

UPDATE #34
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LMS USER'S MANUAL

VOLUME 1

PREFACE

When a change is made which affects a system documented in the manual, the programmer making the change will be responsible for an updated replacement/addition to the manual. The update page(s) should have a cover page addressed to "LMS Programmers" explaining where and how to insert the changes. It will be the Programming Secretary's responsibility to be aware of these changes and update the master copy accordingly.

The end result of a completely up-to-date Programmer's Manual can be accomplished only through full cooperation of everyone concerned.

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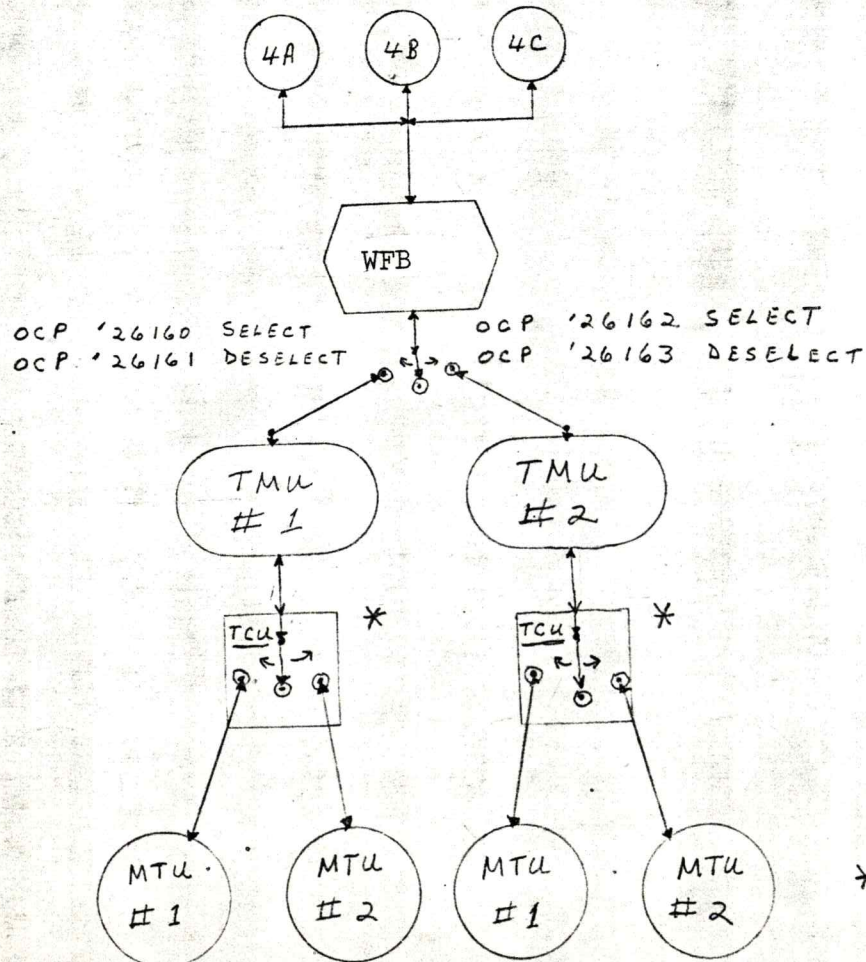
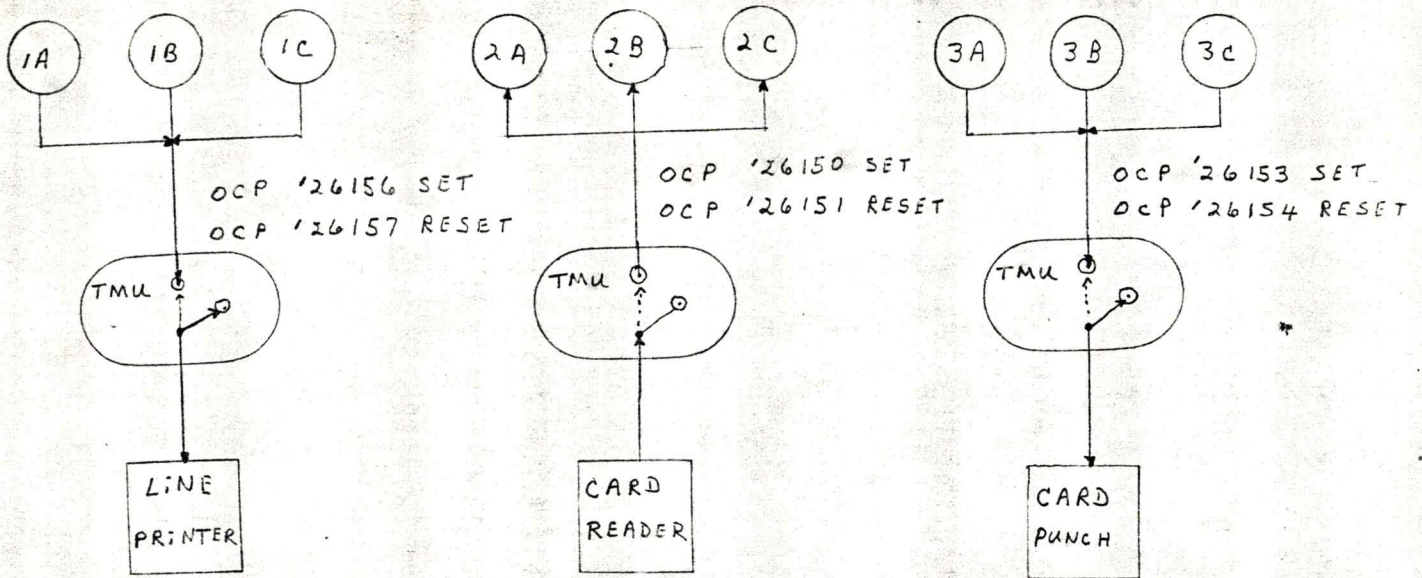
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I LMS Complex



* MTU IS SPECIFIED WITH THE OCP FUNCTION.

1. The LMS Complex uses two standard DDP 224 Central Processing Units (CPU) - A and B - similar to D and E of the CMS complex - and one specially modified DDP 224 CPU - C - similar to F of the CMS complex.
2. Each CPU has two banks of memory - lower and upper. Each bank is made up of four 8K memory modules. Lower and upper banks of A, lower and upper banks of B and lower bank of C each contain three private modules and share one common module. Upper bank of C contains four private modules and does not share any modules.
3. Each module has an addressing range of '00000 to '17777. Each bank has an address range of '00000 to '77777. Addressing locations '60000 to '77777 from AL, AU, BL, BU, and CL will access the shared common module.
4. Each CPU has its own Direct Memory Access (DMA) which can access memory only if the CPU is not accessing. There is one Fully Buffered Channel (FBC) which can access one module while the CPU accesses another module. The FBC is used for I/O to the simulator hardware to allow the CPU's to be active during I/O activity. All I/O data is located in common to allow the I/O to be done directly between memory and hardware without the burden of a prior memory to memory transfer.

COMMON CORE LAYOUT

	REAL TIME I/O DATA POOL ←
DBI	← DIGITAL BIT INPUT TABLE
SCS	← STABILIZATION AND CONTROL INPUT TABLE
DWI	← DIGITAL WORD INPUT TABLE
DBO	← DIGITAL BIT OUTPUT TABLE
A/D	← ANALOG TO DIGITAL TABLE (INPUT)
DBO	← DIGITAL BIT OUTPUT TABLE
D/A	← DIGITAL TO ANALOG TABLE (OUTPUT)
DWOR	← DIGITAL WORD OUTPUT (RELAY) TABLE
DWOD	← DIGITAL WORD OUTPUT DIRECT
AMSI	← DATA TRANSFER FROM CMS
AMSO	← DATA TRANSFER TO CMS
CCBI	← DATA TRANSFER FROM MCC (GSSC)
CCBO	← DATA TRANSFER TO MCC (GSSC)
TM	← TELEMETRY OUTPUT TABLE
	REAL TIME I/O DATA POOL ←
PATCH AREA	
	← TIMING STUDY BOOLEANS
	← MALFUNCTIONS
CCM	← CONSTANTS
BCM	← BOOLEANS
VCM	← VARIABLES
	← XY, XT, EVENT AND PARAMETER DISPLAY.
PATCH AREA	

LB

TSAFEA	← COMPUTER STORE, SAFE STORE, RESET BUFFER
LGCBUFF	← LGC CHANNELS, COUNTERS, AND FLAGS
	← LGC DOWN TELEMETRY BUFFER
YO2DATA	← A&B LOG BUFFER (204_{10})
BCDIØBUF	← GENERAL BCD I/Ø BUFFER (30_{10})
PATCH AREA	
	← LOAD-DUMP-VERIFY (LDV)

MALFUNCTIONS

Effective for Load ML1011-A; the following changes have been made to the malfunctions:

	<u>System</u>	<u>Additional Spares</u>	<u>Total Available</u>
1.	EP	0	108
2.	EC	0	131
3.	S & C	10	167
4.	RC	0	233
5.	ED	0	31
6.	PG	0	133
7.	CM	8	40
8.	PR	-9	156
9.	AG	-9	0
10.	IN	0	24
			<u>1023</u>

The MIU program will access the total number of malfunctions available for Load ML1011-A.

The following list should be used to see how many core locations a particular malfunction group should be changed:

<u>System</u>	<u>ML10-01 Starting Address</u>	<u>Address Change</u>	<u>New Starting Address</u>
EP	'66000	0	'66000
EC	'66154	0	'66154
SC	'66357	0	'66357
ED	'66614	+10	'66626
RC	'66653	+10	'66665
PG	'67224	+10	'67236
CM	'67431	+10	'67443
PR	'67471	+18	'67513
IN	'67747	0	'67747

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COMPUTER FAILURE

1. Information Required from User:

- 1.1 Fill out Dump Form.
- 1.2 Describe failure symptoms, any unusual observations, any special circumstances of your run.
- 1.3 Describe actions taken to recover, which diagnostics were run (if any), results of recovery and diagnostic efforts.
- 1.4 Note date, time, tape numbers, personnel involved, etc.

2. Dump Information:

- 2.1 Load ID, Date, Revision Level, and MIT load ID; Reset ID, Date, Revision Level, and Reset Point Number.
- 2.2 Register contents.
- 2.3 OS History of Execution to show computations leading up to the failure.
- 2.4 IS/CS History of action to show manual operations leading up to the failure.
- 2.5 Contents of Data Pool area in memory.
- 2.6 Contents of program area in memory.
- 2.7 Status of Computer Complex.
- 2.8 Major options in effect (DAS, some DCE deselected, etc.).

3. The significance of certain important portions of the dump information is outlined below:

3.1 Registers and Indicators:

Z - Register = instruction currently being executed.

P - Register = location of next instruction to be executed..

P09 Light - Upper bank

INTERRUPT Light - failure occurred in interrupt processing routine.

I/O HOLD Light - output commanded with no device enabled to receive the output or input commanded with no device enabled to send input.

3.2 A & B Lower OS State Variables

<u>TERMS</u>	<u>INTERPRETATION</u>
WHIGPRØG	Contains the NTRY point of the last high priority program called (including JST UPPERH and JMP ENDHIGH).
WLØWPRØG	Contains the NTRY point of the last low priority program called (including JST UPPERL and JMP ENDLØW).
WHFCNT	Counter is incremented once for each high Priority program called within one frame, including the JST UPPERH and JMP ENDHIGH. Counter is reset before proceeding with execution of the high priority programs of the next frame.
WHØPRI	Flag is set prior to starting the high priority program execution in a frame (BGINFRAM). Flag is reset after all high priority programs have been executed in each frame (ENDHIGH).
WLØPRI	Flag is set after all high priority programs have been executed in each frame and prior to starting the low priority execution in a frame. Flag is reset after all low priority programs have been executed in each frame (ENDLØW).
WLØFCNT	Counter is incremented once for each low priority program called within one major cycle (16 frames), starting with the first program of the low priority table. Maximum value of counter is equal to low priority table length, JST UPPERL and JMP ENDLØW instructions inclusive. Counter is reset after all low priority programs have been executed in a major cycle.
FRAMECNT,WUMI	Frame number, (FRAMECNT B-Computer and WUMI A-Computer) is incremented at each 50ms interrupt starting at 1 and running to 16, then recycling.

3.3 A & B Upper OS State Variables

TERMS

INTERPRETATION

WFCABH, WFCBUL	Counter (WFCBUL B-Upper and WFCABH A-Upper) is incremented once for each high priority program called within one major cycle, starting with the first program of the high priority table. Maximum value of counter is equal to high priority table length, JST RETURN instructions inclusive. Counter is reset by lower executive at beginning of new major cycle.
WFCAL, WFCBUL	Counter (WFCBUL B-Upper and WFCAL A-Upper) is incremented once for each low priority program called within one major cycle, starting with the first program of the low priority table. Maximum value of the counter is equal to low priority table length, JST RETURNL instructions inclusive. Counter is reset to zero by lower executive at beginning of new major cycle.
LOCATION '37	Contains location at which last interrupt occurred in upper core.
WHIGPR/G	Contains the NTRY point of the last high priority program called (JST RETURN inclusive).
WLØWPRØG	Contains the NTRY point of the last low priority program called (JST RETURNL inclusive).

4. A & B Recovery Procedure

- 4.1 Check the day's Computer Sign On/Off Utilization, and Dump Forms to determine if this failure has occurred previously. If an identical failure occurred previously, no solution to the problem was found, and no tape was dumped, dump a tape and log it in to the Tape Library. Note its number on the Computer Sign On/Off Utilization, and Dump Forms.
- 4.2 If a halt occurred at an executable instruction of the last operational program called, use the display/enter routine to dump the area around this location and correct bad instructions using the information provided on the verify error printout of LDV. Do a search to determine if these locations were destroyed by another program. In this case NØP this program. Start complex; if computer does not halt, proceed with examination of NØPed program. If computer halts, further diagnosis of the problem may be time consuming. Use your discretion as to whether to pursue the problem or reload.

SPECIAL HARDWARE FEATURES

1. Maintenance Test Fixture

1.1 Indicators:

P Register - Bank and Address of last instruction fetched.

P-1 Register - Bank and Address of next to last instruction fetched.

J Register - Bank and Address of last jump instruction executed.

J-1 Register - Bank and Address to next of last jump instruction executed.

Trap Loc. - Bank and Address (trap location) of last interrupt received.

Interrupt - illuminates when in interrupt routine.

1.2 Controls:

Computer Select - Selects which computer is to control the test fixture and drive the indicators.

P/P-1 Clear - Resets program registers on test fixture.

J/J-1 Clear - Resets jump registers.

Timer Control Computer Select - Selects which computers are to have \emptyset CP control of clock.

Timer Clear - Resets clock register.

RTI Enable/Disable - Causes the clock register to be reset by Real Time Interrupt.

Auto Start Enable/Disable - Causes the clock to be started with control computer START and stopped with HALT.

FFI Enable/Disable - Enables FBC-Free Interrupt capability. (Applicable to 024 computers only.)

1.3 \emptyset CP Codes for Test Fixture Real Time Readable Clock:

'1100 - Start.

'1101 - Stop (may not be manually executed from a halted computer).

'1102 - Reset.

'1200 - Sets up data path from test fixture via the shared PIU to the input transfer bus of the computer that issued the \emptyset CP. Permits clock to be read with an INA or INM. \emptyset CP '2070 must be used to disable (real-time) typewriter input. \emptyset CP '2000 must be used to re-enable (real-time) typewriter input.

1.4 Clock Operation

- 1.4.1 Starting : Clock may be started by issuing \emptyset CP '1100. Clock will start when control computer is started if AUTO START switch is in ENABLE position.
- 1.4.2 Stopping: Clock will stop when the control computer halts. Clock may be stopped (under program control) by issuing \emptyset CP '1101.
- 1.4.3 Resetting: Clock may be reset by issuing \emptyset CP '1102. Clock will be reset each time a Real Time Interrupt is received in the control computer if RTI switch is in ENABLE position.
- 1.4.4 Reading:
 - 1.4.4.1 The clock register is marked off in seven BCD digits (four bits each), and elapsed time may be read directly in BCD. Note that the least significant digit gives a reading in microseconds X10. The clock register will display time intervals up to 100 seconds with a resolution of 10 μ s.
 - 1.4.4.2 Elapsed time may be read into the A register or directly into memory by issuing \emptyset CP '1200 and then executing an INA or INM as appropriate. Since only twenty-four data bits may be transferred from the test fixture, the most significant digit of the clock register is not available to the computer. This means that elapsed times greater than ten seconds cannot be transferred from test fixture to computer.
 - 1.4.4.3 Use of 30-series S-PAC logic in the test fixture results in slightly increased response times. Consequently, a few NOP instructions should separate the \emptyset CP from the INA (or INM) to allow adequate time for data path setup.
 - 1.4.4.4 The clock register can be read simultaneously by all the computers that are cabled to the test fixture, i.e., LMS A and B or CMS C, D, and E.
 - 1.4.4.5 If the clock register is to be read in real time while typewriter input is also enabled, an \emptyset CP '2070 must be executed before the \emptyset CP '1200 and an \emptyset CP '2000 must be executed after the INA or INM.

TIMING

1. Test Procedure

- 1.1 A procedure for simulation configuration should be prepared that would most effectively exercise the system. Landings, ascents and descents are good examples.
- 1.2 Logging of timing data for A or B computer is accomplished through the A/B Log program, utilizing the Maintenance Test Fixture. Data is taken for one computer at a time.

2. Using the Maintenance Test Fixture

- 2.1 Computer Select should be moved to indicate the computer for which data is to be taken.
- 2.2 Timer Control Computer Select Switch should be set to agree with 1 above.
- 2.3 The RTI Enable/Disable Switch should be set to 'disable'.
- 2.4 The Auto-Start Enable/Disable Switch should be set to 'disable'.
- 2.5 The FFI Enable/Disable Switch should be set to 'disable'.

3. Timing Study Logging Procedures

- 3.1 Load the patches to the Executive programs and Y02 programs for the computer to be timed. The patches to Y02 NOP the data snapshot programs and allow logging in freeze.
- 3.2 With computers halted, set the timing switch in cabinet 47 to "Half Time"; this allows the RTI to occur once every 100 milliseconds.
- 3.3 Start all computers and reset.

NOTE: It may be advisable to do the following:

- 3.3.1 Halt the complex.
- 3.3.2 Dump Y02DATA (approx. 240 locations) via C-Computer Octal Dump (q.v.).
- 3.3.3 Examine the printout, checking for the program calls followed by the execution times. The times will be in microseconds, BCD format, X ten.
- 3.3.4 Restart the computers and reset.

- 3.4 Mount scratch tape for A & B Log.
- 3.5 Set cabin configuration desired.
- 3.6 Log data as desired during phases such as engine ignition, engine thrusting, attitude maneuvers, and landing. For every two seconds of data logged one second of Real World data is logged.
- 3.7 When logging for one computer is completed, halt the complex and write an EOF on the log tape.
- 3.8 Identify the log tape noting computer, load tape, and reset tape. Reload the complex.
- 3.9 Proceed to step 3.1 to log timing data for the other complex.

PRIMARY OS FUNCTIONS

1. Initial Startup:

1.1 P-Register: '100: SIM mode

'101: SYS mode

'102: SETUP

1.2 A-Register: Set to '1 to wait on minute pulse before transferring to SIM mode.1.3 Index Registers: X1: Set to 'lnn (where nn is reset point desired) to cause an automatic reset on transfer to SIM mode.

X2: Set to '1 to set Q775 for GSSC Logging (must set X3 to '0).

X3: Set to '1 to set Q776 for GSSC Log Playback (must set X2 to '0).

2. Sense Switch Options (SIM Mode):

2.1 A & B:

2.1.1 SSW1: spare

2.1.2 SSW2: spare

2.1.3 SSW4: Forces the complex to clear-and-halt at end of current major cycle (16 frames).

2.2 A Only:

2.2.1 SSW3: Real Time Print.

2.2.2 SSW5: With neither Q775 or Q776 set, the PCM buffer loads from Drive 4.

With Q775 set, in LMS/GSSC or LMS/CMS/GSSC mode, GSSC inputs are logged on Drive 4.

With Q776 set, in LMS only or LMS/CMS mode, GSSC data stored on Drive 4 are read to simulate GSSC inputs.

2.2.3 SSW6: Real Time I/Ø bypass.

2.3 B Only:

2.3.1 SSW3: A&B Log.

2.3.2 SSW6: Line printer activity bypass for entire complex,

3. Executive Philosophy

- 3.1 The programs are divided into three classes: high priority (those programs with a function of time), low priority (those not using Delta T), and Data Displays (X-Y/X-T/Event, Digital Readout, and Parameter Display).
- 3.2 There are two options for calling these three groups of programs. Either option may be selected at any time. The sequence in calling priority is shown below for both options.

WSELECT = 1 : High Priority
 Data Displays
 Low Priority

WSELECT = 2 : High Priority
 Low Priority
 Data Displays

- 3.3 There are two different call table executors for high priority and low priority programs similar to the following instructions:

LOOP	IRX	CALLPTR, 1
	LDA	CALLTABL, 1
	STA	CALL
	XEC	CALL
	SKS	'40700
	NOP	
	NOP	
	JMP	LOOP

- 3.4 The high priority programs should be completed every frame. Should they fail for any reason to be completed the executive will set a flag which will type out the data associated with the interrupt (see RTI typeout). The executive will then complete the interrupted high priority program and all remaining high priority programs in the interrupted frame. The executive will then do the next frame's High Priority Programs. This means that the execution of the Data Display Programs in the interrupted frame will be omitted. The necessary controls, however, will be set such that the Low Priority Programs remaining in the interrupted frame will, time permitting, catch up with the High Priority Programs.
- 3.5 If WSELECT = 1, the Data Display programs should be completed in every frame. Should they fail for any reason to be completed the executive will set a flag which will type out the data associated with the interrupt. The executive will then do the next frame's high priority programs. This means that the interrupted Data Display program as well as the remaining Data Display programs in the interrupted frame will not be executed. The necessary controls, however, will be set such that the Low Priority Programs remaining in the interrupted frame will, time permitting, catch up with the High Priority Programs.

- 3.6 If WSELECT = 2, the Data Display programs are more or less in a low priority position; therefore, they do not have to be completed in each frame. If the executive does not complete them in a frame, it omits the remaining programs and goes to the next frame. This means that those programs remaining in the interrupted frame will not be executed.
- 3.7 The symbol, WREC, in each Exec is decremented by one at the beginning of each frame and incremented by one each time a low priority frame is completed. Hence, if the low priority programs are executed at the normal rate and no program is taking more time than was originally allotted to it, WREC should be zero at the completion of each frame. If it has a negative value of 2 or less, the low priority programs are not completing.

Although the low priority programs are divided in sixteen (16) frames similar to those of the high priority programs, the low priority programs do not have to be completed each frame. If the Exec does not complete them in a frame, it will complete them in the next frame before executing the low priority programs of that frame. If low priority programs start to fall behind the high priority programs, the Executive will try to catch up.

4. Absolute Storage:

Locations from 0-100 are all being used by the the ØS. They must not be used for any other purposes.

<u>LOCATIONS</u>	<u>PURPOSE</u>
0 - 1	PFI - Power Failure Interrupt
2 - 3	RTI - Real Time Interrupt
4 - 5	DCE - Interrupt - <u>A Only</u>
6 - 7	AMSXFER Interrupt - <u>A Only</u>
10 - 14	RT I/Ø - <u>A Only</u>
15 - 17	Gamma Exec (if any)
20 - 32	Quick Look & Change
33 - 37	Exec. for RTI go ahead mode
40 - 43	Exec. for normal up and down
50 - 63	Search routine
64 - 65	RT I/Ø - <u>A Only</u>
66 - 74	Spare
75 - 77	Check Sum Routine

5. RTI Timeout:

The format of the RTI Timeout is as follows:

INTERRUPT: CB PP FRM FF NTRY NNNNN LOC LLLLL

CB = Computer and bank

PP = HP - High Priority Program

DD - Data Display Program

LP - Low Priority Program having endless loop

FF = octal number representing the frame.

NNNNN = octal number representing the interrupted program's entry point.

LLLLL = octal number representing the location at which the interrupt occurred.

6. Real Time Interrupt Recovery Procedures:

The RTI timeout should by no means be disregarded but should be considered as a malfunction in the simulator. Repeated RTI timeouts are certainly such an indicator. The following outline may be followed as a guide in determining the fault or as a recovery plan.

- 6.1 Look at the RTI timeout for the entry point of the program in which the RTI occurred. If more than one RTI occurs, look for a common entry point to be printed. (Can a pattern be established?)
- 6.2 If pattern can not be established and new patches have been loaded, reload without the patches to see if the RTI timeout still occurs. (Does an error exist in a patch?)
- 6.3 If steps 1 and 2 fail to establish a cause for the RTI, verify the load tape against core. (Are some locations changed in the last program called that should not have been changed?)
- 6.4 Reload the load tape and verify before cycling. (Was there a bad load? Is there a hardware problem?)
- 6.5 If all of the above fail, dump a tape soon after the RTI timeout occurs again and label the tape properly. (Can the RTI condition be established again for further analysis?)
- 6.6 Attach the RTI timeout to the computer utilization report. (The analysis may show the EXEC GROUP that a change in frame loading may be necessary.)
- 6.7 There is really no definite recovery procedure for clearing a continuous real time interrupt short of reloading. If the interrupt occurs in a low priority program the following events will occur:

- 6.7.1 There will be no output by any of the data output programs in the affected computer.
 - 6.7.2 The pattern of flashing lights on the console of the affected computer will not be normal.
 - 6.7.3 There will be no typeout by the B computer typewriter.
- 6.8 If the interrupt occurs a high priority program the following events will occur:
- 6.8.1 There will be no output by any of the data output program in the affected computer.
 - 6.8.2 The pattern of flashing lights on the console of the affected computer will not be normal.
 - 6.8.3 There will be a continuous typeout of the interrupt information by the B computer typewriter.

TYPEWRITER CODES

1. A & B:

1.1 Run or Freeze

1.1.1 L = Look AAAAAACB1.1.2 E = Enter AAAAAACB $\phi\phi\phi\phi\phi\phi\phi\phi$

A = Address, 1 to 5 octal digits

C = Computer (A, B, or C)

B = Bank (L or U)

 ϕ = Data, 1 to 8 octal digits

2. B Only:

2.1 Run or Freeze

2.1.1 C = Convert DDDDDDDDBSSS2.1.2 U = Convert and Store AAAAAACB DDDDDDDDBSSS

D = Decimal Data, 1 to 8 characters, including sign (if any) and decimal point (if any).

S = Decimal scale factor, 1 to 3 characters, including sign (if any), with no decimal point. Limits are ± 63 .2.1.3 K = Percentage Malfunction Insertion MM PPPPPPPP

M = Malfunction number, 2 decimal digits

P = Percentage, same format as D in Convert/Convert Store, but not to be followed by scale factor. Limits are 0-100.

2.1.4 Q = Safe Store Log Control C

C = On/Off Switch: 0 = off, 1 = on

2.1.5 F = RCS Refuel command LMS2.1.6 \$ - See Loading Procedures

2.2 Freeze Only

2.2.1 S = Step Ahead Time

HHH/MMSS

H = Hours, 3 decimal digits

M = Minutes, 2 decimal digits. Limits are 00-59.

S = Seconds, 2 decimal digits. Limits are 00-59.

3. C Only

3.1 Freeze only

3.1.1 L = Look AAAAAAB

3.1.2 E = Enter AAAAAAB $\phi\phi\phi\phi\phi\phi\phi\phi$

A = Address, 5 octal digits

B = Bank (L or U)

ϕ = Data, 8 octal digits

COMPUTER-STORE/SAFE-STORE, SAFE-STORE LOGGING & WRITE-RESET1. Computer-Store/Safe-Store

1.1 Purpose:

1.1.1. Computer-Store:

1.1.1.1. To manually save in core at a time selected by the instructor the data necessary to:

1.1.1.1.1. Perform a Core-Reset to an instructor-selected point, or

1.1.1.1.2. Write on a Reset Tape an instructor-selected point, or

1.1.1.1.3. Log on a Safe-Store Tape an instructor-selected point.

1.1.2. Safe-Store:

1.1.2.1. To automatically save in core at each minute pulse the data necessary to:

1.1.2.1.1. Perform a Core Reset to a last-minute-pulse point, or

1.1.2.1.2. Write on a Reset Tape a last-minute-pulse point, or

1.1.2.1.3. Log on a Safe-Store Tape a last-minute-pulse point.

1.2. Procedure:

1.2.1. If the Computer-Store light on the Problem Control panel is off, Safe-Store causes the area in core reserved for the reset buffer to be updated at each minute pulse while the LMS complex is in run mode and on the first minute pulse after the LMS complex goes to freeze mode if:

1.2.1.1. There is no CPU failure or off-nominal exec status, and

1.2.1.2. There is no thrusting activity, and

1.2.1.3. CMS has also met the above criteria if integrated with CMS, and

1.2.1.4. The Safe-Store Logging process is not in operation (i.e., not actually writing on tape), and

1.2.1.5. The Write-Reset light is off.

- 1.2.2. If the Computer-Store light is off, pressing the Computer-Store button just until the light comes on and then releasing the button causes the light to flash until the above criteria are met and a Computer-Store has been performed at which time the light remains on. If the criteria are met and the Computer-Store is done immediately, the light will not flash before remaining on.
- 1.2.3. If the Computer-Store light is on, Safe-Store is terminated.
- 1.2.4. If the Computer-Store light is on, pressing the Computer-Store button just until the light goes off and then releasing the button or performing a Core-Reset, Reset Tape Reset, or Safe-Store Tape Reset returns to the status of (A) above.
- 1.2.5. To perform a Core-Reset to the last point preserved in the reset buffer area:
 - 1.2.5.1. Dial "00" on the Initial Condition digiswitch on the Problem Control Panel.
 - 1.2.5.2. Press the Reset button until the light comes on.
 - 1.2.5.3. If the Computer-Store light was on, observe that it goes off when the Reset light goes off.

