theassessmentgroup

710 Wilshire Boulevard, Suite 301
Santa Monica, California 90401
213/394-6778

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SLIDE-RULE MODEL SYSTEM
USER'S GUIDE,

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(10) Thomas M. Neches

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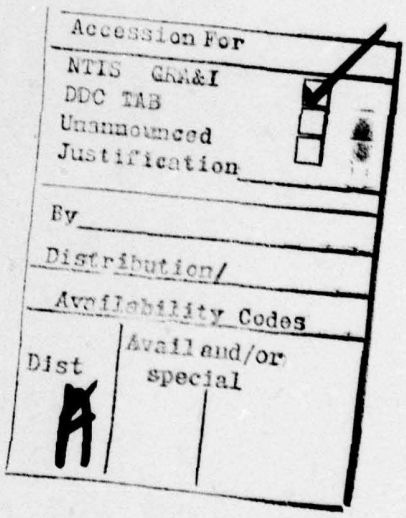


INTRODUCTION

The Level I "Slide-Rule" Cost Model System is implemented on a Texas Instruments TI-59 programmable calculator coupled to a TI-PC-100A Print/Security Cradle.

The model system consists of four linked programs, the Top-Down Model, (TDM), the Lowest Removable Assembly Model (LRAM), the System Aggregation Model (SAM), and the System Confidence Model (SCM). Each program and its data input sets are stored on magnetic cards. The output of each program is used as input to succeeding programs, together with additional input data.

The TI-59 has 120 program/data registers, which can be partitioned as desired between program instruction steps and data memory registers. When the calculator is turned on, 60 memory registers are automatically reserved for data storage. All programs other than the TDM use the default allocation. The TDM, however, uses only 40 registers for data storage; the remainder is used to store the program code. Therefore, when running the TDM, the first step after turning on the calculator will be to repartition the memory registers.

Model output and all cost inputs are given in thousands of dollars. TDM running time is approximately 1 minute; LRAM running time is approximately 40 seconds (slightly greater if the LRA is coded depot repair); the SAM requires approximately 10 seconds per aggregation run; SCM running time is approximately 10 seconds per LRA input.

If program execution is interrupted in the models of a run, it is likely that the calculator will be in the Fix 2 display mode. If this

occurs, press [INV] [2nd] [■] before reading in any new data cards.

