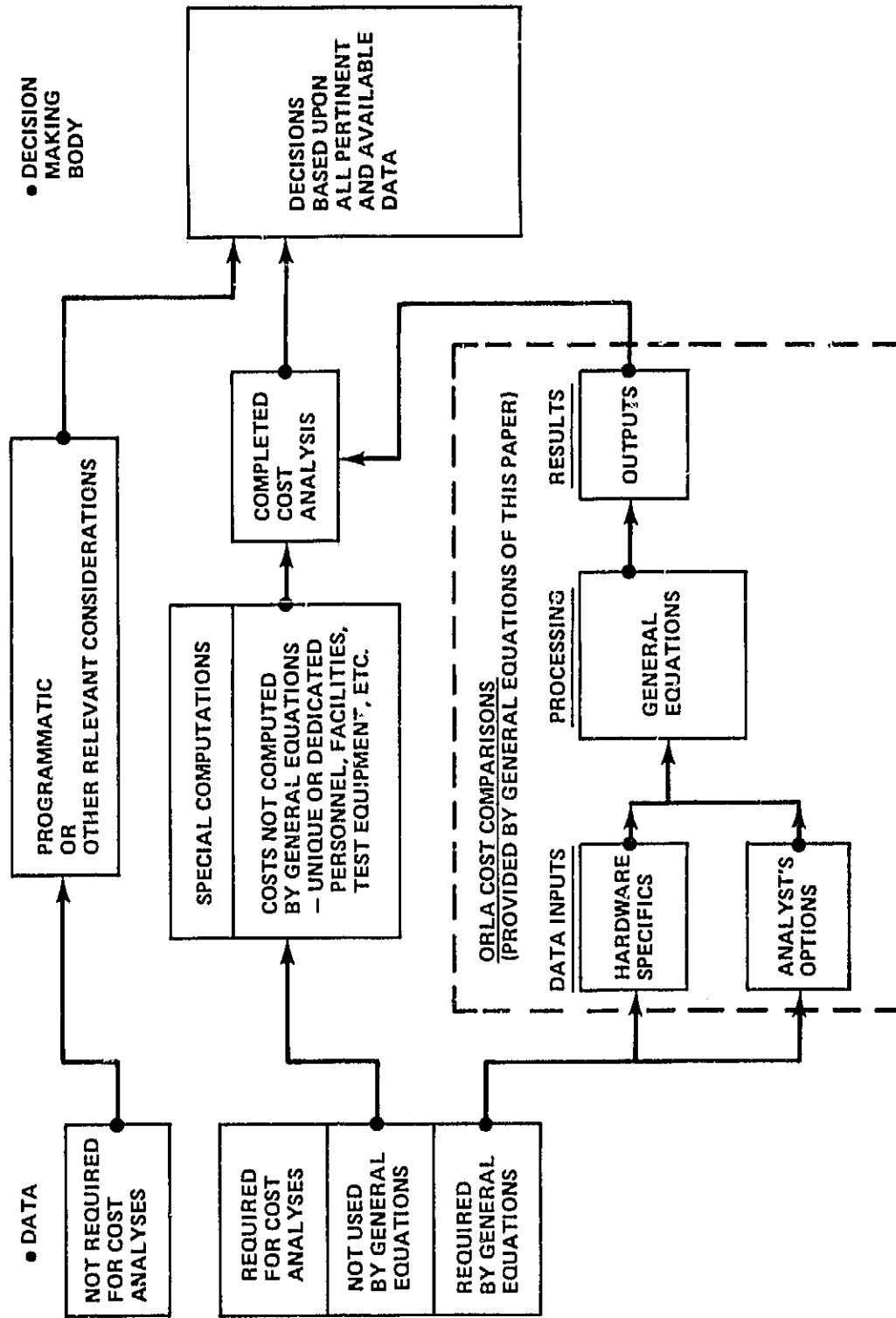
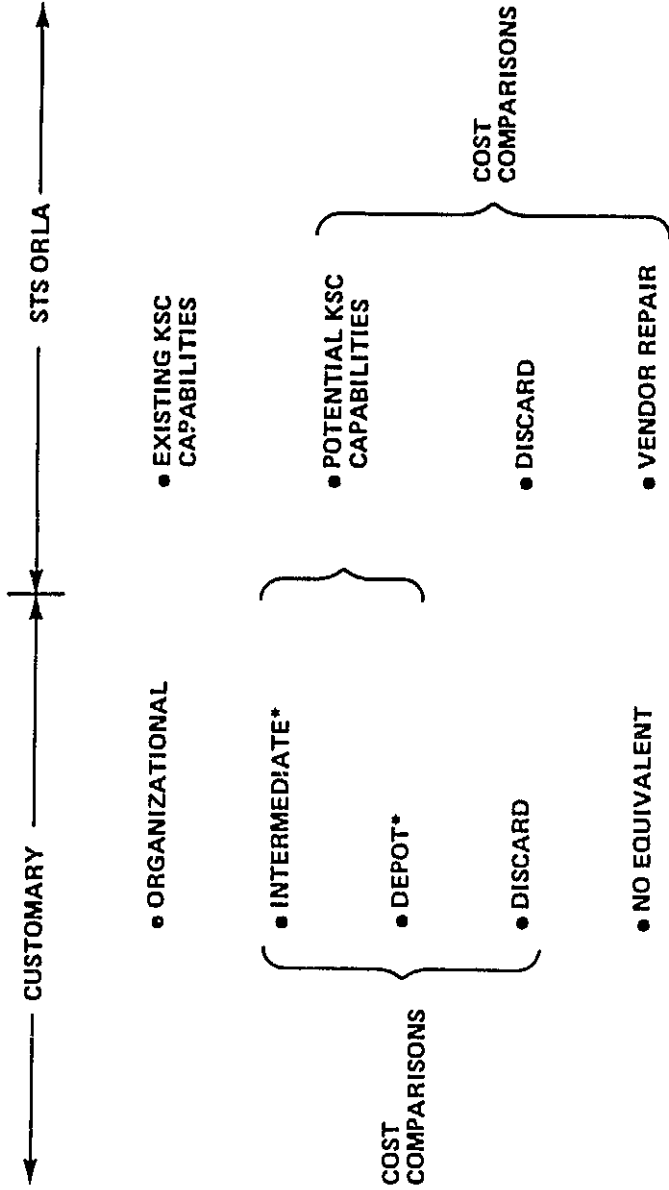


