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⑭ AG-PR-A101-VOL-4

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DEMONSTRATION MODEL SYSTEM.

VOLUME IV:

SLIDE-RULE MODEL SYSTEM PROGRAM MANUAL.

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by

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SEP 1979
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⑪ July 1979

⑫ 57p.

⑮ Contract No. N00014-78-C-0465

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Submitted to:

Office of Naval Research
Department of the Navy
Arlington, Virginia

393 637

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1.0 INTRODUCTION

The Slide-Rule Life Cycle Cost Model System (SRS) has been designed as an aid to system, subsystem and assembly designers in making cost estimates and trade-offs early in the design process. At this stage it is still possible for cost analysis to influence design - system cost has not yet been "locked in" due to the lack of flexibility in system configuration which occurs in the later phases of design.

The SRS consists of four linked programs implemented on a Texas Instruments TI-59 programmable calculator coupled to a TI PC-100A printer. Each program is appropriate to a different design phase and aggregation level. The first estimates the life cycle costs of a system by making simplifying assumptions about its subelements; the second is used for the design of a single Lowest Removable Assembly (LRA); the third estimates system or subsystem costs by aggregating the costs of its subelements, computed in the second program; the fourth is a specialized program used to compute the achieved system confidence level against a stock-out of spare parts.

The running times of all programs are less than one minute. This, combined with the "no-cost" running feature of the program, makes the SRS an excellent design tool for experimenting with design/cost trade-offs early and often in the design process.

Sections 2 through 5 describe each program, including the cost equations, input variable definitions, and flow charts, where appropriate. Annotated program listings are provided in four Appendices.

2.0 THE TOP-DOWN MODEL

The Top-Down Model (TDM) computes total life-cycle cost as the sum of nine cost categories: maintenance personnel compensation, maintenance training, operator compensation, operator training, production and spares, support and test equipment, repair costs, item entry and management, and documentation. The first seven cost categories are computed for each ship and then multiplied by the number of ships on which the system is to be deployed.

The program requires as input 27 data elements which characterize the design of a system. An additional 21 constants, describing the operating environment of the system, are incorporated into the program code. Design/cost trade-offs are accomplished by altering the input data elements and observing the effect on life-cycle cost.

Some of the main features of the cost model are: a sophisticated routine for determining on-board spares for repairable items (a flow chart of this routine is presented in Figure 1, a learning curve routine which adjusts the estimated unit production cost of the system based on the total number of systems and spares procured, discounting to present value of recurring costs (this option can be suppressed, if desired), and a new approach to manpower costing based on the concept of opportunity cost.

Program operation is simple and quick. Data elements are input to the model by storing them in appropriate memory registers. Execution is initiated by pressing a single button. Output consists of each of the cost categories and total life-cycle cost. To further

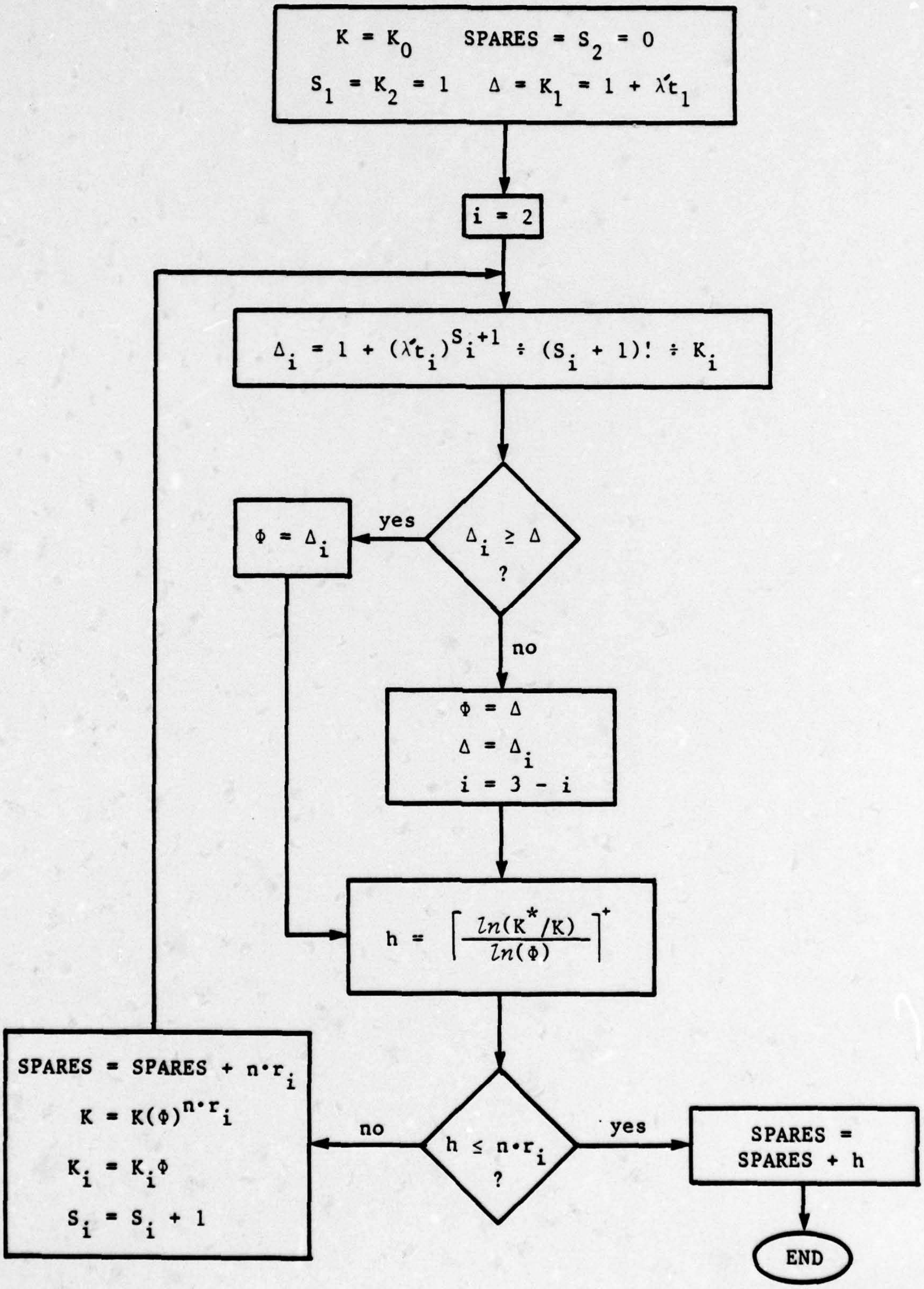

Figure 1 TDM Spares Algorithm

simplify the output, the printing of any or all of the cost categories can be suppressed by setting an appropriate flag. Turn-around time for cost results is approximately one minute.

The next sections summarize the TDM cost equations and present detailed definitions of the input variables.

TDM Cost Equation Summary

System failure rate: $\lambda = Q\cdot AHR/MTBF$

LRA peak failure rate: $\lambda' = s\lambda/n$

On-board spares: $S = SPARES/n'$

Demand at depot: $\mu = \lambda'\cdot N/d\cdot DRT$

Depot spares: $B = \lceil \mu + Z_b\sqrt{\mu} \rceil \cdot d\cdot r_2\cdot n/n'$

Replenishment spares: $S' = \lambda\cdot D\cdot h\left[1+(r_1+r_2)(1-COND)\right]/n'$

Adjusted unit production cost:

$$UC = UC_\ell\left[\frac{N(Q+S+S')+B}{\ell}\right]^{\log RRATE/\log 2}$$

Life cycle discount factor:

$$L = \begin{cases} \dfrac{(1+\rho)^{LC}-1}{\rho(1+\rho)^{LC}} & \rho \neq 0 \\ LC & \rho = 0 \end{cases}$$

Peak operator demand: $M'_o = s\cdot Q\cdot \theta\cdot PHR/WH_o$

Peak maintenance manpower demand: $M'_m = (s\lambda MTTRS(1+\tilde{M}r_1)+Q\cdot SM)/(U\cdot WH_m)$

Maintenance "C" training course cost: $TC_m = TS_m(1+\tilde{T}nr_1)$

TDM Cost Equation Summary (cont'd)

Maintenance wage: $C_1 = \text{Wage}(M'_m, AN_m, BN_m)$

Maintenance training: $C_2 = \text{Trn}(M'_m, AN, TC_m)$

Operator wage: $C_3 = \text{Wage}(M'_o, AN_o, BN_o)$

Operator training: $C_4 = \text{Trn}(M'_o, AN_o, TC_o)$

Production and spares: $C_5 = [(Q+S+S'L)\cdot N + B]UC$

Support and test equipment: $C_6 = STE(1+SGM(r_1)\tilde{S})(1+mL)\cdot N$

Repair: $C_7 = \lambda\cdot D\cdot h(r_1 RP + r_2 COD)\cdot N$

Item entry and management: $C_8 = IECn + IMC\cdot L\cdot n\,[\,1 + PP(r_1 + r_2)]$