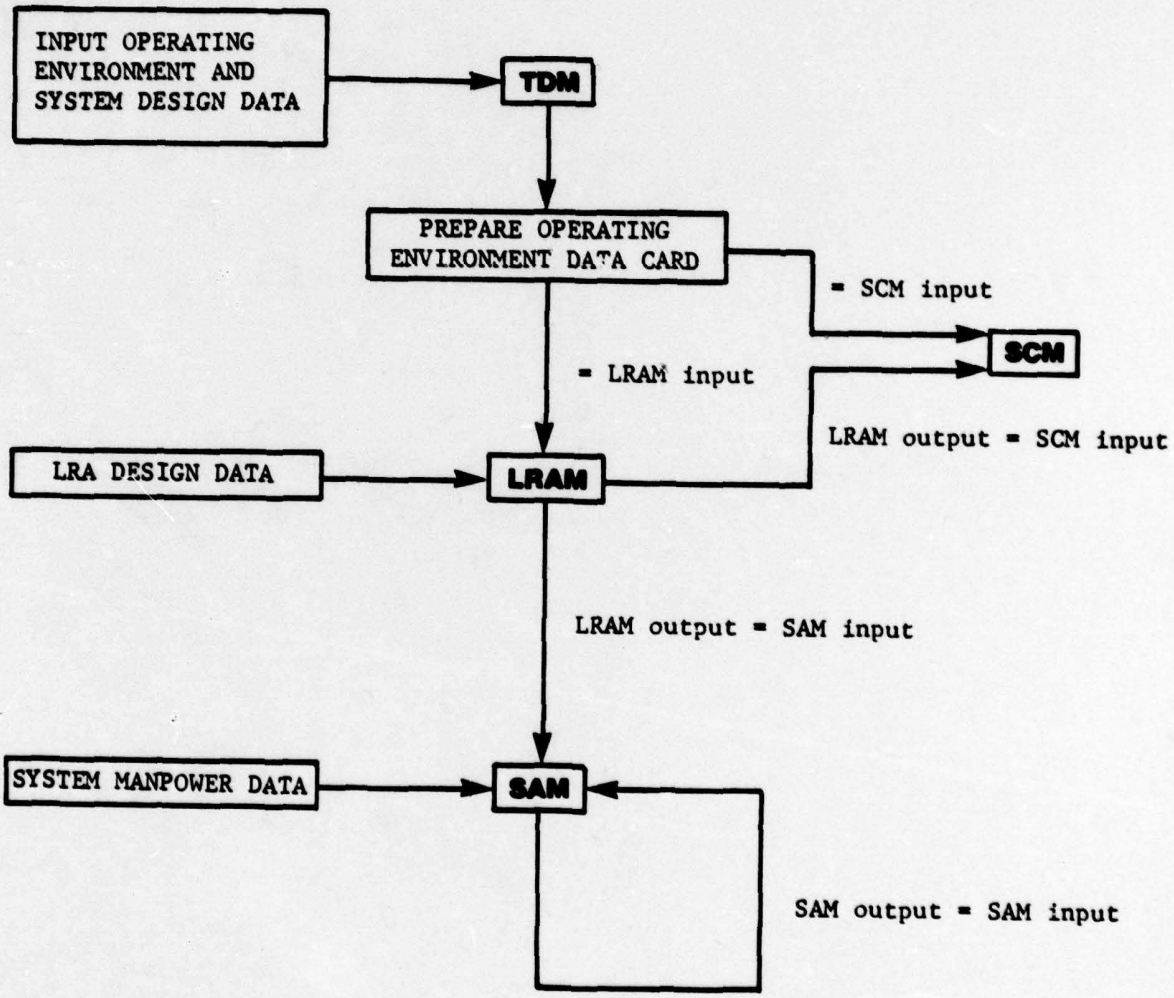
In order to conserve memory register space, several constants describing the operating environment of the system have been incorporated into the program code. A list of these constants and their location in the program is presented for each model. Values of the code constants can be altered by adjusting the program code. The routine for altering the values of the code constants is the following:

1. Press [GTO].
2. Enter Program Location.
3. Press [LRN].
4. Enter New Value.
5. Press [LRN].

New values of the code constants must have *exactly* the same numbers of decimal places (including any decimal points) as the original value. (For example, 1.0 may be replaced by 10., .01, 100, 9.5, 000, etc., but *not* by 1, 1.00, .0, 10.0, 2., etc.) Failure to do this will almost certainly cause program execution errors.

Figure 1 presents the input/output linkage between the four models. Program operation for the TDM, LRAM, SAM and SCM is described in the User's Guide Supplements A, B, C and D. Each subsection is a self-contained unit presenting program operating instructions, data input/output instructions, code constant program locations, and program data register allocation and usage.

Figure 1 Level I Input/Output



USER'S GUIDE SUPPLEMENT

FOR TOP-DOWN MODEL

Figure A-1 TDM Operating Instructions

Step	Procedure	Press	Display/Printer
1	Repartition memory	4 [2nd] [ ] 17	639.39
2	Load program and input data	[CLR] (load banks 1, 2, 3, 4)	1, 2, 3, 4
3	Alter input data* (i.e., set MTBF = 240 hrs.)	240 [STO] 21	240.
4	Run program (To suppress printing of C_j press [2nd] [ ] j. To restore printing option press [INV] [2nd] [ ] j.+ To suppress discounting option press [2nd] [ ] 0. To restore option press [INV] [2nd] [ ] 0.) +Both C_8 and C_9 are operated by flag 8. Do *not* set flag 9 for any reason.	[A]	C_1 = maintenance wage C_2 = maintenance training C_3 = operator wage C_4 = operator training C_5 = production and spares C_6 = support and test eqpt. C_7 = repair C_8 = item entry and management C_9 = documentation life cycle cost = $\sum C_j$
5	For new design variant go to Step 3		
6	Record input data for future use	3 [2nd] [ ] (load bank 3) 4 [2nd] [ ] (load bank 4)	3. 4.

* See Figure A-3.

Figure A-2 Altering Operating Environment Output Data Card

Step	Procedure	Press	Display/Printer
1	Load Operating Evironment data card*	CLR (load Bank 3)	3.
2	Alter input data** (example: set L = 6.67)	6.67 STO 47	6.67
3	Record op. env. data card for use in LRAM and SCM	3 2nd [illegible] (load Bank 3)	3.