Figure 1. Total ORLA procedure.



*IDENTICAL EQUATIONS WITH DIFFERING CONSTANTS

Figure 2. Comparison of maintenance designations.

2. STS Nomenclature. The maintenance designations for this scenario, which assumes that KSC is the operational site, relate to the customary nomenclature as follows.

"Existing KSC capabilities" is analogous to "organizational" maintenance. It may be considered to include any established or agreed to maintenance and support activities, regardless of level, having costs which would not be discriminators in a new cost study.

The category "potential KSC capabilities" may contain any level of repair under consideration. In the equations it is assumed that labor and overhead rates are independent of level of repair and that other variations between "intermediate" and "depot" levels such as training, documentation, etc., are accounted for by inputs specific to the items being studied.

The "discard" options correspond between the two systems of nomenclature.

An automatically available repair option for much of the space transportation system (STS) hardware will be "vendor repair." A primary concern of the STS ORLA is to investigate the feasibility of initiating repair at KSC which would be cost effective by comparison to "vendor repair." If actual vendor cost data is available, it obviously should be used for comparisons. The equations assembled for this option; however, build up vendor repair costs by the procedure normal to industry and based upon the same manhours and parts costs assumed for the other repair options. Therefore, it should provide a reasonable basis for comparison. The customary ORLA procedure does not contain an analogous program.

B. Logic Flow

The assumed logic flow is depicted in Figure 3.

1. Existing KSC Capabilities. Figure 3(a) identifies as "existing KSC capabilities" some of the actions and decisions which are common to all subsequent modes of hardware replacement and repair. "Existing KSC capabilities" are not costed by the equations.

The first decision to discard or repair failed hardware occurs at this level. At the "existing KSC capabilities" level the decision to discard hardware having an estimated repair cost exceeding 65 percent of the original cost of an