Technical data: $C_9 = DOC(1+\tilde{D}r_1 n)$

Life cycle cost: $LCC = \sum_{j=1}^{9} C_j$

TDM Cost Equation Summary (cont'd)

Personnel Costs:

$$A(M') = \lceil M' - \min(M', AN) \rceil$$

$$\mathrm{Wage}(M', AN, BN) = \left[M \cdot BG + A(M')(BN-BG) \right] \cdot L \cdot N,$$

$$\mathrm{Trn}(M', AN, TC) = \left[\lceil M' \rceil \cdot TC + A(M')TA \right] (1+TOR \cdot L) \cdot N,$$

TDM Input Variable Summary

r_1	The fraction of LRA types in the system coded local repair.
r_2	The fraction of LRA types in the system coded depot repair. $1-r_1-r_2$ is the fraction of LRA types coded discard on failure.
LRT (weeks)	The average time for an item coded local repair to be returned to ready for issue status.
D (weeks)	The length of the deployment period.
n'	The total number of LRA's in the system.
n	The number of LRA types in the system. (Each LRA appears an average of n'/n times in the system.) Note: because of logic of the sparing algorithm, the smaller the value of n, the longer the program running time.
s	The ratio of peak operating hours to average operating hours. The input s can be seen as a policy variable which determines the ability of the supply system to withstand periods of increased activity.
N	The number of ships on which the system is to be deployed.
AN_m	The size of the pool of available, trained maintenance personnel on-board ship.
BN_o ($'000)	Annual billet cost for trained personnel used to maintain the system. Value taken from the Billet Cost Model (BCM). The undiscounted value should be used.
TC_m ($'000)	System repair training course cost for maintenance personnel. Does not include the course cost of training to repair individual LRA's coded local repair.
AN_o	Same as AN_m for operators.
BN_o	Same as Bn_m for operators.
TC_o ($'000)	Operator training course cost.

TDM Input Variable Summary (cont'd)

LC	(years)	Length of system life cycle.
MTBF	(hours)	Mean time between failure of the system. The value used should be adjusted for fixed field operations.
UC_ℓ	($'000)	The estimated unit production cost of the system assuming that ℓ units are produced.
ℓ		The lot size used to define UC_ℓ.
Q		The number of systems deployed per ship.
AHR	(hr./wk.)	The average weekly operating hours of the system per operating week.
MTTRS	(manhour)	The number of manhours required to restore the system to operational status after the failure of an LRA.
SM	(man-hr./wk.)	The weekly scheduled maintenance requirement. Includes all facility and preventative maintenance.
θ		The number of operators required to man the system when fully operational.
STE	($'000)	Purchase cost of all support and test equipment necessary for the repair of the system. Does not include common or specific STE used for the repair of failed LRA's.
COD	($'000)	The average cost of a repair at a contractor operated depot repair facility. COD includes the round-trip transportation cost of the item in addition to all other costs, direct and indirect, of a repair.
RP	($'000)	The average repair parts material cost required for the local repair of an LRA.
DOC	($'000)	The cost of documentation for system operation and repair. Does not include the documentation cost for the repair of individual LRA's.

TDM Variable Summary (Code Constants)*

BG ($'000)	The undiscounted annual billet cost for general labor personnel. Value taken from the BCM.
TA ($'000)	Average cost of "A" school training for operators and maintenance personnel.
TOR ($'000)	Average annual personnel attrition rate for military personnel.**
K*	Desired system level confidence level against stock-out of on-board spares.
DRT/d (weeks)	The average time for an item sent to a repair depot to be returned to the holding depot stock-pile divided by the number of holding depots.
Z_b	The number of standard deviations from the mean required to achieve the desired confidence level against stock-out at the depot.
d	The number of holding depots at which failed LRA's from ships are replaced by ready-to-issue LRA's.
h	The number of deployments in a year.
1-COND	1 minus the ratio of failed LRA's coded repair which cannot be repaired to the total number of LRA's coded repair. COND is an average value for local and depot repair facilities.**
log RRATE/log 2	The learning curve cost reduction coefficient. Equal to the log of the reduction rate divided by log 2.
ρ	Annual discount rate.**
$\tilde{M}$	The ratio of the mean time to repair a failed LRA coded local repair to the mean time to remove and replace the LRA (MTTRS, defined above).

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*Code constants are input variables, describing the operating environment in which the system is placed, which have been incorporated into the code of the cost model programs.

**Default value taken from "Naval Air Systems Command Avionics Level of Repair Model, Mod III Default Data Guide, 1 July 1977," NWESA, Washington Naval Yard.

TDM Variable Summary (Code Constants)* (cont'd)

$WH_m \cdot U$ (hr./wk.)	Available weekly work hours at sea for maintenance personnel (non-watchstanders), times the utilization rate, which serves to decrease available work time by accounting for delays arising from fatigue, environmental effects, personal needs, unavoidable interruptions, in addition to maintenance put-away, administrative, and overhead time.***
$\tilde{T}$	The ratio of the average training course cost specific to the repair of an individual LRA coded local repair to the system repairs training course cost (TC_m, defined above).
WH_o	Available weekly work hours for operators, that is, total available hours weekly (168) minus sleep, messing, personal needs and free time.***
$\tilde{S}$	The ratio of purchase cost of the common support and test equipment which would be needed if any of the LRA's in the system are coded local repairs to system repair STE (STE, defined above).
m	Annual support of support equipment maintenance factor.**
IEC ($´000)	Cost of entering a new item into the Naval Stock System (NSN) inventory.**
IMC ($´000)	Annually recurring cost of retaining an item in the NSN.**
PP	The average number of unique new components in each LRA type; n^{PP} gives the total number of new components in the system.
$\tilde{D}$	The ratio of the cost of specific documentation required for an individual LRA coded local repair to the cost of system repair documentation (DOC, defined above).

**Default value taken from "Naval Air Systems Command Avionics Level of Repair Model, Mod III Default Data Guide, 1 July 1977," NWESA, Washington Naval Yard.

***Default value taken from OPNAV 10P-23, "Guide to the Preparation of Ship Manning Documents, Volume I: Policy Statement," OPNAV 10P-23 Washington, D.C., 1971.

3.0 The Lowest Removable Assembly Model

The Lowest Removable Assembly Model (LRAM) computes total life-cycle cost as the sum of seven cost categories: maintenance personnel wage, maintenance personnel training, production and spares, support and test equipment, repair, item entry and management, and documentation. The first five categories are multiplied by the number of ships on which the LRA is to be deployed.

The program requires as input 16 data elements which characterize the design of the LRA. An additional set of 21 variables are input to the model on an operating environment card provided by the system designer. This card also includes the printing op. codes for the program output labels. Design/cost trade-offs are accomplished by altering the input data element and observing the effect on life cycle cost.

Some of the main features of the model are: level of repair analysis capabilities which include local repair, depot repair and discard options, a sophisticated spares routine which automatically calculates the (near) optional mix of on-board and depot spares required to meet the LRA confidence level, complete manpower cost formulations for maintenance personnel, and full output labeling capabilities. As in the TDM, printing of individual cost categories can be suppressed by setting appropriate flags. Turn-around time for cost results is approximately forty seconds.

The next sections summarize the LRAM cost equations and present detailed definitions of input variables. Flow charts of model subroutine logic are presented in Figure 2.

Figure 2 LRAM Subroutine Flowcharts

Figure 2-A

S(t,K): Number of spares needed to meet confidence level K given demand lead time t.

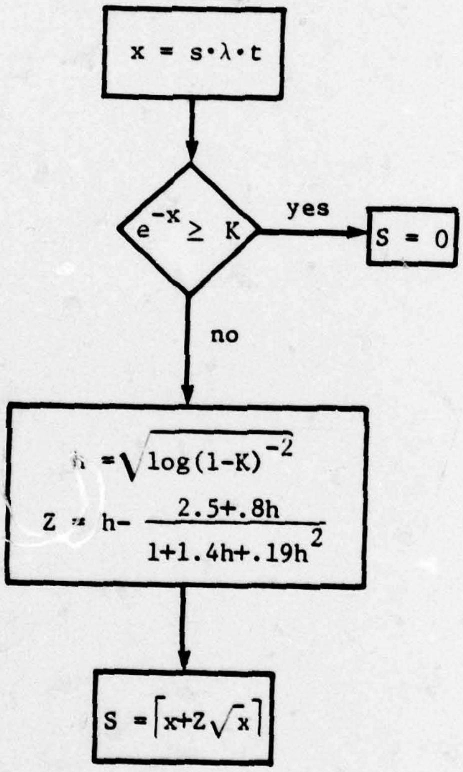
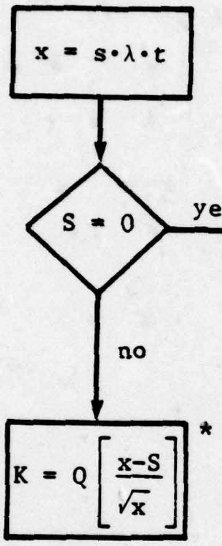


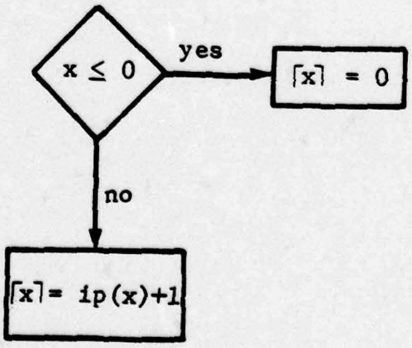
Figure 2 LRAM Subroutine Flowcharts (cont.)