*Turn calculator off for a few seconds to insure normal partitioning (479.59).
**See Figure 2.5.

Figure A-3 TDM Input Data

(Sample Data Collection Worksheet)

Variable Name	Units	(Sample) Value	Storage Address	Definition
r_1	---		02	Fraction LRA's coded local repair
LRT	weeks		03	Average local repair response time
r_2	---		06	Fraction LRA's coded depot repair
D	weeks		07	Deployment period
n´	---		10	Total # LRA's in system
n	---		11	# Unique LRA types in system
s	---		12	Ratio peak operating hrs. per wk. to av. op. hrs./wk.
N	---		13	# Ships
AN_m	men		14	On-board available maintenance personnel
BN_m	$´000		15	Annual billet cost for maintenance personnel
AN_o	men		17	On-board available operators
BN_o	$´000		18	Annual billet cost for operators
TC_o	$´000		19	"C" School training cost for operators
LC	years		20	System life cycle
MTBF	hours		21	System mean time between failure
UC_ℓ	$´000		22	Estimated unit production cost at lot size LOT
ℓ	---		23	LOT size used for UC_{LOT}
Q	---		24	# Systems per ship
AHR	hrs/wk		25	Av. system operating hrs./ operating wk.
MTTRS	manhour		26	Mean time to repair system
SM	manhrs/ week		27	Weekly scheduled maintenance manhour requirement

Figure A-3 TDM Input Data (cont'd)

Variable Name	Units	(Sample) Value	Storage Address	Definition
TC_m	$'000		28	System level maintenance training requirement
θ	men		29	# Operators/system
STE	$'000		30	System level support and test equipment purchase cost
COD	$'000		31	Cost of repair at contractor operated depot
RP	$'000		32	Repair materials cost for local repair of LRA
DOC	$'000		33	System level documentation cost

Figure A-4 TDM Code Constant Program Location

Variable Name	Units	Program Location	Current Value	Available Program Steps*	Definition
BG	$'000	062	10.5	4	Annual billet cost for general labor personnel
TA	$'000	090	10.0	4	Average cost of "A" school training course
TOR	---	099	.45	3	Annual personnel turn-over rate
K*	---	230	.95	3	Confidence level against on-board spare stock-out
DRT/d**	weeks	288	13	2	(Depot response time = 26 wks.)/(# depots = 2)
Z_b	---	295	1.65	4	Standard deviation for .95 confidence level against LRA stock-out at depot
d**	---	305	2	1	# Depots
h	---	334	2	1	# Deployments/year
1-COND	---	355	.98	3	1 - (Condemnation Rate = .02)
log RRATE/ log 2	---	374	.15	4	Learning curve reduction factor = log .90/ log 2
ρ	---	384	.10	3	Discount rate
$\tilde{M}$	---	430	1.0	3	Ratio ($MTTR_{LRA}/MTTR_{SYS}$)
$WH_m \cdot U$	hr./wk.	445	53	2	(Maintenance personnel wkly. avail. work hrs. = 67)·(Util. Rate = .8)
$\tilde{T}$	---	456	1.0	3	Ratio (TC_{LPA}/TC_{SYS})

*Includes decimal point and change-sign operator.
**Altering d requires altering DRT/d as well.

Figure A-4 TDM Code Constant Program Location (cont'd)

Variable Name	Units	Program Location	Current Value	Available Program Steps	Definition
WH_o	hr./wk.	492	74	2	Operator wkly. available work hrs.
$\tilde{S}$	---	529	1.0	3	Ratio (STE_{LRA}/STE_{SYS})
m	---	537	.12	3	Annual support of support eqpt. factor
IEC	$\$'000$	569	.45	3	Item entry cost
IMC	$\$'000$	573	.23	3	Item management cost
pp	---	583	1.0	3	Av. unique components per LRA
$\tilde{D}$	---	611	1.0	3	Ratio (DOC_{LRA}/DOC_{SYS})