2. Safe-Store Logging Operating Procedures

2.1. Purpose:

- 2.1.1. To automatically log, on a Safe-Store Tape, all points preserved in core by Computer-Stores or Safe-Stores. The Safe-Store Tape does not contain LTS or Ephemeris data and thus must be used with a Reset Tape.

2.2. Procedure:

- 2.2.1. Place a scratch tape or a Safe-Store Tape containing a write ring on Tape Drive 1.
- 2.2.2. If the Safe-Store Logging process is to be continued on a Safe-Store Tape without destroying the previous points on the tape execute Step (F) before proceeding to Step (C), otherwise place the scratch tape on load point.
- 2.2.3. With the LMS complex cycling, type in a "Q1" on the B-computer typewriter to initialize the Safe-Store Logging process.

- 2.2.4. Every time a point is logged, the Ground Elapsed Time (GET) and an octal number associated with the point are typed out in the following format: XXXXXX HHH/MM/SS, where X = Octal number, H = Hours, M = Minutes, and S = Seconds (leading zeros for X and H are deleted).
- 2.2.5. To terminate the Safe-Store Logging process type in a "Q0" on the B-Computer typewriter.
- 2.2.6. To perform a Safe-Store Tape Reset to one of the Reset Points logged(after a Reset Tape Reset has brought in the LTS and Ephemeris data):
 - 2.2.6.1. Dial "77" on the Initial Condition digiswitch on the Problem Control panel.
 - 2.2.6.2. Press the Reset button until the light comes on.
 - 2.2.6.3. The B-Computer typewriter types out "TYPE IN DESIRED RESET POINT".
 - 2.2.6.4. Type in the octal number generated in Step (D) or (G) associated with the Safe-Store point desired
 - 2.2.6.5. If the Computer-Store light was on, observe that it goes off when the Reset light goes off.
- 2.2.7. To generate a list of numbers and times of points logged on a Safe-Store Tape:
 - 2.2.7.1. Place the Safe-Store Tape on Tape Drive 1.
 - 2.2.7.2. Stop the LMS Complex via Sense Switch 4 on A or B, Master Clear A.
 - 2.2.7.3. Start at A-Lower '102. When "IS TAPE TO BE FORMATTED" is typed out.
 - 2.2.7.4. Type in "N". "ARE TIMES TO BE TYPED-" is typed out.
 - 2.2.7.5. Type in "Y", and the list will be generated.

3. Write-Reset Operating Procedures

3.1. Purpose:

- 3.1.1. To manually write on a Reset Tape the point preserved in core by a Computer-Store or Safe-Store. The Reset Tape contains LTS and Ephemeris data.

3.2. Procedures:

- 3.2.1. Place an existing Reset Tape or a formatted scratch tape containing a write ring on Tape Drive 1. To obtain a formatted scratch tape:
 - 3.2.1.1. Place a scratch tape on Tape Drive 1 and the Reset tape on Tape Drive 3.
 - 3.2.1.2. Stop the LMS Complex via Sense Switch 4 on A or B, Master Clear A.
 - 3.2.1.3. Start at A-Lower '102. When "TAPE TO BE FORMATTED" is typed out:
 - 3.2.1.4. Type in "Y", and the tape will be formatted.
- 3.2.2. Select a number on the Initial Condition digiswitch on the Problem Control panel not already assigned to a point on the Reset Tape mounted on Tape Drive 3.
- 3.2.3. Press the Write-Reset button just until the light comes on. When the light goes off the operation is complete.
- 3.2.4. If the number selected was already assigned, the B-computer typewriter types out "RESET POINT ALREADY EXISTS".

RESIDENT UTILITIES

1. Quick Look and Change: This routine is used to display in the A-Register the contents of any word in core or change any word in core in non-real time.
 - 1.1 P-Register = '20
 - 1.2. Index Register 1 = starting address
 - 1.3 Press START. The word whose address is in Index Register 1 will be displayed in the A-Register.
 - 1.4 To change the contents of that word one can change the A-Register to the desired configuration or change the B-Register which will be exclusively ored (ERA) with the A-Register to produce the desired configuration. Then press START. The new word will be stored, Index Register 1 will be incremented by 1 and the contents of the next consecutive location will be displayed in the A-Register.
2. Search: This routine is used to search core for any bit configuration.
 - 2.1 P - Register = '50
 - 2.2 A - Register = Configuration to search for
 - 2.3 B - Register = Mask for applicable bits
 - 2.4 Index Register 1 = Starting address
 - 2.5 Press START. The computer searches and halts when the bit configuration is found, displaying the word in the B-Register and its address in Index Register 1.
 - 2.6 To continue the search, just press START again. One should notice Index Register 1 being incremented until the desired bit configuration is located.
3. Typewriter Dump and Change: This routine is used to change Core Manually and Receive a Typewriter Listing of Results.
 - 3.1 P - Register = '113
 - 3.2 Index Register 1 = Starting Address
 - 3.3 Press START. The word whose address is in Index Register 1 will be displayed in the A-Register and on the typewriter.
 - 3.4 Make change in A-Register or by setting B-Register bits for an EXCLUSIVE or (example: to change 07112345 to 07454321, insert in B-Register 00546064).

- 3.5 Press start to store change and display on typewriter.
- 3.6 SSW1 clears A-Registers before halting. SSW2 bypasses halt.
- 4. SETUP Operating Procedures: To select or deselect any DCE I/Ø-devices through the typewriter.
 - 4.1 Start A computer at '102 Lower.
 - 4.2 A typeout will occur asking if you want the I/Ø to occur for SCS, D/A, DBØ, DWØD, DWØR, A/D, DBI, PCM, CCBI, and CCBØ. To each of which a reply of "Y" for yes or "N" for no is required.

PERCENTAGE MALFUNCTIONS

Percentage Malf.
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RCS

INPUT CODE	PROGRAM SYMBOL	MIU INPUT	DESCRIPTION LEAKAGE CONSTANT	MAX. DECIMAL VALUE sq. in./sec.
01	RTYP1	RC027	Fuel A Manifold	0.022648
02	RTYP2	RC116	Fuel B Manifold	0.022648
03	RTYP3	RC024	Oxidizer A Manifold	0.045297
04	RTYP4	RC113	Oxidizer B Manifold	0.045297
05	RTYP5	RC021	Prop. Fuel A Tank	0.022648
06	RTYP6	RC110	Prop. Fuel B Tank	0.022648
07	RTYP7	RC018	Oxidizer A Tank	0.045297
08	RTYP8	RC107	Oxidizer B Tank	0.045297
09	RTYP9	RC001	Helium Resv. A	8.568×10^{-6}
10	RTYP10	RC090	Helium Resv. B	8.568×10^{-6}

2E

RCS

INPUT CODE	PROGRAM SYMBOL	MIU INPUT	DESCRIPTION LEAKAGE CONSTANT	PERCENTAGE OF OF DEGRADE
31	RTYP11	RC002	Thruster 1, (B4U) Degraded	0-99
32	RTYP12	RC003	Thruster 2, (A4D) Degraded	0-99
33	RTYP13	RC004	Thruster 3, (B4F) Degraded	0-99
34	RTYP14	RC005	Thruster 4, (A4R) Degraded	0-99
35	RTYP15	RC006	Thruster 5, (A3U) Degraded	0-99
36	RTYP16	RC007	Thruster 6, (B3D) Degraded	0-99
37	RTYP17	RC011	Thruster 7, (B3A) Degraded	0-99
38	RTYP18	RC012	Thruster 8, (A3R) Degraded	0-99
39	RTYP19	RC013	Thruster 9, (B2U) Degraded	0-99
40	RTYP20	RC019	Thruster 10, (A2D) Degraded	0-99
41	RTYP21	RC020	Thruster 11, (A2A) Degraded	0-99
42	RTYP22	RC022	Thruster 12, (B2L) Degraded	0-99
43	RTYP23	RC023	Thruster 13, (A1U) Degraded	0-99
44	RTYP24	RC025	Thruster 14, (B1D) Degraded	0-99
45	RTYP25	RC026	Thruster 15, (A1F) Degraded	0-99
46	RTYP26	RC028	Thruster 16, (B1L) Degraded	0-99

MPS

INPUT CODE	PROGRAM SYMBOL	MIU INPUT	DESCRIPTION LEAKAGE CONSTANT	MAX. DECIMAL VALUE sq. in./sec.
11	PTYP1	PR101	Ascent Helium Tank 1	0.6×10^{-4}
12	PTYP2	PR104	Ascent Helium Tank 2	0.6×10^{-4}
13	PTYP3	PR126	Ascent Oxidizer Bi-Prop Valve	0.014
14	PTYP4	PR128	Ascent Fuel Bi-Prop Valve	0.047×10^{-2}
15	PTYP5	PR107	Ascent Oxidizer Tank	0.077
16	PTYP6	PR110	Ascent Fuel Tank	0.048
17	PTYP7	PR001	Descent Helium Reservoir	0.4×10^{-3}
18	PTYP8	PR007	Descent Oxidizer Tank	0.30
19	PTYP9	PR004	Descent Fuel Tank	0.30
20	PTYP10	PR022	Descent Oxidizer Valve	0.60
21	PTYP11	PR024	Descent Fuel Valve	0.60
22	PTYP22	PR011	Descent Start Tank Helium Leak	9.0×10^{-4}
23	PTYP23	PR013	Descent Helium Leak between Quad Check and Oxid. Tank	4.25×10^{-3}
24	PTYP24	PR015	Descent Helium Leak between Quad Valves and Fuel Tank	4.25×10^{-3}
25	PTYP25	PR017	Descent Helium Leak between the Regulators and Quad Check Valves	5.3×10^{-3}
26	PTYP26	PR040	Ascent Helium Leak between Quad Check Valves and Oxid. Tank	3.3×10^{-2}
27	PTYP27	PR041	Ascent Helium Leak between Quad Check Valves and the Fuel Tank	2.64×10^{-2}
28	PTYP28	PR042	Ascent Helium Leak between the Regulators and Quad Check Valves	1.16×10^{-3}
29	PTYP29	PR043 PR044	Thrust Change due to Damper	6.4×10^{-2}

INPUT CODE	PROGRAM SYMBOL	MIU INPUT	DESCRIPTION LEAKAGE CONSTANT	LIMITS
54	PTYP30	PR032	Limits for Heat Soak Malfunctions	30
55	PTYP31	PR035	Limits for Cold Soak Malfunctions	30

ECS

INPUT CODE	PROGRAM SYMBOL	MIU INPUT	DESCRIPTION LEAKAGE CONSTANT	MAX. DECIMAL VALUE sq. in./sec.
47	FETYP1	EC025	Cabin Rupture Leak	1.027
48	FETYP2	EC045	H ₂ O ASCTK #1 Leak	.0833
49	FETYP3	EC048	H ₂ O ASCTK #2 Leak	.0833
50	FETYP4	EC051	H ₂ O DECS. TK Leak	.1653
51	FETYP5	EC054	O ₂ ASCTK #1 Leak	.0000056
52	FETYP6	EC057	O ₂ ASCTK #2 Leak	.0000056
53	FETYP7	EC060	O ₂ DESCENT TK Leak	.00373
62	FETYP8	EC026	Suit Sublimator Rupture (Variable)	.112
65	FETYP9	EC046	PRI, HTS Relief Valve Fails Open, Glycol Pump #1	.899
66	FETYP10	EC047	PRI, HTS Relief Valve Fails Open, Glycol Pump #2	.899
67	FETYP11	EC052	Sec. HTL Glycol Leak	.021
68	FETYP12	EC061	DES. O ₂ Tank Thermal Leak	.0036
69	FETYP13	EC050	H ₂ O DECS. TK. #2 Leak	.167
70	FETYP14	EC058	O ₂ DESC. TK #2 leak	.000346

S & C

INPUT CODE	PROGRAM SYMBOL	MTU INPUT	DESCRIPTION LEAKAGE CONSTANT	MAX, DECIMAL VALUE
56	HTYP1	SC022 SC116	Yaw. Demod. Offset	1.0
57	HTYP2	SC021 SC115	Pitch Demod. Offset	1.0
58	HTYP3	SC020 SC114	Roll Demod. Offset	1.0
59	HTYP4	SC056	Pitch Output Gain	1.0
60	HTYP5	SC058	Yaw Output Gain	1.0
61	HTYP6	SC058 <i>Roll</i>	<i>Roll</i> Yaw Output Gain	1.0

CIRCUIT BREAKER MALFUNCTION.

The capability exists on the LMS to "POP" any one (1) of twenty-seven (27) circuit breakers, listed on page 2, dependent upon the status of a given boolean in any bank of A & B machine. The circuit breaker can be popped by a control boolean in either the "1" or "0" condition dependent upon a typewriter entry. The typewritten entry is made into one of eight variables whose name is CADDZXX or CADDXX, where XX signifies the computer and bank. The Z signifies that if the control boolean is "0" the circuit breaker should "pop." The lack of a "Z" signifies that if the control boolean is "1" the circuit breaker should "pop." The eight control variables are located in common core.

The following is the procedure to use the circuit breaker malfunction capability:

1. Select a circuit breaker you wish to pop from the C/B description sheet (see page 2).
2. Dial up the appropriate digiswitch* using the key on the right side of C/B descriptions sheet (page 2). The digiswitches are located on the lower left hand side of the IOS main panel. The code for the digiswitch numbers is X - Y where X signifies which digiswitch 1, 2, or 3 (left to right) and Y signifies which number to dial up.
3. Decide which boolean and which state ("1" or "0") you wish to cause the circuit breaker to pop. The address must be known.
4. Find the address of the CADDXX or CADDZXX variable for the appropriate computer and bank.
5. Using the E typewriter routine place the address of the control boolean into the variable CADDXX or CADDZXX. Three leading zeros will be required when making your entry.

EXAMPLE: E AAAAABC 000DDDDD
 Where AAAA - address of CADDXX on CADDZXX
 B - computer (A or B)
 C - bank (U or L)
 DDDDD - address of control boolean

6. ENTER EP015 via the malfunction insertion unit.
7. When the appropriate state ("1" or "0") is reached by the control boolean the selected circuit breaker will pop.

CAUTION: The variables CADDXX and CADDZXX are cleared only by reset. If an address is left in one of these variable address it will continue to control the circuit breaker selected provided EP015 is entered.

* "Circuit Breaker Malfunction"

PANEL	LOCATION		LINK BOOLEAN	GAEC C/B NUMBER	DBI	CIRCUIT BREAKER DESCRIPTION	***
	ROW	COLUMN					
11	1	2	C497	4CB-169	143	AC Bus B He/PQGS Propul Disp	1-9
11	1	4	C492	4CB-226	205	AC Bus B Ordeal	2-9
11	2	1	C370	4CB-72	124	RCS Sys A Main SOV	2-7
11	3	8	C398	4CB-238	614	Stab Cont AEA	1-2
11	3	9	C308	4CB-13	72	Stab Cont Abort Stage	1-5
11	3	10	C379	4CB-81	130	Stab Cont ATCA PGNS	1-4
11	3	11	C338	4CB-40	102	Stab Cont AELD	1-3
11	3	13	C357	4CB-59	114	Stab Cont Att Dir Cont	3-6
11	3	17	C374	4CB-76	128	ED Logic PWR A	1-1
11	4	8	C413	4CB-117	157	ECS Gly Pump #1	3-7
11	4	9	C423	4CB-215	217	ECS Gly Pump Auto TRNFR	3-5
11	4	5	C434	4CB-138	174	Suit Fan No. 1	3-1
11	L/H	6	C312	4CB-8	76	Descent ECA Control	2-3
11	L/H	8	C310	4CB-6	74	Ascent ECA Control	2-2
16	4	15	C313	4CB-9	77	Descent ECA Control	1-7
16	4	13	C311	4CB-7	75	Ascent ECA Control	1-6
16	1	14	C401	4CB-103	146	Propul Disp/Eng OVRD Logic	2-8
16	1	15	C309	4CB-32	73	Propul PQGS	3-4
16	2	5	C373	4CB-75	127	ED Logic Pwr B	2-6
16	2	6	C332	4CB-28	96	Stab Cont AEA	2-5
16	2	8	C377	4CB-79	216	Stab Cont ASA	3-3
16	2	9	C339	4CB-41	103	Stab Cont AELD	1-8
16	2	10	C380	4CB-82	132	Stab Cont ATCA	3-2
16	2	11	C307	4CB-2	71	Stab Cont Abort Stage	2-1
16	2	12	C472	4CB-230	195	Stab Cont ATCA ACS	2-4
16	3	16	C416	4CB-120	159	ECS Suit Fan P	3-9
16	4	1	C477	4CB-222	201	Heaters RCS Sys A/B 2 Quad 1	3-8

*** Digiswitch Wheel Number

The three digiswitches are numbered 1, 2, and 3 from left to right. The second number following the dash is the digit dialed up on the digiswitch.

III : Loading Procedures

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8.1 UNIFIED SIMULATION SYSTEM: Phase 2 (USS 2)

8.1.1 Introduction

8.1.1.1 The LMS UNITAPE consists of Load Files comprising the NASA training load (with its nominal MIT load) and up to two (2) optional MIT loads, Correction Files comprising card images of all Link Approved Patch decks not yet incorporated into the NASA training load, and a Test File comprising other Patch decks, Data Acquisition System (DAS) decks, and Test decks.

8.1.1.2 Load/Dump/Verify (LDV) provides automatic load, dump, verify, and MIT load selection from the UNITAPE load files. Manual operation of LDV provides the following additional capabilities: one, two, or three computers may use LDV for any partial simulator load requirement; location '100, '101, or '102 may be preselected for automatic simulator startup when LDV has finished; line printer and/or typewriter outputs may be suppressed; any portion of a load may be verified; an automatic verify after a load or dump may be requested; and a system-wide clear-and-halt may be specified.

8.1.1.3 The Card Image Analyzer (CIA) provides selectable loading of Patch decks, DAS decks, and Test decks from the UNITAPE Correction Files and Test File as well as regular non-selectable loading from the card reader and Computer B (or IS) typewriters. A DAS deck may be A & B Log, X-Y/X-T/Event Recorder, Real Time Print, DEDA Enter Print, Parameter Display or C-Log. A Test deck is a named group of Patch decks and/or DAS decks used to perform a certain test.

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8.1.1.4 The USS Monitor provides the capability of interpreting control commands and requesting execution of LDV and CIA to perform the functions specified by the control commands. USS features control commands for transfers between normal real-time simulation (SIM) mode and non-real-time system (SYS) mode. Control commands may come from the Computer B (or IS) typewriters or from the card reader.

8.1.1.5 Simulator startup at '100 transfers to SIM mode; '101 transfers to SYS mode; '102 transfers to the initialization routines.

8.1.1.6 In SIM mode, any control command will cause the LMS to go to freeze and transfer to SYS mode. In SYS mode, the \$SIM will cause the LMS to transfer to SIM mode and go to freeze; and the \$HLT will cause a system-wide clear-and-halt.

8.1.2 General Control Commands:

8.1.2.1 \$SIM - transfers to SIM mode and transfers source of input to typewriter.

8.1.2.2 \$HLT - causes system-wide clear-and-halt.

8.1.2.3 \$CRD - transfers source of input to cards (card reader EOF button should have been reset at the time this command is typed in -- see below).

8.1.2.4 \$TYP - transfers source of input to typewriter (card reader EOF or Power OFF buttons have save results). \$SIM also transfers source of input to typewriter, since the LMS Complex is not suitable for reading cards in real time.

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8.1.3 LDV and CIA Control Commands:

8.1.3.1 These commands are of the form \$XXn where n specifies tape drive 1, 2, 3, or 4.

8.1.3.2 \$LDn - transfers control to LDV and requests load. The NASA training load (with its nominal MIT load) is loaded, as well as the load tape ID and nominal MIT load ID. Types 'LOADED' on each computer's typewriter. Transfers control back to USS.

8.1.3.3 \$DMn - transfers control to LDV and requests dump. The resident load (with its MIT load) is dumped, as well as the load tape ID, flagged as a dump, and the resident MIT load ID. The dump tape will not contain any optional MIT loads or the Correction File or the Test File which are present on a UNITAPE. Types 'DUMPED' on each computer's typewriter. Transfers control back to USS.

8.1.3.4 \$VRn - transfers control to LDV and requests verify. The resident load (with its resident MIT load) is verified. If the load tape ID does not match its core image, types out 'BAD ID' on the Computer A typewriter and Computer A halts with Z-Register = '14. Press start to continue, if desired. If none of the MIT load ID's match the core image, types out 'BAD ID' on the Computer C typewriter and Computer C halts with Z-Register = '14. Press start to continue, if desired. Types either 'VER OK' or 'VER ER' on each computer's typewriter. Transfers control back to USS.

8.1.3.5 \$GCn - informs USS that the next card image will be an MIT load ID, with columns 09-80 ignored. Once the ID has been input, transfers control to LDV and requests load (of the desired MIT load). The load tape ID is ignored, and LDV searches the tape for the desired MIT load ID. If not found, types out 'BAD ID' on the Computer C typewriter and Computer C halts with Z-Register = '14. Press start to continue, if desired. If found, types out 'GLOAD' on the Computer C typewriter. Common core is then reloaded. Transfers control back to USS.

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- 8.1.3.6 If parity on tape is detected on each of four (4) attempts, LDV types out 'PARITY' on the typewriter of the computer which found it and that computer halts with Z-Register = '14. Press start to continue, if desired. If the verify option is being exercised or is exercised after the current option, the 'VER OK' or 'VER ER' messages will have no meaning for the Computer (or computers) where 'PARITY' was typed out.
- 8.1.3.7 \$ALn - loads all Patch decks on the UNITAPE Correction Files, types and prints 'INPUT COMPLETE'.
- 8.1.3.8 \$LYn - informs USS that the next card images will be Patch deck, DAS deck, or Test deck header card format with columns 17-80 ignored, all followed by a \$END control command. Columns 01-16 (which will be called the Deck Request Number) of each unique card image are stored in a table. Once up to 20 such unique Deck Request Numbers have been input, USS processes the UNITAPE Correction Files and Test File and loads only those Patch decks, DAS decks and Test decks whose Deck Request Numbers were specified. If any requests are not found, types and prints all such Deck Request Numbers followed by 'NOT ON LOAD TAPE'. More Deck Request Numbers may be input at this time, with USS servicing them in groups of 20 until the \$END image is input. The \$LYn command may be used more than once per reload. Types and prints 'INPUT COMPLETE'.
- 8.1.3.9 \$NTn - similar to \$LYn, but processes the Correction Files only and loads all Patch decks except those whose Deck Request Numbers were specified. A total of 20 such Deck Request Numbers may be input, and the \$NTn command may be used only once per reload. Types and prints 'INPUT COMPLETE'.

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8.1.4 LDV and CIA Sense Switch Options:

- 8.1.4.1 These options provide special I/O and manual intervention capabilities. Since these options (in SYS mode) generally differ from the sense switch options in SIM mode, USS types 'SENSE SWITCHES' as a warning and waits on a carriage return when transferring between SYS mode and SIM mode if any sense switches are set.
- 8.1.4.2 Nominally, all control commands, header card images, \$GCn MIT load ID's, Deck Request Numbers, and comment card images having an 'P' in column 02 are printed. Comment card images having a 'T' in column 02 are printed and typed.
- 8.1.4.3 SSW1 - Set to print entire Patch deck, DAS deck or Test deck being loaded (for CIA); clear-and-halt at end of process (for LDV).
- 8.1.4.4 SSW2 - Set to print Patch deck overlays in addition to nominal printout (for CIA); pause before processing each bank (for LDV) (lower to continue).
- 8.1.4.5 SSW3 - Set to print all inputs without analysis (for CIA); halt before processing each load record (for LDV) (Z-Register = '3) (press start to continue).
- 8.1.4.6 SSW4 - Set to print all inputs except control commands without analysis (for CIA); automatically verify at end of process (for LDV) (must be raised on all computers to work).
- 8.1.4.7 SSW5 - Set to suppress typewriter outputs (CIA and LDV).
- 8.1.4.8 SSW6 - Set to suppress line-printer outputs (CIA and LDV).

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8.1.5 CIA Error Detection and Recovery:

8.1.5.1 'QVL' - Patch overlay message appears at far right end of line printer output for SSW1 or SSW2 options. An overlay is detected when the contents of the old word are non-zero and not equal to the contents of the new word, unless the contents of the new word are zero. If Patch decks are loaded twice with the SSW1 or SSW2 option used the second time, overlays internal to the group of Patch decks will be pinpointed.

8.1.5.2 For all detected errors of the types listed below, an error message and (if applicable) the incorrect card image are typed out. Typing a carriage return allows processing to continue with the incorrect card image being ignored. Typing a backspace allows the operator to type in a correct card image and continue.

<u>SSW5 DOWN</u>	<u>UP:</u>	
'I/O ERROR 1'	'65601	(If SSW5 up, halts with octal code in Z and X3 Registers.) Illegal computer or bank letter on Patch header card.
'I/O ERROR 2'	'65602	Character in octal or BCD field, or BCD in octal field.
'I/O ERROR 3'	'65603	Illegal relative base, reference to a base for which no base card has been read, calculated absolute address exceeds range allowed on base card, or wraparound addressing (i.e. exceeds '77777).
'I/O ERROR 4'	'65604	Parity on tape, unexpected end of tape or load point encountered, illegal tape drive number, or DMA failure.

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'I/O ERROR 5'	'65605	Deck Request Number exceeds 16 characters before a blank character; \$GCh MIT load ID exceeds 8 characters before a blank character, the card image input from the typewriter exceeds 80 characters, typewriter has input parity, or illegal upper case character typed in.
'I/O ERROR 6'	'65606	Card reader failure (except validity check).
'I/O ERROR 7'	'65607	Unrecognizable input.
'I/O ERROR 8'	'65610	More than 20 Deck Request Numbers for \$NTn, or \$NTn attempted more than once per reload.
'I/O ERROR 9'	'65611	Illegal channel number on Plotter/Recorder card, error on Real Time Print card, or error on C Log Tape Drive/Rate card.
'I/O ERROR 10'	'60100	C Log card error: illegal name slot.
'I/O ERROR 11'	'60101	C Log card error: illegal precision.
'I/O ERROR 12'	'60102	C Log card error: illegal address.
'I/O ERROR 13'	'60103	C Log card error: too many specials.

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8.1.6 LDV Manual Operation:

- 8.1.6.1 Master clear all computers, mount UNITAPE or dump tape on any drive.
- 8.1.6.2 Fill LDV at address specified on fill deck, Master Clear.
- 8.1.6.3 Set Sense Switches 1, 4, and/or 6 on all computers as desired; 2, 3, and/or 5 on each computer as desired for that computer. If SSW1 is not set, LDV will wait on all SSW's to be reset before transferring to a startup location.
- 8.1.6.4 Set P and A Registers on all computers (right justified in register).
P: Address specified on fill deck.
A: Computer number (1=A, 2=B, 3=C, 5=special MIT load option).
- 8.1.6.5 Set B, X1, X2, and X3 Registers only on first computer started (right justified):
- B : Desired startup location '101 or '102 ---. '100 is assumed if B Register is not set.)
- X1: Reset number if desired (format 1XX where XX is reset number).
- X2: Tape Drive (1, 2, 3, or 4).
- X3: 1 - Load, 2 - Dump, 3 - Verify, 4 = special MIT load option.
- 8.1.6.6 Start 1, 2, or 3 computers in order A-B-C. (A, B, C, A & B, B & C, A & C, or A & B & C may be started.) If tape is at load point, use the SSW2 option on the first computer started to give more time to start other computers -- when all have been started, lower SSW2.
- 8.1.6.7 TRELQD must be manually set to 1 on a manual dump for the LTS to reinitialize, etc. This is automatically done on the \$DMn option.