Figure 2-B

K(t): Confidence level achieved with S spares and demand lead time λt.



⌈x⌉ : Round-up to next higher integer.



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*Q(x) is computed in a program contained in the master library module which comes with the TI-59 calculator.

LRAM Cost Equation Summary

LRA peak failure rate: $\lambda = sqQ\delta AHR/MTBF$

Lead time: $t = r_1 LRT + r_2 D$

On-board spares: $S = S(t,K)$

Depot confidence level: $b = \frac{K-K(XD)}{K(D)-K(XD)}$

Depot spares: $B = r_2 S(N/d \cdot DRT, b) \cdot d$

Replenishment spares: $S' = \lambda \cdot D \cdot h\ 1-(r_1 + r_2)(1-COND)$

Adjusted unit production cost: $UC = UC_\ell \left[\frac{N(q \cdot Q+S+S') + B}{\ell}\right]^{\log RRATE/\log 2}$

Maintenance manpower peak demand: $M'_m = s\lambda(MTPR + r_1 MTTR)/(U \cdot WH_m)$

"A" school training requirement: $A(M'_m) = \lceil M'_m - \min(M', AN_m) \rceil$

Maintenance wage: $C_2 = \left[M'_m/s \cdot BG + A(M'_m)(BN_m - Bg)\right] L \cdot N$

Maintenance training: $C_3 = \left[M'_m\ (TFI + r_1 TR) + A(M'_m) TA_m\right] \cdot (1+TOR \cdot L) \cdot N$

Production and spares: $C_4 = \left[(q \cdot Q+S+S'L)N + B\right]UC$

LRAM Cost Equation Summary (cont'd)

Support and test equipment:
$$C_5 = (STE+r_1 STE_{rpr})(1+mL)\cdot N$$

Repair:
$$C_6 = \lambda D\cdot h\cdot L(r_1 UC/c+r_2 \cdot COD)\cdot N$$

Item entry and management:
$$C_7 = (IEC+IMC\cdot L)(1+(r_1+r_2)\bar{c})$$

Technical data:
$$C_8 = P_f + r_1 P_r$$

Life cycle cost:
$$LCC = \sum_{j=2}^{8} C_j$$

LRAM Input Variable Summary

q		Number of LRA appearances in the system as a whole.
δ		LRA duty cycle: the ratio of LRA to system operating hours.
MTBF	(hrs.)	LRA mean time between failure.
r_1		Level of Repair switch which is set equal to 1 if the LRA is coded local repair, otherwise it is set equal to zero.
r_2		Level of Repair switch which is set equal to 1 if the LRA is coded depot repair, otherwise it is set equal to zero. If $r_1 = r_2 = 0$ the LRA is coded discard on failure.
UC_ℓ	(\$´000)	Estimated unit cost of the LRA assuming a production lot size of ℓ.
MTTRS	(manhrs.)	The average manhours required to restore the system to operational status after a failure of the LRA. Equivalently, the mean time to fault isolate to, remove and replace the LRA upon failure.
MTTR	(manhrs.)	The average maintenance manhours needed to repair the LRA if it is coded local repair.
TFI	(\$´000)	The addition to the system level maintenance training course cost needed to train personnel to fault isolate to, remove and replace this particular LRA. (In other words, TFI > 0 only if this LRA would require special mention in the system repair training course.)
TR	(\$´000)	The course cost required to train personnel to repair the LRA locally.
STE	(\$´000)	The purchase cost of any additional system repair support and test equipment needed to fault isolate to, remove and replace this particular LRA.

LRAM Input Variable Summary

STE_{rpr} ($'000)	The purchase cost of all support and test equipment necessary to the local repair or maintenance of this particular LRA.
c	The number of components in the LRA. (Repair of the LRA consists of removing and replacing components.)
$\bar{c}$	The number of new components, unique to the LRA, which must be entered in the Naval inventory management system.
DOC ($'000)	The addition to the system repair documentation cost needed to document the fault isolation, removal and replacement of this LRA.
DOC_{rpr} ($'000)	The cost of documentation of the procedure to repair the LRA locally.

All other variables are as defined in the TDM, with three exceptions:

K	is the desired confidence level against stock-out for the LRA, K_i's for each LRA are assigned so that $\prod K_i = K^*$.
AN_m	is the available pool of trained maintenance personnel available to the LRA. $AN_{m,i}$'s are assigned so that $\sum AN_{m,i} = M$, the desired system level maintenance manpower requirement.
L	is the discounted life cycle computed in the TDM.

4.0 THE SYSTEM AGGREGATION MODEL

The System Aggregation Model (SAM) computes life cycle cost as the sum of the same nine cost categories as the TDM. The input of the program is the output of the LRAM for each LRA type used in the system, plus system level input data. Design trade-offs are accomplished by altering the number and type of LRA's used to build up the system.

One of the most powerful features of the SAM is that SAM program output can be input to the model. Thus, for example, the SAM can be used to aggregate LRA's into sybsystems, and then used again to aggregate these subsystems and systems. Mixed aggregation levels are possible; input to the SAM can consist partially of LRA's (LRAM output) and partially of subsystems (LRAM output preaggregated using the SAM). And, of course the multiple aggregation-level option is available.

Other features of the SAM include: automatic calculation of achieved system MTBF and MTTR, based on the MTBF's and MTTR's of the LRA's used in a given system configuration; manpower cost calculations based on aggregated personnel demand and training course requirements, and complete output labeling capabilities. As in the other models, intermediate cost outputs can be suppressed by setting appropriate flags. Program running time is approximately ten seconds per LRA input, plus an additional 20 seconds to compute and print system level costs.

The next sections present a summary of SAM cost equations and input variables.

SAM Cost Equation Summary

Aggregation Factor: $R_i = \frac{q \cdot QIPA_i}{q_i}$

Peak maintenance demand: $M'_m = Q \cdot SM / U \cdot WH_m + \sum^n R_i M'_{m,i}$

Maintenance training cost: $TC_m = TS_m + \sum^n R_i TC_{m,i}$

Operator training cost: $TC_o = TS_o + \sum^n R_i TC_{o,i}$

Peak operator demand: $M'_o = s \cdot Q \cdot q \cdot \theta \cdot AHR / WH_o$

Maintenance wage: $C_1 = \mathrm{Wage}(M'_m, AN_m, BN_m)$

Maintenance training: $C_2 = \mathrm{Trn}(M'_m, AN_m, TC_m, TA_m)$

Operator Wage: $C_3 = \mathrm{Wage}(M'_o, AN_o, BN_o)$

Operator training: $C_4 = \mathrm{Trn}(M'_o, AN_o, TC_o, TA_o)$

Hardware: $C_5 = PT_\ell \left[\frac{N \cdot Q \cdot q}{\ell}\right]^{\log RRATE / \log 2} + \sum^n R_i HRDW_i$

Support and
test equipment: $C_6 = STE_{sys}(1+mL)N + \sum^n R_i STE_i$

Repair: $C_7 = \sum^n R_i RPR_i$

Item entry
and management: $C_8 = \sum^n R_i IEMC_i$

SAM Cost Equation Summary (cont'd)

Technical Data: $$C_9 = DOC_{sys} + \sum^{n} R_i DOC_i$$

Life cycle cost: $$LCC = \sum_{j=1}^{9} C_j$$

System mean time to repair: $$MTTR = \frac{\sum QIPA_i MTTR_i \cdot \lambda_i}{\sum QIPA_i \cdot \lambda_i}$$

System MTBF: $$MTBF = \left[\sum^{n} \frac{QIPA_i}{MTBF_i}\right]^{-1}$$

SAM Input Variable Summary

q		The number of units in the system. If the SAM is being used at the system level, $q = 1$.
SM		Same as above. If the SAM is used at the subsystem level, refers to subsystem scheduled maintenance requirement.
AN_m		Same as above. If the SAM is used at the subsystem level, AN_m is assigned to the subsystem in the same manner as AN_m in the LRAM.
TA_m	(\$'000)	"A" school training course cost for maintenance personnel.
AN_o		Same as AN_m, above, but refers to operators.
TA_o	(\$'000)	"A" school training course cost for operators.
PT_ℓ	(\$'000)	The estimated assembly, or put-together, cost of the system. Equivalently, the total production cost of the system less the production costs of all sub-elements.