Figure A-5 Operating Environment Variable Card*

Variable Name	Units	(Sample) Value	Storage Address	Definition
Q	---		30	# Systems per ship
AHR	hr./wk.		31	Av. system operating hr./ operating week
s	---		32	Ratio peak operating hrs. per wk. to av. operating hrs. per week
LRT	weeks		33	Average local response time
D	week		34	Deployment period
K	---		35	Desired LRA confidence level**
XD	weeks		36	Lead time if depot stock-out
N			37	# Ships
DRT	---		38	Depot response time
ℓ	---		39	Lot size used for unit cost estimations
1-COND	---		40	1-(condemnation rate)
log RRATE/ log 2	---		41	Learning curve factor
IEC+IMC•L	$'000		42	Item entry and management factor
COD	$'000		43	Cost of repair at contractor operated depot
AN	men		44	Maintenance manpower available to LRA**
BN	$'000		45	Annual billet cost for trained maintenance personnel

*This card, prepared by the system designer, is input to the LRAM and SCM.

**Value may vary for different LRA's.

Figure A-5 Operating Environment Variable Card (cont'd)

Variable Name	Units	(Sample) Value	Storage Address	Definition
BG	$'000		46	Annual billet cost for general labor personnel
L	yrs.		47	Discounted life cycle
TA	$'000		48	"A" School course cost for maintenance personnel
(1+TOR·L)	---		49	Discounted personnel attrition factor
(1+mL)	---		50	Discounted support and test equipment maintenance factor

Figure A-6 TDM Memory Register Allocation

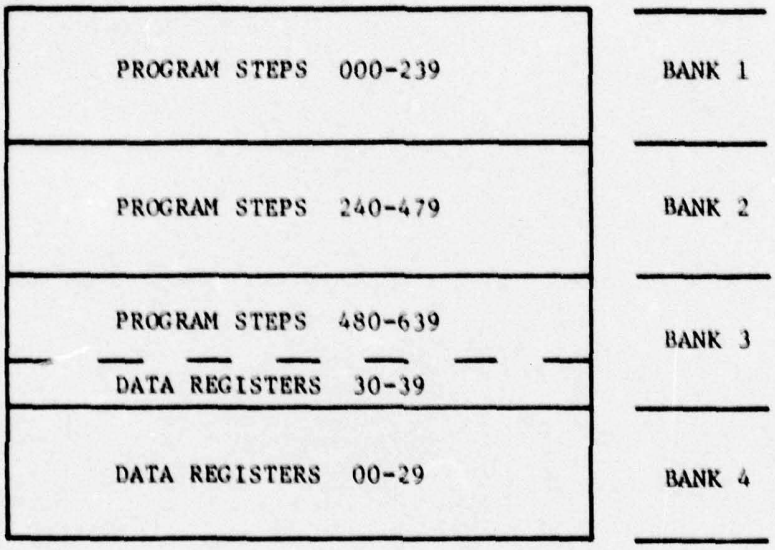


Figure A-7 TDM Data Register List

BANK 4			BANK 3		
00	indirect		30	STE	●
01	hold, μ, indirect flg		31	COD	●
02	LRT	●	32	RP	●
03	S_1, ρL	●	33	DOC	●
04	K, A		34	SPARES, S	
05	r_1		35	K, B	
06	D	●	36	λ', h•D	
07	S_2, S'	●	37	λ, LCC	
08	K_2, UC		38	V	
09	r_2		39	$r_1 + r_2$	
10	n	●	40		
11	n	●	41		
12	s	●	42		
13	N	●	43		
14	AN_m	●	44		
15	BN_m	●	45		
16	TC_m		46		
17	AN_o	●	47		
18	BN_o	●	48		
19	TC_o	●	49		
20	LC	●	50		
21	MTBF	●	51		
22	UC_ℓ	●	52		
23	ℓ	●	53		
24	Q	●	54		
25	AHR	●	55		
26	MTTRS	●	56		
27	SM	●	57		
28	TS_m	●	58		
29	θ	●	59		

● Marks input variable

USER'S GUIDE SUPPLEMENT

FOR LOWEST REMOVABLE ASSEMBLY MODEL

Figure B-1 LRAM Operating Instructions

Step	Procedure	Press	Display/Printer
1	Load program	CLR (load Bank 1) CLR (load Bank 2)	1. 2.
2	Load operating environment data card	CLR (load Bank 3)	3.
3	Load input data	CLR (load Bank 4)	4.
4	Alter input data*	1000 STO 1 4	1000.
5	Run program (To suppress printing of C_j, j = 2-8, press 2nd [illegible] j. To restore printing option press INV 2nd [illegible] j. Note: there is no C_1.)	A	C_2 WAGE C_3 TRN C_4 HRDW C_5 STE C_6 RPR C_7 IEMC C_8 DOC $\sum C_j$ *LCC
6	For new design variant go to Step 4		
7	Record input/output data	4 2nd [illegible] (load Bank 4)	4.