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8.1.7 Miscellaneous Information:

- 8.1.7.1 The load tape ID, resident MIT load ID, and the Deck Request Number table are available in core. By printing or typing this data, the simulator load configuration is firmly established in hard copy.
- 8.1.7.2 On all SYS mode typewriter inputs a backspace allows retype, a carriage return terminates the input. In SIM mode the 4 character control commands may be input, and the typewriter will respond with a carriage return.
- 8.1.7.3 More than one Deck Request Number may appear in the header cards for one deck. Selection of a deck by any of its Deck Request Numbers is allowed.
- 8.1.7.4 Since the number of MIT load patches is normally zero, any (C-Upper and C-Super) patches will be handles in card form only. When these patches become NASA approved, they will be incorporated into the MIT load by AGCEDIT.
- 8.1.7.5 Since there will be no form of patch loader resident in C or A computers, a bootstrap called OCTLB00T is available to read absolute patches in emergencies and to patch USS when it cannot patch itself.
- 8.1.7.6 The 'I/O ERROR 7' error (unrecognizable input) causes all input until the next *END, \$XXX, or header to be ignored, (i.e., not analyzed, not loaded, and not printed).
- 8.1.7.7 The 'XXXXXB' base card is no longer allowed -- the 'B' must be followed by an R, S, T, or U.
- 8.1.7.8 Upper shift characters 'b', '@', '-', 'φ', '!', '~', and '†' are illegal.

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8.1.7.9 Card reader failure error recovery:

Validity Check: (No 'I/O ERROR 6' typeout) observe that the Not Ready light is on; examine card in output hopper, either fix and replace in input hopper for reread (if desired), or leave as is and replace in output hopper; press Reset and Start buttons to continue. (The analysis and loading of such a card has already been done at the time processing is interrupted for this error, so results of analysis and loading should be checked).

Feed Check: Observe typeout and Not Ready light is on; examine card in input hopper, either fix, replace in input hopper for reread, type carriage return to ignore the card image typed out (if any) and press Reset and Start buttons to reread and continue or remove to fix later, type backspace to allow correction, type corrected card image and carriage return to terminate input, and press Reset and Start buttons to continue.

Read Check: Observe typeout; if the Not Ready light is off, press the Stop button and observe that the Not Ready light comes on; remove card from read mechanism, then handle error in same manner as Feed Check.

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8.1.8 UNITAPE FORMAT: Tape Parity is Binary.

LOAD POINT			
12 LOAD FILES	Load Tape ID: 1 Record of 10 Words (40 characters)	LTID	
	A-Lower Load:	A-L	Base Load with incorporated NASA Approved patch decks
	A-Upper Load:	A-U	
	B-Lower Load:	B-L	
	B-Upper Load:	B-U	
	C-Lower Load:	C-L	
	MIT Load ID: 1 Record of 2 Words (8 characters)	MITID	Nominal MIT Load
	C-Upper Load:	C-U	
	C-Super Load:	C-S	
	MIT Load ID: 1 Record of 2 Words (8 characters)	MITID	Optional MIT Load
	C-Upper Load:	C-U	
	C-Super Load:	C-S	
	MIT Load ID: 1 Record of 2 Words (8 characters)	MITID	Optional MIT Load
	C-Upper Load:	C-U	
	C-Super Load:	C-S	
	Common Core Load:	CMN	
5 CORRECTION FILES	A-Lower Patch Decks	A-L	Link Approved Patch decks not yet NASA Approved and incorporated
	A-Upper Patch Decks	A-U	
	B-Lower Patch Decks	B-L	
	B-Upper Patch Decks	B-U	
	C-Lower Patch Decks	C-L	
Variable number of records of 20 words each (80 characters)			
1 TEST FILE	Patch Decks	TEST	Flexible set of decks to perform certain tests.
	DAS Decks		
	Test Decks		
Variable number of records of 20 words each (80 characters)			

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8.1.9 Card Formats:

8.1.9.1 Comment Card (may be used freely in any patch deck, DAS deck or Test deck):

<u>COLUMN</u>	<u>DESCRIPTION</u>
01	*
02-80	Free Field (77-80 must not be 001*) (if column 02 is 'P', card will nominally be printed, if 'T' - printed and typed).

8.1.9.2 A Patch deck consists of one or more header cards, one or more body groups, and one end card:

8.1.9.2.1 Header Card:

<u>COLUMN</u>	<u>DESCRIPTION</u>
01	*
02-16	DR, Mod, Action Memo or AV0 Number (column 17 must be blank)
18-26	SCR number
28-34	Load name
36-40	MM DD (month and day written)
42	Computer (A, B, or C)
44	Bank (L or U)
46-61	Originator's name
63-70	Program name (@CCUR NTRY point)
76	H or K (location where patch area was reserved)
77-80	001*

} Deck
Request
Number

EXAMPLES:

0 1 2 3 4 5 6 7 8
123456789012345678901234567890123456789012345678901234567890
L1011-110227-2A HMO4B-101 ML1011B 08-05 B L ZIEGELMAIR, L. OCTLOAD H001

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8.1.9.2.2 A Body group consists of one or more base card (s) followed by code change cards which reference these base card (s) or the base card (s) of any previous body group in the same Patch deck:

8.1.9.2.2.1 Base Card:

<u>COLUMN</u>	<u>DESCRIPTION</u>
01-05	Base (absolute, octal)
06	B
07	R, S, T, or U
10-14	Range (absolute or relative, octal)
15	A if absolute; R, S, T, or U if relative
17-80	Free field

EXAMPLES:

0	1	2	3	4	5	6	7	8
123456789012345678901234567890123456789012345678901234567890								
10235BR	00034R	PATCH	BASE	MEANS	LOCATION	10271	IS	LAST TO BE USED
10235BR	10271A	PATCH	BASE	MEANS	SAME			

8.1.9.2.2.2 Code Change Card:

<u>COLUMN</u>	<u>DESCRIPTION</u>
01-05	Address (absolute or relative, octal)
06	A if absolute; R, S, T, or U if relative
07-14	Change (absolute or relative, octal)
15	A if absolute; R, S, T, or U if relative
17-24	DAP Location field (1-8)
26-30	DAP Opcode and Flag field (10-14)
32-44	DAP Operand, Decrement/Increment, & Tag field (16-28) or (16--XX)
46-80	DAP Comments field (30-64) or (XX+2--64)

0	1	2	3	4	5	6	7	8
123456789012345678901234567890123456789012345678901234567890								
00001R12445670A	PATCH	LDA	OCTAL1+12, 1	RESTORE	PATCHED	INSTRUCTION		
12037A000000000A	DATA	PZE						

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8.1.9.2.3 End Card:

<u>COLUMN</u>	<u>DESCRIPTION</u>
01-04	*END
05-80	Free field (77-80 must not be 001*)

8.1.9.3 A DAS deck consists of only one header card, one body, and one end card; (see 8.1.9.2.3 for end card format):

8.1.9.3.1 Header Card:

<u>COLUMN</u>	<u>DESCRIPTION</u>
01-05	*DAS-
06-16	DAS deck number (column 17 must be blank)
18-20	PL0 for X-Y/X-T/Event Plotters & Recorders-Octal PLD for X-1/X-T/Event Plotters & Recorders-Decimal DEP for DEDA Enter Print RTP for Real Time Print - Link NRT for Real Time Print - NASA PAR for Parameter Display CLG for C-Log ABL for A&B Log
28-34	Load name
36-40	MM-DD (month and day written)
46-57	Originator's name
59-75	Free field
77-80	001*

} Deck Request Number

EXAMPLES:

0	1	2	3	4	5	6	7	8
1234567890123456789012345678901234567890123456789012345678901234567890								
DAS-001	RTP	ML1011B	04-27	LATADY	EOM STATE VECT.	001		
DAS-000123	CLG	ML1011B	04-27	BESSANT	LGC FLAGWORDS	001		

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8.1.9.4 A Test deck consists of one or more header cards, one or more Patch decks and/or DAS decks, and one end card:

8.1.9.4.1 Header Card:

COLUMN	DESCRIPTION
--------	-------------

01-06	/TEST-
-------	--------

07-16	Test deck number (column 17 must be blank)
-------	--------------------------------------------

28-34	Load name
-------	-----------

36-40	MM-DD (month and day written)
-------	-------------------------------

46-57	Originator's name
-------	-------------------

59-75	Free field
-------	------------

77-80	001*
-------	------

} Deck Request
Number

EXAMPLES:

0	1	2	3	4	5	6	7	8
123456789012345678901234567890123456789012345678901234567890								
/TEST-0123456789			ML1011B 04-30		LATADY		L10-120,537	001*

8.1.9.4.2 End Card:

COLUMN	DESCRIPTION
--------	-------------

01-04	/END
-------	------

05-80	Free field (77-80 must not be 001*)
-------	-------------------------------------

HEADER CARD FORMATS AND TRANSMITTAL CARD

The purpose of this document is to describe the Formats for LMS Header Cards. The first sixteen (16) columns, which are called the Deck Request Number in USS will vary as follows:

1. DR's

*DL-7272

Houston DR's

*DK-7233

KSC DR's

The following are for both KSC and Houston:

2. MOD's

*L-100,199 (2A)

*L8-110,199

*L-3928

NOTE: If mod does not fit the 16 columns, omit the dashes and commas as necessary.

3. ACTION MEMO's

*AM-6000

*AM-1322

4. AVO's

*AVO-3214

*AVO-1012-N

Where N further defines patch

5. KLUDGE's

*KLUDGE-XXX^H_K

6. DAS Decks

*DAS-XXX^H_K

7. TEST Decks

/TEST-XXX^H_K

XXX - These numbers will be checked out from the LMS Kludge/DAS/Test Deck Number book. The next sequential number will be used.

APPENDIX A

SCR TRANSMITTAL CARD(S)

- Purpose:
1. Describe completely a Mod/DR/AM/AVO patch deck (excluding Kludges, DAS decks, and Test Decks) set allowing Load Clerk and Site Coordinator to check on completeness.
 2. Once Link Accepted, requests that those patch decks specified be placed on the correction files.
 3. Following Link Acceptance and placement of decks on correction files serves as a data card for loading decks from correction files.
 4. Once NASA Accepted, requests that those decks specified be moved from the correction files to the load files.
 5. Following NASA Acceptance, serves as a data card for loading NASA accepted decks from the correction files during NASA training until moved to the load files.
 6. Once on the load files, signifies that the decks are ready for SCM update into the new load.
 7. Serves as NASA's instrument for rejecting decks when REJECTED is written on the card and signed by the proper NASA authority.

- Format:
1. Columns 1-16 is the Mod/DR/AVO/AM number. This must match at least one header card in each patch deck listed.
 2. Column 18 is NASA Accepted code: PUNCHED by Load Clerk.
 3. Columns 20-21 sequence number and total number (i.e. 12 & 22 would be a 2 card set).
 4. Columns 23-80 are SCR numbers, each corresponding to one (1) patch. All SCR numbers must be punched onto the card and should be separated by commas.

KLUDGE/DAS/TEST TRANSMITTAL CARDS

- Purpose:
1. Link Accepted, requests that the corresponding Kludge/DAS/Test deck be placed on the test file.
 2. Following Link Acceptance and placement of decks on test file, serves as a data card for loading deck from test file.

- Format:
1. Columns 1-16 are the Deck Request Number. This must match at least one header card in the Kludge or DAS deck and must match the only header card allowed in a Test Deck.
 2. Columns 18-80 are free field. If applicable to a Mod/DR/AM/AVO, begin this field with that number.

AUTOLOAD/DUMP/VERIFY (ALDV)

Revision 0 (6-9-69) Operating Instructions

- A. AutoLoad/Dump/Verify combines the functions of AUTOLOAD and AUTODUMP into one 15 card Hollerith fill deck. A paper tape is also available.
1. Mount load tape on Drive 1 (must be ALDV format, i.e. 100 word records).
 2. Master Clear A, B, & C.
 3. Fill @ '77400, Master Clear.
 4. Index Register 1 Setting (All CPU's):
 - a. '0 is no reset is desired subsequent to loading or dumping;
 - b. Reset Number + '100, if reset is desired.
 5. Index Register 2 Settings (All CPU's):
 - a. '0 for Load;
 - b. '1 for Dump.
 6. Sense Switch 1 Setting (All CPU's):
 - a. Up to halt each machine (with all registers cleared) after loading, dumping, or verifying.
 - b. Down to go to freeze (and reset if Index Register 1 so specifies) after all loading or dumping is complete.
 7. Sense Switch 2 Setting (All CPU's):
 - a. Up to Verify (overrides Index Register 2 Setting);
 - b. Down to Load or Dump (per Index Register 2 Setting).
 8. Start A, B, & C in order @ '77400.
 9. LOADED, DUMPED or VERIFY will be typed upon successful completion of the option desired.
 10. PARITY will be typed if the tape is bad. This will halt all loading and should be followed by a complete restart beginning with 4 above.
 11. If a VERIFY Error is detected, a halt will occur with Z Register bits 10-24 set ('77777). The word read from tape will appear in the B Register and the corresponding word from core will appear in the A Register. To ignore, press start; to correct core to agree with tape, change the A Register to equal the B Register and press start.
NOTE: A Verify Error in Loading indicated failure of CPU or Memory, not DMA.
NOTE: '77776 in X1 indicates upper bank, '77777 indicates lower bank.

READ/WRITE/VERIFY

This utility program will write the contents of core on magnetic tape, verify the contents of magnetic tape against core, or load a file from tape into core. The operation performed is determined by the setup of the console.

```
A-Register = 'X00YYYYY
B-Register = '000ZZZZZ
Index 1    = '000FF
Index 2    = '0000T
Index 3    = '0000M
```

where X = 0 for start of a new file
X = 4 if one wishes to add to an existing file.

This option for adding new information to an existing file on tape should only be utilized when one is adding to the last file on tape.

```
YYYYY = starting address of core to be written on tape
ZZZZZ = last address of core to be written on tape
FF     = the number of files on tape to be skipped before this utility pro-
        gram performs the READ, WRITE or VERIFY operation (OCTAL)
T      = 1 for TMU#1
        3 for TMU#2
M      = 1 for MTU#1 on any TMU
        2 for MTU#2 on any TMU
```

WRITE:

1. Set up the A, B and Index Registers.
2. Set the P-Register = '77220
3. Depress the START BUTTON twice.

READ:

1. Set up the Index Registers for the proper file and MTU. A and B registers are zero.
2. Set the P-Register = '77221
3. Raise Sense Switch #1.
4. Depress the START button twice.

VERIFY:

1. Set up the Index Registers for the proper file and MTU. A and B registers are zero.
2. Set the P-Register = '77221.
3. Make sure Sense Switch #1 is down.
4. Depress the START button twice.

The words ADDRESS, CORE and TAPE will be printed on the line printer. If the contents of core and the corresponding word on tape do not agree, the program will output on the line printer, the absolute address of the word, its contents in core and the word on tape. Only those words which do not agree will be output.

ØCTLBØFT

Purpose: To load absolute patch cards for one bank and, if desired, to print the patch cards and the old values.

1. Fill at '77100, Master Clear.
2. Raise SSW1 for printout.
3. Start at '77100 in the bank desired (set P09 for upper bank).
4. Cards will be read when card reader is ready.
5. When input hopper is empty, press EOF or POWER ØFF button to terminate.

NOTE: No relative patches will be handled correctly, only one bank of one computer may be patched at any one usage.

BINBØFT

Purpose: To load absolute ASM binary cards (e.g. as output from ASM pass of ØCCUR/binary option).

1. Fill at '77100, Master Clear.
2. Start at '77100 in the bank desired (set P09 for upper bank).
3. Cards will be read when card reader is ready.
4. A halt with '55555 in Z-Reg indicates checksum error on card. Terminate the process, or press start to ignore checksum error and continue.
5. When input hopper is empty, press EOF or Power Øff button to terminate.

NOTE: No relative binaries will be handled correctly, only one bank of one computer may be patched at any one usage.

II Data Outputs

DECIMAL READOUT

To read the contents of a desired location in the computer and display the contents in decimal or octal format.

a. SETTING OF MODE (1st) DIGIT SWITCH

The setting of the first (left-most) digit switch selects the mode of operation. In modes 0, 1, 2, and 3 the setting of the first digit switch also tells the program the sign of the scaling of the data word to be read out.

MODE 0: Set the first switch to 0 to read out in decimal the most significant (approximately) 19 bits of a data word which has a plus scale factor. The sign of the data word will appear on the sign readout. (The scale factor digit switches must be set to the proper scale).

MODE 1: Set the first switch to 1 to read out in decimal the most significant (approximately) 19 bits of a data word which has a minus scale factor. The sign of the data word will appear on the sign readout. (The scale factor digit switches must be set to the proper scale).

MODE 2: Set the first switch to 2 to read out in decimal the least significant (approximately) 19 bits of a data word which has a plus scale factor. Net effect will be like taking readout from MODE 0 above and moving the decimal digits and the understood decimal point two decimal places left, such that the two left-most digits disappear off the left end of the readout unit and the two least significant decimal digits of the memory word appear in the right-most two positions of the readout. Sign of the data word will appear on the sign readout. (The scale factor digit switches must be set to the proper scale).

MODE 3: Set the first switch to 3 to read out in decimal the least significant (approximately) 19 bits of a data word which has a minus scale factor. Net effect will be like taking readout from MODE 1 above and moving the decimal digits and the understood decimal point two decimal places left, such that the two left-most digits disappear off the left end of the readout unit and the two least significant decimal digits of the memory word appear in the right-most two positions of the readout.

(The scale factor digit switches must be set to the proper scale).

MODE 4: Set first digit switch to 4 to read the index register and OP code portion of an instruction word on the left-most three positions of the readout. If the indirect address bit is set, a minus sign will appear on the sign readout. (Scale factor digit switches have no meaning).

MODE 5: Set first digit switch to 5 to read the address portion of an instruction word on the right-most five positions of the readout. If the indirect address bit is set, a minus sign will appear on the sign readout. (Scale factor digit switches have no meaning).

MODE 6: Set first digit switch to 6 to read out in decimal the 19 least significant bits of a data word as though that word were scaled at B23. The sign of the data word will appear on the sign readout. (Scale factor digit switches have no meaning).

MODE 7: Set first digit switch to 7 to read out a Boolean quantity. The Boolean one or zero will appear in the right-most position of the readout. The left most five positions of the readout will display zeros provided bits 2 through 23 of the data word are all zeros. The sign of the data word will appear on the sign readout and should be plus for a Boolean quantity. (Scale factor digit switches have no meaning). Note: This mode can also be used to display in BCD those words which are in BCD format, for example, DWOR output to the GMT display on the IS.

b. SETTINGS OF THE SCALE FACTOR (2nd & 3rd) DIGIT SWITCHES

Set the second and third digit switches to the magnitude (in octal) of the scaling of the data word to be read out. The program will interpret the scaling switches only in MODES 0, 1, 2, and 3. The switches may be left at any setting in MODES 4, 5, 6, and 7.

c. SETTING OF THE ADDRESS DIGIT SWITCHES

(Right most five Switches)

Set into the right-most five digit switches the address (in octal) of the memory word to be read out.

Setting of First 3 Switches vs Scaling
and Resultant Location of Decimal Readout

Scaling: -16, -15, -14 Setting: 120, 117, 116	±.0000 □□□□□□XX
Scaling: -13, -12, -11, -10 Setting: 115, 114, 113, 112	±.000 □□□□□□XX
Scaling: -09, -08, -07 Setting: 111, 110, 107	±.00 □□□□□□XX
Scaling: -06, -05, -04 Setting: 106, 105, 104	±.0 □□□□□□XX
Scaling: -03, -02, -01 Setting: 103, 102, 101	±. □□□□□□XX
Scaling: +00, +01, +02, +03 Setting: 000, 001, 002, 003	±. □□□□□□XX
Scaling: +04, +05, +06 Setting: 004, 005, 006	±. □□□□□□XX
Scaling: +07, +08, +09 Setting: 007, 010, 011	±. □□□□□□XX
Scaling: +10, +11, +12, +13 Setting: 012, 013, 014, 015	±. □□□□□□XX
Scaling: +14, +15, +16 Setting: 016, 017, 020	±. □□□□□□XX
Scaling: +17, +18, +19 Setting: 021, 022, 023	±. □□□□□□XX
Scaling: +20, +21, +22, +23 Setting: 024, 025, 026, 027	±. □□□□□□XX.X
Scaling: +24, +25, +26 Setting: 030, 031, 032	±. □□□□□□XX.
Scaling: +27, +28, +29 Setting: 033, 034, 035	±. □□□□□□XX0.
Scaling: +30, +31, +32, +33 Setting: 036, 037, 040, 041	±. □□□□□□XX00.
Scaling: +34, +35, +36 Setting: 042, 043, 044	±. □□□□□□XX000

Scaling:	+37, +38, +39	□ □ □ □ □ □ □ XX0000.
Setting:	045, 046, 047	
Scaling:	+40, +41, +42, +43	□ □ □ □ □ □ □ XX00000.
Setting:	050, 051, 052, 053	

NUMERICAL READOUT

+	9	3	7	6	2	8
---	---	---	---	---	---	---

POWER
ON
OFF

COMPUTER
SELECT
A B C

MEMORY
BANK
UPPER
LOWER

SIGN SCALE FACTORY ADDRESS OF WORD
TO BE READ

0	7	3	7	7	7	7
---	---	---	---	---	---	---

DIGITAL READOUT: MODE & SCALING SETTINGS VS. RESULTANT DISPLAY

SCALING REQUIRED	DECIMAL	COMPUTER MODE	- SCALING : ODD MODES																+ SCALING : EVEN MODES																POWER OF 10 TO BE USED IF DEC. PT. IS AT 0 ALWAYS	
			19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 60 57 54 50 47 44 40 37 34 30 27 24 20 17 14 10 7 4 1 61 52 55 51 43 45 41 38 35 31 28 25 21 18 15 11 8 5 2 62 59 56 52 49 46 42 39 36 32 29 26 22 19 16 12 9 6 3 63 53 43 33 23 13																0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 Y Y Y Y Y X X 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 4 7 10 14 17 20 24 27 30 34 37 40 44 47 50 54 57 60 1 5 8 11 15 18 21 25 28 31 35 38 41 45 48 51 55 58 61 2 6 9 12 16 19 22 26 29 32 36 39 42 46 49 52 56 59 62 3 13 23 33 43 53 63																	
SCALING REQUIRED	DECIMAL	A,B	0,1	[E] (Single precision) as above																[E] Y Y Y Y Y 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0																as above
		A,B,C	2,3	[E] as above																[E] X X Y Y Y Y Y Y 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0																	as above
SCALING IGNORED	OCTAL	A,B,C	4	[E] Sign/Indirect Bit 1 [Y] Index Register Bits 2,3 [NY] Op Code Bits 4-7 [AAA] (MIT Program will give +0000000 +3770000)																																
		A,B,C	5	[E] Sign/Indirect Bit 1 [Y] Index Register Bits 2,3 [YYYYYY] Address Bits 10-24 (MIT Program will give +0YYYYY +3YYYYY)																																
	SPECIAL	A,B	6	[E] XX Y Y Y Y Y Y. Decimal Values Scaled @ B23 (Useful for counters) (Approximately 19 least signif. bits)																																
		A,B	7	[E] Where Y = 0 or 1 Booleans														[E] Y Y Y Y Y Y Y for 4Bit BCD (example: DWORS)													Other Words: Undefined					
SCALING REQUIRED	DECIMAL	A,B	0	Approximately 19 Most Significant Bits of Data Word having positive scale factor																																
		A,B	1	" " " " " " " " " " " negative " "																																
		A,B	2	" " " " " " " " " " " positive " " (times 10 ²)																																
		A,B	3	" " " " " " " " " " " negative " " (" ")																																
		C	0	" " " " " " " " " " " positive " " (Single Precision)																																
		C	1	" " " " " " " " " " " negative " " (" ")																																
		C	6	" " " " " " " " " " " positive " " (Double ")																																
		C	7	" " " " " " " " " " " negative " " (" ")																																
		C	2	" " " " " " " " " " " positive " " (D.P. times 10 ²)																																
		C	3	" " " " " " " " " " " negative " " (" " " ")																																
NOTES		A,B	2,3	If 24 bits of data are converted into 8 decimal digits, A&B modes 0&1 will display the first six digits while A&B modes 2&3 will display the last six digits. For scale factors between -9 and +19 the 3 rd , 4 th , 5 th , & 6 th digits should be identical in display, (shifted to different windows) when changing from modes 0&1 to 2&3; but for scale factors not in this range, these digits may differ slightly when changing modes due to limited machine accuracy.																																
		C	2,3																																	
		C	2,3 6,7	Double precision values of 30 bits are truncated to the 24 most significant bits before transmission to A&B. Thus, when reading the description of C modes 2&3, it must be understood that the "Approximately 19 Least Significant Bits" refers to the 19 least significant bits of the 24 most significant bits of the 30 bit double word.																																

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X-Y/X-T/EVENT RECORDERS

INDEX

1. Initialization Card Format for XY, XT Plotters and Event Recorders (Octal Format).
2. Initialization Card Format for XY, XT Plotters and Event Recorders (Decimal Format).
3. Initialization Procedures for XY, XT Plotters and Event Recorders and Special Procedures.
4. Zeroing of XY Recorders.
5. Offset and Expansion constants.

INITIALIZATION CARD FORMAT

(OCTAL FORMAT)

1	2	3	5	10	13	20	25	32	35	36	
N	N	N	b	N	N	N	N	N	bb	N	N
A	B	C		D		E		F			

For Event Recorders, only Columns 1-3 and 5-10 are punched.

A. Columns 1-2: Channel Number in octal with leading zero where necessary.

XT Recorders	01 - 20 ₈
XY Plotters	21 - 30 ₈
Event Recorders	31 - 54 ₈

Note: For X-Y Channel number vs. Arm/Pen & Recorder number see "X-Y Zeroing".

B. Column 3: Computer in which parameter is located.

1 = Computer A
 2 = Computer B
 3 = Common Core

C. Columns 5-10: Absolute address of parameter to be plotted is punched in Cols. 6-10. Upper core memory is designated by 1 in Col. 5 while lower core memory is designated by zero in Col. 5.

D. Columns 13-20: Offset Constant, an octal word whose scaling is the same as that of the parameter to be plotted.

E. Columns 25-32: Expansion Constant, an octal word used in multiplication.

F. Columns 35-36: Scale Factor, the octal sum of the scaling of D and E with leading zero if necessary.

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29

- 40 41

F F F F F F F F F F F F G G G

01 - 16

17 - 24

25 - 44

See "X-Y Zeroing".

- Computer where parameter is located:

1 = A Computer

2 = B Computer

3 = Common Core

- Absolute address (octal) of parameter to be plotted is punched in card Columns 7 - 11. Upper core memory is designated by a 1 in Column 6 while lower core is designated by a zero in Column 6.

- Offset constant in decimal with trailing zeros; sign and decimal point and 10 digits.

- Scaling of offset constant; sign and 2 digits. This scale factor must be the same as that of the parameter to be plotted.

- Expansion constant in decimal with trailing zeros; sign and decimal point and 10 digits.

- Scaling of expansion constant; sign and 2 digits. Note: the sum of the scaling of the offset constant and the expansion constant must be a positive number.

INITIALIZATION PROCEDURES

1. Loading of Cards

- A. The initialization deck consists of a header card as described in the Unified Simulation System under LOADING PROCEDURES, up to 44 initialization cards, a blank card, and an *END card.
- B. The deck is loaded in the same fashion as all other card inputs described in the Unified Simulation System.

2. Special features for the XY Plotters.

- A. The XY Recorder Program has been modified to allow automatic table output and table output selection via typewriter. The automatic feature will be in effect under normal circumstances because the control boolean "NALINK" will be equal to "1" unless changed. The typewriter mode is selected by setting "NALINK" equal to "0".
- B. The parameters of the output tables are explained in the LMS COMPLEX Section of this manual under "Pre-Programmed Display Outputs".
- C. In the automatic mode, 1 of 2 tables will be selected depending upon the altitude of the vehicle. The descent table will be selected below 70,000 feet altitude and the rendezvous table will be used above 70,000 feet. These tables are independent of vehicle configuration (i.e. staged, unstaged, descent engine on, etc.).
- D. In the typewriter mode the output table will be selected by changing the value of "XYSET". A two (2) in "XYSET" causes use of the rendezvous output table and a one (1) in "XYSET" causes use at the pre-landing output table. "XYSET" is set to zero following a table selection. X-Y Recorder cards may be read to overlay the output table when in the typewriter mode, NALINK equal to "0".

NOTE:

- 1. To output rendezvous (Table B) data at all times, do the following in the sequence shown:
 - a. Set "NALINK" equal to "0".
 - b. Set "XYSET" equal to "2".

2. To output descent (Table A) data at all times, do the following in the sequence shown:
 - a. Set "NALINK" equal to "0".
 - B. Set "XYSET" equal to "1".
3. To output in the automatic mode at all times do the following:
 - a. Set "NALINK" equal to "1".

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ZEROINGX-Y RECORDERS

- (1) Locate address of 'XYZERO' in Memory Map.
- (2) Change the value of 'XYZERO' from '00000000' to '00000001' via typewriter. At this time the D/A output of all X-Y plotters will be zero.
- (3) Set up X-Y Recorders at zero points.
- (4) Change the value of 'XYZERO' from '00000001' to '00000000' via typewriter. At this time the D/A outputs at all X-Y plotters are normal.
- (5) 'XYZERO' will be located in an area of common core such that when the LMS is reset it will be set to zero.