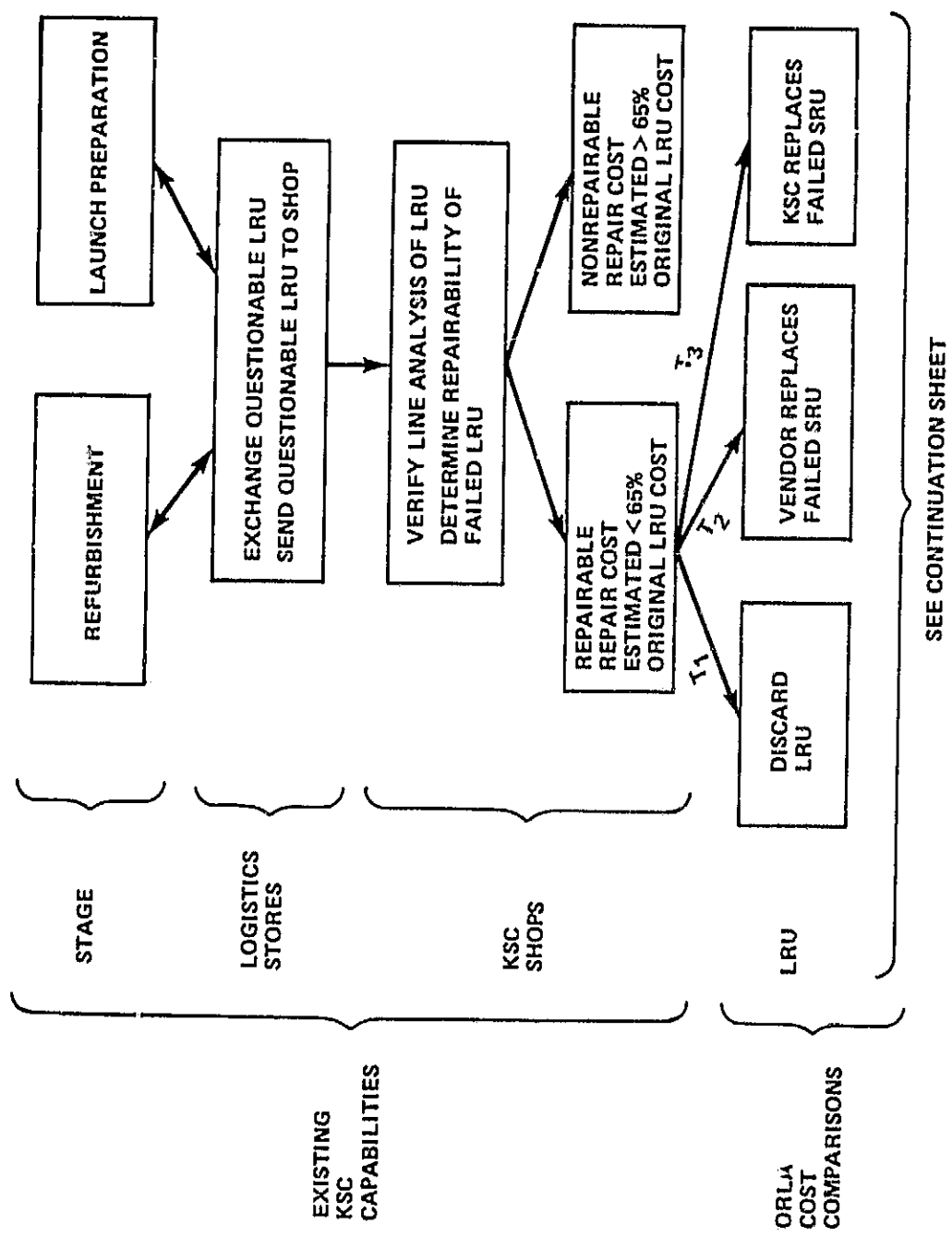


Figure 3(a). ORLA scenario.

SEE CONTINUATION SHEET

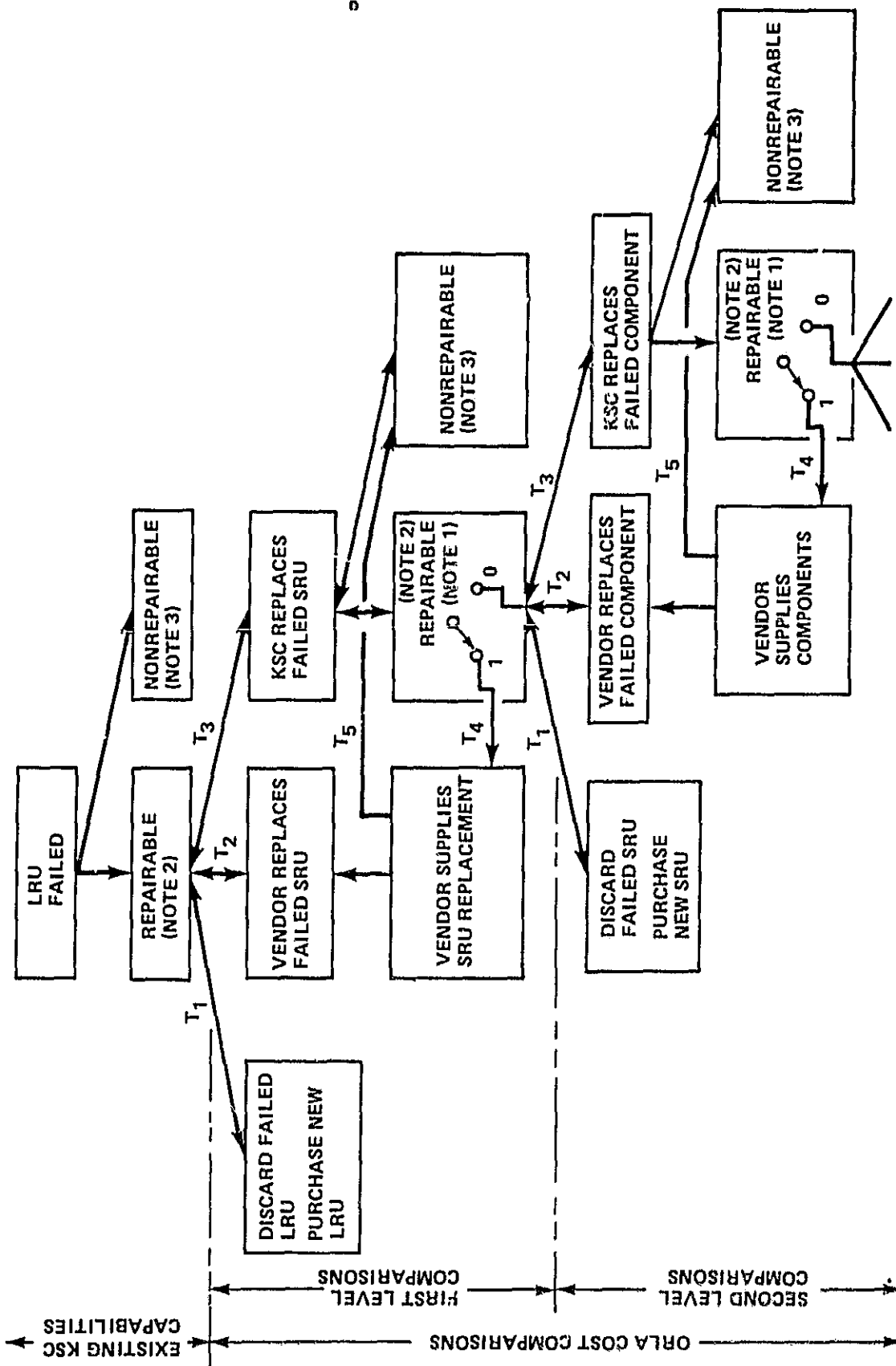


Figure 3(b). (Continued).