*See Figure B-2.

Figure B-2 LRAM Data Input Instructions

(Sample Data Collection Worksheet)

Variable Name	Units	(Sample) Value	Storage Address	Definition
"IDEN"	---		11	OP Code for LRA identifier*
q	---		12	Total # of units in the system
δ	---		13	Ratio (LRA oper. hrs./system op. hrs.
MTBF	hrs.		14	Mean time between failure
r_1	---		15	Local repair LOR switch**
r_2	---		16	Depot Repair LOR switch**
UC_{ℓ}	$'000		17	Estimated unit cost at lot size (specified in op. envir. data)
MTTRS	manhour		18	Mean time to repair system due to LRA failure
MTTR	manhour		19	Mean time to repair LRA***
TFI	$'000		20	Specific training cost to remove and replace LRA
TR	$'000		21	Training cost to repair LRA***
STE	$'000		22	Purchase cost of system support
STE_{rpr}	$'000		23	Purchase cost of support and test eqpt. to repair LRA***
c	---		24	Total # of components in LRA
$\bar{c}$	---		25	# of new components unique to LRA
DOC	$'000		26	Documentation cost to describe LRA
DOC_{rpr}	$'000		27	Documentation cost for repair of LRA***

*A four letter identifier used when the LRAM output is input to the SAM.
**For local repair set $r_1 = 1$, $r_2 = 0$.
For depot repair set $r_1 = 0$, $r_2 = 1$.
For discard set $r = 0$, $r_2 = 0$.
***If coded local repair.

Figure B-3 LRAM Code Constant Program Location

Variable Name	Units	Program Location	Current Value	Available Program Steps	Definition
d	---	221 and 228*	2	1	# Depots
h	---	247	2	1	# Deployments/yr.

*d must be altered in both locations.

Figure B-4 LRAM Memory Register Allocation

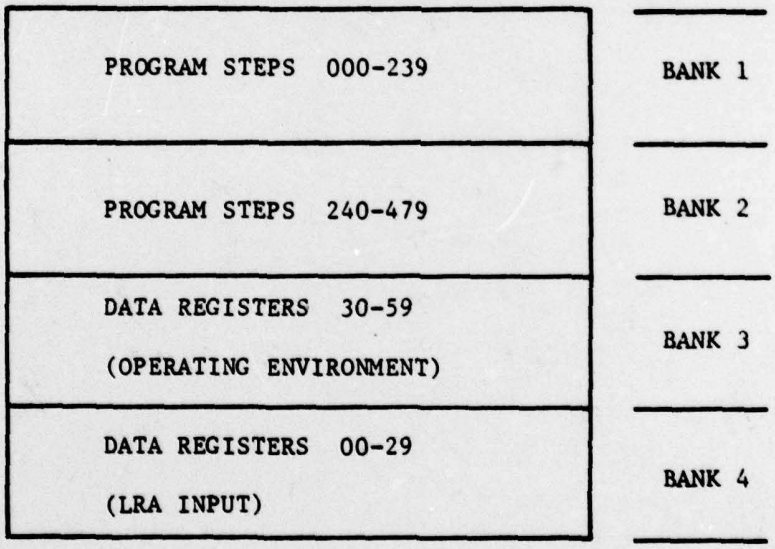


Figure B-5 LRAM Data Register Listing

BANK 4

00	ind. lbl.	
01	ind. C_j	
02	LCC, hold	
03	TC_o, C_4, A, X	
04	C_5, S	
05	C_6, S´	
06	C_7, $\bar{\lambda}$	
07	C_8, $r_1 + r_2$, K	
08	C_9, B	
09	M_m', hold	
10	K(XD)	
11	"IDEN"	●
12	q	●
13	δ	●
14	MTBF	●
15	r_1	●
16	r_2	●
17	UC_ℓ	●
18	MTTRS	●
19	MTTR	●
20	TS	●
21	TR	●
22	STE	●
23	STE_{rpr}	●
24	c	●
25	$\bar{c}$	●
26	DOC	●
27	DOC_{rpr}	●
28	B. K(t)	●
29	λ	●