X-Y Channel Numbers vs. Arm/Pen and Recorder

	<u>D/A Address</u>	
Channel 17	62655	Arm 1 Recorder 1
Channel 18	62656	Arm 2 Recorder 1
Channel 19	62657	Pen 1 Recorder 1
Channel 20	62660	Pen 2 Recorder 1
Channel 21	62661	Arm 1 Recorder 2
Channel 22	62662	Arm 2 Recorder 2
Channel 23	62663	Pen 1 Recorder 2
Channel 24	62664	Pen 2 Recorder 2

Offset and Expansion Constants

In order to prepare the punched cards for initialization of the XY Plotters and XT Recorders there are several things one must determine for each parameter to be displayed:

- (a) Absolute Address
- (b) Scaling
- (c) Range of the Parameter
- (d) Offset Constant
- (e) Expansion Constant
- (f) Scale Factor

As an example, consider the parameter ABC scaled at B8. While the range may be from -256 to +256, we may only be interested in those values from -47 to +209. By limiting ourselves to this smaller range, we will be able to observe a greater displacement of the Plotter/Recorder for a change in the parameter than if we had used the maximum range of -256 to +256.

The Offset Constant is always the median of the limits of the range, that is, halfway between the limits. In this example it would be 128B8. If we consider the maximum DA output of 10 volts as 1B0 (or '37774000), we have to multiply the expected maximum value of 128 by 1/128 to get a product of 1. Thus our Expansion Constant is 1/128 in this example.

Basically the XY,XT output program executes the following instructions:

LDA	Parameter	
SUB	Offset Constant	
TAB		
MPY	Expansion Constant	
LLS	Scale Factor	Scale at B0
SKS	'40400	Test for Overflow
ORA	='37774000	Set to Maximum
STA	DA	

In this example the Offset Constant is 128B8, the Expansion Constant is 1/128 B-6 ('2000 0000). By adding the scaling of the Offset Constant and the Expansion Constant in octal, one arrives at the Scale Factor of 02 which is necessary to achieve a result scaled at B0. The SKS and ORA instructions provide the maximum value if overflow occurs. For those quantities not needing to be offset, the Offset Constant is zero (octal 00000000). For those not requiring an Expansion Constant, it may be made equal to '37777777 while the Scale Factor is set equal to zero.

By choosing a suitable Scale Factor and Expansion Constant some variations are possible as the following examples will show. If one wishes to plot another DA voltage, for example, a DA driving a meter, he has a choice.

Example A

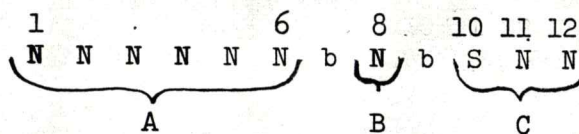
```
LDA    DA
SUB    ZERO      Offset Constant
TAB
MPY =  '37777777 Expansion Constant
LLS    0      Scale Factor
SKS    '40400
ORA    ABSVAL
STA    DA Output
```

Example B

```
LDA    DA
SUB    ZERO
TAB
MPY =  1B1
LLS    1
SKS    '40400
ORA    ABSVAL
STA    DA Output
```

In Example A the Expansion Constant is effectively 1B0, hence the product of the multiplication does not need to be rescaled and the Scale Factor must be zero. In Example B the DA (whose value is XB0) is multiplied by 1B1 ('20000000) and the product is XB1; hence a Scale Factor or shift of 01 is necessary to rescale the output at B0.

PARAMETER DISPLAY

I. Card Format for Pre-Mission Initialization

The order in which the cards are read will correspond to the value of the parameter display thumbwheel.

- A. Columns 1-6: The absolute address of the parameter to be displayed (with leading zeros if necessary) is punched in columns 2-6. If the parameter is in upper core, 1 is punched in column 1. If the parameter is in lower core, zero is punched in column 1.
- B. Column 8: The computer in which the parameter is located where 1 = Computer A
2 = Computer B
3 = Common Core
- C. Columns 10-12: The scaling in octal of the parameter (with leading zero if necessary). The sign must be punched in Column 10. For B0 one must use +00.

II. Loading of Cards;

- A. The initialization deck consists of a header card as described in the Unified Simulation System under "Loading Procedures", up to 50 initialization cards, a blank card, and an *END card.
- B. The deck is loaded in the same fashion as all other card inputs described in the Unified Simulation System.

REAL TIME PRINT

RTP uses the DAP symbolic coding format. A blank terminates the address field (c.c. 16-71), thus allowing for comments.

INITIALIZATION CARD FORMAT:

Columns 1-8 Label - variable name for parameter cards, blank for control cards.

Columns 10-13 Control Mnemonic Field - defines type of card.

Columns 16-26 Variable Field - specific information such as print rate, address, scaling, etc.

TYPES OF PARAMETER CARDS:

1. DEC - specific data to be printed in decimal format.
 - A. Label field - optional - variable name.
 - B. Control Mnemonic field - required - DEC.
 - C. Variable field - order of control elements is insignificant (except for address which must start in c.c. 16), but commas must separate each control element and a blank terminates the field.
 - 1) Address - required - 5 digit octal address of variable.
 - 2) Bank - optional - L for Lower bank, U for Upper bank, if not included, lower bank is assumed.
 - 3) Scaling - optional - Bsnn where s is the sign (assumed positive if omitted) and nn is a two digit decimal integer denoting the scaling.
 - 4) Print - a P must be included for the variable to be printed.

- 5) Conversion factor - Inn, where nn is a two digit octal integer specifying the proper conversion factor for printing values in the British (FPS) system.

<u>REF NO.</u>	<u>CONV. FACTOR</u>	<u>FROM</u>	<u>TO</u>
00	0.999999B0	No Change	
01	3.281B2	Meters	Feet
02	0.000539B-10	Meters	Nautical Miles
03	3281B12	Kilometers	Feet
04	0.5396B0	Kilometers	Nautical Miles
05	328.1B9	Meters/CSec	Feet/Sec
06	2.205B2	Kilograms	Pounds
07	0.06854B-3	Kilograms	Slugs
10	220.5B8	Kilograms/CSec	Pounds/Sec
11	6.854B3	Kilograms/CSec	Slugs/Sec
12	360B9	Revolutions	Degrees
13	36000B16	Revolutions	Degrees/Sec
14	6.283B3	Revolutions	Radians
15	628.3B10	Revolutions/CSec	Radians/Sec
16	0.000625B-10	625 u sec count	Milliseconds

- 6) Precision - optional on C-Computer, not available for A or B Computer - D for double-precision, S for single-precision, if not included single-precision (15 bits) is assumed.

2. ØCT - specific data to be printed in octal format.

A. Label field - optional - variable name.

B. Control Mnemonic Field - required - ØCT.

C. Variable Field - order of the control elements is insignificant. (except for address which must start in c.c. 16), but a comma must separate each control element and a blank terminates the field.

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- 1) Address - same as DEC, see 1.c.1
- 2) Bank - same as DEC, see 1.c.2.
- 3) Scaling - not applicable.
- 4) Print - same as DEC, see 1.c.4.

TYPE OF CONTROL CARDS

1. PDT - optional - specifies the data print rate (time increment between output. If used, it must precede the first parameter card. The time variable field starts in c.c. 16 and is of the following format:

HH/MM/SS/TT

Where HH - is an integer denoting hours

MM - is an integer denoting minutes

SS - is an integer denoting seconds

TT - is an integer denoting 20's of seconds

All time components smaller than the major time component present must be delimited.

Examples:

<u>Time</u>	<u>Variable Field</u>
1 second	1/
1 minute	1//
1.5 seconds	1/10
1.5 minutes	1/30/

2. ENDx - required - defines computer from which the preceding parameter cards were for.
3. EOF - required - defines the physical end of the initialization cards.

OPERATING PROCEDURES

1. Loading of cards:

- A. The initialization deck consists of a (Link) header card as described in the Unified Simulation System under "Loading Procedures", an initialization card deck as just described, and an *END card.
 - B. The deck is loaded in the same fashion as all other card inputs described in the Unified Simulation System.
2. RTP may be initiated by SSW3 on A-Computer or by depressing the "RTP" spril on the I/S.

OPTIONAL PROCEDURES FOR VARIED OUTPUT FREQUENCY

(1/10 second in powered flight; 1/minute in coasting flight)

1. See above 1., but use a NRT header card.
2. NRT may be initiated by SSW3 on A-Computer or by depressing the "RTP" spril on the I/S.

NOTE: It is possible to use only one of these RTP procedures at a given time and whenever going from one to the other it will be necessary to reinitialize.

DEP (DEDA ENTER PRINT)

- PURPOSE:** To allow preprogrammed or initialized outputs to be displayed via Real Time Print upon command from the ABORT GUIDANCE SYSTEM. There are presently two (2) conditions which command this print, an 'ENTRY' on the AGS DEDA, and the completion of a Rendezvous Radar to AGS Update. This mode has no effect when it is required that there be normal RTP utilization.
- RESTRICTIONS:** The DEP and RTP are functionally the same Hence, one must be in print control but not both. The DEP is presently the controlling function; however, selection of R.T.P. via Sense Switch 3 on A-Computer or the IØS RTP button causes R.T.P. to be in print control. While in DEP Mode "RTP TØP ØF FØRM LØGIC" and "NASA VARIABLE PRINT RATE LØGIC" is inhibited.
- INITIALIZATION:** The DEP mode is presently preprogrammed to display 15 parameter values plus R.T.P. formatted Mission Time. As many as 18, however, may be displayed using the DEP INITIALIZATION Cards. The following PARAMETERS are presently preprogrammed for DEP Display:

<u>Variable</u>	<u>Scale Factor</u>	<u>Definition</u>
INPUT1	OCT	DEDA Address Entered
INPUT2	B+23	DEDA Date Entered
IV6	B+15	MAG of INCRT in VEL REQ for TRI + SEL XFER ORB
I1J28	B+15	X COMP of Manual Change in LM VEL
I2J28	B+15	Y COMP of Manual Change in LM VEL
I3J28	B+15	Z COMP of Manual Change in LM VEL
IVPY	B+15	MAG of VEL Along LM Y-Axis after CDH or CSI
IMU19	B+17	Radar Update Counter (XXØYY) XX=#RNG Updates, YY=RNG-RT Updates
HLDZ2LS	B+8	Elevation Angle Between LM and CMS
EMAAPO	B+14	EOM Apogee Minus AGS Calculated Apogee
EMAPERI	B+14	EOM Perigee Minus AGS Calculated Perigee
EMARNGE	B+14	EOM Range Minus AGS Calculated Range
EMARNGRT	B+15	EOM Range-Rate Minus AGS Calculated Range-Rate
EMAALT	B+23	EOM Altitude Minus AGS Calculated Altitude
EMAALTRT	B+15	EOM Altitude-Rate Minus AGS Calculated Altitude-Rate

DATA RECORDING

I. DESCRIPTION

Any double-precision or single-precision parameter from A-Upper, A-Lower, B-Upper, B-Lower, or Common Core may be recorded on magnetic tape in real-time and printed at a later time on the DDP-024 or 224. Control cards are read in order to initialize the on-line Data Recording programs. This same deck of control cards is used to initialize the off-line de-log program. The initialization deck consists of a header card as described in the Unified Simulation System under "Loading Procedures", all cards for Computer A (up to 100 cards which must be grouped together), one blank card, all cards for Computer B (up to 75 cards which must be grouped together), another blank card, and an *END card.

The LMS Data Recording Delog Program now has the capability of converting parameters logged by the on-line computer from the unit logged to another unit such as from radians to degrees depending upon a conversion factor which is placed on the initialization cards.

II. INITIALIZATION PROCEDURE

- A. Mount scratch tape on TMU #1, MTU #2.
- B. Load the initialization deck in the same fashion as all other card inputs described in the Unified Simulation System.

III. COMPUTER/CONSOLE CONTROLS

- A. When the simulator is in run and Sense Switch 3 of B machine or the Data Record Switch at the IOS is active, data will be recorded on tape at the specified rate. To stop recording, simply put Sense Switch 3 down or reset the Data Record switch at the IOS.
- B. At the end of the run, halt the complex. By starting B at '102 and responding to the typeout with a Y, an end-of-file will be written on tape and it will be rewound. The tape should now be removed for Off-Line processing.
- C. Mark Flag

Pushing the switch labeled "MARK" will initiate action within the program so that when RTP and/or Data Recording are in process a Mark Flag will be recorded. Also, the light on the Instructor's Console will be lit while the flag is being recorded. Data Recording prints **** to the left on the time line as flagged by the last word of recording buffer.

IV. FORMAT FOR DATA RECORDING INITIALIZATION CARDS:

- A. Format for Card 1 - The iteration rate for recording must be specified along with either the A or B inputs. This card contains table address "00000" in columns 1-5, R in col. 6, an octal control integer in cols. 7-14 specifying the rate, and A in column 15. Below is a table for the most common rates:

<u>Recording Rate</u>	<u>Control Integer</u>
20 times/sec.	1
10 times/sec.	2
5 times/sec.	4
2.5 times/sec.	10
1.25 times/sec.	20
Once/sec.	24
Once/5 sec.	144
Once/10 sec.	310
Once/15 sec.	454
Once/30 sec.	1130
Once/Min.	2260

B. Format for Cards 2 thru N

Cols. 1-5	Table address in octal (00001-00144 ₈).
Col. 6	R
Cols. 7-9	400 is parameter is in upper core. 000 if parameter is in lower core or common core.
Cols. 10-14	Address of parameter to be recorded.
Col. 15	A
Col. 16	Spare
Col. 17	+ if scaling is positive - if scaling is negative
Cols. 18-19	Scaling of parameter in decimal.
Cols. 21-28	Symbol name (left justified)
Cols. 30-37	Conversion factor in decimal with trailing zeros; sign + decimal point +6 digits.
Col. 38	+ if scaling is positive - if scaling is negative
Cols. 39-40	Scaling of conversion factor
Cols. 41-80	Comments

Scaling limits are + or -29 with the exception of two special cases. It is possible to have a variable printed in octal or a boolean printed as a 0 or a 1 by specifying the scaling as +63 or -00 respectively.

C. Double Precision

To record in Double Precision value, the following guidelines must be observed.

1. Place the digits 07 in the op-code field of the data recording card. This informs both the recording and post-processor programs that it is handling a Double Precision value.
2. A Double Precision value recorded will occupy the table address specified on the data recording card, and the next sequential table address. Therefore the table address which would sequentially follow that address specified must be omitted, eg.....

00001R00736100A	¹⁷ +06	²¹ WTEMP	³⁰ +003100 -02	⁴¹ FW95T
00003R00035250A	-00	X	+001212 +02	Miles

- V. Once data has been recorded on tape an end-of-file should be written on tape by starting at 116g in B-Lower. The only items needed for off-line processing are the data recording tape, and the initialization cards. These two items must be submitted with an Operations Request when the data is to be post-processed.
- VI. If the computer is reset with A & B Log enabled an end-of-file will be written on the log tape and the logging process will be continued as soon as the reset has been completed.

GSSC RECORD/READ

The I/O control system provides the capability to either record GSSC INPUT BUFFERS, or read in a previously recorded tape to simulate GSSC INPUT. When utilized, this program assumes a tape is mounted on MTU #4. All Index Register and Sense Switch settings are from Computer "A".

DATA RECORDING:

The GSSC Input Buffers will be recorded at a rate of three (3) buffers every 600 milliseconds when the following conditions are satisfied:

1. INTEGRATED MODE (LMS/GSSC or LMS/CMS/GSSC).
2. RUN or FREEZE
3. Record option selected at start-up by setting Index Register 2 to 00001.
4. SSW5 set

Upon completion of RESET, an End of File is written on the output tape to separate recording periods.

GSSC INPUT SIMULATION:

In lieu of actual GSSC inputs, a previously recorded tape may be read in to simulate GSSC when the following conditions are satisfied:

1. NON-INTEGRATED MODE (LMS ONLY or LMS/CMS)
2. RUN
3. READ option selected at start-up by setting Index Register 3 to 00001.
4. SSW5 set.

Upon completion of RESET, the tape is advanced to the next file of data, and the first record containing three buffers is read in.

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PRE-PROGRAMMED DATA OUTPUTS

A list of the parameters programmed for each device is enclosed. It must be clearly understood that these parameters will be programmed on each load tape that Link delivers to NASA. When other load tapes are made from the basic or first load tape delivered by Link, the man making the new load tape must not have read in other initialization cards or the new parameters inserted via the initialization cards will replace these parameters.

The following parameters have been programmed for the XT Recorders:

<u>XT CHANNEL NO.</u>	<u>SYMBOL</u>	<u>RANGE RECORDED</u>	<u>DESCRIPTION</u>
01	AFXB	0 to + 10,000	+X BODY FORCE
02	HTHPG	+ 40	PITCH TRIM GIMBAL
03	HPSPG	+ 40	ROLL TRIM GIMBAL
04	ARDNL	0 to 24'/sec.	EOM ALTITUDE RATE
05	GROD		ROD + TO - DISCRETES
06	HQAC	+ HARDSTOP	PITCH ACA COMMAND
07	HRAC	+ HARDSTOP	ROLL ACA COMMAND
08	HPAC	+ HARDSTOP	YAW ACA COMMAND
09	GATHEC	+ 80	PITCH ERROR - PGNS
10	IEY	+ 80	PITCH ERROR - AGS
11	GAPSEC	+ 80	ROLL ERROR - PGNS
12	IEZ	+ 80	ROLL ERROR - AGS
13	GAPHEC	+ 80	YAW ERROR - PGNS
14	IEX	+ 80	YAW ERROR - AGS
15	AUVOPMAG	0 - 40'/sec	/OUT-OF-PLANE VELOCITY/
16	VYRELPLT	0 - 16,000'	/OUT-OF-PLANE DISTANCE/

The following parameters represent the standard pre-programmed X-Y plotter outputs and are effective only if Option A or B have not previously been selected:

<u>Channel No.</u>	<u>Symbol</u>	<u>Range Recorded</u>	<u>Description</u>
17	VXRELHNM	<u>+500</u>	RANGE-ALONG ORBIT AXIS (NAUT. MILES)
18	VXRELHNM	<u>+500</u>	
19	VZRELHNM	<u>+250</u>	RANGE-VERTICAL AXIS (NAUT. MILES)
20	VZRELHNM	<u>+250</u>	
21	VXRELH	<u>+100</u>	RANGE-ALONG ORBIT AXIS (NAUT. MILES)
22	VXRELH	<u>+100</u>	
23	VZRELH	<u>+100</u>	RANGE-VERTICAL AXIS (NAUT. MILES)
24	VZRELH	<u>+100</u>	

The following options (A or B) overlay the standard X-Y table. Setting XYSET (address in memory map) =1 or 2 activates tables A or B respectively. Note: Once one of these options is exercised, the above table cannot be recovered without re-loading.

<u>XT Channel No.</u>	<u>Symbol</u>	<u>Range Recorded</u>	<u>Description</u>
<u>Tabel A (Descent)</u>			
17	VHNLTEMP	0 to +70,000	ALTITUDE (FT)
18	GALTBIAIS	<u>+2,000</u> / <u>+5,000</u>	LUNAR TERRAIN WRT LANDING SITE (FT)
19	ARDNL	<u>+300</u>	ALTITUDE RATE (FT/SEC)
20	VLONGPLT	0/+400,000	RANGE WRT NOM. TRAJECTORY (FT)
21	VLONGPLT	-5,000/+70,000	RANGE WRT NOM. TRAJECTORY (FT)
22	VLONGPLT	-25,000/+50,000	RANGE WRT NOM. TRAJECTORY (FT)
23	VCROSPLT	+25,000	CROSS RANGE WRT NOM. TRAJECTORY (FT)
24	VHNLTEMP	0/+10,000	ALTITUDE (FT)

<u>XT Channel No.</u>	<u>Symbol</u>	<u>Range Recorded</u>	<u>Description</u>
<u>Table B (Rendezvous)</u>			
17	PROTECTED		
18	VARCDIST	± 5000	ORBIT ARC DIST WTO CSM (NAUT. MI.)
19	PROTECTED		
20	VRADIFF	± 1150	RAD. VECTOR DIFF WTO CSM (NAUT. MI.)
21	PROTECTED		
22	VXRELH	± 300	RANGE ALONG ORBIT AXIS (NAUT. MILES)
23	PROTECTED		
24	VZRELH	± 300	RANGE-VERTICAL AXIS (NAUT. MILES)

The following parameters have been programmed for the EVENT RECORDERS:

<u>Channel No.</u>	<u>Symbol</u>	<u>Description</u>
25	H695	RCS THRUSTER NO. 1 (B4U)
26	H703	RCS THRUSTER NO. 2 (A4D)
27	H697	RCS THRUSTER NO. 3 (B4F)
28	H706	RCS THRUSTER NO. 4 (A4R)
29	H708	RCS THRUSTER NO. 5 (A3U)
30	H700	RCS THRUSTER NO. 6 (B3D)
31	H701	RCS THRUSTER NO. 7 (B3A)
32	H710	RCS THRUSTER NO. 8 (A3R)
33	H696	RCS THRUSTER NO. 9 (B2U)
34	H704	RCS THRUSTER NO. 10 (A2D)
35	H705	RCS THRUSTER NO. 11 (A2A)
36	H698	RCS THRUSTER NO. 12 (B2L)
37	H707	RCS THRUSTER NO. 13 (A1U)

<u>Channel No.</u>	<u>Symbol</u>	<u>Description</u>
38	H699	RCS THRUSTER NO. 14 (B1D)
39	H709	RCS THRUSTER NO. 15 (A1F)
40	H702	RCS THRUSTER NO. 16 (B1L)
41	M011	HOS MARK DISCRETE

The Parameter Display Initialization Routine has been programmed to display the following variables when the corresponding number is dialed:

<u>Parameter No.</u>	<u>Symbol</u>	<u>Description</u>
01	VARHOLS	RANGE LM TO CSM (LESS THAN 128,000 FT)
02	ARRHODLS	RANGE RATE, FT/SEC.
03	ARRHONM	RANGE, NAUTICAL MILES
04	AUHP1	LM PERIGEE, N. MI.
05	AUHA1	LM APOGEE, N. MI.
06	AULAT	LM LATITUDE
07	GEDELE	ELEVATION ANGLE BETWEEN LOS & X AXIS
08	TPPC	PITCH ANGLE FOR S-BAND ANTENNA
09	AURTRM	PITCH CG IN TRIM GIMBAL COORDINATES
10	AUWLM	WEIGHT OF LM ONLY
11	VHNLTEMP	ALTITUDE ABOVE L.S.
12	ARDNL	ALTITUDE RATE, FT/SEC.
13	SPARE	
14	AUHP	CSM PERIGEE, N. MI.
15	AUHA	CSM APOGEE, N. MI.
16	AULON	LM LONGITUDE
17	GEDELA	AZIMUTH ANGLE BETWEEN LOS & X AXIS
18	TYPC	YAW ANGLE FOR S-BAND ANTENNA
19	AURTRM	ROLL CB IN TRIM GIMBAL COORDINATES
20	AUWCM	WEIGHT OF CSM
21	AUROL	LM LOC. HORIZ. ROLL, DEG.
22	AUPIT	LM LOC. HORIZ. PITCH, DEG.
23	AUYAW	LM LOC. HORIZ. YAW, DEG.
24	AUAV1	LM ANGULAR VELOCITY, DEG/MIN
25	AUWL	LM ARG. OF PERIGEE, DEG.
26	AUNUL	LM TRUE ANOMALY, DEG.
27	AUI1	LM INCLINATION, DEG.

<u>Parameter No.</u>	<u>Symbol</u>	<u>Description</u>
28	TCSSBD	COS OF CENTRAL ANGLE BETWEEN EARTH/MOON
29	AUPERI	LM ORBIT PERIOD
30	AUGAM	LM TO CSM CENTRAL ANGLE, DEG.
31	AUCMGA	CSM MIDDLE GIMBAL ANGLE
32	AUCIGA	CSM INNER GIMBAL ANGLE
33	AUCOGA	CSM OUTER GIMBAL ANGLE
34	AUAV	CSM ANGULAR VELOCITY, DEG/MIN
35	AUW	CSM ARG. OF PERIGEE, DEG.
36	AUNU	CSM TRUE ANOMALY, DEG.
37	AUL	CSM INCLINATION, DEG.
38	TCSSBL	LM SIN OF LIMIT ANGLE BETWEEN MOON/ LM VECTOR
39	AUPER	CSM ORBIT PERIOD, MIN.
40	AUVOP	LM OUT-OF-CSM-PLAN VEL, FT/SEC.
41	VXRELHNM	RANGE-ALONG ORBIT AXIS
42	VYRELHNM	OUT OF ORBIT PLANE DISTANCE
43	VZRELHNM	RANGE-VERTICAL AXIS
44	PWOAU	ASCENT OXIDIZER WEIGHT MINUS UNUSEABLES
45	PWFAU	ASC FUEL WEIGHT MINUS UNUSEABLES
46	GECTL	ANGLE BETWEEN LOS AND TRACKING LINE
47	RWFA	QTY. OF FUEL IN RCS-A FUEL TANK
48	RWFB	QTY. OF FUEL IN RCS-B FUEL TANK
49	RWOA	QTY. OF OXIDIZER IN RCS-A OXID. TANK
50	RWOB	QTY. OF OXIDIZER IN RCS-B OXID. TANK

The pre-programming of these parameters does not prevent anyone else from using these devices for other parameters or variables. It merely means that no initialization cards are required for these parameters. If you have need of other parameters on the XY Recorders, XY Plotters, Parameter Display and/or Event Recorders, the LMS software still has the capability of being initialized by card input. The format of these cards has not changed.

ADDX, SUBX, MPYX, DIVX

A. Purpose:

To perform arithmetic operations on double-precision, fixed-point binary quantities giving double-precision, fixed-point binary results.

B. Argument:

Enter with the double-precision operand in the A and B Registers. The parameter word immediately following the call command consists of the pseudo-operator, PZE, and the address of the high-order portion of the double-length operand (augend, subtrahend, multiplier, or divisor). It is assumed that the address of the low-order portion is one greater than the address of the high order portion.

C. Calling Sequence

```
LDA      ARGUMENT
LDB      ARGUMENT +1
CALL     ADDX OR SUBX OR MPYX OR DIVX
PZE      ADDRESS* OF HIGH-ORDER PORTION OF (AUGEND, SUBTRAHEND, MULTIPLIER,
          OR DIVISOR). *(ADDRESS CANNOT BE INDEXED.)
STA      RESULT
STB      RESULT +1
```

D. Result:

The result of the operation is a double-precision fixed-point binary number.

E. Scaling:

ENTRY POINT	SF OF RESULT
ADDX	SAME AS INPUTS
SUBX	SAME AS INPUTS
MPYX	SF=SF(ARG)&SF(ARG2)
DIVX	SF=SF(ARG) -SF(ARG2)

F. Error Return:

None

For ADDX or SUBX, if overflow occurs both registers will be loaded with '37777777. Control will be returned to the calling program with the overflow flop set.

For DIVX, if an improper divide condition exists, the operation will not be attempted and the improper divide flop will be set.

G. Core Requirements:

253 Octal Locations

H. Timing:

	Time	
	Min.	Max.
ADDX	68.39	
SUBX	68.39	
DIVX	205.17	220.4
MPYX	91.2	

ARCTRIGV

A. Purpose:

To compute an angle in radians given its sine and cosine.

B. Arguments:

The sine of the angle in the A-Register scaled at a B1. The cosine in the B-Register scaled at a B1.

C. Calling Sequence:

```
LDA      SINE B1
LDB      COSINE B1
CALL     ARCTRIGV
STA      ANGLE B3
```

D. Result:

The output of ARCTRIGV is a single-precision angle expressed in radians in the A-Register. The output is in an interval of $(0, 2\pi)$.

E. Scaling:

The result is scaled at a B3.

F. Error Return:

None

G. Core Requirements:

141 Octal Locations

H. Timing:

	<u>Time</u>	
	<u>Min.</u>	<u>Max.</u>
ARCTRIGV	144.4	164.08

ASN_X, ACS_X

A. Purpose

To compute the arc sine or arc cosine of a single-precision, fixed-point binary quantity.

B. Arguments

The operand is in the A-Register. The scale factor of the operand is in the B-Register scaled at B23.

C. Calling Sequence

LDA	ARG
LDB	Scaling
CALL	ASN _X (or ACS _X)
JOF	ERROR

D. Result

The result of the operation is a single-precision fixed-point binary number expressed in radians in the A-Register.

E. Scaling

The result is scaled at B2.

F. Error Return

If the absolute value of the input is greater than 1, the operation will not be attempted, the overflow flop will be set, and control will be returned to the calling program.

G. Core Requirements

123 octal locations.

H. Timing

	<u>Time</u>	
	<u>Min.</u>	<u>Max.</u>
1. ASN _X	6.84	328.50
2. ACS _X	20.52	349.02

ATNX

A. Purpose:

To compute the arc tangent of a single-precision, fixed point binary number.

B. Arguments

The operand is in the A-Register. The scale factor of the input is in the B-Register scaled at a B23.

C. Calling Sequence:

```
LDA      ARG
LDB      Scaling
CALL     ATNX
STA      Result Bl
```

D. Result:

The result is a single-precision, fixed point binary number expressed in radians in the A-Register.

E. Scaling:

The result is scaled at a B1.