NOTES:

1. PATH 1 APPLIES IF LOWER LEVEL REPAIR WILL NOT BE PERFORMED AT KSC. THIS COMPARISON WILL INCLUDE COSTS FOR OBTAINING REPAIR OF LOWER LEVEL HARDWARE FROM A VENDOR.
PATH 0 APPLIES IF LOWER LEVEL REPAIR WILL BE PERFORMED AT KSC. THIS COMPARISON ASSUMES THAT COST-EFFECTIVE REPAIR CAPABILITIES FOR THE LOWER LEVEL HARDWARE EXIST AND EXCLUDES THIS COST FROM THE ANALYSIS.
2. REPAIRABLE – ESTIMATED REPAIR COST < 65% ITEM COST.
3. CLASSIFY AS NONREPAIRABLE
ESTIMATED REPAIR COST > 65% ITEM COST
ITEM COST < \$300 (OR OTHER AGREED TO VALUE)
4. AVERAGE HARDWARE FLOW TIMES (YEARS) – THE FOLLOWING DEFINITIONS APPLY TO FLOW PATHS OF A "FIRST LEVEL" COMPARISON. FOR "SECOND LEVEL" COMPARISON CHANGE LRU TO SRU AND SRU TO COMPONENT IN THESE DEFINITIONS.
 - DISCARD OPTION
 - T₁ – PROCUREMENT OF REPLACEMENT LRU
 - VENDOR REPAIR OPTION
 - T₂ – ROUND TRIP BETWEEN KSC AND VENDOR FOR LRU REPAIR
 - REPAIR AT KSC OPTION
 - T₃ – DWELL TIME OF LRU IN POTENTIAL KSC SHOP
 - T₄ – ROUND TRIP BETWEEN KSC AND VENDOR FOR REPAIRABLE SRU
 - T₅ – PROCUREMENT OF REPLACEMENT NONREPAIRABLE SRU

Figure 3(c). (Concluded).

LRU does not affect the subsequent decision making process; however, the same decision on Figure 3(b) in the "first" and "second level comparisons" results in hardware attrition which is costed by the equations.

2. First and Second Level Comparisons. First or second level comparisons are made individually by use of the same ORLA program. The nomenclature throughout this publication applies to a "first level" comparison; i.e., cost related to stocking and replacing shop replaceable units (SRU) into LRU's. For "second level comparisons" (cost related to stocking and replacing components into SRU's), all procedures and equations apply when references to LRU's and SRU's are changed to SRU's and components respectively. The similarity of these two levels of comparison is illustrated in Figure 3(b).

The preceding definitions of "first" and "second" level comparisons state "stock" and "replace" rather than "repair" in order to emphasize that the ORLA process uses stocking and replacing of identical items as the basis for maintaining comparability between cost options.

Hardware flow times identified as T_1 , etc., determine the investments in hardware to which they pertain. Definitions for these times are shown in Figure 3(c). The flow times indicated by T_1 , T_2 , and T_3 determine the investment in LRU's for each option. It was assumed that for STS flight hardware all SRU's and most components would not be readily available. Therefore, investment costs for replacement items are established by flow times T_4 and T_5 rather than by the more conventional computation of the cost of an economic order quantity of short lead time replacements.

IV. REQUIRED INPUT DATA

The most valuable feature of a formal ORLA program is the discipline which it adds to the cost analysis process. The firm definition of a cost evaluation procedure provides a basis for timely and cost effective acquisition of information pertinent to, and restricted to, the procedure. The input data for this ORLA may be defined under the following two heads.

A. Equipment Data

These data (Fig. 4) relate directly to the equipment under consideration. The logistics organization must obtain these primarily from the responsible design and procurement organizations. Ideally, these requirements should be established as deliverable data to be provided with the hardware.