LRAM Input/Output Card

BANK 3

30	Q
31	AHR
32	s
33	LRT
34	D
35	K
36	XD
37	N
38	DRT
39	ℓ
40	1-COND
41	log RRATE/log 2
42	IEC+IMC·L
43	COD
44	AN
45	BN
46	BG
47	L
48	TA
49	(1+TOR·L)
50	(1+mL)
51	"WAGE"
52	"TRN"
53	"HRDW"
54	"STE"
55	"RPR"
56	"IEMC"
57	"DOC"
58	"*LCC"
59	hold UC

Op. Env. Data Card

● Marks Input Variable

USER'S GUIDE SUPPLEMENT

FOR SYSTEM AGGREGATION MODEL

Figure C-1 SAM Operating Instructions

Step	Procedure	Press	Display/Printer
1	Load program	CLR (load Bank 1)	1.
		CLR (load Bank 2)	2.
2	Initialize aggregation registers(load initializing card)	CLR (load Bank 3)	3.
3	Load output card for LRA_i*	CLR (load Bank 4)	4.
4	Aggregate		
	Add QIPA LRA's	QIPA A	QIPA IDEN
	Remove QIPA LRA's	QIPA B	-QIPA IDEN
5	Repeat Step 3 and 4 for all LRA's in system		
6	Load system manpower cost card	CLR (load Bank 4)	4.
7**	Alter system input data (i.e., set SM = 2 hrs.)	2 STO 13	2.
8**	Record new system data for future use	4 2nd Write (load Bank 4)	4.

*Output can also from SAM.
**This step may be skipped.

Figure C-1 SAM Operating Instructions (cont'd)

Step	Procedure	Press	Display/Printer
9	Compute system costs	C	C_1 MWGE C_2 MTRN C_3 OWGE C_4 OTRN C_5 HRDW C_6 STE C_7 RPR C_8 IEMC C_9 DOC $\sum C_j$ *LCC
10	For new design variant go to Step 3 or Step 6		
11	Compute system MTBF and MTTR	D	MTBF MTBF MTTR MTTR
12	Record output data for future use (as input to SAM)	4 2nd Write (load Bank 4)	4.

Figure C-2 SAM Input Data

(Sample Data Collection Worksheet)

Variable Name	Units	(Sample) Value	Storage Address	Definition
s	---		05	Ratio peak to average weekly operating hours
Q	---		06	# Systems per ship
BG	$'000		07	Annual billet cost for general labor personnel
N	---		08	# Ships
L	yrs.		09	Discounted life cycle
AHR	hrs/wk.		10	Av. weekly operating hrs.
"SYS"	---		11	System identifier*
q	---		12	# Units per system**
SM	manh./ week		13	Weekly scheduled maintenance requirement
AN_m	men		14	Available pool of trained maintenance personnel
BN_m	$'000		15	Annual billet cost of trained maintenance personnel
TA_m	$'000		16	"A" School course cost for maintenance personnel
TC_m	$'000		17	System orientation course cost for maintenance personnel
θ	men		18	# Operators/unit
AN_o	men		19	Available pool of trained operators
BN_o	$'000		20	Annual billet cost of trained operators

*Used only if SAM output is used on SAM input.
**q = 1 if SAM us used system level.

Figure C-2 SAM Input Data (cont'd)

Variable Name	Units	(Sample) Value	Storage Address	Definition
TA_o	$'000		21	"A" school course cost for operators
TC_m	$'000		22	System orientation course cost for operators
PT_ℓ	$'000		23	Estimated system assembly cost at lot size ℓ
ℓ	---		24	Lot size used for system assembly cost estimate
log RRATE /log 2	---		25	Learning curve factor (log reduction rate)/log 2
DOC	$'000		26	System level documentation cost
STE	$'000		27	System level support and test equipment cost
(1+mL)	---		28	Discounted support of support equipment factor
(1+TOR·L)	---		29	Discounted personnel attrition factor