All other variables are as defined above.

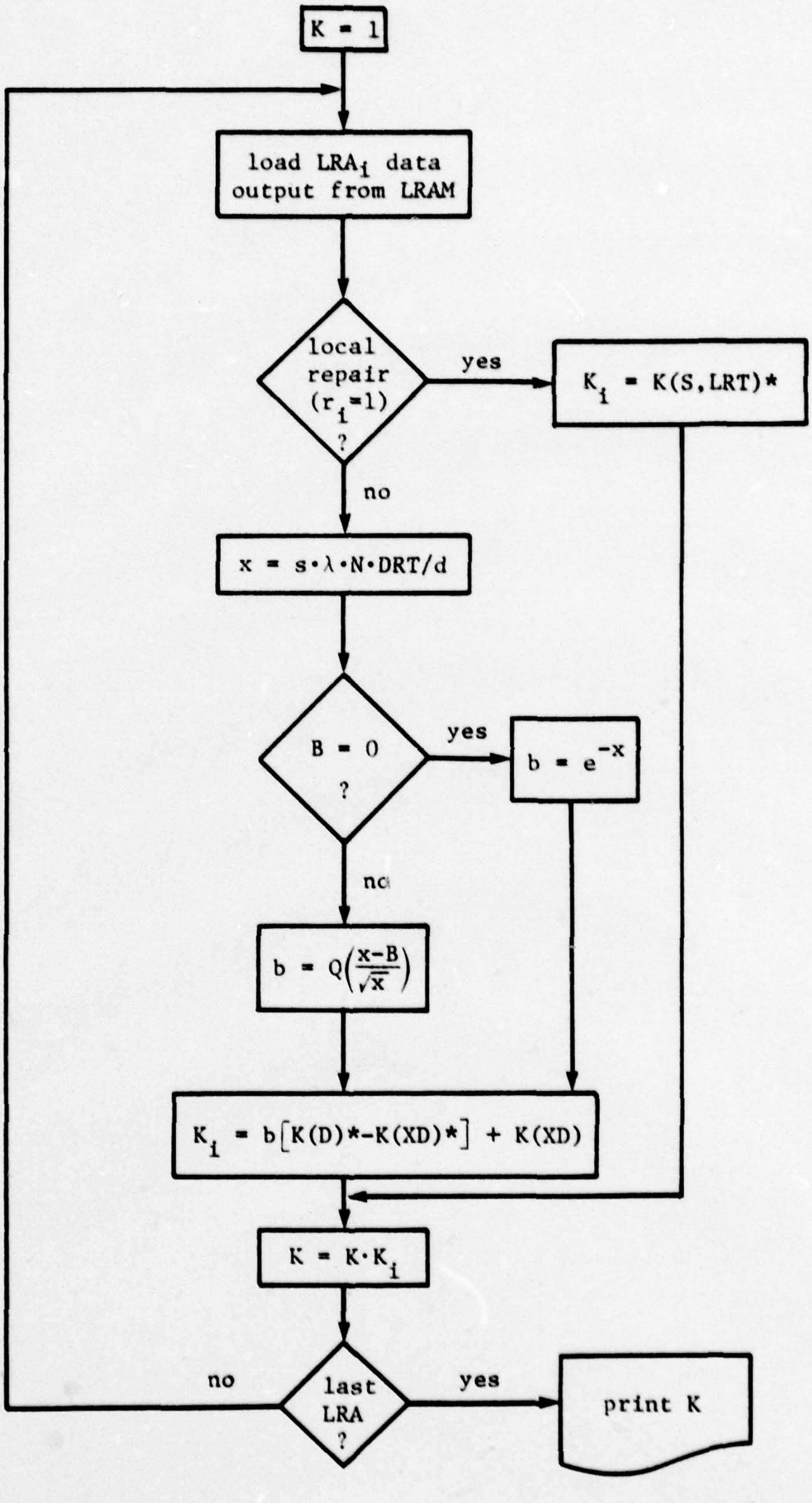
5.0 The System Confidence Model

The System Confidence Model (SCM) is a specialized program which determines the achieved confidence level against stockout for each LRA type and for the system as a whole.

SCM input consists of LRAM output for each LRA type plus a system operating environment card. The program multiplies LRA confidence levels into an accumulation register containing the current system confidence level. Once all LRA's have been read into the SCM, this register, containing the achieved system confidence level, is printed.

A flow chart of SCM logic is presented in Figure 3. All input variables to the SCM are as defined above.

Figure 3 SCM Program Logic



*These values were calculated and stored as part of the sparing algorithm in the LRAM.

APPENDICES:

ANNOTATED PROGRAM LISTINGS FOR

A: TOP-DOWN MODEL

B: LOWEST REMOVABLE ASSEMBLY MODEL

C: SYSTEM AGGREGATION MODEL

D: SYSTEM CONFIDENCE MODEL

APPENDIX A:

TOP-DOWN MODEL

PROGRAM LISTING

INDIRECT RECALL

```
000   76 LBL
001   43 RCL
002   73 RC*
003   00   00
004   69 OP
005   20   20
006   92 RTN
```

Recalls values used in SPARES and PERSONNEL routines

$\lceil x \rceil$

```
007   76 LBL
008   59 INT
009   95   =
010   32 X:T
011   00   0
012   77   GE
013   00   00
014   20   20
015   32 X:T
016   59 INT
017   85   +
018   01   1
019   95   =
020   92 RTN
```

$\lceil x \rceil = \begin{cases} 0 & x \leq 0 \\ ip(x)+1 & x > 0 \end{cases}$

PRINT and SUM to LCC

```
021   65   ×
022   43 RCL
023   13   13
024   95   =
025   44 SUM
026   37   37
027   69 OP
028   21   21
029   87 IFF
030   40 IND
031   01   01
032   00   00
033   35   35
034   99 PRT
035   92 RTN
```

$LCC = LCC + N \cdot c_j$ if $j \leq 7$ (enter at 021)

$LCC = LCC + c_j$ if $j \geq 8$ (enter at 024)

SUBROUTINE PERSONNEL

```
036   43 RCL
037   38   38
038   32 X:T
039   43 RCL
040   38   38
041   75   -
042   71 SBR
043   43 RCL
044   22 INV
045   77   GE
046   00   00
047   49   49
048   32 X:T
049   71 SBR
050   59 INT
051   42 STO
052   04   04
```

$A(m', AN) = \lceil m' - \min(m', AN) \rceil$

Wage = $(m'/6 \cdot BG + A(BN - BG)) \cdot L \cdot N$

```
053   94 +/-
054   85   +
055   43 RCL
056   38   38
057   55   ÷
058   43 RCL
059   12   12
060   95   =
061   65   ×
062   01   1
063   00   0   ← BG
064   93   .
065   05   5
066   85   +
067   71 SBR
068   43 RCL
069   65   ×
070   43 RCL
071   04   04
072   95   =
073   65   ×
074   43 RCL
075   03   03
076   71 SBR   print Wage
077   00   00
078   21   21
```

Trn = ([M'] TC + A·TA)(1+TOR·L)·N

```
079   43 RCL
080   38  38
081   71 SBR
082   59 INT
083   65  ×
084   71 SBR
085   43 RCL
086   85  +
087   43 RCL
088   04  04
089   65  ×
090   01  1  ← TA
091   00  0
092   93  .
093   00  0
094   95  =
095   65  ×
096   53  (
097   01  1
098   85  +
099   93  .  ← TOR
100   04  4
101   05  5
102   65  ×
103   43 RCL
104   03  03
105   54  )
106   71 SBR
107   00  00 Print Trn
108   21  21
109   92 RTN
```

end of subroutine PERSONNEL

BEGIN EXECUTION

```
110   76 LBL
111   11  A
112   43 RCL
113   24  24
114   65  ×
115   43 RCL
116   25  25
117   55  ÷
118   43 RCL
119   21  21
120   95  =
121   42 STO  λ = AHR·Q/MTBF
122   37  37
123   65  ×
124   43 RCL
125   12  12
126   55  ÷
127   43 RCL
128   11  11
129   95  =
130   42 STO  λ' = sλ/n
131   36  36
132   65  ×
133   43 RCL
134   11  11
135   65  ×
136   53  (
137   43 RCL
138   02  02
139   65  ×
140   43 RCL
141   05  05
142   85  +
143   43 RCL
144   06  06
145   65  ×
146   43 RCL
147   09  09
148   54  )
149   95  =
150   94 +/-
151   22 INV
152   23 LNX
153   42 STO
154   35  35 K_0 = e^-[sλ(r_1 LAT + r_2 D)]
```

```
155   00   0
156   42  STO
157   34   34
158   42  STO   SPARES: s_2 = 0
159   07   07
160   01   1
161   42  STO
162   08   08
163   42  STO   s_1 = K_2 = 1
164   03   03
165   85   +
166   43  RCL
167   36   36
168   65   ×
169   43  RCL
170   02   02
171   95   =
172   42  STO
173   04   04
174   42  STO   Δ = k_1 = 1 + λ't_1
175   38   38
176   06   6          0 is ind reg
177   42  STO  i=2    for i. r_2 is
178   00   00         stored in reg. 6
```