EQUIPMENT OR SUBASSEMBLY NAME _____
 IDENTIFYING NUMBER _____

REQUIRED DATA	
Q	QUANTITY PER LAUNCH
UR	USAGE RATE (OPERATING HOURS PER LAUNCH)
MTBF	MEAN TIME BETWEEN FAILURES (HOURS)
FPL	FAILURES PER LAUNCH (ESTIMATED OR EXPERIENCED)
UW	UNIT WEIGHT (POUNDS)
UC	UNIT COST (DOLLARS)
SW	WEIGHT OF REPAIR MATERIALS PER REPAIR TASK (POUNDS)
SC	COST OF REPAIR MATERIAL INCLUDING PIECE PARTS (DOLLARS PER TASK)
LA	NUMBER OF REPAIRABLE ASSEMBLIES INTRODUCED INTO INVENTORY (IF UNIT COST < \$300, CLASSIFY AS LP)
LP	NUMBER OF NONREPAIRABLE ASSEMBLIES INTRODUCED INTO INVENTORY
EMH	ESTIMATED MAN HOURS TO REPLACE FAILED ASSEMBLY (AVERAGE)
E	COST OF SPECIAL TEST EQUIPMENT (INCLUDE PACKING, SHIPPING, AND SETUP COSTS)
D	DEDICATION OF SPECIAL TEST EQUIPMENT TO THIS TASK (%)
J	NUMBER OF TECHNICAL DATA PAGES REQUIRED
TD	DURATION OF TRAINING (WEEKS)
B	VENDOR DIRECT LABOR OVERHEAD (%) (USE PROPOSED VALUE, IF AVAILABLE. IF NOT AVAILABLE, ANALYST WILL USE 163%.)
T ₁	PROCUREMENT OF REPLACEMENT LRU (YEARS)
T ₂	ROUND TRIP BETWEEN KSC AND VENDOR FOR LRU REPAIR (YEARS)
T ₃	DWELL TIME OF LRU IN POTENTIAL KSC SHOP (YEARS)
T ₄	ROUND TRIP BETWEEN KSC AND VENDOR FOR REPAIRABLE SRU (YEARS)
T ₅	PROCUREMENT OF REPLACEMENT NONREPAIRABLE SRU (YEARS)

Figure 4. Equipment data.

B. Instructions to Analyst

The values (AR) and (W) may either be calculated and entered as program inputs or they can be programmed for automatic computation (Fig. 5). The other values are available to the analyst to facilitate sensitivity analyses, point to point plots, or other tests for identification of major cost drivers in an analysis.

V. DISCUSSION OF COST EQUATIONS

A. General

The reader will be able to understand the logic of the analysis by directing his attention to the dimensions of the terms comprising each equation. Additional comments are included with those equations which were originated for this ORLA or which are previously published forms with altered constants.

As with other cost estimation processes, assumptions and logic simplifications applied in order to obtain simple yet generally applicable equations reduce the absolute accuracy of the results of individual equations. Compromises are consistently applied across the three options (discard, vendor repair, KSC repair); however, to minimize their influence on the discrimination process.

Cost comparisons are made in constant dollars rather than with consideration of the effects of interest and inflation rates. A method for considering these influences can be provided upon request.

All equations calculate only costs required for direct support of repair actions. It is assumed that appropriate facilities and personnel exist because of other projects and that the task being investigated will be able to draw from these resources as needed. Therefore, if additional special dedicated resources are required, appropriate cost adjustments should be made to the estimates provided by the general equations.

All abbreviations contained within equations represent input data requirements which are defined by Figures 4 and 5.

EQUIPMENT OR SUBASSEMBLY NAME _____
 IDENTIFYING NUMBER _____

INPUT THE FOLLOWING FACTORS
L LAUNCHES PER YEAR USE APPROPRIATE VALUE
PI PERIOD OF INVESTIGATION (YEARS) USE APPROPRIATE VALUE
C FAILURE RATE CORRECTION FACTOR FIRM DATA -- USE 1 QUESTIONABLE DATA -- USE 2.5 OR APPROPRIATE VALUE
X INVENTORY ENTRY COST SELECTOR INCLUDE IE -- USE 1 EXCLUDE IE -- USE 0
AR ASSEMBLY REPLACEMENT RATIO REPLACEMENT OF REPAIRABLE ASSEMBLIES OVER A SELECTED TIME PERIOD $AR \text{ (ACTUAL)} = \frac{\text{TOTAL ASSEMBLY (REPAIRABLE + NONREPAIRABLE) REPLACEMENT OVER SAME TIME PERIOD}}{\text{TOTAL ASSEMBLY (REPAIRABLE + NONREPAIRABLE) REPLACEMENT OVER SAME TIME PERIOD}}$ OR $AR \text{ (ESTIMATED)} = \frac{0.80 \times LA}{LA + LP}$
W NUMBER OF PERSONNEL TO BE TRAINED IF NOT INCLUDED IN COMPUTER PROGRAM, COMPUTE AS FOLLOWS AND ENTER VALUE MANUALLY $W = 2 + \left[\frac{(EMH \times YRR)}{1900} - 2 \right]$ OMIT IF NEGATIVE
Z WILL NEXT LOWER LEVEL OF REPAIR BE AT KSC? NO -- USE 1 YES -- USE 0

Figure 5. Instructions to analyst.

B. Hardware Investment Computations

The form $(\lambda t + \sqrt{K\lambda t})$ is an estimate of the term S in the Poisson equation,

$$P = e^{-\lambda t} \sum_{N=0}^S \frac{(\lambda t)^N}{N!} .$$

Thus, a value chosen for K will correspond to a value of P. When K = 3, the corresponding P will be approximately 96 percent. This value is used throughout the equations as the required support level for LRU's. A value of K = 9 is used in equations (BSLA) and (BSLP) for a support level of approximately 99 percent in order to assure that the repair of LRU's is not delayed for lack of SRU's.