Figure C-3 SAM Memory Register Allocation

PROGRAM STEPS 000-239	BANK 1
PROGRAM STEPS 240-396	BANK 2
DATA REGISTERS 30-59 (Initialization and Accumulation)	BANK 3
DATA REGISTERS 00-29 (LRAM output, System Manpower, SAM output)	BANK 4

Figure C-4 SAM Data Register Listing

BANK 4

00	
01	
02	
03	/ TC_o
04	/ HRDW
05	s / STE
06	Q / RPR
07	BG / IEMC
08	N / DOC
09	L / M_m'
10	ANR
11	"SYS" / "SYS"
12	q / q
13	SM
14	AN_m / MTBF
15	BN_m / r = 0
16	TA_m
17	TC_m
18	θ / MTTR
19	AN_o
20	BN_o / TC_m
21	TA_o
22	TC_o
23	PT_ℓ
24	ℓ
25	log RRATE ÷ log 2
26	DOC
27	STE
28	1 + mL
29	1 + TOR·L

Manpower Input/SAM Output

BANK 4

00	
01	
02	
03	TC_o = 0
04	HRDW
05	STE
06	RPR
07	IEMC
08	DOC
09	M_m'
10	
11	"IDEN"
12	q
13	
14	MTBF
15	r_ℓ
16	
17	
18	MTTRS
19	MTTR
20	TS
21	TC_m
22	
23	
24	
25	
26	
27	
28	
29	

LRAM Output

BANK 3

30	
31	
32	ΣTC_m = 0
33	ΣTC_o = 0
34	ΣHRDW = 0
35	ΣSTE = 0
36	ΣRPR = 0
37	ΣIEMC = 0
38	ΣDOC = 0
39	ΣM_m = 0
40	LCC = 0
41	ΣQIPA = 0
42	ΣMTBF = 0
43	ΣMTTR = 0
44	n hold
45	QIPA, M_o' hold
46	R, A hold
47	"MWGE"
48	"MTRN"
49	"OWGE"
50	"OTRN"
51	"HRDW"
52	"STE"
53	"RPR"
54	"IEMC"
55	"DOC"
56	"LCC"
57	"MTBF"
58	"MTTR"
59	

Initialize/Aggregation Registers

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FOR SYSTEM CONFIDENCE MODEL

Figure D-1 SCM Operating Instructions

Step	Procedure	Press	Printer/Display
1	Load Program	CLR (load Bank 1)	1.
2	Load Operating Environment Card	CLR (load Bank 3)	3.
3	Initialize	A	CONFIDENCE LEVEL (%)
4	Load Output Card for LRA	CLR (load Bank 4)	
5	Compute achieved confidence level, add to system confidence*	B	K_i IDEN
6	Repeat Steps 4 and 5 for every LRA in the system		
7	Compute achieved system confidence	D	SYSTEM $\bar{K}$

*If an LRA is added by mistake in Step 5, load the card in again and press C.

Figure D-2 SCM Memory Register Allocation

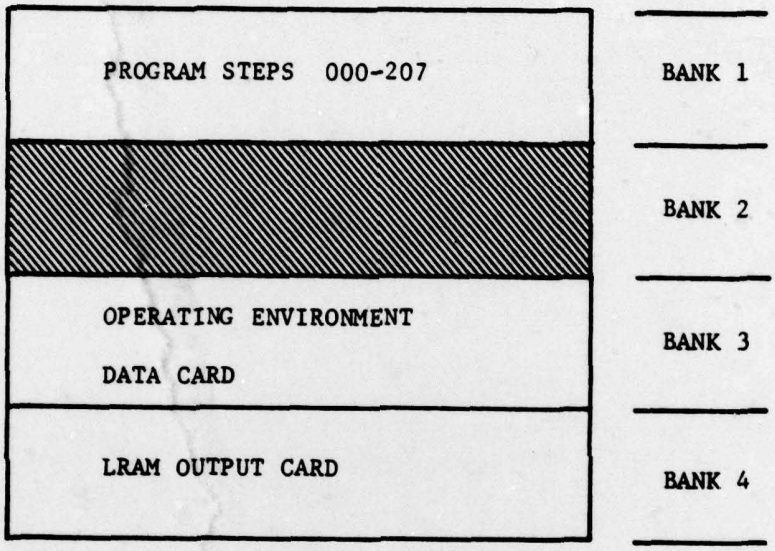

Figure D-3 SCM Data Register Listing