F. Error Return:

None

G. Core Requirements:

103 Octal Locations

H. Timing:

	<u>Time</u>	
	<u>Min.</u>	<u>Max.</u>
ATNX	197.6	228.0
I = 0	15.2	

LG10X

A. Purpose:

To compute the logarithm of any fixed-point single-precision number to base 10.

B. Arguments:

The input parameter goes in the A-Register. The scaling for this parameter goes in the B-Register.

C. Calling Sequence:

```
LDA      ARG
LDB      SCALING      B23
CALL LG10X
STB      NEW SCALING
STA      RESULT
```

D. Result:

The result of LG10X is a single-precision number.

E. Scaling:

The scaling of the output is in the B-Register.

F. Error Return:

None

For LG10X, if the base is zero or negative, the overflow flop will be set and normal return taken.

G. Core Requirments:~

H. Timing:

	<u>Time</u>
	<u>Min.</u> <u>Max.</u>

LG10X

ARG = 0, -

220.3

5F1

MATRIXMU

- A. Purpose -(1) to multiply a 3 X 3 single-precision, fixed-point matrix times a 3 X 3 single-precision, fixed-point matrix (2) to multiply a 3 X 3 single-precision, fixed-point matrix times a fixed point, single-precision vector of length three.
- B. Arguments - All elements of a matrix must have a scaling of B1 or greater and have the same scaling. All components of vector must have the same scaling. The resultant of any multiplication using MATRIXMU will have a scaling of one less than the sum of the scalings of the multiplicand and the multiplier.

- C. Calling Sequence for a Matrix Times a Matrix: $[C] = [A][B]$

(1) If all matrices are stored row-wise:

```
LDX B11,1 (B11 is 1st element of 2nd matrix)
LDX A11,2 (A11 is 1st element of 1st matrix)
LDX C11,3 (C11 is 1st element of resultant matrix)
CALL MATRIXMU
```

(2) If all matrices are stored column-wise:

```
LDX A11,1 (A11 is 1st element of 1st matrix)
LDX B11,2 (B11 is 1st element of 2nd matrix)
LDX C11,3 (C11 is 1st element of resultant matrix)
CALL MATRIXMU
```

- D. Calling Sequence for a Matrix Times a Vector: $[C] = [A][B]$

*(1) If matrix is stored row-wise:

```
LDX A11,1 (A11 is 1st element of matrix)
LDX B11,2 (B11 is 1st component of vector)
LDX C11,3 (C11 is 1st component of resultant vector)
CALL MATXRVEC
```

*(2) If matrix is stored column-wise:

```
LDX A11,1 (A11 is 1st element of matrix)
LDX B11,2 (B11 is 1st component of vector)
LDX C11,3 (C11 is 1st component of resultant vector)
CALL MATXCVEC
```

- E. Error return - none.

- F. Restrictions - MATRIXMU uses all of the index registers; therefore, if one calls MATRIXMU within an index loop, one should store the contents of the index registers before calling MATRIXMU.

*These may be used for matrix multiplications when the matrices are not all stored column-wise or the matrices are not all stored row-wise.

- G. Core Requirements: '260

- H. Timing: 512 usecs = matrix X matrix
180 usecs = matrix X vector

541

MPYSXD

A. Purpose:

To multiply a single-precision fixed-point binary parameter by a double-precision fixed point binary parameter.

B. Arguments:

High order word of double-precision operand in A-Register. Low order word of DP operand in B-Register. Address of single-precision operand is in the address portion of the "PZE" word following the call statement.

C. Calling Sequence:

LDA	ARG	
LDB	ARG&1	
CALL	MPYSXD	
PZE	ADDRESS OF ARG2	SINGLE PRECISION
STA	RESULT	

D. Result:

The result is a single-precision fixed-point binary quantity.

E. Scaling:

The scale factor of the result is the sum of the scale factors of the inputs.

F. Error Return:

None

G. Core Requirements:

27 Octal Locations

H. Timing:

	<u>Time</u>	
	<u>Min.</u>	<u>Max.</u>
MPYSXD		75.99

5H1

SINCOSDA

A. Purpose

1. To compute the sine and cosine of a given angle in reduced (14 bits) precision for driving hardware.

B. Argument

1. Enter the angle in radians into the A-Register

C. Calling Sequence

- | | | |
|---------|-----------|---------------------|
| 1. LDA | ARGUMENT | B3, angle in radius |
| 2. CALL | SINCOSDA | |
| 3. STA | SINRESULT | B0, sin |
| 4. STB | COSRESULT | B0, cos |

D. Result

1. The sine of the given angle is stored in the A-Register and the cosine of the angle is stored in the B-Register.

E. Scaling

1. Input argument must be scaled at B3. The resulting sine and cosine are scaled at B0.

F. Error Return

1. None

G. Core Requirements

1. 173 Octal Locations

H. Timing

	<u>Time</u>	
	<u>Minimum</u>	<u>Maximum</u>
SINCOSDA	112.10	121.60

511

SINX, COSX, TANX

A. Purpose:

To compute sine, cosine, or tangent of a single-precision fixed-point binary quantity in radians.

B. Arguments:

Angle expressed in radians in the A-Register. Scale factor of input in the B-Register at a B23.

C. Calling Sequence:

```
LDA      ARG
LDB      SCALING
CALL     SINX (OR COSX OR TANX)
STA      RESULT      B1
```

D. Result:

The result is a single-precision fixed-point number in the A-Register.

E. Scaling:

The output for SINX and COSX is scaled at a B1, the scale factor for the output of TANX is in the B-Register scaled at a B23.

F. Error Return:

None

G. Core Requirements:

144 Octal Locations

H. Timing:

	<u>Time</u>	
	<u>Min.</u>	<u>Max.</u>
SINX		167.18
COSX		167.18
TANX	402.77	433.2

SQDFIX

A. Purpose:

To compute the square root of a double-precision, fixed-point binary quantity.

B. Argument:

Input - most significant part of the double-precision quantity must be in A-Register, least significant part in B-Register.

C. Calling Sequences:

LDA	ARG	MSP
LDB	ARG + 1	LSP
CALL	SQDFIX	
JOF	Error	
STA	Result	MSP
STB	Result + 1	MSP

D. Result:

Most significant part of the double-precision quantity is stored in the A-Register, least significant part in B-Register.

E. Scaling:

Scaling of input should be even. The result will then be stored at one half the original scaling.

G. Core Requirements:

122 Octal locations

H. Timing:

	<u>Time</u>	
	<u>Min.</u>	<u>Max.</u>
SQDFIX	281.2	303.99

5K1 SQRR, SQRZ

A. Purpose:

SQRR computes the square root of a single-precision fixed-point number.
 SQRZ computes the square root of the 23 most significant bits of a number in the A and B-Registers.

B. Arguments:

For SQRR, the operand is in the A-Register. For SQRZ, the high order portion of the operand is in the A-Register, the low order portion is in the B-Register.

C. Calling Sequence:

```

LDA      ARG
(LDB     ARG&1      FOR SQRZ)
CALL     SQRR       (OR SQRZ )
JMP      ERROR
STA      RESULT
  
```

D. Result:

The output of the subroutine is a single-precision fixed-point number in the A-Register.

E. Scaling:

The scale factor of the result will be one half the SF of the input. If the input SF was not even, the output will not be valid.

F. Error Return:

If the input is negative (unless it is -0), the error return will be taken.

G. Core Requirements:

75 Octal Locations

H. Timing:

	<u>Time</u>	
	<u>Min.</u>	<u>Max.</u>
SQRR	159.6	182.37
ARG = -		22.8
ARG = 0		53.2
SQRZ	167.18	189.97
ARG = -		22.8
ARG = 0		30.4

SQRX

SL1

A. PURPOSE:

To compute the square root of a single-precision, fixed point binary quantity.

B. CALLING SEQUENCE:

LDA	ARG
LDB	N
CALL	SQRX
STA	RESULT

N = Scaling of input argument

C. RESULTS:

SQRX returns a single-precision, fixed point binary quantity located in the A-Register with the positive or negative scale factor located in the B-Register.

D. RETURN ARGUMENT SCALING:

The scale factor of the return argument will always be in the B-Register.

1. For arguments scaled greater than B1, the following statements will always be valid:
 - a. If the input argument is scaled at B2 or some multiple of 2, the result will be scaled at one-half the input scaling.
 - b. If the input argument is scaled at B1, the result will be scaled at B1.
 - c. If the input argument is scaled at B3 or larger odd scale factor, the result will be scaled at one less than the input scaling.

E. ERROR RETURN:

None

- F. If the input argument is zero, SQRX will immediately return with a zero result. If the input argument is negative, SQRX will force the argument positive and proceed normally.

5M1

XBXD

A. Purpose:

To convert a double-precision fixed-point number to BCD data for output.

B. Arguments:

The high order word of the data to be converted goes in the A-Register. The B-Register holds the low order word if the input is DP, otherwise it is zero. There is a 3-word parameter list following the call statement as follows:

1. The first word holds the scale factor preceded by a minus sign. If the SF is negative, use the two's complement of the scale factor.
2. The second word holds the address of the first location into which XBXD will store the converted data.
3. The third word gives the structural information about the data to be converted.

The format of the word is 'FSSLL' where:

F	IS	0 IF NO SIGN, NO DEC. PT
		1 NO SIGN, DEC. PT
		2 IF SIGN, NO DEC. PT
		3 SIGN, DEC. PT
SS		NUMBER OF DECIMAL DIGITS TO LEFT OF DECIMAL PT
		$SS = (3SF/10) + 1$
LL		TOTAL NUMBER OF CHARACTERS IN ANSWER INCLUDING THE SIGN AND DECIMAL POINT IF REQUESTED.
		MAXIMUM OF '20.

C. Calling Sequence:

LDA	ARG	
LDB	ARG&1	
CALL	XBXD	
OCT	***	SCALE FACTOR (WITH SIGN BIT SET)
MZE	**	STARTING ADDR
MZE	**	FSSLL
JMP	ERRRETURN	

D. Result:

The output of XBDX is decimal data stored left-justified into sequential locations specified by parameter word 2.

E. Scaling:

The decimal data is scaled as specified by the scaling program.

F. Error Return:

Inconsistencies - such as an improper format parameter will terminate conversion and the subroutine will take the error return path. The result of the conversion will not be valid.

G. Core Requirements:

503 Octal locations.

521

XDXB

A. Purpose:

To convert decimal data into a double-precision fixed-point number.

B. Arguments:

The A-Register has the address of the starting location of the block holding the decimal data. This data must be numeric with 2 exceptions - the decimal point and the sign. The B-Register holds the number of characters in the block (digits plus sign and decimal point). The location following the call statement provides the scaling for XDXB.

C. Calling Sequence:

```
LDA      SCALING      B23
STA      N1
LDA      WT
LDB      NUMB          NUMBER OF CHARACTERS
CALL     XDXB
N1 ***      **
STA      RESULT
STB      RESULT &1
```

D. Result:

The result is a signed (if sign was included in input) double precision number in the A and B-Registers.

E. Scaling:

The output is scaled according to the scale factor inputted to XDXB.

F. Error Return:

None

If an invalid character is inputted to XDXB, the conversion is not completed and the results are not valid.

The overflow flop is usually set by XDXB. This does not indicate an error.

G. Core Requirement:

205 Octal locations

LINK GROUP - SYSTEMS DIVISION
GENERAL PRECISION, INC.
BINGHAMTON, N.Y.

6A1

LMS RESET POINT DEFINITION

LMS-DS-001

REV. G

REVISIONS	PREPARED BY	DATE	PREPARED BY	DATE	CHECKED BY	DATE	APPROVED	DATE
ORIGINAL	<i>Longlight</i>	10/17/68						
A	<i>Longlight</i>	12/3/68						
B	<i>Longlight</i>	2/14/69						
C	<i>Longlight</i>	3/20/69						
D	<i>Longlight</i>	5/19/69						
E	<i>Longlight</i>	10/14/69						
F	<i>Longlight</i>	11/23/70						
G	<i>John Bennett</i>	11/2/70						

DATE 10-12-70

SINGER-GENERAL PRECISION, INC.
LINK DIVISION

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REV. G

BINGHAMTON, NEW YORK

REP. NO.

6A2

The following changes have been made to LMS-DS-001 Rev. F
to update it to the Rev. G configuration.

- 1) Delete H-2A Mission Reset Points.
- 2) Add A14 (H3) Mission Reset Points.

DATE 10-12-70	SINGER-GENERAL PRECISION, INC. LINK DIVISION	PAGE NO. 2
REV. G	BINGHAMTON, NEW YORK	REP. NO.

6A3

APOLLO 14 (H3) MISSION

Apollo 14, AS-509/CSM-110/LM-8 is a lunar landing mission to be launched January 31, 1971 at 1420 (2:20 PM) CST.

- Ref: 1) Apollo 14 Draft Flight Plan prepared by Apollo Flight Planning Section of Flight Planning Branch of Flight Crew Support Division, 23 September 1970.
- 2) Apollo 14 (H3) Mission Operational Trajectory Simulator Data Package, Memo 70-FM13-348, 21 September 1970.

RESET NUMBER	GET	MISSION PHASE
1	81:38:00	LM is docked and cold, 1 hr 14 sec prior to L ₀ I burn at 82:38:14 of 6 min. 6.6 sec. duration.
3	86:37:00	LM is docked and cold, 19 min 58 sec. prior to CSM D ₀ I burn at 86:56:58 of 21.4 sec. duration.
5	101:58:00	LM is docked and cold, end of rest period, start of activation checklist.
7	104:08:00	LM is docked and powered up 19 min 31 sec prior to undocking and separation at 104:27:31.
11	105:27:00	LM is undocked, AGS initialized, landing site photographed, R/R checked-out, IMU aligned to landing site REFSEMMAT, LPD calibrated and awaiting CSM circularization burn at 105:46:48.
14	106:42:00	LM undocked, AGS has been aligned to PGNS and calibrated, systems check performed, DPS pressurized and checked-out; L/R checked-out, AGS state vectors initialized and awaiting PDI burn at 108:42:01.
15	108:22:00	LM undocked, IMU re-aligned to landing site REFSEMMAT, maneuvered to PDI burn attitude, systems check performed and 20 min 1 sec to PDI burn at 108:42:01 of 11 min 58 sec duration.
16	108:37:00	LM undocked, L/R on and 5 min 1 sec from PDI burn at 108:42:01 of 11 min 58 sec duration.

DATE 10-12-70

SINGER-GENERAL PRECISION, INC. .
LINK DIVISION

PAGE NO., 3

REV. G

BINGHAMTON, NEW YORK

REP. NO.

6A4

RESET
NUMBER

GET

MISSION PHASE

20	110:24:00	LM on lunar surface, ascent batteries off, IMU aligned to landing site, AGS aligned to PGNS, partial power down accomplished and beginning of eat period. LM has been on surface 1 hr 30 min 27 sec.
24	139:54:00	LM on lunar surface, second EVA complete, beginning of eat period and awaiting Lunar lift-off at 142:24:29.2. LM has been on surface 31 hours 0 min 27 sec.
26	142:04:00	LM on lunar surface, R/R checked-out, AGS ready for ascent, DPS vented, APS pressurized 20 min 29.2 sec from Lunar lift-off at 142:24:29.2.
27	142:14:00	LM on lunar surface, 10 min 29.2 sec from the lunar lift-off burn at 142:24:29.2 of 7 min 10.7 sec duration.
30	142:33:00	LM is staged and in Lunar orbit 1 min 20 sec after Ascent burn cut-off. APS is off, preparation for TWEAK burn at 142:34:40 or BAILOUT burn at 142:36:40 if necessary.
40	142:50:00	LM staged and in lunar orbit prepared for TPI burn in 19 min 40 sec of 4 sec duration resulting in a 61.0 X 44.6 nmi orbit.
42	143:11:00	LM staged and in Lunar orbit 1 min 20 sec past TPI burn and 18 min 40 sec from MCC-1 burn. Docking at 144:10:00.
45	144:11:00	LM docked in lunar orbit preparing for transfer to CSM.

VII Source Decks

LMS INDEX

PROGRAM/NTRY POINT

TITLE

A41AB1 A41ab2 A41ae1 A41ae2		EQUATIONS OF MOTION - CMS & LMS TRANSLATIONAL
A41BB0 A41bb1	BL	EQUATIONS OF MOTION - FORCE AND RELATIVE
A41CA1 A41ca2		EQUATIONS OF MOTION
A41DA1		EQUATIONS OF MOTION - PARAMETER DISPLAY
B42XE0	BL	WEIGHTS AND BALANCES
C81AE1 C81ae2		ELECTRICAL POWER - BATTERY (EPS)
C81BA0	BL	ELECTRICAL - ELECTRICAL CONTROL ASSEMBLY
C81CE0		ELECTRICAL POWER - POWER DISTRIBUTION (EPS)
D89XB0 D89xe0	BL	EXPLOSIVE DEVICES (ED)
E83XA0	BL	MASTER ALARM
F84F F84xco F84Xdo F84xe2 F84xe5	Au	ENVIRONMENTAL CONTROL SYSTEM (ECS)
F84G F84xe1 F84xe3 F84xe6		ENVIRONMENTAL CONTROL SYSTEM (ECS)
F84H Table	AL	ENVIRONMENTAL CONTROL SYSTEM - TABLE H (ECS)
G61AA0		INERTIAL MEASUREMENT UNIT (IMU)
G61AB0		INERTIAL MEASUREMENT UNIT (IMU)
G61AC0		INERTIAL MEASUREMENT UNIT (IMU)

PROGRAM/NTRY POINT	TITLE
G61AEO	INERTIAL MEASUREMENT UNIT (IMU)
G61BAO	FDAI DRIVE EQUATIONS
G62XC0	Bu GUIDANCE AND NAVIGATION - RENDEZVOUS RADAR (RR)
G62xe1	
G62xe2	
G62xao	
G63AC0	BL GUIDANCE AND NAVIGATION - LUNAR LANDING RADAR (LR)
H63bco	
G63cc0	
G63cao	
G65XA1	ISLGC INTERFACE
G65xa2	
G65xb1	
G65xb2	
G65xc1	
G65xc2	
H66AEO	STABILITY AND CONTROL - ATTITUDE AND TRANSLATION CONTROL ASSEMBLY (ATCA)
H66ado	
H66aa1	
H66aa2	
H66BAO	AL STABILIZATION AND CONTROL - DESCENT ENGINE (DECA)
H66BB0	
H66CB0	
H66cco	STABILIZATION AND CONTROL - ENGINE SEQUENCER
H66cao	
IDRIVE	INITIALIZATION AFTER RESET
INT2VAR2	DOUBLE VARIABLE INTERPOLATION ROUTINE
I67AA0	AL ABORT GUIDANCE SYSTEM (AGS)
I67cao	
I67aeo	
I67CA0	ABORT GUIDANCE - DATA ENTRY AND DISPLAY ASSEMBLY (DEDA)
I67cdo	
K85XEO	An COMMUNICATION AND INSTRUMENTATION - INSTRUMENTATION

LMS INDEX

PROGRAM/NTRY POINT	TITLE
L90XD0 <i>Au</i>	LIGHTING
LDV	LOAD-DUMP-VERIFY
LMSBAL	DATA POOL - BOOLEANS A LOWER
LMSBAU	DATA POOL - BOOLEANS A UPPER
LMSBBL	DATA POOL - BOOLEANS B LOWER
LMSBBU	DATA POOL - BOOLEANS B UPPER
LMSBCM	DATA POOL - BOOLEANS COMMON
LMSCCM	DATA POOL - CONSTANTS/Common
LMSICM	DATA POOL - INPUT/OUTPUT-COMMON
LMSRAL	DATA POOL - RESERVED - A LOWER
LMSRAU	DATA POOL - RESERVED - A UPPER
LMSRBL	DATA POOL - RESERVED - B LOWER
LMSRBU	DATA POOL - RESERVED - B UPPER
LMSRCM	DATA POOL - RESERVED - COMMON
LMSVAL	DATA POOL - VARIABLES - A LOWER
LMSVAU	DATA POOL - VARIABLES - A UPPER
LMSVBL	DATA POOL - VARIABLES - B LOWER
LMSVBU	DATA POOL - VARIABLES - B UPPER
LMSVCM	DATA POOL - VARIABLES - COMMON
M06AEO <i>Au</i> M06beo	MALFUNCTION INSERTION UNIT/MALFUNCTION DISPLAY UNIT - PANEL CONTROL AND UPDATE
M08AC1	PLOTTERS AND RECORDERS - A LOWER
M08AC2 <i>Ac/Bc</i>	PLOTTERS AND RECORDERS - B LOWER
M08BX0	PLOTTERS AND RECORDERS - INITIALIZATION

LMS INDEX

PROGRAM/NTRY POINT	TITLE
M08DE1	PARAMETER DISPLAY - A LOWER
M08DE2	PARAMETER DISPLAY - B LOWER
M08DX0	PARAMETER DISPLAY - INITIALIZATION
M37XA1	SIX DIGIT DECIMAL READOUT - A LOWER
M37XA2	SIX DIGIT DECIMAL READOUT - B LOWER
M88XA0	AURAL CUE
P47AD0 P47aco P47abo	PROPULSION - ASCENT (PROP)
P47BB0 P47bdo P47beo	PROPULSION - DESCENT - ENGINE (PROP)
P47CE0 P47cdo P47cco P47cao	PROPULSION - DESCENT - ASCENT INTEGRATION (PROP)
Q05AA1	LMS-CMS-MCC INTERFACE
Q05AB1 Q05ac1	LMS-CMS-MCC INTERFACE
Q05BB1	LMS TO MCC DATA TRANSFER
RANDOM	PSEUDO RANDOM NUMBER GENERATOR FOR G63
R46AA0	REACTION CONTROL - THRUSTERS - HIGH RATE (RCS)
R46BA0 R46dbo	REACTION CONTROL - VALVE STATUS DISCRETES (RCS)
R46CD0	REACTION CONTROL - THRUSTERS (RCS)
R46DD0	REACTION CONTROL - PROPELLANT MANIFOLD (RCS)
R46ED0	REACTION CONTROL - RELIEF VALVE AND PROPELLANT TANK RATE (RCS)
R46FE0	REACTION CONTROL (RCS)

LMS INDEX

PROGRAM/NTRY POINT

TITLE

R46GD0	REACTION CONTROL (RCS)
R95	RESETS
SDRIVE	EXECUTED 20/SEC AT THE BEGINNING OF EACH FRAME
SLNTRP	REACTION CONTROL INTERPOLATION
S09AA0	COMMUNICATION AND INSTRUMENTATION - UPDATA LINK
T04AE1	SIMULATOR MASTER TIMING
T04BE1	MASTER CONTROL - A LOWER
T04BE3	
T04BX1	
T04BIO	
T04BE2	MASTER CONTROL - B LOWER
T04BE4	
T04BX2	
T04BR3	MASTER CONTROL - A UPPER
T04BM3	
T04BS3	
T04BR4	MASTER CONTROL - B UPPER
T04BM4	
T04BS4	
T07BD1	LGC DOWN LINK MONITOR
T07XE1	T/M MEASUREMENTS AND CONSOLE - B LOWER
T07XE2	T/M MEASUREMENTS AND CONSOLE - A LOWER
T07xe3	
T07xa1	
T86AE0	COMMUNICATION AND INSTRUMENTATION - S - BAND COMMUNICATION CAPABILITY AND SLEW
T86BE1	COMMUNICATION AND INSTRUMENTATION - VHF COMMUNICATION CAPABILITY
T86be2	
T86DE1	COMMUNICATION AND INSTRUMENTATION - POWER AND SWITCHING LOGIC
T86de2	

LMS INDEX

PROGRAM/NTRY POINT

TITLE

U43AE0 U43bbo	<i>Aa</i>	EPHEMERIS
VEQUCNTL		VISUAL DRIVER EQU CONTROL
V45AA0		VISUAL DRIVER AT 20 CPS
V45AB1 V45ab2 V45AB3		VISUAL - CELESTIAL SPHERES
V45BB0		VISUAL - EARTH/LUNAR OCCULTATION MASK TRANSLATIONAL DEIVE SIGNALS
V45BE0		VISUAL - EARTH/LUNAR OCCULTATION MASK DIAMETER DRIVE SIGNALS
V45CC0		VISUAL - SUN IMAGE PROJECTOR
V45CX0		VISUAL - SUN IMAGE PROJECTOR
V45DB1 V45db2 V45db3 V45db4		VISUAL - MISSION EFFECTS PROJECTOR (MEP)
V45DC0 V45de0		VISUAL - MISSION EFFECTS PROJECTOR (MEP)
V45DX0		VISUAL - MEP EARTH ORBIT FILM FRAME INITIALIZATION
V45EB1 V45eb2 V45eb3		VISUAL - LANDING/ASCENT IMAGE GENERATOR
V45EX0		VISUAL - RENDEZVOUS AND DOCKING (R&D)
V45FB0		VISUAL - RENDEZVOUS AND DOCKING (R&D)
V45FB1		VISUAL - CALCULATION OF CSM POSITION IN LM BODY FR IN HIGH PRIORITY
V45FC0		VISUAL - RENDEZVOUS AND DOCKING (R&D)
V45FCI		VISUAL - GENERATES COORDINATES OF LM IN CMS "H" FRAME FOR IN-OUT PLOTS
V45FEO		VISUAL - RENDEZVOUS AND DOCKING (R&D)

PROGRAM/ENTRY POINT	TITLE
V45FX0	VISUAL - RENDEZVOUS AND DOCKING (R&D)
W01XA1	EXECUTIVE SYSTEM - REAL TIME EXECUTIVE - A LOWER
W01XX1	EXECUTIVE SYSTEM - DRIVER - A LOWER
W01XA2	EXECUTIVE SYSTEM - REAL TIME EXECUTIVE - B LOWER
W01XX2	EXECUTIVE SYSTEM - DRIVER - B LOWER
W01XA3	EXECUTIVE SYSTEM - REAL TIME EXECUTIVE - A UPPER
W01XX3	EXECUTIVE SYSTEM - DRIVER - A UPPER
W01XA4	EXECUTIVE SYSTEM - REAL TIME EXECUTIVE - B UPPER
W01XX4	EXECUTIVE SYSTEM - DRIVER - B UPPER
W28DAD0 W28dinit	AL REAL TIME PRINT
Y02DB0	GSSC INTERFACE ON-LINE I/O - I/F BUFFER EXTRACTION - OR - PLAY BACK
Y02DX1 Y02dx3 Y02dx5	B COMPUTER DATA RECORDING
Y02DX2 Y02dx4	A COMPUTER DATA RECORDING
Y02XA1	ON-LINE INPUT/OUTPUT A LOWER
Y02XA2	ON-LINE INPUT/OUTPUT - B LOWER
Y02XI\$TA Y02X0\$TA Y02X0\$TL Y02XI0ER	ON-LINE INPUT/OUTPUT SUBROUTINES
Y02XI\$CA	ON-LINE INPUT/OUTPUT SUBROUTINES
Y02X0\$LA Y02X0\$LL Y02X0\$LE Y02XC\$MX	ON-LINE INPUT/OUTPUT SUBROUTINES

LMS INDEX

PROGRAM/NTRY POINT

TITLE

Y02XREG0

ON-LINE INPUT/OUTPUT SUBROUTINES

Y02XCLBF

Y02XGTWD

Y02XGTCH

Y02XPTCH

Y02XPRSE

Y02XPACK

Y02XUNPK

Y02XREM0

Y02AA0

REAL TIME INPUT/OUTPUT

Y02AI0

REAL TIME INPUT/OUTPUT SETUP

VIII DDP 224 Sum

APPENDIX C

Numerical Command List

Octal Code	Mnemonic	Description	Execution Time	Page
00	HLT	Halt	1.9 μ sec	2-27
01	RPT	Repeat	$r(t+.76)+3.8$	2-28
02	XEC	Execute	1.9 μ sec+t	2-28
03	STB	Store B	3.8 μ sec	2-4
04	STC	Store Command Portion of A	3.8 μ sec	2-4
05	STA	Store A	3.8 μ sec	2-4
06	STD	Store Address Portion of A	3.8 μ sec	2-5
07	INM	Input to Memory	3.8 μ sec	2-29
10	ADD	Add	3.8 μ sec	2-6
11	SUB	Subtract	3.8 μ sec	2-7
12	SKG	Skip if A Greater	4.18 or 4.94 μ sec	2-20
13	SKN	Skip if A Not Equal	4.18 or 4.94 μ sec	2-20
14	FLD	Floating-Point Load*	5.7 μ sec	2-36
15	ANA	AND to A	3.8 μ sec	2-13
16	ORA	OR to A	3.8 μ sec	2-13
17	ERA	Exclusive OR to A	3.8 μ sec	2-14
20	ADM	Add Magnitude	3.8 μ sec	2-7
21	SBM	Subtract Magnitude	3.8 μ sec	2-8
22	OTM	Output from Memory	3.8 μ sec	2-29
23	LDB	Load B	3.8 μ sec	2-5
24	LDA	Load A	3.8 μ sec	2-5
25	JRT	Jump Return	3.8 μ sec	2-21
26	FSB	Floating-Point Subtract*	7.6+0.38(w+y) μ sec	2-38
27	JST	Jump and Store Location	3.8 μ sec	2-21
30	SMP	Step Multiple Precision	3.8 μ sec	2-8
31	FMB	Fill Memory Block	325 KC	2-30
32	DMB	Dump Memory Block	250 KC	2-31
33	FAD	Floating-Point Add*	7.6+0.38(w+y) μ sec	2-37
34	MPY	Multiply	6.46 μ sec	2-9
35	DIV	Divide	17 μ sec avg.	2-10
36	FMP	Floating-Point Multiply*	10.26 μ sec	2-38
37	FDV	Floating-Point Divide*	24.6 μ sec avg.	2-39
40	ARS	A Right Shift	1.52+x μ sec	2-14
41	ALS	A Left Shift	1.52+x μ sec	2-15
42	LRR	Long Right Rotate	1.52+x μ sec	2-15
43	LLR	Long Left Rotate	1.52+x μ sec	2-16
44	LRS	Long Right Shift	1.52+x μ sec	2-16
45	LLS	Long Left Shift	1.52+x μ sec	2-17
46	NRM	Normalize	2.28+z μ sec	2-17
47	LGL	Logical Left Shift	1.52+x μ sec	2-18
50	OTA	Output from A	2.28 μ sec	2-31
5100	INH	Inhibit Interrupt	1.9 μ sec	2-32
5102	CME	Complement Exponent*	1.9 μ sec	2-10
5104	TXA	Transfer Index to A	1.9 μ sec	2-24
5106	STK	Store Channel Status	1.9 μ sec	2-33
5110	SKT	Skip if True	2.28 or 3.04 μ sec	2-21
5112	LDK	Load Channel Status	1.9 μ sec	2-33
5114	SKF	Skip if False	2.28 or 3.04 μ sec	2-22
5120	CSA	Complement on Sign of A	1.9 μ sec	2-11
5124	CMA	Complement A	1.9 μ sec	2-11
5130	BIN	Binary to BCD Conversion*	19.38 μ sec	2-11
5134	BCD	BCD to Binary Conversion*	19.38 μ sec	2-12
5140	ENB	Enable Interrupt	1.9 μ sec	2-34
52	INA	Input to A	1.9 μ sec	2-34
53	OCF	Output Control Pulse	2.28 μ sec	2-35
54	ADX	Add to Index	1.9 μ sec	2-24

*Optional command

FA2

Numerical Command List (Cont)

Octal Code	Mnemonic	Description	Execution Time	Page
55	TAB	Transfer A to B	1.9 μ sec	2-5
56	LDX	Load Index	1.9 μ sec	2-25
57	IAB	Interchange A and B	1.9 μ sec	2-6
60	CRA	Clear A	1.9 μ sec	2-6
61	SKS	Skip if Sense Line Not Set	3.04 or 4.56 μ sec	2-35
62	RND	Round A	1.9 μ sec	2-12
63	TAX	Transfer A to Index	1.9 μ sec	2-25
64	SCR	Scale Right	1.9+x μ sec	2-18
65	SCL	Scale Left	1.9+x μ sec	2-19
66	STX	Store Index	3.8 μ sec	2-25
67	IRX	Increment, Replace and Load Index	5.7 μ sec	2-26
70	JPL	Jump if A Plus	2.28 μ sec	2-22
71	JZE	Jump if A Zero	2.28 μ sec	2-23
72	JIX	Jump on Index	2.28 μ sec	2-26
73	JOF	Jump on Overflow	2.28 μ sec	2-23
74	JMP	Unconditional Jump	2.28 μ sec	2-23
75	JXI	Jump on Index Incremented	2.28 or 2.66 μ sec	2-27
76	FST	Floating-Point Store*	5.7 μ sec	2-37
77	NOP	No Operation	1.9 μ sec	2-29

Note: See page D-2 for explanation of variables r, t, w, x, y and z.