$$\Delta_i = 1 + \frac{(\lambda' t_i)^{s_i+1}}{(s_i+1)!\ K_i}$$

```
179   01   1
180   85   +
181   53   (
182   43  RCL
183   36   36
184   65   ×
185   71  SBR
186   43  RCL
187   54   )
188   45  YX
189   53   (
190   71  SBR
191   43  RCL
192   85   +
193   01   1
194   54   )
195   42  STO
196   01   01
```

```
197   55   ÷
198   53   (  ⎫
199   01   1  ⎪
200   65   ×  ⎪
201   43  RCL ⎪
202   01   01 ⎬ computes s!
203   97  DSZ ⎪
204   01   01 ⎪
205   02   02 ⎪
206   00   00 ⎪
207   54   )  ⎭
208   55   ÷
209   71  SBR
210   43  RCL
211   95   =
212   32  X:T
```

```
213   43  RCL
214   38   38
215   22  INV   Δ < Δ_i ?
216   77   GE
217   02   02
218   30   30   no
219   32  X:T
220   42  STO   Δ = Δ_i
221   38   38
222   01   1
223   04   4
224   75   -
225   43  RCL
226   00   00
227   95   =
228   42  STO  i = 3-i
229   00   00
230   93   .    ← K*
231   09   9
232   05   5
233   55   ÷
234   43  RCL
235   35   35
236   95   =
237   23  LNX
238   55   ÷
239   32  X:T
240   42  STO   hold φ in R_1
241   01   01
242   23  LNX
243   71  SBR   h = ⌈ ln(K*/K) / lnφ ⌉⁺
244   59  INT
245   32  X:T   hold h in t
```

```
246   73  RC*
247   00   00
248   65   ×
249   43  RCL   if nr_i >h
250   11   11   then end
251   95   =
252   77   GE    otherwise
253   02   02
254   79   79
255   44  SUM   SPARES= SPARES+ nr_i
256   34   34
257   48  EXC
258   01   01
259   69  OP
260   30   30
261   64  PD*    K_i= φK_i
262   00   00
263   45  Y×
264   43  RCL
265   01   01
266   95   =
267   49  PRD    K= Kφ^(nr_i)
268   35   35
269   69  OP
270   30   30
271   01   1
272   74  SM*    S_i= S_i+1
273   00   00
274   69  OP
275   30   30
276   61  GTD
277   01   01
278   79   79
279   32  X:T  final spares buy
280   44  SUM  SPARES= SPARES+h
281   34   34
```

$\tilde{S} = (B/N + S)/n' + Q$

```
282   43  RCL
283   36   36
284   65   ×
285   43  RCL
286   13   13
287   65   ×
288   01   1   ← DRT/d
289   03   3
290   95   =
291   42  STD
292   01   01  μ= λ'N·DRT/d
293   34  ΓX
294   65   ×
295   01   1   ← Z_b
296   93   .
297   06   6
298   05   5
299   85   +
300   43  RCL
301   01   01
302   71  SBR
303   59  INT
304   65   ×
305   02   2   ← d
306   65   ×
307   43  RCL
308   09   09
309   65   ×
310   43  RCL
311   11   11
312   55   ÷
313   43  RCL  B = ⌈μ+ Z_b√μ⌉·d·r_2·n/N
314   13   13
315   85   +
316   43  RCL
317   34   34
318   95   =
319   55   ÷
320   43  RCL
321   10   10
322   85   +
323   43  RCL
324   24   24
325   95   =
326   42  STD
327   34   34
```

$$S' = \bar{\lambda}[1-(r_1+r_2)(1-COND)]/n$$

```
328  43  RCL
329  37   37
330  65   ×
331  43  RCL
332  06   06
333  65   ×
334  02   2   ← h
335  95   =
336  42  STO
337  36   36   λ̄ = λ·D·h
338  55   ÷
339  43  RCL
340  10   10
341  65   ×
342  53   (
343  01   1
344  75   -
345  53   (
346  43  RCL
347  05   05
348  85   +
349  43  RCL
350  09   09
351  54   )
352  42  STO
353  39   39
354  65   ×
355  93   .   ← 1-COND
356  09   9
357  08   8
358  54   )
359  95   =
360  42  STO
361  07   07  S'
```

$$LC = LC_e\left[\frac{N(S'+Z))}{e}\right]^{\log RRATE/\log 2}$$

```
362  85   +
363  43  RCL
364  34   34
365  95   =
366  65   ×
367  43  RCL
368  13   13
369  55   ÷
370  43  RCL
371  23   23
372  95   =
373  45  YX
374  93   .   ← log RRATE/log2
375  01   1
376  05   5
377  94  +/-
378  65   ×
379  43  RCL
380  22   22
381  95   =
382  42  STO
383  08   08
```

$$L = \frac{(1+\rho)^{LC}-1}{\rho(1+\rho)^{LC}}$$

```
384  93   .   ← ρ
385  01   1
386  00   0
387  42  STO
388  03   03
389  85   +
390  01   1
391  95   =
392  45  YX
393  43  RCL
394  20   20
395  87  IFF  if flag 0 is
396  00   00  set then L=LC
397  04   04
398  16   16
399  75   -
400  01   1
401  95   =
402  55   ÷
403  43  RCL
404  03   03
405  55   ÷
406  53   (
407  01   1
408  85   +
409  43  RCL
410  03   03
411  54   )
412  45  YX
413  43  RCL
414  20   20
415  95   =
416  42  STO
417  03   03  L
```

$M'_m = [s\lambda\,MTTRS(1+\tilde{M}r_1) + Q\cdot SM]/(U\cdot WH_m)$

```
418   43  RCL
419   12   12
420   65   ×
421   43  RCL
422   37   37
423   65   ×
424   43  RCL
425   26   26
426   65   ×
427   53   (
428   01   1
429   85   +
430   01   1  ← M̃
431   93   .
432   00   0
433   65   ×
434   43  RCL
435   05   05
436   54   )
437   85   +
438   43  RCL
439   24   24
440   65   ×
441   43  RCL
442.  27   27
443   95   =
444   55   ÷
445   05   5  ← U·WHm
446   03   3
447   95   =
448   42  STO
449   38   38
```

$TC_m = TS(1+\varphi r_1 n)$

```
450   43  RCL
451   28   28
452   65   ×
453   53   (
454   01   1
455   85   +
456   01   1  ← φ
457   93   .
458   00   0
459   65   ×
460   43  RCL
461   05   05
462   65   ×
463   43  RCL
464   11   11
465   54   )
466   95   =
467   42  STO
468   16   16
```

initialize

```
469   01   1
470   04   4
471   42  STO  indirect register for
472   00   00  o and m subscripted
473   00   0   variables
474   42  STO
475   37   37  LCC > 0
476   42  STO  indirect register for
477   01   01  print/no print flag
478   58  FIX
479   02   02
```

manpower costs

```
480   71  SBR  maintenance wage
481   00   00  and training
482   36   36
483   43  RCL
484   24   24
485   65   ×
486   43  RCL
487   29   29
488   65   ×
489   43  RCL
490   25   25
491   55   ÷
492   07   7   ← WHo
493   04   4
494   65   ×
495   43  RCL
496   12   12
497   95   =
498   42  STO  M'o = s·θ·MHR·Q/WHo
499   38   38
500   71  SBR
501   00   00
502   36   36
```

$C_5 = (\bar{S} + S'L)\cdot UC$

```
503   43  RCL
504   34   34
505   85   +
506   43  RCL
507   07   07
508   65   ×
509   43  RCL
510   03   03
511   95   =
512   65   ×
513   43  RCL
514   08   08
515   71  SBR
516   00   00
517   21   21  Hardware
```

$C_6 = STE(1+ SGM(r_1)\tilde{S})(1+mL)\cdot N$

```
518   43  RCL
519   30   30
520   65   ×
521   53   (
522   01   1
523   85   +
524   43  RCL
525   05   05
526   69  OP
527   10   10
528   65   ×
529   01   1   ← S̃
530   93   .
531   00   0
532   54   )
533   65   ×
534   53   (
535   01   1
536   85   +
537   93   .   ← m
538   01   1
539   02   2
540   65   ×
541   43  RCL
542   03   03
543   54   )
544   71  SBR  support and
545   00   00  test equipment
546   21   21
```

$C_7 = \bar{\lambda} L (r_2 COD + r_1 RP)\cdot N$

```
547   43  RCL
548   36   36
549   65   ×
550   43  RCL
551   03   03
552   65   ×
553   53   (
554   43  RCL
555   09   09
556   65   ×
557   43  RCL
558   31   31
559   85   +
560   43  RCL
561   05   05
562   65   ×
563   43  RCL
564   32   32
565   54   )
566   71  SBR
567   00   00  repair
568   21   21
```