C. Preliminary Computations

1. Yearly Replacement Rate (YRR). The customary term used to indicate the reliability of hardware is mean time between failures (MTBF). Data accumulated from various known usage periods are expressed on the common basis of MTBF and then used to estimate failures for the same hardware in other applications. The reliability of STS hardware will normally be expressed by this term.

For some items of STS hardware, life can be expressed as a repetitive series of essentially identical usage periods. As an example, the period in the life of a missile from the beginning of checkout through launch and burnout is a completely planned sequence which is, except for anomalies, the same for each missile in the family. For such hardware, failure data could be expressed on the basis of the repetitive life period and predictions made without conversion to MTBF.

Since all support of missile launches has customarily been addressed on a per launch basis, equation (YRR) is written to accept reliability data inputs in either the usual unit, MTBF, or a unit representative of the repetitive launch sequence, failures per launch (FPL). This facilitates the direct use of failure rates based upon repetitive program activities.

With the input of launch rate per year (L) and related correction factors the basic demand factor, YRR, is calculated for use throughout all comparisons.

2. Number of Personnel to be Trained (W). Equation (W) was formulated to maintain a consistent relationship between the estimated workload and the estimated number of technicians to be trained for the task.

VI. GENERAL EQUATIONS

A. Preliminary Computations

1. YRR — Yearly Replacement Rate

$$YRR = \left[\frac{(UR)}{(MTBF)} + (FPL) \right] (L)(C)(Q) \quad .$$

2. W — Number of Personnel to be Trained

$$W = 2 + \left[\frac{(EMH \times YRR)}{1900} - 2 \right]$$

Omit if Negative

Assumptions:

- a. If a task is undertaken, a minimum of two personnel will be trained.
- b. Hours per year per technician = 1900.

3. AR — Assembly Replacement Ratio

$$AR = \frac{0.80 \times LA}{LA + LP}$$

Assumptions:

a. All assemblies have the same failure rate; therefore, replacements are directly proportional to assembly counts.

b. Repairable assemblies have a 20 percent mortality rate.

B. Program No. 1, Discard

$$\text{Discard Cost} = \text{RCD} + \text{RPS} + \text{BSLDO}$$

where

RCD = Replacement Cost, Discard Option

RPS = Replacement Packing and Shipping Cost

BSLDO = Base Stock Level Cost for Discard Option.

1. RCD

$$\text{RCD} = (\text{YRR})(\text{UC})(\text{PI})$$

2. RPS

$$\text{RPS} = (\text{YRR})(\text{PI})(\text{UW}) \left[\frac{\text{Cost of Packing Labor}}{\text{lb}} + \frac{\text{Cost of Packing Material}}{\text{lb}} + \left(\frac{\text{Packed Weight}}{\text{Unpacked Weight}} \times \frac{\text{Shipping Cost}}{\text{lb}} \right) \right]$$

where

$$\frac{\text{Cost of Packing Labor}}{\text{lb}} = 0.333$$

$$\frac{\text{Cost of Packing Material}}{\text{lb}} = 0.09875$$

$$\frac{\text{Packed Weight}}{\text{Unpacked Weight}} = 1.285$$

$$\frac{\text{Shipping Cost}}{\text{lb}} = 0.148 \text{ (assumes a distance of 1,000 mi.)}$$

$$\begin{aligned} \text{RPS} &= (\text{YRR})(\text{PI})(\text{UW}) [0.333 + 0.9875 + (1.285 \times 0.148)] \\ &= 0.622 (\text{YRR})(\text{PI})(\text{UW}) \end{aligned}$$

3. BSLDO

$$\text{BSLDO} = (\text{UC}) [(\text{T}_1)(\text{YRR}) + \sqrt{3(\text{T}_1)(\text{YRR})}]$$

C. Program No. 2, Vendor Repair

$$\text{Vendor Cost} = \text{RCV} + \text{VPS} + \text{BSLVO} + \text{IE}$$

where

RCV = Repair Cost, Vendor Option

VPS = Vendor Option Packing and Shipping Cost = 2 (RPS)

BSLVO = Base Stock Level Cost for Vendor Option

IE = Inventory Entry Cost.

1. RCV. This equation builds up costs in the same manner as normally used by vendors.

Assumptions:

Task would be the same if performed either by vendor or KSC.

- a. Vendor direct labor (hours) = KSC direct labor (hours) = EMH.
- b. Vendor would replace same parts as KSC.

$$\frac{\text{Packed Weight}}{\text{Unpacked Weight}} = 1.285$$

$$\frac{\text{Shipping Cost}}{\text{lb}} = 0.148 \text{ (assumes a distance of 1,000 mi.)}$$

$$\begin{aligned} \text{RPS} &= (\text{YRR})(\text{PI})(\text{UW}) [0.333 + 0.9875 + (1.285 \times 0.148)] \\ &= 0.622 (\text{YRR})(\text{PI})(\text{UW}) \end{aligned}$$

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Assumptions:

Task would be the same if performed either by vendor or KSC.

- a. Vendor direct labor (hours) = KSC direct labor (hours) = EMH.
- b. Vendor would replace same parts as KSC.

- c. Charge by vendor for parts (SC) would be identical whether supplied separately to KSC or after cost build-up as parts included in a repair action.