* Optional command

TABLE 3-1.
PERIPHERAL DEVICE CODES

1	2	3	4	5	6
DDP Octal Code	DDP Character (except typewriter)	Typewriter		Card Code (Hollerith)	Magnetic Tape Code (BCD)
		Lower Case	Upper Case		
00	0 ^①	0	b	0	0*
01	1	1		1	1
02	2	2		2	2
03	3	3		3	3
04	4	4		4	4
05	5	5		5	5
06	6	6		6	6
07	7	7		7	7
10	8	8		8	8
11	9	9		9	9
12	?			All Other Codes	Nonexistent*
13	=	#	-	8-3	=
14	'			8-4	'
15	:			8-5	
16	!			8-6	
17	>			8-7	
20	* ^②	*	¢	11-8-4	Blank
21	/	/		0-1	/
22	S	S		0-2	S
23	T	T		0-3	T
24	U	U	=	0-4	U
25	V	V	%	0-5	V
26	W	W	"	0-6	W
27	X	X	'	0-7	X
30	Y	Y		0-8	Y
31	Z	Z		0-9	Z
32	'			0-8-2	
33	,	,		0-8-3	,
34	(			0-8-4	(
35	=			0-8-5	
36	]		TAB	0-8-6	
37	"			0-8-7	
40	-	-	-	11	-
41	J	J		11-1	J
42	K	K		11-2	K
43	L	L		11-3	L
44	M	M	)	11-4	M
45	N	N	*	11-5	N
46	O	O	Δ	11-6	O

1. A zero recorded in BCD mode on magnetic tape will be translated into an octal 12 when written and back to zero when read. An octal 12 may be recorded in BCD mode on magnetic tape, but will be read back as zero.

2. An asterisk (20) recorded in BCD mode on magnetic tape will be translated into an octal 54 when written and back to 20 when read. An octal 54 may be recorded in BCD mode on magnetic tape, but will be read back as 20.

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TABLE 3-1. (Cont)
PERIPHERAL DEVICE CODES

1	2	3	4	5	6
DDP Octal Code	DDP Character (except typewriter)	Typewriter		Card Code (Hollerith)	Magnetic Tape Code (BCD)
		Lower Case	Upper Case		
47	P	P	;	11-7	P
50	Q	Q		11-8	Q
51	R	R		11-9	R
52	;	S		11-0	o
53	\$	\$		11-8-3	\$
54	✓	Backspace		11-8-6	*
55	[			11-8-5	
56	Blank ③	Space		Blank	
57	<			11-8-7	
60	+	&	&	12	+
61	A	A		12-1	A
62	B	B		12-2	B
63	C	C		12-3	C
64	D	D	(	12-4	D
65	E	E	⌘	12-5	E
66	F	F	⌘	12-6	F
67	G	G	<	12-7	G
70	H	H		12-8	H
71	I	I		12-9	I
72	↑			12-0	⌘
73	.	.	✓	12-8-3	.
74	)	Lower Shift		12-8-4)
75	%	Upper Shift		12-8-5	
76	\	Car. Return		12-8-6	
77	←	Line Feed		12-8-7	

3. A space (56) recorded in BCD mode on magnetic tape will be translated into an octal 20 when written and back to 56 when read.

Peripheral Device Codes

Table 3-1 shows the various characters used by the several most common peripheral devices and the equivalent octal codes used by the DDP-224 to identify the characters. Columns 3 and 4 contain the characters for the typewriter in the lower and upper cases. A coded instruction must first select whether lower case or upper case is desired, and this is done by an octal code 74 for lower shift and 75 for upper shift, as shown. Column 5 indicates the Hollerith card code, one of the codes that can be used by the card reader or

STANDARD EQUIPMENT SENSE LINE CODES

OCP CODES

01000	Punch stop code on paper-tape punch.
02000	Typewriter input select and character buffer enable.
02010	Typewriter output select and character buffer enable.
02070	Disconnect all three I/O devices (typewriter, Paper Tape Reader, Paper Tape Punch). (Only ways to disconnect character buffer are to reset bit 24 of channel status register, enable DMA, or select Line Printer/Parallel Output Channel).
02100	Enable Paper-Tape Reader and Character Buffer.
02200	Turn Punch Power on, enable Paper-Tape Punch and Character Buffer.
02210	Turn Punch Power off.
02220	Turn Punch Power on, feed one sprocket hole on Paper-Tape Punch.

SKS CODES

*00100	Character Buffer Input Parity
*01000	Typewriter Stop Code (Backspace)(may not be resettable)
02000	Character Device (Typewriter, Paper-Tape Reader, Paper-Tape Punch) Busy.
14000	Character Buffer Ready

FBC CODES

OCP CODES

06010	Select FBC
06110	Enable FBC Range Register Readback (A Only)
26140	Enable FBC Free Interrupt
26141	Disable FBC Free Interrupt
26142	Connect FBC to CMS
26143	Connect FBC to DCE (M.C. automatically connects FBC to DCE).
26144	Release FBC from CPU
26145	Enable FBC transfer to DCE ?
26146	Disable FBC transfer to DCE ?
26147	External FBC Shutdown

SKS CODES

26010	FBC Busy (is transmission complete)
26140	FBC Connected
26143	Invalid CMS/LMS Interrupt

DMA CODES

OCP CODES

06000	Enable DMA
06100	Enable DMA Range Register Readback

SKS CODES

26000	DMA Busy
-------	----------

EXTENDED MEMORY

OCP CODES

34000	Enable Extended Memory
34001	Disable Extended Memory

MISCELLANEOUS (and not necessary)

OCP CODES

0	Enable Character Buffer
1	Enable Parallel Input Channel #1
2	Enable Parallel Output Channel #1

SKS CODES

11000	Parallel Output Channel #1 Ready
-------	----------------------------------

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LMS DCE CODES

<u>OCP Codes</u>	<u>Device</u>	<u>Address</u>	<u>Max. Range</u>
03000	Reset all DCE		
03001	SCS	SCSTABAB+1	38
03002	DWI	DWITABAB+1	28
03003	DBI	DBITABAB+1	648
03004	A/D	ADTABAB+1	64
03005	CCI	CCBITBAB+1	60
03021	DBO	DBOTABAB+1	528
03022	DWOR	DWRTABAB+1	80
03023	DWOD	DWDTABAB+1	48
03024	PCM	PCMTABAB+1	580
03025	CCO	CCBOTBAB+1	60
03026	D/A	DATABAB+1	320
03040	Enable DCE Interrupt		
03041	Disable DCE Interrupt		
03042	Reset DCE Interrupt		
03100	Enable PCM equipment to accept Format Data		
03101	Enable PCM equipment to accept Data		
03102	PCM.High Bit Rate		
03103	PCM Low Bit Rate		
03104	Landmass		
03105	Loading - Computer Status		
03106	Fault - Computer Status		
03107	Normalize Trajectory Buffer (CCI, CCO)		
03110	Enable LGC Interrupt		
03111	Reset LGC Interrupt		

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LMS DCE CODES (CONT.)

<u>SKS Codes</u>	<u>Device</u>	<u>Address</u>	<u>Max. Range</u>
20000	Device Enabled		
20001	Device Error		
20002	Trajectory Buffer - ready to transmit		
20003	Trajectory Buffer - ready to receive		
20004	PCM Format Error		
20005	PCM Data Error		
20006	CTE Minute		

MAGNETIC TAPE CODES

OCP Codes

```
26160 - Select TMU #1
26161 - Deselect TMU #1
26162 - Select TMU #2
26163 - Deselect TMU #2
```

```
20000 - Read odd parity on MTU #1
20001 - Read odd parity on MTU #2
```

```
20100 - Read even parity on MTU #1
20101 - Read even parity on MTU #2
```

```
20200 - Write odd parity on MTU #1
20201 - Write odd parity on MTU #2
```

```
20300 - Write even parity on MTU #1
20301 - Write even parity on MTU #2
```

```
20400 - Write End of File on MTU #1
20401 - Write End of File on MTU #2
```

```
30000 - Backspace 1 record on MTU #1
30001 - Backspace 1 record on MTU #2
```

```
30100 - Backspace 1 file on MTU #1
30101 - Backspace 1 file on MTU #2
```

```
30200 - Skip 1 record on MTU #1
30201 - Skip 1 record on MTU #2
```

```
30300 - Skip 1 file on MTU #1
30301 - Skip 1 file on MTU #2
```

```
30400 - Rewind MTU #1
30401 - Rewind MTU #2
```

SKS Codes

26161 - TMU #1 selected?

26163 - TMU #2 Selected?

31000 - MTU #1 or #2 busy?

```
31100 - MTU #1 rewinding?
31101 - MTU #2 rewinding?
31200 - End of Tape?
31300 - Load Point?
31400 - End of File
*30300 - Parity?
```


LINE PRINTER CODES

OCP Codes

26156 - Select Line Printer TMU
26157 - Deselect Line Printer TMU

02300 - Enable Line Printer Buffer for
Character Mode
02301 - Enable Line Printer Buffer for Word Mode
02302 - Print one line

02304 - Advance Paper Line
02310 - Advance Paper to Channel 1 (top of form)
02311 - Advance Paper to Channel 2
02312 - Advance Paper to Channel 3
02315 - Advance Paper to Channel 4
02314 - Advance Paper to Channel 5
02315 - Advance Paper to Channel 6
02316 - Advance Paper to Channel 7
02317 - Advance Paper to Channel 8

SKS Codes

26157 - TMU selected?

22300 - Line Printer busy?
*22301 - Line Printer Buffer parity?
22302 - Paper advancing?

CARD PUNCH

26153 - Select Card Punch TMU
26154 - Deselect Card Punch TMU

02500 - Start Punch Cycle (punch 1 row)

26154 - TMU Selected?

22500 - Card Punch busy?
22501 - Ready to punch next row?
22502 - Card Punch not ready and
Invalid Punch

CARD READER

26150 - Select TMU
26151 - Deselect TMU

02400 - Read one Hollerith card
02401 - Read one binary card
02410 - Read Hollerith cards continuously
02411 - Read binary cards continuously
02420 - Stop Card Reader

26151 - TMU selected?

22400 - Card Reader busy?

*22401 - Card Reader EOF and Stop Code
22402 - Card Reader not ready and fault

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INTERRUPT ASSIGNMENTS FOR ASGC/LSGC

<u>Name</u>	<u>Interrupt Level</u>	<u>Trap Location</u>	<u>Description</u>
OCP '27050	L0 (Lowest)	'20	Computer Store
OCP ;27051	L1	'22	Hand Controller
OCP '27052	L2	'24	Up-Link
OCP '27053	L3	'26	Radar
20 MilRupt	L4	'30	Down-Link
OCP '27054	L5	'32	Mark/Mark Reset for AOT
OCP '27055	L6	'34	DSKY Input
T1RPT	L7	'36	Time 1
T4RPT	L10	'40	Time 4
T3RPT	L11	'42	Time 3
T5RPT	L12	'44	Time 5
T6RPT	L13	'46	Time 6
50 MilRupt	L14	'50	50 Milliseconds
OCP '27056	L15	'52	Moding
OCP '27057	L16	'54	No Function
Unassigned	L17	'56	
Power Failure	N/A (Highest)	'0	

INTERRUPT ASSIGNMENTS FOR COMPUTERS A & B

Power Failure	N/A	'0	(Also for 'C')
50 ms.	N/A	'2	
DCE	N/A	'4 (Used in "A" Computer Only)	
CMS/LMS Transfer	N/A	'6 (Used in "A" Computer Only)	

REAL TIME INTERRUPTS

<u>OCP</u> 05040	Enable RTI
05041	Disable RTI

8M1

STATUS WORDS BIT ASSIGNMENTS

RT Interrupt Trap Bit Assignments

<u>Bit</u>	<u>Assignments</u>
------------	--------------------

1	0 = SMP set up for SUB 1 = SMP set up for ADD
2	0 = SMP no carry 1 = SMP carry
3	0 = SMP sign same, magnitude may need complementing 1 = SMP sign complement necessary

4-9 = Priority (on sixteen line system)

10-24 = Address (P-CTR at time of interrupt)

Channel Status - LMS, A & B Computers (STK to read in A-Reg.)

<u>Bit</u>	<u>Assignments</u>
------------	--------------------

10	= FBC enabled for range readback
11	= DMA enabled for range readback
12	= DMA enabled for range and address loading
14	= DMA enabled for range and address loading
17	= Line Printer enabled for data word loading
20	= Extended address flop
24	= Character buffer enabled

Channel Status - LSGC, C-Computer (STK to read in A-Reg.)

<u>Bit</u>	<u>Function</u>
------------	-----------------

10	Index Register 2 Bit 9 Set
11	DMA Enabled for Range Readback
12	DMA Enabled for Loading Range and Address Registers
13	Special Interrupt Inhibit Mask Enabled
14	Readable Input Counter Enabled
15	Extended Memory Inhibit Flip-Flop Set

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<u>Bit</u>	<u>Function</u>
16	Real Time Clock Enabled for Mask Selection
17	Line Printer Enabled for Loading of Data
20	Extended Address Flip-Flop Set
22	Index Register 3 Bit Set
24	Character Buffer Enabled

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EXAMPLES

I. Typewriter I/O

	REL		
IN	LDX	0, 1	INITIALIZE INDEX 1
	OCP	'2000	SELECT TYPEWRITER INPUT
	INA		INPUT TO A REGISTER
	STA	DATA, 1	STORE CHARACTER
	SKN	SLASH	=/ (TERMINATION OF I/O)
	JMP	*+2	YES - STOP
	JXI	*-4, 1	NO - LOOP
	OCP	'2070	DESELECT
	HLT	'77777	HALT END INPUT
OUT	LDX	0, 1	INITIALIZE INDEX
	OCP	'2010	SELECT OUTPUT
	LDA	DATA, 1	PICK UP DATA
	SKN	SLASH	=/ (TERMINATION)
	HLT	'55555	YES - HALT
	OTA		NO - OUTPUT IT
	JXI	*-4, 1	LOOP
SLASH	OCT	21	
DATA	***	**	DATA BEGINNING
	END		

The above example illustrates the very basic requirements for I/O through the typewriter. Sensing the typewriter ready condition (SKS '2000 or '2010) and the character buffer loaded status (SKS '14000) are not required here since this is a non-real-time example and the typewriter will automatically wait for the next character to be inputted (or outputted).

CARD READER

RDCD	JMP	**	
	OCF	'26150	SELECT TMU
	SKS	'26151	TMU SELECTED?
	JMP	*+2	
	JMP	*-3	
SKS	SKS	'22402	CARD READER NOT READY
	JMP	*+2	
	JMP	*+4	
	SKS	'22401	EOF?
	JMP	EOF	
	JMP	SKS	
	SKS	'22400	CARD READER BUSY
	JMP	*-1	
	LDX	-20, 3	
WORD	LDX	-4, 1	
	OCF	'2400	READ ONE HOLLERITH CARD
CHAR	SKS	'22402	CARD READER NOT READY
	JMP	RDERR	
	INAM	'77	PICK OFF CHARACTERS
	LGL	18	THRU THE CHARACTER BUFFER
	LLR	6	AS THE CARD PASSES THROUGH
	JXI	CHAR, 1	THE CARD READER
	STB	INBUF+20,3	AND FORMAT
	JXI	WORD, 3	
	OCF	'26151	DESELECT TMU
	JMP*	RDCD	
EOF	HLT	'77777	
RDERR	HLT	'55555	ERROR IN READING CODE
	JMP	CHAR	
INBUF	BSZ	20	

Note that the above procedure takes advantage of the card reader reading column-wise starting with C.C. 1. A more common and easier technique is illustrated in Example III. However, the FMB/DMB instructions and the corresponding procedures leaves something to be desired. The FMB/DMB instructions may be thought of as no more than an INA and a JXI, *-1, x set of instructions. There is no built-in packing-unpacking technique nor is there any way of recognizing a card reader error and providing a recovery routine.

8J3

III. Line Printer

PRT	JMP	**	
	LDX	-30, 1	
	OCP	'26156	SELECT LINE PRINTER TMU
	SKS	'26157	TMU SELECTED?
	JMP	*+2	
	JMP	*-3	
	SKS	'22300	LINE PRINTER BUSY
	JMP	*-1	
	OCP	'2304	ADVANCE PAPER ON-LINE
	SKS	'22302	PAPER ADVANCING?
	JMP	*-1	
	OCP	'2301	ENABLE LINE PRINTER BUFFER FOR WORD MODE
	DMB	OUTBUF+30, 1	
	OCP	'2302	PRINT
	OCP	'26157	DESELECT LINE PRINTER
	JMP*	PRT	
OUTBUF	BSZ	30	

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IV. Honoring 50ms. Interrupt

Problem: Increment X1 by 1 every 50 ms.

```

                                ORG      '2
                                PZE                      50 ms. TRAP LOC. A & B COMPUTERS ONLY
                                JMP      INTRUP
                                *
                                ORG      '100
START                          ENB                      ENABLE INTERRUPT
                                JMP      *              SIMULATED NORMAL FRAME
                                HLT
INTRUP                        STX      SAVEX1, 1  SAVE ALL NECESSARY REGISTERS
                                IRX      0, 1      INCREMENT X1
SAVEX1                        LDX      **, 1
                                JRT      '2        RETURN TO NEXT INSTRUCTION TO BE EXECUTED WHEN
                                                INTERRUPTED.
                                END
```

LEM DCE I/O

VI. DCE input/output is accomplished through the address and range register enabled through the FBC. Although the complete range of the desired device need not be transferred, to ensure a complete transmission of all words needed, one will normally input/output the maximum number of words possible.

	OCP	'2614	Connect FBC to DCE
	OCP	'6010	Select FBC
	OTM	X	Address of data
	OTM	Y	Range of data
	OCP	'XXXX	Select device
	SKS	'26010	Is Transmission complete?
	JMP	* - 1	No, wait
X	MZE	ADDR	Address of data (for output)
or			
X	PZE	ADDR	Address of data (for input)
Y	DEC	NUM	

For example, to output D/A values:

	OCP	'2614	
	OCP	'6010	
	OTM	X	
	OTM	Y	
	OCP	'3026	
	SKS	'26010	
	JMP	* - 1	
	;		
	.		
	.		
X	X	MZE	DATABAB + 1
Y	Y	DEC	320
DATABAB		REFN	
		END	

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~~878~~

V. Write Odd Parity Binary On Tape Unit 2 (TMU1, MTU2)

WTAPE	JMP	**	
	OCF	'26160	SELECT TMU1
	SKS	'26161	IS TMU 1 SELECTED?
	JMP	*+2	YES
	JMP	*-3	NO
	SKS	'70300	RESET PARITY FLOP
	JMP	*-1	SET
	JST	BUSY	CHECK FOR
	SKS	'26000	DMA BUSY
	JMP	*-1	YES
	OCF	'6000	ENABLE DMA
	OTM	STRT	STARTING ADDRESS
	OTM	RNG	RANGE
FUNCTION	OCF	'20201	ODD PARITY BINARY ON MTU 2
	JST	BUSY	CHECK FOR TAPE ACTIVITY
	SKS	'70300	PARITY ERROR
	JMP	PARITY	YES
	NOP		NO
	OCF	'26160	DESELECT TMU 1
	JMP*	WTAPE	
*			
STRT	MZE	X	STARTING ADDRESS FOR OUTPUT MODE
RNG	PZE	N	RANGE
*			
BUSY	JMP	**	
	SKS	'31000	MTU 1 or 2 BUSY
	JMP	*-1	YES
	SKS	'31101	MTU 2 REWINDING
	JMP	*-1	YES
	JMP*	BUSY	
*			
PARITY	HLT	'52525	

SM1

ISLGC DELOG

1. Mount DEPSYS tape on drive 1, delog tape on drive 2.
2. Topform line printer and typewriter; set typewriter tabs at 1, 6 and 12.
3. Load 7 card loader and job control deck in card reader.
4. Clear core, master clear.
5. Fill, master clear, start.
6. When "SELECT" is typed, type "GO", carriage return.
7. When computer goes to I/O hold, type "\$, tab, CON, tab, CARDS," carriage return.
8. The delog program types a message at each end of file. Press start each time to delog the number of files specified on the computer operations request form.
9. At end of job, deliver typewriter listing to originator of job, along with tape and listing output.

ISLGC DELOG JOB CONTROL DECK

1	6	12	25
\$	JOB	1	TITLE
1	6	12	
\$	CALL	POSTPROC,00000002,,,,,,,,,1	
1	5	12	15
JOB	00000	3	99999

DELOG DECK

1
END

1 6
\$ EOJ

IX Other utilities

SYSTEM TAPE UPDATE

1. Load the object program of the one to be put on the DEPSYS into core.
2. Load MPUC (or MPUCLO) into core from DEPSYS.
3. Put starting address of dump area in A. Ending address in B and jump address in XR1.
4. Put the file number to write on in XR2 and tape drive number in XR3.
5. Set SS 1. Start type in 8 character name. Rewind the tape.
6. Load BTUD from DEPSYS.
7. Set SS1. Set Bit 1 of A-Register.
8. XR1 put Old DEPSYS tape drive number
 XR2 put new DEPSYS tape drive number
 XR3 tape drive number of MPUC generated tape - put control cards in card reader

1	6	12	
\$	COPY	XXXXXXXX	} MUST BE USED TO POSITION TAPE FOR ADDED 8 CHARACTER NAME
\$	OMIT	XXXXXXXX	
\$	ADD	XXXXXXXX	
\$	COPY		
\$	DONE		

9. Restart BTUD with SS1 down and A-Register = 0.
 Have \$ INDEX in card reader.
 Have \$ DONE in card reader.
10. Use VLRTCC to copy file 3.

ASSEMBLY PROCEDURES

The following are steps that may be employed for obtaining an assembly listing and a binary deck:

1. Mount the Link/Dep/Blocked I/O Systems Tape on magnetic tape unit one of tape multiplex unit one.
2. Mount scratch tapes on magnetic tape units two and three.
3. Fill the seven card bootstrap at location zero.
4. Master clear and press start.
5. After the typewriter types SELECT, type ASM, hit the tab, type GO, and hit the carriage return.
6. The computer will load the assembler and halt such that assembler control words may be changed.
7. Without changing any registers, press start which will cause the assumed I/O configurations to be printed by the typewriter.
8. Load the source cards in the card reader and press start. After the cards have been read, END OF PASS ONE will be typed by the typewriter and the computer will be in an SKS loop waiting for cards to be read.
9. Ready the line printer.
10. Reload the source cards in the card reader and ready the card reader. An assembly and a binary deck will be produced.

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FILL DECK PROCEDURES

The following steps may be used to obtain a Hollerith fill deck from a binary deck:

1. Mount the Link/Dep/Blocked I/O Systems tape on magnetic tape unit one of tape multiplex unit one.
2. Fill the seven card bootstrap at location zero.
3. Master clear and press start.
4. After the typewriter types out SELECT, type MONS, hit the tab, type GO, and hit the carriage return. After MONS has been found and loaded, MONS will be typed by the typewriter and the computer will halt.

If the loader overlays an area of core that is to be used by the binary deck, the loader must be relocated. After step four of this write-up has been executed, the loader may be relocated by performing the following:

- A. Master clear.
 - B. Enter a one in bit three of the A-Register.
 - C. Enter the address for the relocation of the loader in bits ten through twenty-four of the A-Register.
 - D. Enter one hundred in the P-Register.
 - E. Press start.
 - F. When the typewriter types SELECT, type loader and hit the carriage return.
 - G. After the loader has been relocated, READY will be typed by the typewriter.
 - H. Master clear.
5. Place the binary deck in the card reader and ready the card reader and card punch.
 - *6. Put a five in bits, 1, 2, and 3 of the A-Register and the starting address for the fill deck in bits 10-24 of the A-Register and press start. LOAD-ING COMPLETED will be typed out as well as the ending address and SELECT.
 7. Master clear and press start. After SELECT is typed, type FDUMP, hit the tab, type GO, and hit the carriage return. The FDUMP program will start at location one hundred. If FDUMP overlays the area of core that is to be dumped for a fill deck, relocate FDUMP in the same manner as the relocation of the LOADER was described in step 4 of this write-up.

8. FDUMP is typed out and the computer halts.
- *9. Put the starting address for the fill deck in bits 10-24 of the A-Register, put the loading completed address in bits 10-24 of the B-Register, put the starting address of FDUMP in the P-Register, and press start which will produce the Hollerith fill deck.

*The P-Register must contain the starting address of the utility to be exercised, if relocated. (LOADER on FDUMP)

ABSLOAD is used to convert a format produced by a load to a Read/Write/Verify format. One may use ABSLOAD by using the following procedure:

1. Master clear.
2. Enter seventy-seven thousand in the P Register of A, B, or C computer.
3. Press the fill button.
4. Master clear.
5. Enter a one, two, three, or four in the first three bits of the A Register, according to which magnetic tape unit has the tape mounted on it.
6. Enter seventy-seven thousand in the P Register.
7. Press start.
8. After ABSLOAD has been executed, LOADING COMPLETE will be typed by the typewriter.

P DUMP may be used to dump core by using the following procedure:

1. Put the prescribed address for the particular deck in the P Register.
2. Press the fill button.
3. Master clear.
4. Put the starting address for the core dump in the A Register.
5. Put the ending address for the core dump in the B Register.
6. Put the starting address of P DUMP in the P Register.
7. Enter one of the following in index register one:
 - A. One for an octal dump.
 - B. Two for an instruction dump.
 - C. Three for a BCD dump.
 - D. Four for a numeric dump.
8. Ready the line printer.
9. Press start.