$C_8 = IECn + IMCnL(1+PP(r_1+r_2))$

```
569   93   .   ← IEC
570   04   4
571   05   5
572   85   +
573   93   .
574   02   2   ← IMC
575   03   3
576   65   ×
577   43  RCL
578   03   03
579   65   ×
580   53   (
581   01   1
582   85   +
583   01   1   ← PP
584   93   .
585   00   0
586   65   ×
587   43  RCL
588   39   39
589   54   )
590   95   =
591   65   ×
592   43  RCL
593   11   11
594   71  SBR  item entry and
595   00   00  management
596   24   24
```

$C_9 = BOC(1+ r_1 n \tilde{\delta})$

```
597   69  OP
598   31   31
599   43  RCL
600   33   33
601   65   ×
602   53   (
603   01   1
604   85   +
605   43  RCL
606   05   05
607   65   ×
608   43  RCL
609   11   11
610   65   ×
611   01   1   ← δ̃
612   93   .
613   00   0
614   54   )
615   71  SBR
616   00   00  Documentation
617   24   24
```

Print System Life Cycle Cost

```
618   98 ADV
619   43 RCL
620   37  37
621   99 PRT
622   98 ADV
623   22 INV
624   58 FIX
625   92 RTN
626   00  0
627   00  0
628   00  0
629   00  0
630   00  0
631   00  0
632   00  0
633   00  0
634   00  0
635   00  0
636   00  0
637   00  0
638   00  0
639   00  0
```

APPENDIX B:

LOWEST REMOVABLE ASSEMBLY

MODEL PROGRAM LISTING

PRINT and SUM to LCC

```
000   65   ×
001   43  RCL
002   37   37
003   95   =    LCC = LCC + N·Cj
004   44  SUM   if j ≤ 6 (enter at 000)
005   02   02
006   72  ST*   LCC = LCC + Cj
007   01   01   if j ≥ 7  (enter at 003)
008   87  IFF
009   40  IND   store Cj in Rj j≥2
010   01   01
011   00   00   if flag j is set
012   15   15   do not print Cj
013   69  OP
014   06   06
015   69  OP
016   20   20
017   69  OP
018   21   21
019   73  RC*
020   00   00   load op. code
021   69  OP    for next lable
022   04   04
023   92  RTN
```

x= y·s·λ

```
024   65   ×
025   43  RCL
026   32   32   used
027   65   ×    three
028   43  RCL   times
029   29   29
030   95   =
031   42  STO
032   09   09
033   92  RTN
```

K(t)

```
034   29  CP
035   71  SBR
036   00   00
037   24   24   x = s·λ·t
038   75   -
039   43  RCL
040   04   04
041   67   EQ   if S=0
042   00   00   then K = e^-x
043   57   57   otherwise ↓
044   95   =
045   55   ÷
046   43  RCL
047   09   09
048   34  √X
049   95   =
050   36  PGM
051   14   14
052   11   A
053   36  PGM
054   14   14   K = Q((x-S)/√x)
055   12   B
056   92  RTN
```

if S=0

```
057   95   =
058   43  RCL
059   09   09
060   94  +/-
061   22  INV   K = e^-x
062   23  LNX
063   92  RTN
```

S(t,K)

```
064   71  SBR
065   00   00
066   24   24   x = s·λ·t
067   94  +/-
068   22  INV
069   23  LNX
070   32  X:T
071   43  RCL
072   07   07
073   22  INV   if e^-x ≥ K then
074   77   GE   S=0, otherwise ↓
075   01   01
076   37   37
```

```
077   75   -
078   01   1
079   95   =
080   33  X²
081   35  1/X
082   23  LNX
083   34  ΓX
084   42  STO
085   02   02
```

$h=\sqrt{\log(\frac{1}{1-\kappa})^2}$

```
086   75   -
087   53   (
088   02   2
089   93   .
090   05   5
091   85   +
092   93   .
093   08   8
094   65   ×
095   43  RCL
096   02   02
097   54   )
098   55   ÷
099   53   (
100   01   1
101   85   +
102   01   1
103   93   .
104   04   4
105   65   ×
106   43  RCL
107   02   02
108   85   +
109   93   .
110   01   1
111   09   9
112   65   ×
113   43  RCL
114   02   02
115   33  X²
116   54   )
117   95   =
```

$Z = h - \frac{2.5+.8h}{1+1.4h+.19h^2}$

```
118   65   ×
119   43  RCL
120   09   09
121   34  ΓX
122   85   +
123   43  RCL
124   09   09
125   95   =
```

$h = x + Z\sqrt{x}$

$\lceil x \rceil$

```
126   32  X:T
127   00   0
128   77   GE
129   01   01
130   36   36
131   32  X:T
```

$\lceil x \rceil = \begin{cases} 0 & x \leq 0 \\ \text{INT}(x)+1 & x > 0 \end{cases}$

```
132   85   +
133   01   1
134   95   =
135   59  INT
136   92  RTN
137   00   0
138   92  RTN
```

end of $S(t,K)$

```
139   76  LBL
```

BEGIN EXECUTION

```
140   11   A
141   43  RCL
142   30   30
143   65   ×
144   43  RCL
145   12   12
146   65   ×
147   43  RCL
148   13   13
149   65   ×
150   43  RCL
151   31   31
152   55   ÷
153   43  RCL
154   14   14
155   95   =
156   42  STO
157   29   29
```

$\lambda = g \cdot Q \cdot \delta \cdot \text{AHR}/\text{MTBF}$

```
158   43  RCL
159   35   35
160   42  STO
161   07   07
```

$K = K_i$

```
162   43  RCL
163   15   15
164   65   ×
165   43  RCL
166   33   33
167   85   +
168   43  RCL
169   16   16
170   65   ×
171   43  RCL
172   34   34
173   95   =
174   42  STO
175   28   28
```

$t = r_1 \text{LRT} + r_2 D$

```
176   71  SBR
177   00   00  S= S(t,Ki)
178   64   64
179   42  STO
180   04   04
181   43  RCL
182   28   28
183   71  SBR
184   00   00
185   34   34
186   42  STO
187   28   28  Save K(t)

188   43  RCL  if r2=0
189   16   16  then B=0
190   67   EQ
191   02   02  otherwise ↓
192   32   32

193   43  RCL
194   36   36
195   71  SBR
196   00   00  K(XD)
197   34   34
198   42  STO
199   10   10
200   75    -
201   43  RCL
202   35   35
203   95    =
204   55    ÷
205   53    (
206   43  RCL
207   10   10
208   75    -
209   43  RCL
210   28   28
211   54    )
212   95    =
213   42  STO      Ki - K(XD)
214   07   07  b = -------------
                   K(D) - K(XD)

215   43  RCL
216   37   37
217   65    ×
218   43  RCL
219   38   38
220   55    ÷
221   02    2  ← d
222   71  SBR
223   00   00
224   64   64  B= S(N·DRT/d,b)
```

```
225   44  SUM
226   28   28  save B as B.K(t)
227   65    ×
228   02    2  ← d
229   55    ÷
230   43  RCL
231   37   37  B̄= B·d/N

232   85    +
233   43  RCL
234   30   30
235   65    ×
236   43  RCL
237   12   12
238   95    =
239   44  SUM
240   04   04  S= S+ B̄ + g·Q
```

Replenishment Spares

```
241   43  RCL
242   29   29
243   65    ×
244   43  RCL
245   34   34
246   65    ×
247   02    2  ← h
248   95    =
249   42  STO
250   06   06  λ̄ = λ·D·h
251   65    ×
252   53    (
253   01    1
254   75    -
255   53    (
256   43  RCL
257   15   15
258   85    +
259   43  RCL
260   16   16
261   54    )
262   42  STO
263   07   07  r̄ = r1+r2
264   65    ×
265   43  RCL  ← 1-COND
266   40   40
267   54    )
268   95    =
269   42  STO
270   05   05  s' = λ̄(1-r̄(1-COND))
```

$uc = uc_e\left[\frac{N(s+s')}{e}\right]^{\log RRATE/\log 2}$

```
271   85   +
272   43  RCL
273   04   04
274   95   =
275   65   ×
276   43  RCL
277   37   37
278   55   ÷
279   43  RCL
280   39   39
281   95   =
282   45  YX
283   43  RCL ← log RRATE/log 2
284   41   41
285   65   ×
286   43  RCL
287   17   17
288   95   =
289   42  STO
290   59   59
```

Initialize for printing

```
291   58  FIX
292   02   02
293   02   2
294   42  STO  indirect register
295   01   01  for cj
296   05   5
297   01   1
298   42  STO  indirect register
299   00   00  for lables
300   71  SBR
301   00   00  place op code for
302   19   19  C2 in print register
```

$M_m' = s\lambda(MTRR + r_1\ MTTR\ \ )/u \cdot wt_m$

```
303   43  RCL
304   18   18
305   85   +
306   43  RCL
307   15   15
308   65   ×
309   43  RCL
310   19   19
311   95   =
312   55   ÷
313   05   5
314   03   3  ← u·wtm
315   71  SBR
316   00   00
317   24   24
```