General Equation:

$$\text{RCV} = (\text{YRR})(\text{PI})[\text{SC} + (\text{EMH Labor Rate})(1 + \% \text{ Direct Labor Overhead}) \\ \times (1 + \% \text{ Other Direct Costs})(1 + \% \text{G\&A})(1 + \% \text{ Profit})]$$

Data:

An investigation of current contracts for similar services provided the following values.

- a. Values with such minor variations between vendors as to allow generalization

$$= \text{Direct Labor Rate} = \$ 10.50 \text{ per hour}$$

$$= \text{Other Direct Costs} = 5\%$$

$$= \text{G\&A} = 20.7\%$$

$$= \text{Profit} = 12\%$$

Built up successively

$$\text{These} = 1.42$$

$$\text{i. e., } (1.05)(1.207)(1.12) = 1.42$$

- b. Direct labor overhead varied greatly. An average value of the contracts reviewed was 163 percent. The equation has been written to provide that 163 percent or a better value, B (if available), be used.

Final Equation:

$$\text{RCV} = (\text{YRR})(\text{PI}) \left[\text{SC} + \text{EMH}(10.50) \left(\frac{100 + B}{100} \right) \times 1.42 \right]$$

$$= (\text{YRR})(\text{PI}) [\text{SC} + 0.149(\text{EMH})(100 + B)]$$

$$2. \text{ VPS} = 2 (\text{RPS})$$

$$\text{VPS} = 1.244 (\text{YRR})(\text{PI})(\text{UW})$$

$$\text{Note: VPS} = 2 \times \text{RPS} .$$

3. BSLVO

$$\text{BSLVO} = (\text{UC})[(\text{T}_2)(\text{YRR}) + \sqrt{3(\text{T}_2)(\text{YRR})}] \quad .$$

4. IE

$$\text{IE} = (\text{X})(\text{LP} + \text{LA} - 1)[46.60 + 104.20(\text{PI} - 1)] \quad .$$

D. Program No. 3, Repair at KSC

$$\begin{aligned} \text{KSC Repair Cost} = & \text{IE} + \text{KTD} + \text{KT} + \text{KSA} + \text{TE} + \text{TF} + \text{KMLA} + \text{KMLP} \\ & + \text{KRL} + \text{PSLA} + \text{BSLA} + \text{PSLP} + \text{BSLP} + \text{BS} \end{aligned}$$

where

IE = Inventory Entry Cost

KTD = Technical Data Cost

KT = Training Cost

KSA = Supply Administration Cost

TE = Test and Repair Equipment Cost

TF = Test and Repair Facilities Cost

KMLA = Costs for Vendor Repair of Repairable Assemblies

KMLP = Costs for Nonrepairable Assemblies Replacement

KRL = Repair Labor Cost (Direct and Indirect)

PSLA = Packing and Shipping Costs for Repairable Assemblies Repair

BSLA = Base Stock Level Cost to Support Vendor Repair of Repairable Assemblies

PSLP = Packing and Shipping Costs for Nonrepairable Assemblies Replacement

BSLP = Base Stock Level Cost to Support Replacement of Nonrepairable Assemblies

BS = Spares Cost to Support Dwell Time of LRU in KSC Shops.

1. IE

$$IE = (X)(LP + LA - 1)[46.60 + 104.20(PI - 1)] .$$

2. KTD

$$KTD = 220(J)$$

Assumption: Cost of Data = \$ 220 per page.

3. KT

$$KT = \left[1 + \frac{\text{Technician Attrition}}{\text{Year}} (PI - 1) \right] [(W)(TD)\{ZI + 40(FLWR)\}]$$

where

$$\frac{\text{Technician Attrition}}{\text{Year}} = 0.12$$

ZI = \$ 200 (cost of training instruction and materials, dollars/man-week)

FLWR = \$ 20 (contracted hourly wage rate for trainees)

$$\begin{aligned} KT &= [1 + 0.12(PI - 1)] [(W)(TD)\{200 + 40(20)\}] \\ &= [1 + 0.12(PI - 1)] [1\ 000 (W)(TD)] . \end{aligned}$$

4. KSA

$$KSA = 36.59(PI) [LA + LP] .$$

5. TE

Assumptions:

- a. Ten percent of the cost of special test equipment relates to components having a 2 000 hour usage life. The other 90 percent of cost is for property or services which will not be purchased again during this program.

- b. The cost of technician labor to replace failed parts is equal to the cost of the replaced parts.

Therefore,

$$TE = \frac{(E)(D)}{100} \left[1 + \left(\frac{EMH}{2000} \right) \times 0.1 \times 2 (YRR)(PI) \right]$$

$$= \frac{(E)(D)}{100} [1 + 0.0001 (EMH)(YRR)(PI)] .$$

6. TF

This equation estimates costs for office and shop area used by technicians. If additional major or dedicated facilities are required, the costs should be added separately.

Assumptions:

- a. Each technician will require a total of 150 ft² when working on this hardware.
- b. Costs related to these facilities will be charged to this task only while repairs are in progress.
- c. Normal facility availability (no overtime) = 2000 hours per year.
- d. Facility costs per square foot.