SEARCH AND DUMP ROUTINE

The Search and Dump routine can be used for two (2) purposes:

1. Search core for words with certain bit patterns and output these words and their absolute addresses to the line printer in octal format.
2. Dump any area of core on the line printer.

These are the operating instructions:

1. Place fill deck of Search and Dump in the Card Reader.
2. Ready the Card Reader.
3. Master Clear the computer.
4. Fill at location specified on fill deck.
5. When the computer halts after reading the deck into the computer, Master Clear the computer.
6. Set the A Register equal to the word or bit pattern to be searched.
7. Set the B Register equal to the Mask of the bits to be searched.
8. Set the P Register equal to the address where the program was loaded.
9. Set IR1 = Starting address of search.
10. Set IR2 = Ending location of search.
11. Depress the Start button. All output is on the line printer.

NOTE: To Dump any desired area of core, perform Steps 1 through 5.

Step 6 - Set A Register = 0

Step 7 - Set B Register = 0

Perform Steps 8 through 11.

Total number of locations used by the program: 1220

9E2

Example of Mask:

Set each bit of the B Register to "1" for each bit of the A Register that you want checked.

If I want to determine which instructions store into location '62071, I could perform two (2) Searches:

Search 1 A Register = '00562071
 B Register = '77777777

Search 2 A Register = '00362071
 B Register = '77777777

or I could perform one (1) Search operation if I set up the register accordingly:

A Register = '00062071
B Register = '77077777

Thus, all STA (OP CODE = '05) and STB (OP CODE = '03) would be determined in one (1) Search as well as STC (OP CODE = '04) and STD (OP CODE = '06).

PROGRAM: VLRICC

COMPUTER: DDP- ϕ 24 AND DDP-224

SENSE SWITCH OPTIONS

SSW 1 - UP TO COMPARE, DOWN TO COPY.
 SSW 2 - UP FOR BCD, DOWN FOR BINARY.
 SSW 4 - DOWN FOR INSTRUCTION TYPEOUT, UP TO IGNORE.
 SSW 6 - UP TO IGNORE ERRORS, DOWN TO REIRY.

OPERATING INSTRUCTIONS

1. LOAD (ϕ 24) OR FILL (224).
2. A REGISTER = NO. OF FILES TO SKIP ON READ TAPE.
 B REGISTER = NO. OF FILES TO SKIP ON WRITE TAPE.
 P REGISTER = ϕ .
 INDEX REG 1 = NO. OF FILES TO COPY OR COMPARE.
 INDEX REG 2 = NO. OF READ TAPE.
 INDEX REG 3 = NO. OF COPY OR COMPARE TAPE.
3. START.
4. AT END OF JOB, COMPUTER WILL HALT. TO REWIND TAPES,
 SET THE FOLLOWING:
 A REGISTER (READ TAPE) TO 1.
 B REGISTER (WRITE TAPE) TO 1.
5. PROGRAM IS NOW READY FOR NEXT OPERATION.

I LGC "C" comp

C C O M P U T E R

I. C Computer Operating Procedures

A. Computer/IOS/CS Checklist

Before starting C Computer the following switches should be checked:

- 1) C enable should be on at the IOS console.
- 2) LGC circuit breaker in
- 3) Computer panel status:
 - a. Common core lockout switch disabled.
 - b. DDP configuration switch set to SGC.
 - c. All sense switches down.
 - d. Interrupt switch set.

B. Loading/Start Up Procedures

1) Octal Loader

SEE UNIFIED SIMULATION SYSTEM UNDER "LOADING PROCEDURES"

2) Initial Start up with a Reset

- a. Start at 100g
- b. XR1 1RR, RR = Reset Number
- * c. C must be started before A or B.

3) Normal Start up After Halting Computers

- a. Start at 100g
- b. If simulator mode has changed with C stopped, start up with reset is required.
- c. C need not be started before A and B.

4) Clear E-Memory on Start up

- a. Of questionable value since overridden by reset.
- b. Start at 103g

5) Calculate Banksum

- a. Seldom used option to re-calculate banksums when F-memory patch is made. (Mandatory for making a load tape.)
- b. Start at 105g

II. Octal Dump

- A. The purpose of octal dump is to allow a line printer dump of any selectable consecutive core area in C lower (0-'57777) or common ('60000-'77777). Eight words per line are dumped.
- B. Operating Instructions
 - 1) Put LMS Simulator in FREEZE.
 - 2) Raise SS 2 on C which will halt.
 - 3) A-Reg and B-Reg may be changed to lower and upper dump limits. ('53700-'57777 which include LGC channels and E-memory are standard dump limits.)
 - 4) To avoid suppressing lines of all zero, raise SS 1.
 - 5) Put SS 2 down.
 - 6) Press START (after print completion, C will return to FREEZE).

III. C Log

- A. Description
C Log is the counterpart of A/B Tape data recording. 100 variables may be logged at rates down to 20 times/sec. Fifty-seven of the variables to be logged are selectable. Channels and counters are always selected. Processing of the tape produced on-line is accomplished via the ISAGC post-processor.
- B. Manual Log Initialization
 - 1) Place LMS in FREEZE.
 - 2) Raise SS 4 (C will halt).
 - a. Index Register 1 identifies the selectable log variable (1 - '71).
 - b. The B-Reg contains the address of the variable presently to be logged.
 - c. To select a different variable for logging, key address into A-Reg.
 - d. Push START.
 - e. Continue a through d until all desired variables (up to '71) have been keyed in.
 - f. Mount log tapes.
 - g. Lower SS 4, set bit 1 of A-Reg. push START.
 - h. Set A-Reg as follows on Halt:
 1. Bit 1 = 1 rewind 1st log tape.
 2. Bits 2-9 log interval (50 millisec per bit) i.e. 1 sec. = 20 X 50 millisec., set 2-9 = 024 20 decimal.
 3. Bits 13-24 (in groups of 3) represent log drives 1, 2, 3 & 4.
 - i. If log header print is desired put SS 1 up.
 - g. Push START, first log tape will be initialized, C will return to FREEZE.

C. Standard DSKY Log

- 1) Mount log tape on Drive 4.
- 2) If log header print is desired, raise SS 1.
- 3) Raise and then immediately lower SS 6.

D. Card Controlled Log Initialization

SEE UNIFIED SIMULATION SYSTEM UNDER "LOADING PROCEDURES".

E. Log Card Format

1) First Card

- | | |
|--------------------|---------------------------------------------------------------------------------------------------------------------------------------------|
| a. Columns 1 - 4 | \$LOG |
| b. Column 6 | Blank or R for rewind |
| c. Columns 7 - 13 | Log tape drive specifications starting with the first through the last. 4,2 would specify TMU 4 as the 1st and TMU 2 as the 2nd tape drive. |
| d. Columns 15 - 18 | Log interval specified in seconds and hundredths of seconds. I.E. 1.01 would request a log every 1.01 seconds. |
| e. Columns 21 - 80 | Comments for tape identification. |

2) Selection Cards

- | | |
|-------------------|--------------------------------------------------------------------------------------|
| a. Columns 1 - 3 | S01 through S57 (logging location assignment must be in sequence with no omissions). |
| b. Columns 5 - 12 | Name of parameter. |
| c. Column 14 | Successive locations (DP = 2, TP = 3, etc.) |
| d. Column 16 - 20 | Address |

3) Last Card

- | | |
|------------------|-------|
| a. Columns 1 - 4 | \$END |
|------------------|-------|

F. Start/Stop Procedures for Log

- 1) Turn on initialized log with SS 5 up or C log enable.
- 2) Data separation is effected by writing an EOF on the log tape upon reset if C log is on (SS 5 or C log enable).

- 3) Upon terminating run several EOF's should be written on the log tape. Should the log tape be on unit 4, raising and lowering SS 6 will accomplish this.
- 4) Submit tape to off-line for postprocessing.

IV. Auxiliary Options

A. Search routine

By starting at '140 and specifying a desired pattern in A reg with comparison field in B Reg, search through C lower is possible. The unmasked version of the word will appear in the B Reg and Xr1 will denote its address. The core location may be changed by changing the B Reg.

B. Quick- Look- Change

- 1) Start location '160 to interrogate and possibly change consecutive locations specified by Xr1.
- 2) SS 1 up change option only. Specify change in B Register.
- 3) SS 1 down, A Register will contain value, and B Register will be exclusively ored with A Register.

V. Operation of C-Computer Clocks and Interrupts

When the LMS is operated with the Central Timing Equipment, CTE, switched to "half-time" the A. B. and C Computer interrupts and clocks function as follows:

A, B, and C-Computers:

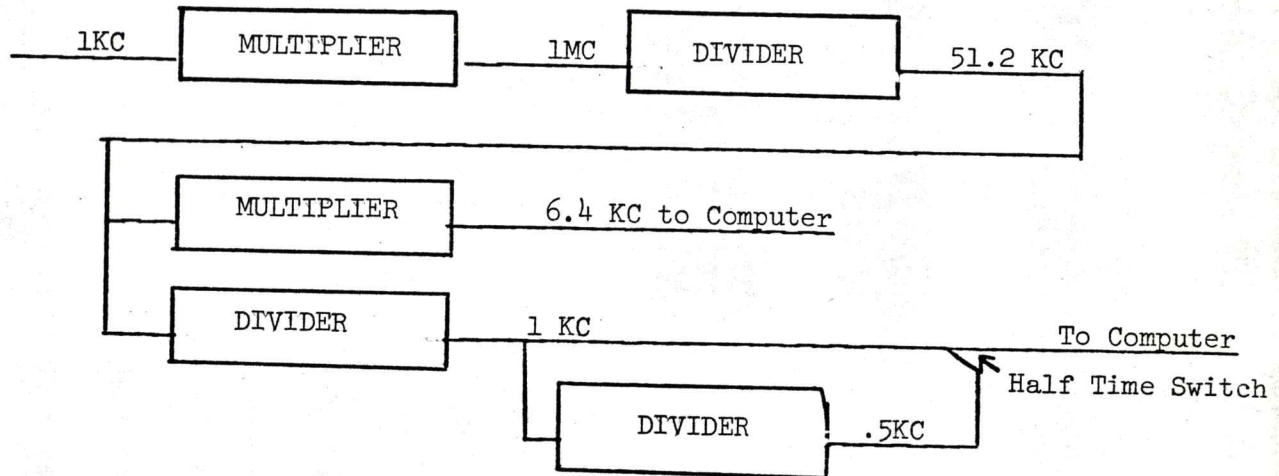
1. The minute pulse is not effected by changing the CTE timing.
2. The 50 millisecond pulse is extended to 100 milliseconds.

C-Computer:

1. The 10 millisecond pulse which is used to increment the T1, T2, T3, T4 and T5 readable/programmable clocks is extended to 20 milliseconds.

2. The 20 millisecond interrupt is extended to 40 millisecond.
3. The T6 clock which counts at 6.4. KC is not effected by the CTE.

A functional diagram of the hardware used to develop the timing clocks follows:



VI. ISLGC CORE LAYOUT

0 1		PFI
2 17		UNUSED
20 ↓ 60		INTERRUPT TRAP/TRANSFER
	61 77	<u>UNUSED</u>
100 ↓ 12300		PART IV
	12301 ↓ 13577	<u>UNUSED</u>
13600 ↓ 13677		MALFUNCTION TABLE PART IV
13700 ↓ 17777		SAFE STORE BUFFER IV
20000 ↓ 23777		PART I
24000 ↓ 30007		PART II
30010 ↓ 30077		SPECIAL DATA POOL
30100 ↓ 31777		PART II
32000 ↓ 33311		PART III
33340 ↓ 33360		JET TIMES
33400 ↓ 35777		PART III
36000 ↓ 37777		PART I (good sized gaps)
40000 ↓ 47777		FIXED
50000 ↓ 53277		MTP LOADER
53000 ↓ 53777		TM PARITY TABLE IV
53700 57777		PRIVATE CHANNELS E-MEMORY

XI - Special On
Line Oper Proceed

BIASING THE LUNAR TERRAIN BY A SLOPE

The lunar datum plane may be biased by a slope (not to exceed 5 degrees) which is measured from the predicted landing site. Also, the max. delta altitude permitted is ± 5000 ft. unless GFKM5000 (B20) is changed via the typewriter.

To effect a change of slope of the lunar terrain, one must enter into GFTYTH1 @ B10 the co-tangent of the desired angle of inclination. The conversion/store routine in B Computer provides the tool for converting co-tangent to octal @ B10 and entering it into GFTYTH1. (The address of GFTYTH1 is located in the B-L Memory Map). The table below gives the co-tangent of slope of $.1^\circ$ through 5.0° 's.

<u>SLOPE</u>	<u>GFTYTH1</u>	<u>SLOPE</u>	<u>GFTYTH1</u>
$.1^\circ$	572.96	2.6°	22.022
$.2^\circ$	286.48	2.7°	21.205
$.3^\circ$	190.98	2.8°	20.446
$.4^\circ$	143.24	2.9°	19.740
$.5^\circ$	114.59	3.0°	19.081
$.6^\circ$	95.489	3.1°	18.464
$.7^\circ$	81.847	3.2°	17.886
$.8^\circ$	71.615	3.3°	17.343
$.9^\circ$	63.657	3.4°	16.832
1.0°	57.290	3.5°	16.350
1.1°	52.081	3.6°	15.895
1.2°	47.740	3.7°	15.464
1.3°	44.066	3.8°	15.056
1.4°	40.917	3.9°	14.669
1.5°	38.188	4.0°	14.301
1.6°	35.801	4.1°	13.951
1.7°	33.694	4.2°	13.617
1.8°	31.821	4.3°	13.300
1.9°	30.145	4.4°	12.996
2.0°	28.636	4.5°	12.706
2.1°	27.271	4.6°	12.429
2.2°	26.031	4.7°	12.163
2.3°	24.898	4.8°	11.909
2.4°	23.859	4.9°	11.664
2.5°	22.904	5.0°	11.430

IOS CSM CONTROL PANEL OPTIONS

I. CSM ΔV

On the CSM Control Panel of the IOS, the desired X, Y and Z velocities in 0.1 fps units are dialed on the Digiswitches. These velocities will be inserted in the BODY or LOCAL VERTICAL frame of the CMS (as selected on the sprills above the Digiswitches) when the CSM ΔV sprill is pushed.

II. CSM GIMBAL ANGLE MANEUVERS

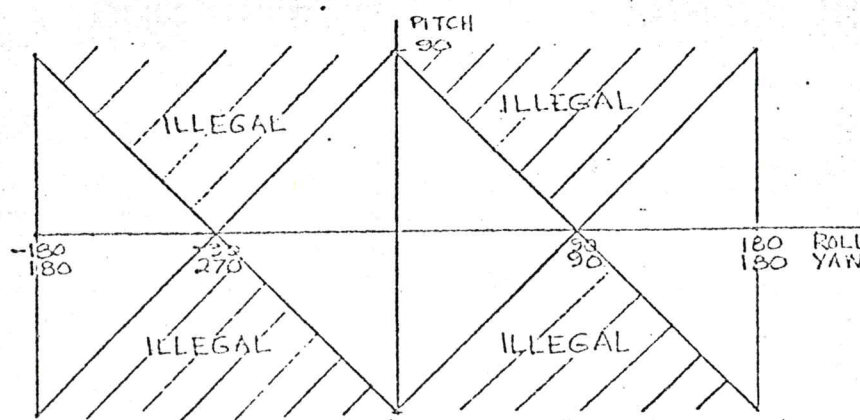
Whether the vehicles are docked or not, the CSM will maneuver to the CSM outer, Inner and Middle Gimbal Angles entered on the Digiswitches when the CSM MNVR sprill is pushed. Angles are entered in INTEGER DEGREES, ignoring the decimal point on the Digiswitches. The final CSM gimbal angles may be checked by reading Parameter Display values 31, 32, 33 (AUCMGA, AUCIGA and AUCOGA) which are automatically calculated after CSM is maneuvered. When docked, both CSM and LM will maneuver. When in LMS/CMS or LMS/CMS/GSSC mode, the CSM MNVR sprill is ignored.

III. LM LOCAL VERTICAL MANEUVERS

When the LM LV MNVR sprill is pushed the LM will be maneuvered to the Local Vertical Angles entered on the Digiswitches in INTEGER DEGREES, ignoring the decimal point. Final altitude may be checked against Parameters 21, 22 and 23 on the Parameter display (AUROL, AUPIT, and AUYAW). Entries must be orthogonal attitude combinations (see Figure 1). All vehicle angular rates and accelerations will be set to zero when the sprill is depressed.

LOCAL VERTICAL ATTITUDE LIMITS

11B2



DEFINITIONS

PITCH - ANGLE BETWEEN LM +Z AXIS AND LOCAL HORIZONTAL PLANE, POSITIVE UP

ROLL - ANGLE BETWEEN LM +Y AXIS AND THE RIGHT HALF OF THE LOCAL HORIZONTAL PLANE, POSITIVE RIGHT

YAW - ANGLE BETWEEN LM +Z AXIS AND THE FRONT HALF OF THE ORBIT PLANE, POSITIVE LEFT

LOCAL HORIZONTAL PLANE - THE PLANE PASSING THROUGH THE LM WHICH IS NORMAL TO THE PRESENT POSITION VECTOR

LOCAL VERTICAL FRAME -

X-AXIS - POSITIVE IN THE DIRECTION OF THE POSITION VECTOR

Y-AXIS - RIGHT-HAND-RULE THIRD MEMBER OF THE FRAME

Z-AXIS - POSITIVE IN THE DIRECTION OF VELOCITY IN THE ORBIT PLANE

FIGURE 1

LINK GROUP, CPI
HOUSTON, TEXAS

REV:
DATE:

MOD KIT:

SHEET NO.

IOS DOCKING AND UNDOCKING PROCEDURESI. TO UNDOCK AND SEPARATE

1. Turn PROBE CONTROL-ON (if it is off)
2. Turn PROBE CONTROL-OFF
3. Observe CAPTURE goes off in two (2) seconds and vehicles separate at 0.5 fps.

II. TO UNDOCK TO SOFT-DOCK POSITION

1. Turn PROBE CONTROL-ON (if it is off).
2. Turn PROBE CONTROL-OFF, then on.
3. Observe range goes to 22.8 ft and CAPTURE stays on. Vehicles are soft-docked.
4. To release, turn PROBE CONTROL-OFF then turn CAPTURE-OFF. Vehicles are now free. Fire RCS in LMS or add CSM ΔV to separate vehicles.

III. TO FORCE DOCK

1. Push PROBE CONTROL while CAPTURE is off. Vehicles will hard-dock immediately, providing range is less than 6000 ft.
2. A safety latch A097 has been added to the logic to prevent inadvertent forced dockings. To enable Force Dock logic set A097 = 1.

IV. TO REDOCK

1. Fly vehicles to 22.8 ft. range. If dock criteria are met (see Figure 1) the CAPTURE light will come on steady.
2. To retract probe and hard-dock, turn PROBE CONTROL - ON.
3. If dock criteria are not met, the CAPTURE light will flash and vehicles remain relatively motionless.
4. To recover from an improper dock push CAPTURE. The light will go out, and the vehicles will separate beyond 22.8 ft. Docking may then be re-attempted.

FIGURE 1

DOCKING PRINTOUT

<u>PRINTOUT</u>	<u>MNEMONIC</u>	<u>DEFINITION</u>	<u>UNITS</u>	<u>SAFE LIMITS</u>
RANGE	VARHOLS	Range 22.8 = Soft Dock 22.0 = Hard Dock	Ft.	Not checked
RNG RT	ARHODLS	Range Rate	Ft./Sec.	>-1.0
LAT VEL	ARHODYZ	Sideways Velocity	Ft./Sec.	< 0.5
YAW RT	APB	Yaw Rate	Rad./Sec.	Not checked
PIT RT	AQB	Pitch Rate	Rad./Sec	$\pm .01745$
ROLL RT	ARB	Roll Rate	Rad./Sec.	$\pm .01745$
OFFSET	ARHLYZ	Probe Misalignment	Ft.	0.833
XX AXIS	VDQ11	X-X Axis Alignment	Cosine	<-0.966
YY AXIS	VDQ22	Y-Y Axis Alignment	Cosine	Not checked
STATUS	A095	0 = Proper Dock 1 = Improper Dock	None	Not checked

1163

POST LANDING DYNAMICS

I. SOFTWARE SELECTION:

The surface slope, APLALFA, of the landing site and the initial gear striking the surface, APLGEAR, are now selected by the EQUATIONS OF MOTION programs. APLALFA is selected by picking up a value from RANDOM each time the simulator goes to run and has a range of 0 to 12.5 degrees at a binary scaling of +9. APLGEAR is selected by monitoring the flight dynamics of the vehicle below 200 feet and will have a value between 1 and 4 (gears are numbered clockwise from the +Z axis) at a binary scaling of +23.

II. MANUAL SELECTION

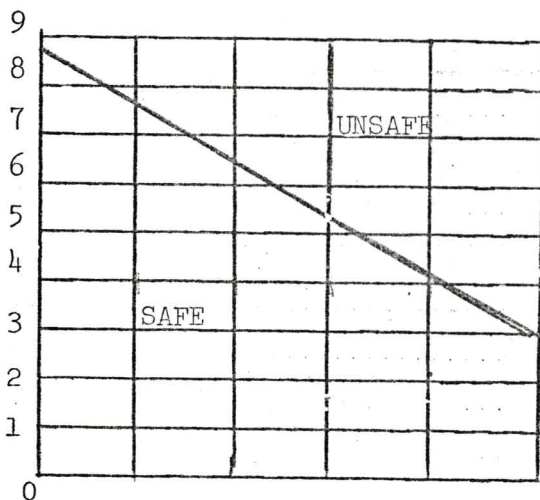
APLGEAR and APLALFA that have been selected by the software may be overridden by use of the hardware at the IOS. The CSM ROLL Digiswitch (found at the right side of the IOS) and LANDING CONTROL Spril (found at the left side of the IOS) are used for this purpose. The desired surface slope and initial gear strike are dialed up on the CSM ROLL Digiswitch using the format XY.Z, where XY is the desired surface slope, and Z is the desired initial gear strike. The values are entered by turning the LANDING CONTROL Spril on and then off. This must be done after the simulator has gone to run since the software will select a new value for APLALFA. The LANDING CONTROL Spril must be turned off. Since it is used for a different purpose when the LM is on the surface. A value of zero for the initial gear strike will suppress POST LANDING DYNAMICS.

III. IMPROPER LANDING RECOVERY

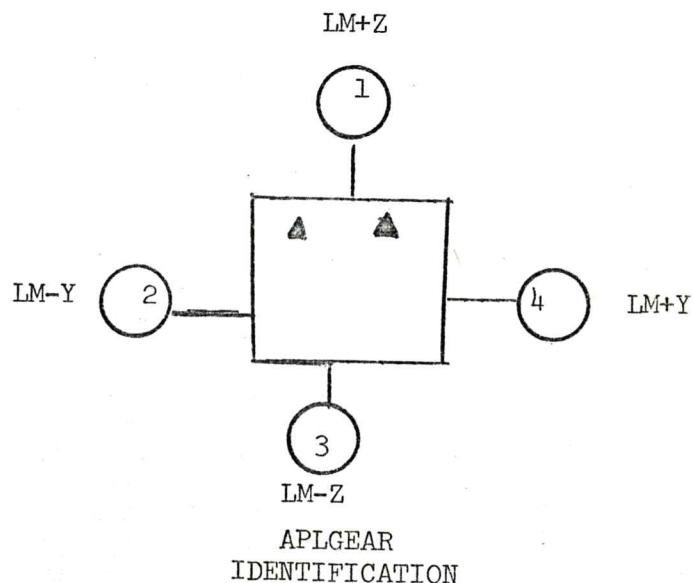
If the safe landing criteria (see figure 1 and 2) are not met at lunar contact, the LANDING CONTROL Spril will flash. The vehicle may be re-erected by turning the LANDING CONTROL Spril on and then off. Normal simulation may then be continued.

LANDING PRINTOUT

<u>PRINTOUT</u>	<u>MNEMONIC</u>	<u>DEFINITION</u>	<u>UNITS</u>	<u>SAFE LIMITS</u>
STATUS	ALDG	0 = Safe 1 = Improper 2 = Tilt Over 3 = Both		Not checked
ALT RT	ARDNL	Altitude Rate	Ft./Sec.	See Figure 2
LAT VEL	GFYDBS	Lateral Velocity	Ft./Sec.	See Figure 2
FWD VEL	GFZDBS	Foward Velocity	Ft./Sec.	See Figure 2
LGC ALT	ALGCALT	LGC Altitude	Feet	Not checked
D NORTH	VNORTHZL	Distance North of Landing Site	Feet	Not checked
D EAST	VEASTYL	Distance East of Landing Site	Feet	Not checked
SLOPE	APLALFA	Surface Slope	DEG.	Not checked
LV PIT	AUPIT	Local Vertical Pitch	DEG.	Not checked
LV ROLL	AUROL	Local Vertical Roll	DEG.	Not checked
L GEAR	ALPGEAR	Initial Gear Strike	See Fig. 3	Not checked
LAG TIME	AULAG	Time from Lunar Contact to Engine Stop	Sec.	Not checked
MX TILT	ATILTMX	Maximum Tilt while on Surface	DEG.	41.4°
D F QTY	PWF	DPS Fuel Weight	LBS.	Not checked
D O QTY	PWO	DPS Oxid Weight	LBS.	Not checked



$$AUVYZ = \sqrt{(GFYDBS)^2 + (GFZDBS)^2}$$



11E1

7.8. OPERATING INSTRUCTIONS FOR AUTO UPLINK

To use AUTO UPLINK, the switch labeled AUTO UPLINK located on the UDL panel must be depressed. Communications must be setup properly or set SNOCHECK equal to a ONE to by-pass comm. checks.

The I/S DSKY is used to initiate the uplinks.

DSKY INPUT

V710E

V711E

V713E

V714E

V730E

UPLINK

IM STATE VECTOR

CSM STATE VECTOR

REFSMAT

GENERAL UPDATE

TIME UPDATE

The general update V714 is loaded by cards. The format of the cards is the same as the OCTAL correction patch cards. The core area into which the data is read starts at SCARDTBL (Check A-U Memory Map for address). This location should denote the type of update 71 or 72. Location SCARDTBL +1 should contain the number of components in OCTAL which will be between 3 and 24. The minimum of 3 would consist of (1) number of components (2) ISLGC address, and (3) one data word.

The cards should be formatted as follows:

V71

WWWWWB

00000R00000071A

00001R0000000XXA

00002R0000000YYYA

00003R0000000ZZZZA

00004R0000000ZZZZA

00005R0000000ZZZZA

V72

WWWWWB

00000R000000072A

00001R0000000XXA

00002R0000000YYYA

00003R0000000ZZZZA

00004R0000000YYYA

00005R0000000ZZZZA

W - Address of SCARDTBL
X - Number of Components
Y - Address to be Updated
Z - Data

The "enters" following each word and the V33E at the end of each block is initiated automatically by the UDL software and does not have to be on cards.

The basic difference between V71 and V72 update is, V71 allows updates of consecutive locations starting with the address called out on the cards and V72 allows updates of scattered locations throughout core. The ISLGC must be in P00 to accept any uplink.

11 E2

UP-DATA-LINK (UDL) VIA COMMUNICATIONS LINK

For Up-Data-Link (UDL) to be possible:

1. The XMTR/RCVR switch must be in either Primary or Secondary;
2. All circuit breakers for Comm. must be in;
3. The UDL circuit breaker must be in.

To receive data by UDL (T324=1):

1. UDL mode switch (in cabin on Panel 12 - lower left corner) must be in "DATA".
2. UDL VOICE B-U SPRIL must be unlit (not in VOICE mode)(left side of instructor's panel).
3. Correct S-Band Antenna must be selected: Panel 12
 - a. If Steerable Antenna is selected:
 - i.) Mode switch in auto.
 - ii.) Signal Strength (SS) must be 4.01.
 - b. Select one of the omni antennas if the SS with the steerable antenna is too low. Switch back & forth between the two omni antennas to determine which has the greater SS and leave switch on that antenna.
 - c. The lunar stay antenna will work on the lunar surface only.
 - d. UDL SPRIL in "AUTO" or "MANUAL".

To receive Voice and Back-Up (T346=1):

1. UDL Mode Switch in "VOICE" (T118=1)(in Cabin, Panel 12).
2. VOICE B-U SPRIL on instructor's station (extreme left side) in VOICE B-U (SPRIL lit). (T319=1).

If the signal strength remains at 0.5 no matter how you set the antenna switches, you are probably behind the moon. To get around this, set T067 (71457, ML78-01) =1.