$A(m') = \lceil m' - \min(m', AN)\rceil$

```
318   32  X:T
319   43  RCL
320   09   09
321   75   -
322   43  RCL
323   44   44
324   22  INV
325   77   GE
326   03   03
327   29   29
328   32  X:T
329   71  SBR
330   01   01
331   25   25
332   42  STO
333   03   03
```

$C_2 = (m'/s \cdot BG + A(m')(BN - BG))L \cdot N$

```
334   65   ×
335   53   (
336   43  RCL
337   45   45
338   75   -
339   43  RCL
340   46   46
341   54   )
342   85   +
343   43  RCL
344   09   09
345   55   ÷
346   43  RCL
347   32   32
348   65   ×
349   43  RCL
350   46   46
351   95   =
352   65   ×
353   43  RCL
354   47   47
355   71  SBR
356   00   00  print wage
357   00   00
```

$C_3 = (\lceil m' \rceil (TFI + r_1 TR) + A(m')TA)(1+TOR\cdot L)\cdot N$

```
358   43 RCL
359   09   09
360   71 SBR
361   01   01 ←⌈m'⌉
362   26   26
363   65   ×
364   53   (
365   43 RCL
366   20   20
367   85   +
368   43 RCL
369   15   15
370   65   ×
371   43 RCL
372   21   21
373   54   )
374   85   +
375   43 RCL
376   03   03
377   65   ×
378   43 RCL
379   48   48
380   95   =
381   65   ×
382   43 RCL
383   49   49 ← 1+TOR·L
384   71 SBR
385   00   00 Print Training
386   00   00
```

$C_4 = (S+S'\cdot L)\cdot UC\cdot N$

```
387   43 RCL
388   04   04
389   85   +
390   43 RCL
391   05   05
392   65   ×
393   43 RCL
394   47   47
395   95   =
396   65   ×
397   43 RCL
398   59   59
399   71 SBR
400   00   00 Print Hardware
401   00   00
```

$C_5 = (STE_{sys} + r_1 STE_{rpr})(1 + mL)\cdot N$

```
402   43 RCL
403   22   22
404   85   +
405   43 RCL
406   15   15
407   65   ×
408   43 RCL
409   23   23
410   95   =
411   65   ×
412   43 RCL
413   50   50 ← 1+mL
414   71 SBR
415   00   00 Print Support and
416   00   00 Test Equipment
```

$C_6 = \bar{\lambda}\cdot L(r_1 UC/C + r_2 COD)$

```
417   43 RCL
418   15   15
419   65   ×
420   43 RCL
421   59   59
422   55   ÷
423   43 RCL
424   24   24
425   85   +
426   43 RCL
427   16   16
428   65   ×
429   43 RCL
430   43   43
431   95   =
432   65   ×
433   43 RCL
434   06   06
435   65   ×
436   43 RCL
437   47   47
438   71 SBR
439   00   00 Print Repair
440   00   00
```

$C_7 = (1 + \bar{r}\tau)(IEC + IMC \cdot L)$

```
441   01   1
442   85   +
443   43  RCL
444   07   07
445   65   ×
446   43  RCL
447   25   25
448   95   =
449   65   ×
450   43  RCL
451   42   42  ← IEC + IMC·L.
452   71  SBR
453   00   00  Print Item Entry
454   03   03  and Management
```

$C_8 = P_f + r_1 P_r$

```
455   43  RCL
456   26   26
457   85   +
458   43  RCL
459   15   15
460   65   ×
461   43  RCL
462   27   27
463   95   =
464   71  SBR
465   00   00  Print Documentation
466   03   03
```

Print Life-Cycle Cost

```
467   98  ADV
468   43  RCL
469   02   02
470   69  OP
471   06   06


472   00   0
473   42  STO  set TC_0 = 0
474   03   03
475   22  INV
476   58  FIX
477   92  RTN
```

APPENDIX C:

SYSTEM AGGREGATION MODEL

PROGRAM LISTING

PRINT, STORE, SUM to LCC

```
000   76 LBL
001   99 PRT
002   85  +
003   73 RC*
004   00   00   Σi Ci,j
005   65  ×
006   43 RCL
007   44   44
008   95  =
009   72 ST*    output
010   02   02   register
011   69 OP
012   20   20
013   69 OP
014   22   22
015   87 IFF    if flag j is
016   40 IND    set do not
017   03   03   print Cj
018   00   00
019   22   22
020   69 OP
021   06   06
022   44 SUM
023   40   40   sum to LCC
024   73 RC*
025   01   01
026   69 OP     store op code
027   04   04   for next lable
028   69 OP     in print reg.
029   21   21
030   69 OP
031   23   23
032   92 RTN
```

PERSONNEL

```
033   73 RC*
034   00   00
035   69 OP
036   20   20
037   42 STO    M'
038   45   45
039   32 X:T
040   43 RCL
041   45   45
042   75  -
043   73 RC*
044   00   00
045   69 OP
046   20   20
047   22 INV
048   77  GE
049   00   00
050   52   52
051   32 X:T
052   95  =
053   32 X:T
054   00   0
055   77  GE
056   00   00
057   63   63
058   32 X:T
059   59 INT
060   85  +
061   01   1
062   95  =
063   42 STO
064   46   46   A(m') = ⌈m' - min(m', AN)⌉
```

Wage = (m'/s·BG + A(m')(BN-BG)·L·N

```
065  65  ×
066  53  (
067  73 RC*
068  00  00
069  69 OP
070  20  20
071  75  -
072  43 RCL
073  07  07
074  54  )
075  85  +
076  43 RCL
077  45  45
078  55  ÷
079  43 RCL
080  05  05
081  65  ×
082  43 RCL
083  07  07
084  95  =
085  65  ×
086  43 RCL
087  09  09
088  65  ×
089  43 RCL
090  08  08
091  95  =
092  71 SBR
093  00  00 print Wage
094  15  15
```

Trn = (A(m')TA + ⌈m'⌉TC)(1+TOR·L)·N

```
095  43 RCL
096  46  46
097  65  ×
098  73 RC*
099  00  00
100  69 OP
101  20  20
102  85  +
103  53  (
104  43 RCL
105  45  45
106  32 X:T
107  43 RCL
108  45  45
109  59 INT
110  67  EQ
111  01  01
112  15  15
113  85  +
114  01  1
115  54  )
116  65  ×
117  73 RC*
118  00  00
119  69 OP
120  20  20
121  95  =
122  65  ×
123  43 RCL
124  29  29
125  65  ×
126  43 RCL
127  08  08
128  95  =
129  71 SBR
130  00  00 print Training
131  15  15
132  92 RTN
```

end of subroutine PERSONNEL

AGGREGATION

```
133   76  LBL
134   12   B
135   94  +/-  ← -QIPA_i
136   76  LBL
137   11   A
138   42  STD
139   45   45 ← QIPA_i
140   44  SUM
141   41   41
142   55   ÷
143   43  RCL
144   14   14
145   95   =
146   44  SUM   Σ QIPA_i / MTBF_i
147   42   42
148   43  RCL
149   18   18
150   85   +
151   43  RCL
152   15   15
153   65   ×
154   43  RCL
155   19   19
156   95   =
157   65   ×
158   43  RCL
159   45   45
160   95   =
161   44  SUM  Σ MTRR_i + r_{s,i} MTTR_i
162   43   43
163   43  RCL
164   20   20
165   85   +
166   43  RCL
167   15   15
168   65   ×
169   43  RCL
170   21   21
171   95   =
172   42  STD  TC_m = TS_i + r_{s,i} TC_{m(i)}
173   02   02
174   43  RCL
175   45   45
176   55   ÷
177   43  RCL
178   12   12
179   95   =
180   42  STD   R_i = QIPA_i / q_i
181   46   46
```

initialize indirect registers

```
182   09   9
183   42  STD  C_{j,i} ind reg
184   00   00
185   03   3
186   09   9
187   42  STD  Σ_i C_{i,j} ind reg
188   01   01
```

sum in accumulation registers

```
189   73  RC*
190   00   00
191   65   ×    for j = 9-1
192   43  RCL
193   46   46   C_j = C_j + R_i C_{i,j}
194   95   =
195   74  SM*
196   01   01
197   69  OP
198   31   31
199   97  DSZ
200   00   00
201   01   01
202   89   89
```

```
203   43  RCL
204   11   11  print LRA
205   69  OP       identifier
206   04   04
207   43  RCL
208   45   45
209   69  OP
210   06   06
211   92  RTN
```