<u>Item</u>	<u>Dollars per Year</u>
Equivalent Rental } Maintenance }	4.00
Heat	0.31
Light	0.59
Air Conditioning	<u>0.23</u>
	5.13

$$TF = 150 \times 5.13 \frac{(EMH)(YRR)}{2000} \times (PI)$$

$$= 0.385 (PI)(YRR)(EMH) .$$

7. KMLA

$$KMLA = (YRR)(PI)(SC)(AR)(Z)(0.5)$$

Assumption: Average charge for repair of a repairable assembly equals 50 percent of the cost of the assembly.

8. KMLP

$$KMLP = (YRR)(PI)(SC)(1-AR)$$

Assumption: Replacement at full cost.

9. KRL

$$KRL = 20 \times (YRR)(PI)(EMH)$$

Assumption: Labor cost = \$ 20 per hour.

10. PSLA

$$PSLA = 1.244 \times (SW)(YRR)(PI)(AR)(Z) \quad .$$

11. BSLA

$$BSLA = (Z)(SC) [(T_4)(YRR)(AR) + 3 \sqrt{(T_4)(YRR)(AR)}] \quad .$$

12. PSLP

$$PSLP = 0.622 (SW)(YRR)(PI) [1 - (AR)] \quad .$$

13. BSLP

$$BSLP = (SC) [(T_5)(YRR)(1 - AR) + 3 \sqrt{(T_5)(YRR)(1 - AR)}] \quad .$$

14. BS

$$BS = (UC) [(T_3)(YRR) + \sqrt{3(T_3)(YRR)}] \quad .$$

APPENDIX. EQUATIONS AS COMBINED FOR THE HP-97

Operational benefits such as quick response, flexibility of investigations, and reduced analytic costs may be achieved by programming the ORLA for a desk calculator such as the Hewlett-Packard 97 (HP-97) which is at the disposal of the logistics analyst. The ORLA equations, however, need to be programmed very efficiently because of input register and computational step limits of some of these machines. This appendix presents equations which have been programmed for the HP-97. In this application, the equations comprising each repair option were combined algebraically and constants were rounded (with care that changes to totals would not significantly affect decisions) to minimize machine requirements. These equations and methods are readily adaptable to the specifics of the various STS projects.

1. Preliminary computations

a. YRR — Yearly Replacement Rate

$$YRR = \left[\frac{(UR)}{(MTBF)} + (FPL) \right] (L)(C)(Q)$$

b. W — Number of Personnel to be Trained

$$W = 2 + \underbrace{\left[\frac{(EMH \times YRR)}{1900} - 2 \right]}_{\text{Omit if Negative}}$$

2. Program No. 1, Discard

$$\text{Discard Cost} = RCD + RPS + BSLDO$$

$$(YRR)(PI) [(UC) + 0.622(UW)] + (UC) [(T_1)(YRR) + \sqrt{3(T_1)(YRR)}]$$

3. Program No. 2, Vendor Repair

$$\text{Vendor Cost} = RCV + VPS$$

$$(YRR)(PI) [(SC) + \frac{1}{6.7} (EMH)(100 + B) + \frac{1}{8} (UW)]$$

+ BSLVO

$$(UC) [(T_2)(YRR) + \sqrt{3(T_2)(YRR)}]$$

+ IE

$$(X) [LP + LA - 1] [104(PI) - 58] .$$

4. Program No. 3, Repair at KSC

KSC Repair Cost = IE

$$(X) [LP + LA - 1] [104(PI) - 58] \quad \text{(May be computed and stored in Program No. 2 and retrieved for this Program)}$$

+ KTD + TE

$$220(J) + \frac{(E)(D)}{100} [1 + 0.0001 (PI)(YRR)(EMH)]$$

+ KT

$$[7 + (PI)] [120(W) (TD)]$$

+ KSA

$$36(PI) [LA + LP]$$

+ TF + KMLA + KMLP + KRL + PSLA + PSLP

$$(YRR)(PI) \left\{ 20 (EMH) + (Z)(AR) \left[\frac{1}{2} (SC) + \frac{1}{0.8} (SW) \right] \right.$$

$$\left. + (1 - AR) [(SC) + 0.62 (SW)] \right\}$$

+ BSLA

$$(Z)(SC) [(T_4)(YRR)(AR) + 3 \sqrt{(T_4)(YRR)(AR)}]$$

+ BSLP

$$(SC) [(T_5)(YRR)(1 - AR) + 3 \sqrt{(T_5)(YRR)(1 - AR)}]$$

+ BS

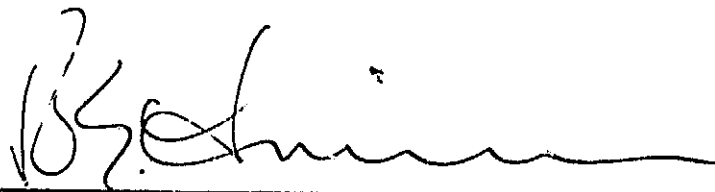
$$(UC) [(T_3)(YRR) + \sqrt{3(T_3)(YRR)}] .$$

APPROVAL

OPTIMUM REPAIR LEVEL ANALYSIS (ORLA) FOR THE SPACE TRANSPORTATION SYSTEM (STS)

By W. R. Henry

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.



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