end of AGGREGATION

SYSTEM COSTS

```
212   76  LBL
213   13   C
214   58  FIX
215   02   02
216   43  RCL
217   12   12
218   65   ×
219   43  RCL
220   06   06
221   95   =
222   42  STO
223   44   44  n= g·Q
224   65   ×
225   53   (
226   43  RCL
227   13   13
228   55   ÷
229   05   5
230   03   3  ← U·WH_m
231   85   +
232   43  RCL
233   39   39
234   54   )
235   95   =
236   42  STO
237   13   13  M'_m = n SM |U·WH_m
238   43  RCL
239   32   32      + Σ_i m'_m(i)
240   65   ×
241   43  RCL
242   44   44
243   95   =
244   44  SUM
245   17   17  TC_m = TS+ nΣ_i TC_m(i)
246   43  RCL
247   05   05
248   65   ×
249   43  RCL
250   10   10
251   55   ÷
252   07   7
253   04   4  ← WH_o
254   65   ×
255   43  RCL
256   44   44
257   95   =
258   49  PRD
259   18   18  m'_o = s·AHR·n·θ/WH_o
260   43  RCL
261   33   33
262   65   ×
263   43  RCL
264   44   44
265   95   =
266   44  SUM
267   22   22  TC_o = TS_o +nΣTC_o
```

initalize indirect registers

```
268   00   0
269   42  STO
270   40   40  LCC
271   42  STO     ind. reg. for print/no print flags
272   03   03
273   01   1
274   03   3
275   42  STO  ind reg. for o and
276   00   00  m subscripted veriables
277   04   4
278   07   7
279   42  STO  ind reg. for lables
280   01   01
281   71  SBR
282   00   00  store op. code for
283   24   24  first lable in print register
```

C_1 = Maintenance Wage
C_2 = Maintenance Training

```
284   71  SBR
285   00   00  call subroutine PERSONNEL
286   33   33
```

C_3 = Operator Wage
C_4 = Operator Training

```
287   71  SBR
288   00   00  call subroutine PERSONNEL
289   33   33
```

initial initialize registers

```
290   04   4
291   42  STO  indirect reg. for
292   02   02  output costs
293   03   3
294   04   4   ind. reg. for
295   42  STO
296   00   00     Σ_i c_i,j
```

$C_5 = N \cdot n \cdot PT_\ell \left(\frac{N \cdot n}{\ell} \right)^{\log RRATE / \log 2} + n \sum_i HRDW_i$

```
297   43  RCL
298   08   08
299   65   ×
300   43  RCL
301   44   44
302   55   ÷
303   43  RCL
304   24   24
305   95   =
306   45  Y×
307   43  RCL
308   25   25   ← log RRATE/log 2
309   65   ×
310   43  RCL
311   23   23
312   65   ×
313   43  RCL
314   08   08
315   65   ×
316   43  RCL
317   44   44
318   71  SBR
319   99  PRT   Print Hardware
```

$C_6 = N \cdot STE \cdot (1 + mL) + n \sum_i STE_i$

```
320   43  RCL
321   08   08
322   65   ×
323   43  RCL
324   27   27
325   65   ×
326   43  RCL
327   28   28
328   71  SBR
329   99  PRT   Print Support &
                Test Equipment
```

$C_7 = n \sum_i RPR_i$

```
330   71  SBR
331   00   00
332   03   03   Print Repair
```

$C_8 = n \sum_i IEMC_i$

```
333   71  SBR
334   00   00
335   03   03   Print Item Entry
                and management
```

$C_9 = DOC_{sys} + n \sum_i DOC_i$

```
336   69  OP
337   33   33   Flag 8 will suppress
338   43  RCL    printing C8 and C9
339   26   26
340   71  SBR
341   99  PRT   Print Documentation
```

Make ouput compatible with Aggregation input

```
342   43  RCL
343   13   13
344   42  STO
345   09   09   STO ni_m
346   43  RCL
347   17   17
348   42  STO
349   20   20   STO TC_m
350   43  RCL
351   22   22
352   42  STO
353   03   03   STO TC_o
354   00   0
355   42  STO   set r_i=0
356   15   15
357   43  RCL
358   43   43
359   55   ÷
360   43  RCL
361   41   41
362   95   =
363   42  STO   MTTRS = Σ MTTR_i / Σ_i QIPA_i
364   18   18
365   43  RCL
366   42   42
367   35  1/X
368   42  STO
369   14   14   MTBF = (Σ_i MTBF_i)^-1
```

Print Life Cycle Cost

```
370  98 ADV
371  43 RCL
372  40  40
373  71 SBR
374  00  00
375  20  20
376  22 INV
377  58 FIX
378  92 RTN
```

Print MTBF and MTTR

```
379  76 LBL
380  14  D
381  58 FIX
382  02  02
383  98 ADV
384  43 RCL
385  14  14
386  71 SBR ← MTBF
387  00  00
388  20  20
389  43 RCL
390  18  18
391  71 SBR ← MTTR
392  00  00
393  20  20
394  22 INV
395  58 FIX
396  92 RTN
```

APPENDIX D:

SYSTEM CONFIDENCE LEVEL

PROGRAM LISTING

```
069   76 LBL
070   13  C
071   00  0   ← divide out
072   75  -
073   76 LBL
074   12  B
075   01  1   ← prod K
076   95  =
077   42 STO
078   42  42


079   29 CP
080   43 RCL
081   15  15  if r1 = 1
082   22 INV  (local repair)
083   67  EQ  K already
084   01  01  computed B=0
085   29  29  K(t)= K(LRT)
```

compute confidence level at depot

```
086   43 RCL
087   41  41
088   65  ×
089   43 RCL
090   29  29
091   95  =
092   42 STO
093   00  00  x= λy
094   75  -
095   43 RCL
096   28  28
097   59 INT
098   67  EQ  if B=0
099   01  01  b= e^-x
100   59  59
101   95  =
102   55  ÷
103   43 RCL
104   00  00
105   34 ΓX
106   95  =
107   36 PGM
108   14  14
109   11  A
110   36 PGM
111   14  14
112   12  B   b= Q((x-B)/√x)
```

compute achieved confidence level

```
113   65  ×
114   53  (
115   43 RCL
116   28  28
117   22 INV
118   59 INT
119   75  -
120   43 RCL
121   10  10
122   54  )
123   85  +
124   43 RCL
125   10  10
126   95  =
127   42 STO
128   28  28  K= b(K(D) - K(XD)) + K(XD)
```

initialize printing register

```
129   43 RCL
130   11  11
131   69 OP
132   04  04
133   58 FIX
134   02  02


135   43 RCL
136   28  28
137   45 YX
138   43 RCL
139   42  42
140   95  =
141   49 PRD
142   40  40  if R92 = -1 then
143   45 YX   divide out of K
144   43 RCL  and print -K×100
145   42  42
146   65  ×
147   43 RCL  else prod K
148   42  42  and print K×100
149   65  ×
150   01  1
151   00  0
152   00  0
153   95  =
154   69 OP
155   06  06
156   22 INV
157   58 FIX
158   92 RTN
```

```
000   76  LBL  BEGIN EXECUTION
001   11   A
002   43  RCL
003   32   32
004   65   ×
005   43  RCL
006   37   37
007   65   ×
008   43  RCL
009   38   38
010   55   ÷
011   02   2   ← d
012   95   =
013   42  STO  y= s.N·DRT/d
014   41   41
015   01   1
016   42  STO
017   40   40  k=1
```

Print Initialization Heading

```
018   01   1
019   05   5
020   03   3
021   02   2
022   03   3
023   01   1
024   02   2
025   01   1
026   02   2
027   04   4
028   69  OP   "CONFI"
029   01   01
030   01   1
031   06   6
032   01   1
033   07   7
034   03   3
035   01   1
036   01   1
037   05   5
038   01   1
039   07   7
040   69  OP   "DENCE"
041   02   02
042   02   2
043   07   7
044   01   1
045   07   7
046   04   4
047   02   2
048   01   1
049   07   7
050   69  OP   "ᵥLEVE"
051   03   03
052   02   2
053   07   7
054   00   0
055   00   0
056   05   5
057   05   5
058   06   6
059   01   1
060   05   5
061   06   6
062   69  OP   "Lᵥ(%)"
063   04   04
064   98  ADV
065   69  OP
066   05   05
067   98  ADV
068   92  RTN
```

if B=0

```
159  95   =
160  43  RCL
161  00   00
162  94  +/-
163  22  INV
164  23  LNX  b=e^-x
165  61  GTO
166  01   01
167  13   13
```

Print System Confidence Level

```
168  76  LBL
169  14   D
170  69  OP
171  00   00
172  03   3
173  06   6
174  04   4
175  05   5
176  03   3
177  06   6
178  69  OP
179  02   02  "vvSYS"
180  03   3
181  07   7
182  01   1
183  07   7
184  03   3
185  00   0
186  00   0
187  00   0
188  00   0
189  00   0
190  69  OP   "TEMvv"
191  03   03
192  98  ADV
193  69  OP
194  05   05
195  58  FIX
196  02   02
197  43  RCL
198  40   40
199  65   ×
200  01   1
201  00   0
202  00   0
203  95   =
204  99  PRT  Print K×100
205  98  ADV
206  22  INV
207  58  FIX
208  92  RTN
```