LGC CONTROLLED DESCENTS/ASCENTS

CABIN MODEING

11F1

<u>CONTROL</u>	<u>DESCENT</u>	<u>ASCENT</u>
GUIDANCE CONTROL	PGNS	PGNS
ENGINE ARM	DES.	ASC.
MASTER ARM	ON	ON
MAN. THROTTLE	CMDR	N/A
THR/JET	THR.	N/A
ENGINE GIMBAL	ENABLE	N/A
BALANCE COUPLES	ON	ON
MODE CONTROL	PGNS-AUTO	PGNS-AUTO
RCS MODE	MODE-CONTROL	MODE-CONTROL
RCS THRUSTERS	AUTO	AUTO
ACA PROPULSION	ENABLE	ENABLE
TTCA ENABLE	UP	UP
ACCA JET ENABLE	UP	UP
ANT	AUTO	N/A
X TRANS.	4 JET	4 JET
THROTTLE	MINIMUM	N/A
DES CMD OVRD	OFF	N/A
RATE ERROR MONITOR	LDG RDR/CMPTR.	N/A
RADAR TEST	OFF	N/A
RNG;RNG RATE/ALT,ALT RATE	ALT/ALT RATE	ALT/ALT RATE
MODE SWITCH	PGNS UNTIL 30,000 FT THEN SW TO LDG RADAR	PGNS
ASCENT PRESSURE	N/A	FIRE
DESCENT PRESSURE	FIRE	N/A
CLOSE ALL CIRCUIT BREAKERS		

11 F2

POWERED ASCENT PROCEDURES

1.) KEY V37E12E
FL V06N33
R1 = HRS
R2 = MIN
R3 = SEC } GET LIFT-OFF (USUALLY ZERO)

2.) IF ACCEPTABLE GO TO 3. OTHERWISE LOAD DESIRED GET.

KEY V25E AND LOAD DESIRED DATA
R1 = +00XXE HRS
R2 = +000XXE MIN (MISSION TIMER + 5 MIN)
R3 = +000XXE SEC

3.) PRO
FL V06N76
R1 = CROSSRANGE
R2 = APOLUNE
R3 = BLANK

PRO

4.) POSSIBLE ALARM. IF NO ALARM GO TO 5.

FL V50N25
R1 = 00203 SET GUIDANCE CONTROL TO PGNS
R2 = BLANK SET ATTITUDE CONTROL TO AUTO
R3 = BLANK

PRO

5.) ENTER

6.) FL V06N64
R1 = TFI IGNITION TIME
R2 = YAW FDAI ANGLES AFTER
R3 = PITCH PITCH OVER

POSSIBLE PROGRAM ALARM: PROG. LIGHT ON. TIG SLIP. HIT RSET (ON DSKY) AND
CONTINUE.

7.) AT TIG -35 DSKY BLANKS. FOR 5 SECS.

FL V06N64 RETURNS

8.) AT TIG = -5

FL V99N74

R1 = TFI

R2 = YAW

R3 = PITCH

PRO TO ALLOW IGNITION

9.) AFTER IGNITION

STATIC V06N63

R1 = VI INERTIAL VELOCITY

R2 = HDOT ALTITUDE RATE

R3 = H ALTITUDE

10.) FDAI ANGLES AFTER PITCHOVER, (AT APPROX. 500 FT.), SHOULD EQUAL VALUES FOR PITCH AND YAW FROM STEP #6.

11.) TO DISPLAY "TIME TO GO TO ORBITAL INSERTION"

KEY V16EN77E

R1 = TG XXBXX

R2 = V(Y) VELOCITY NORMAL TO CSM PLANE

R3 = BLANK

HIT KEY RELEASE TO RETURN TO

STATIC V06N16 DISPLAY

12.) AFTER ENGINE CUT-OFF (AT APPROX. 60,000 FT)

FL V16N63

R1 = VI

R2 = HDOT

R3 = H

PRO

13.) FL

V16N85

R1 = VGX

R2 = VGY

(X,Y,Z VELOCITY COMPONENTS)

R3 = VGZ

PRO

P12 IS TERMINATED AND P00 IS ENTERED.

11F4

11F5

POWERED DESCENT PROCEDURE

- 1.) KEY V37E63E
FL V06N61
R1 = TG TIME TO GO IN BRAKING PHASE
R2 = TFI TIME TO IGNITION
R3 = CROSSRANGE
SET EVENT TIME TO TFI
PRO
- 2.) FL V50N25 (IMU FINE ALIGN OPTION)
R1 = 00014
PRO TO DO FINE-ALIGN (NORMALLY DONE IF TFI IS GREATER THAN 15 MIN)
ENTER TO CONTINUE
- 3.) FL V50N18
R1 = ROLL
R2 = PITCH FDAI ANGLES
R3 = YAW
PRO
- 4.) STATIC V06N18 TRIM ANGLES
LM WILL NOW PITCH TO DISPLAYED ANGLES
- 5.) FL V50N18
ENTER
- 6.) POSSIBLE ALARM
FL V50N25
R1 = 00500
L/R NOT IN DESCENT POSITION: MOVE L/R ANT TO DESCENT, HOLD FOR 10 SECS.
THEN RETURN TO AUTO.
PRO
- 7.) IF DISPLAY DOES NOT CLEAR
ENTER

8.) POSSIBLE ALARM

FL V50N25
R1 = 00203

PGNS GUIDANCE, AUTO ATTITUDE AND AUTO THROTTLE MODES NOT SELECTED.
CORRECT SW SETTINGS
PRO

9.) IF DISPLAY DOES NOT CLEAR
ENTER

10.) FL V06N62
R1 = VI INERTIAL VELOCITY
R2 = TF TIME TO IGNITION
R3 = VM VELOCITY TO BE GAINED

AT TIG = -35 DISKY BLANKS FOR 5 SECS.

"ALT" AND "VEL" LIGHTS COME ON

11.) FL V06N62 RETURNS

12.) AT TFI = -7 SECS + X TRANS (ULLAGE) IS COMMANDED.

13.) AT TFI = -5 SECS.

FL V99N62
PRO FOR IGNITION
FL V06N62 RETURNS

14.) AT TFI = 0

STATIC V06N63
R1 = VI INERTIAL VELOCITY
R2 = HDOT ALTITUDE RATE
R3 = H ALTITUDE

10% THRUST FOR APPROX. 26 SECS.

THEN 100%

VERIFY THIS BY "THRUST METER".

11F6

15.) WHEN "ALT" LIGHT GOES OFF

KEY V57E

FL V06N68

R1 = SLANT RANGE TO LDG SITE XXXX.X NM1

R2 = TIME TO GO IN P63, MIN-SEC.

R3 = LR ALT-PGNS ALT, FT

PRO TO ACCEPT LR UPDATES

FL V50N68

MONITOR CONVERGENCE OF LR ALT & PGNS ALT

PRO TO RETURN TO V06N63

16.) WHEN H IS BETWEEN 6,000 and 8,000 FT. P64 is AUTOMATICALLY CALLED

FL V06N64 TG - TIME LEFT FOR REDESIGNATION

R2 = H-DOT LPD - LANDING POINT (VERIFIED BY CHECKING
ALIGNMENT OF CROSS HAIRS)

R3 = H

17.) TO REDESIGNATE

PRO

SET CROSSHAIRS OF LPD TO DESIRED LANDING SITE. THIS CAN BE DONE ONLY
IF TG IS GREATER THAN 20 SECS, ("H" IS GREATER THAN 250 FT).

18.) LANDING OPTIONS AVAILABLE, SUGGEST USE WHEN H IS LESS THAN 500 FT.

AUTOMATIC: GO TO 22

R.O.D GO TO 22

MANUAL CONTINUE

19.) PLACE THROTTLE SW IN MANUAL

STATIC V06N62 P67 IS CALLED

R1 = V (HORIZ)

R2 = H-DOT

R3 = H

- 20.) CONTROL LM DESCENT BY MANUAL THROTTLE COMMANDS. IF THROTTLE SW IS RETURNED TO AUTO GO TO 22.

FL VO6N60
 R1 = V (HORIZ)
 R2 = H-DOT
 R3 = H

GO TO 26

- 21.) ROD MODE: SET PGNS MODE CONTROL SW TO ATTITUDE HOLD.

P66 IS CALLED, WHEN THE R.O.D SWITCH IS FIRST USED.

NOTE: IF THROTTLE SW IS RETURNED TO AUTO DURING P67, P66 IS CALLED.

- 22.) COMMAND LM RATE OF DESCENT BY SETTING ROD SW UP OR DOWN FOR EACH 1FPS DELTA REQUIRED.

ROD SW IS LOCATED NEAR THE ENGINE STOP BUTTON ON SIDE OF PANEL.

STATIC VO6N60
 R1 = V (HORIZ)
 R2 = H-DOT
 R3 = H

- 23.) GO TO 26

- 24.) AUTOMATIC LANDING

P65 IS CALLED

STATIC VO6N20
 R1 = V (HORIZ)
 R2 = H-DOT
 R3 = H

- 25.) WHEN H = 5.5 FT. LUNAR CONTACT LIGHT COMES ON. PUSH ENGINE STOP SW.

- 26.) KEY V37E68E

FL VO6N43
 R1 = LAT
 R2 = LONG
 R3 = ALT

PRO

RETURN TO POO.

IN FLIGHT IMU ALIGNMENT

USING THE AOT

1191

1) KEY V37E52E
FL V04N06
R1 = 00001
R2 = 0000X

OPTION CODE

ORIENTATION SELECTION

1. PREFERRED
2. NOMINAL
3. REFSMMAT
4. LANDING SITE

IF X = 3 KEY IN PRO, OTHERWISE V22E3E

2) PRO
FL V50N25
R1 = 00015

PERFORM STAR ACQUISITION

3) ENTER
FL V01N70
R1 = 00XYZ

X = AOT DETENT

1. LEFT
2. CENTER
3. RIGHT
4. ANY REAR
5. BACK-UP (COAS)

YZ = 00 PLANET
01-45 STAR
46 SUN
47 EARTH
50 MOON

4) KEY V21E
FL V21N70
R1 = BLANK

5) KEY 2YZ
YZ = 01 POLARIS
03 NAVI
12 RIGEL
14 CANOPUS
15 SIRIUS
ETC:

FL V01N70
R1 = 002YZ 1st STAR

6) PRO
FL

V50N18
R1 XXX.XX
R2 XXX.XX
R3 XXX.XX

FDAI ANGLES FOR STAR CALLED IN 5.)

1152

7) GUIDANCE CONTROL: PNGS
PNGS MODE : AUTO

8) PRO

FL V06N18
R1 XXX.XX
R2 XXX.XX
R3 XXX.XX

AUTO MANEUVER TO STAR LOS
SAME ANGLES AS 6)

FL V50N18

MANEUVER COMPLETED, PRO MAY BE HIT
SEVERAL MORE TIMES FOR FINER ALIGNMENT.

9) ENTER

FL V01N71
R1 = 002YZ

SAME DISPLAY AS 5)

10) KEY

V76E

MIN. IMPULSE MODE

PNGS MODE CONTROL: ATT. HOLD

11) PRO

FL V54N71

MARK X OR Y

NOW READY TO MARK ON STAR 1.

LM IS MANEUVERED BY PULSING ATCA; AS STAR PASSES RETICLE X OR Y, MARK BUTTON IS DEPRESSED. FOR A VALID MARK, AN X AND A Y MARK IS REQUIRED. UP TO FIVE PAIRS MAY BE MADE, FOR AVERAGING, BUT X's AND Y's MUST ALTERNATE.

12) PRO

FL V01N70
R1 = 00200

13) KEY

V21E

FL V01N70
R1 = BLANK

14) KEY

2YZ

YZ = NO. OF 2nd STAR

FL V01N70
R1 = 002YZ

PNGS CONTROL: AUTO

15) PRO

FL V50N18

R1 XXX.XX
R2 XXX.XX
R3 XXX.XX

FDAI ANGLES FOR 2nd STAR LOS

- 16) PRO
FL V06N18 AUTO POSITIONING PERFORMED
R1 XXX.XX
R2 XXX.XX
R3 XXX.XX
WHEN SATISFIED WITH POSTION
- 17) ENTER
FL V01N71
R1 = 002YZ
- 18) PRO
FL V54N71 MARK X OR Y
PNGS CONTROL: ATT. HOLD
MARK ON SECOND STAR
NOTE: V52N71 is MARK X
V53N71 is MARK Y
WHEN MARKS ARE COMPLETE:
- 19) PRO
FL V06N05
R1 = XXX.XX MARK ERROR, DEGREES
IF LESS THAN .05, CONTINUE; IF NOT, KEY V32E (RECYCLE)
- 20) PRO
FL V06N93
R1 XX.XXX X GYRO TORQUING ANGLES
R2 XX.XXX Y GYRO
R3 XX.XXX Z GYRO
IF ACCEPTABLE, CONTINUE; IF NOT, KEY V32E
- 21) PRO
FL V50N25
R1 00014 FINE ALIGN CHECK DESIRED?
- 22) ENTER (NO) OR PRO (YES) RECYCLE
EXIT PROGRAM

SINGER - GENERAL PRECISION, INC.
LINK GROUP - SYSTEMS DIVISION
INTER-OFFICE CORRESPONDENCE

1141

TO: LMS ENGINEERING & PROGRAMMING
FROM: W. A. Ragsdale
SUBJECT: Landing the LMS

DATE: 7 April 1970
FROM LOC: Houston/SIMCOM
MEMO NO: WAR-70-01212

The purpose of this memo is to describe the procedures for manually landing the LMS.

Assuming a nominal descent has been made, P64 (the Approach Program) will begin at about 7000 feet altitude. At this time the LM will pitch down to about 30° nose high. The DSKY Displays V06 N64, which is

R1: Redesignation Time Left (Sec) XXBlankXX
LPD Angle (Deg)
R2: Altitude Rate (XXXX.X Ft/Sec)
R3: Altitude (XXXXX: Ft)

The LPD Angle is used to identify the target landing site. In order to change the target the ACA should be tilted out of detent in the desired direction of Redesignation.

Without manual inputs the LM will fly to the landing site and descend vertically at 3 ft/sec for the last 100 feet of altitude.

Manual takeover is accomplished by switching the PGNS Mode Control to ATT HOLD. At this time the LM will continue to maintain a nominal altitude vs altitude rate profile, but the forward and lateral velocities are pilot-controlled. The nominal altitude vs altitude rate for the last 5000 feet is approximately:

Altitude Rate = 3% of Altitude

Typical values are given below:

Alt = 5000	Alt Rate = 150
2000	60
1000	30
500	15
100	3

If it is desired to change the rate of descent this can be accomplished in one of two ways:

- 1) ROD Switch - Moving the ROD Switch up decreases the rate of descent by 1 ft/sec for each click. Moving it down increases the rate of descent by 1 ft/sec for each click.

1142

Once the ROD Switch has been moved out of detent the DSKY will indicate P66 (the ROD Landing Program) and the pilot must control his descent rate for the remainder of the landing. In P66 the DSKY display is V06 N60:

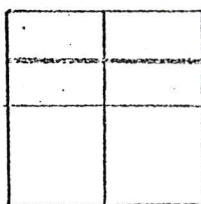
- R1: Forward Velocity (XXXX.X Ft/Sec)
- R2: Altitude Rate (XXXX.X Ft/Sec)
- R3: Altitude (XXXXX. Ft)

- 2) Manual Throttling - If the Throttle Control is left in AUTO, moving the throttle up will add the manual input to the PGNS-commanded thrust, which will result in a decrease in descent rate.

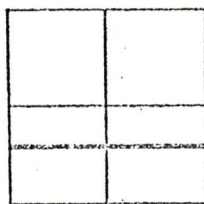
If complete manual throttling is desired the Throttle Control is moved to MANUAL. To decrease the descent rate the throttle is moved so the T/W Meter indicates greater than 1. To increase the descent rate the throttle is moved to a T/W value less than 1. To maintain the present descent rate the T/W value should be kept at 1.

In either ROD or Manual Throttling it is recommended that the descent rate be reduced to zero at some altitude between 200 and 100 feet. This leaves the LM flying parallel to the surface so it can be flown to a target landing site. The fuel quantity should be monitored, because to descend the last 100 feet at 3 ft/sec takes approximately 3% of the fuel.

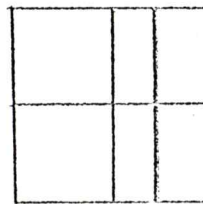
Once the LM is over the target landing site the crosspointers should be set to LO SCALE and the horizontal velocities should be zeroed. This is accomplished by "Zeroing the Crosspointers". This is done by tilting the LM opposite its forward and lateral velocity components until they are zero, then maneuvering to an erect level altitude. The recommended technique for doing this is to think of pulling the crosspointers to the center, as shown in the following sketch.



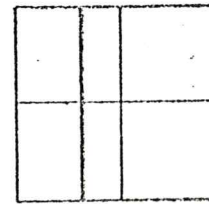
TILT ACA ↓



TILT ACA ↑



TILT ACA ←



TILT ACA →

1143

Once the velocities are approximately zeroed, the descent rate should be incremented to at least 3 feet per second. If fuel is low, the rate of descent may be higher, but at any altitude below 50 feet the rate of descent should be as close to 3 feet per second as possible.

During the final vertical descent the crosspointers should be kept zeroed. This can be accomplished manually, as described above, or automatically, by setting the PGNS Mode Control to AUTO.

When the lunar contact light comes on, the Engine STOP should be depressed. ABORT STAGE should be pushed if either roll or pitch exceeds 30° after lunar contact. If an abort occurs, make certain the PGNS Mode Control is in AUTO as soon as possible.

If the landing is safe the PGNS Mode Control should be turned OFF to stop RCS jets from firing.

The following is a summary checklist for a nominal Rate-of-Descent (ROD) landing.

1. P64 SWITCH POSITIONS (7000 ft Alt)

CDR's X-PNTR Scale-HI MULT
Rate/Err Mon-LDG RDR/CMPTR
Attitude Mon-PGNS
Guid Cont-PGNS
Mode Sel-PGNS
Rng/Alt Mon-ALT/ALT RT
Thr Cont-AUTO
Man Throt-CDR
Attitude Control-(Roll, Pitch, & Yaw)-MODE CONT
PGNS Mode Control-AUTO

2. Monitor DSKY

Prog: 64
V06 N64
R1: Redes Time XX. Sec
LPD Angle XX. Deg
R2: Alt Rate XXXX.X Ft/Sec
R3: Altitude XXXXX Ft

3. 5000 ft: ROD = 150 and Decreasing
Redesignate if desired by tilting ACA
- | Altitude | Alt Rate |
|----------|----------|
| 2000 | 60 |
| 1000 | 30 |
| 500 | 15 |

1144

4. Manual Takeover

PGNS Mode Control - ATT HOLD

(Optional) - Mode Sel-LDG RADAR

NOTE: ALT RATE in LR Mode is X-Axis Velocity, not Vertical Velocity.

5. To begin ROD Mode:

Move ROD Switch Out of Detent.

Monitor DSKY

Prog: 66

V06 N60

R1: Fwd Vel XXXX.X Ft/Sec

R2: Alt Rate XXXX.X Ft/Sec

R3: Altitude XXXXX. Ft

6. Maintain Rate of Descent less than 3% Altitude.
Zero Rate of Descent at about 150 ft.

7. Check X-Pntrs - LO MULT

Zero X-Pntrs

Zero Attitude

8. Set ROD = 3 ft/sec

9. LUNAR CONTACT
ENGINE STOP

10. Possible ABORT STAGE (If Tilt exceeds 30°)

Check PGNS Mode Control - AUTO

11. PGNS Mode Control - OFF (If Safe Ldg)

W. A. Ragsdale

W. A. Ragsdale
LMS G&N Engineer

111

SINGER - GENERAL PRECISION, INC.
LINK GROUP - SYSTEMS DIVISION
INTER-OFFICE CORRESPONDENCE

TO: IMS Engineers & Programmers

FROM: W. A. Ragsdale

SUBJECT: Mod L-100,189/1A Revised State Vector
Dispersions

DATE: 8 December 1969

FROM LOC: Houston/SIMCOM

MEMO NO: WAR-69-01094

The purpose of this memo is to describe the procedure for using the State Vector Dispersion option in the EOM. This procedure has been revised by Mod L-100,189/1A. Dispersions are now entered in the IMU Frame instead of the Local Vertical Frame.

The procedure is as follows:

1. Dispersions are entered by the Convert-Store Option on the IOS typewriter.

<u>MNEMONIC</u>	<u>SCALE FACTOR</u>	<u>DEFINITION</u>
ADPXL	B25	LM Position Dispersion, X-Component
ADPYL	B25	LM Position Dispersion, Y-Component
ADPZL	B25	LM Position Dispersion, Z-Component
ADVXL	B15	LM Velocity Dispersion, X-Component
ADVYL	B15	LM Velocity Dispersion, Y-Component
ADVZL	B15	LM Velocity Dispersion, Z-Component
ADPXC	B25	CSM Position Dispersion, X-Component
ADPYC	B25	CSM Position Dispersion, Y-Component
ADPZC	B25	CSM Position Dispersion, Z-Component
ADVXC	B15	CSM Velocity Dispersion, X-Component
ADVYC	B15	CSM Velocity Dispersion, Y-Component
ADVZC	B15	CSM Velocity Dispersion, Z-Component

2. Type in booleans to indicate desired options in the following order:
 - a. A510 - LM EOM dispersion desired.
 - b. A511 - CSM EOM dispersion desired.
 - c. TMFUD - to Uplink dispersion to the ISLGC. Monitor DSKY for Uplink activity.
 - d. A512 - (after Uplink is complete) to delete dispersion from EOM and leave it in the ISLGC.

This procedure may be used in Run or in Freeze.

W. A. Ragsdale
W. A. Ragsdale
IMS G&N Engineer

WAR/pb

1151

SINGER - GENERAL PRECISION, INC.
LINK GROUP - SYSTEMS DIVISION
INTER-OFFICE CORRESPONDENCE

TO: LMS Programmers and Engineers

FROM: A. A. Anderson

SUBJECT: Operation of LGC Downlink Monitor Console

DATE: January 7, 1970

FROM LOC: Link/Houston

MEMO NO: AAA-70-05

INTRODUCTION

The downlink monitor console is utilized to select and have displayed any telemetry word that is being transmitted by the LGC (i.e. generated by the ISLGC). Each telemetry word is composed of two 15 bit LGC words (plus a word order code and an odd parity bit for each of the two words). The octal values of the two 15 bit LGC words composing the selected telemetry word are displayed in two sets (rows) of 5 numerical readout lights (i.e. two 5 digit octal display registers). The word order code and parity bits are not displayed.

OPERATION OF DOWNLINK MONITOR

In order to examine a particular telemetry word, the user of the console must select the decimal number (1 - 100 for a regular downlist, 1 - 130 for each EBANK of an erasable memory dump, V74E) of the desired telemetry word on two thumbwheel switches. The numbers 00 - 99 can be selected on the thumbwheel switches. Word 100 is chosen by dialing 00 on the thumbwheel selector.

The new option to select words 101 - 130 during an erasable memory dump requires the setting of a flag via a typewriter. When this flag is set to a non-zero value, words 101 - 130 can be selected by setting the switches on 01 - 30. One should note that any time this flag is set 100₁₀ will be added to the value selected. Therefore, the user should be aware of the status of this flag as the downlink monitor will not operate properly when this flag is set during a normal downlist (except for word 100) or for words other than 100 - 130 during an EDUMP (V74E). Also, the user should realize that a word number selected during an EDUMP corresponds to that unique number of a word within each EBANK transmission. There are 8 banks (EBANK's) of erasable memory numbered 0 - 7, and erasable memory is transmitted exactly twice for one execution of a V74E. The banks are transmitted 0, 1, 2, ..., 7, 0, 1, 2, ..., 7. Therefore, the display related to a specific word number will be for that word within bank 0, then that word within bank 1, and so on, where each bank transmission requires 2.6 seconds.

This flag has the following addresses for the corresponding loads:

Load 78-01 - 76343g (with patches for Mod L7-110,135)
Load 78-02 - 76013g

The mnemonics associated with this flag are EFLG (in C-Lower) and KMEFLG (in A-Upper).

11J2

The flag is set to zero in the following situations:

1. On completion of a V74E (EDUMP)
2. By performing a reset (only for 78-02)
3. By user via typewriter or computer console
4. An LGC freshstart or restart
5. Whenever the simulator is changed from freeze to run mode

Although the flag is reset when the telemetry program returns to the interrupted downlist after performing an erasable memory dump, it may be set and remain set during regular downlist transmission in case the user wishes to have the flag set prior to requesting an EDUMP (V74E) on the DSKY.

The flag is never set other than by a typewriter or computer console manual operation by the user.

SUMMARY OF CONSOLE OPERATION

A. Regular Downlist

1. Word 1 - 99 - select 01 - 99 on thumbwheel selector.
2. Word 100 - select 00 on thumbwheel selector.

B. Erasable Memory Dump (V74E)

1. Words 1 - 99 - select 01 - 99 on thumbwheel selector.
2. Word 100 - select 00 on thumbwheel selector
3. Words 100 - 130
 - a. Set location 76013₈ for load 78-02 (or 76343₈ for 78-01) before or after keying V74E, yet must be after entering run mode.
 - b. Select 00 - 30 on thumbwheel selector (00 will yield word 100 for either flag setting).

If there are any questions concerning the operation of the LGC Downlink Monitor contact the author.

A. A. Anderson
A. A. Anderson

Approved:

K. R. Altman

AA/krm
cc: B. Fulbright
J. Neubauer
F. Frederick (KSC) - (4)

GENERAL PRECISION, INC.
LINK GROUP - SYSTEMS DIVISION
INTER-OFFICE CORRESPONDENCE

11K1 RECEIVED

AUG-10 1967

LINK HOUSTON
G. J. SACCANE

TO: All LMS Engineers
FROM: G. Saffioti
SUBJECT: LMS Communications Utilization

DATE: August 10, 1967

MEMO NO: SIMCOM (LMS)
GS-67-

Magbelle copy to all programs
ggg

As of late, difficulties have arisen in maintaining the alignment of the simulator communications system. Alignment is necessary for the proper operation of this system. It has been brought to my attention, that many subsystem engineers who are unfamiliar with this system, have requested that the on-site personnel remedy certain difficulties they encounter with the simulated loops of this system. This has caused considerable re-adjustments which have had a detrimental effect to the system as a whole.

The communications system provides the user with two Astro Loops. These loops are direct, non-simulated, hardwire connections between the cabin and the IOS station. One loop provides direct communication with the commander and the other provides direct communication with the system engineer. Non-communication type subsystem engineers should concern themselves only with these two loops. If communications cannot be established on these loops then they cannot be established---period!

The buttons needed to connect the IOS and the cabin via the Astro Loops are the white (Talk/listen) keys labeled LMS SE and LMS CDR. As the labels imply, one loop connects the IOS to the system engineer's headset (LMS SE) and the other connects to the commander's headset (LMS CDR). The headsets referred to are in the cabin. The keysets are located at three points on the console. One is on the left hand wedge, another is on the left hand main and the last one is on the right hand main display panels on the IOS console.

Your cooperation in this matter would be appreciated.

Enclosed is a diagram of a CCS keyset with the pertinent keys denoted by solid lines.

The console headsets connect into plugs located on the face edge of the console. There are two connects. They are labeled TALK/LISTEN and LISTEN. Thier function is implied by the label.

GS/lb

Enclosure

G. Saffioti
G. J. Saffioti
LMS OBS Engineer

TYPICAL CICS KEY SET

11K2

YELLOW KEYS



WHITE KEYS



YELLOW KEYS



WHITE KEYS



LMS VHF B	LMS VHF-B	LMS VHF-A	LMS VHF-A
LMS ICS	LMS ICS	LMS S-BAND	LMS S-BAND
LMS CDR	LMS CDR	LMS CONF 2	LMS CONF 1
LMS SE	LMS CDR	LMS CONF 3	LMS S/T
LMS S/C	LMS S/C	LMS LIL	LMS LIL
LMS ML	LMS ML	LMS CL	LMS CL
RELEASE	RING	BUZZER	M.A.

- NOTE
- (WHITE) DESIGNATES TALK / LISTEN CAPABILITY
 - (YELLOW), DESIGNATES LISTEN ONLY CAPABILITY
 - THE HEADSET JACK CONNECTIONS LOCATED ON THE FACE EDGE OF THE CONSOLE DIRECTLY BELOW THE KEYSER PANELS, MUST CONNECT THE HEAD SET FOR THE DESIRED CAPABILITY (TALK / LISTEN OR LISTEN), THE CONNECTIONS ARE MARKED ACCORDINGLY.

11K3

SINGER - GENERAL PRECISION, INC.
LINK GROUP - SYSTEMS DIVISION
INTER-OFFICE CORRESPONDENCE

TO: LMS PROGRAMMERS & ENGINEERS

FROM: Susan P. Smith

SUBJECT: Communications in ML56-02
and Future Mods


DATE: January 16, 1970

FROM LOC: Link/Houston

MEMO NO: SPS-70-018

As of ML56-02, COMMUNICATIONS subsystem now simulates lunar occultation in the S-Band loop. In other words, when the moon is between the earth and the LM, there will be no S-Band communications. (This is true only of LMS ONLY and LMS/CMS Modes.)

If you wish to use the S-Band communication loop, but do not want communications to cease behind the moon, there is an override boolean (T067). It must be set (to a "1") after each reset.


Susan P. Smith
LMS Programming

SPS/krm

cc: K. Altom
G. Saccane
P. Sivillo
LMS Supervision

1141

OPERATING INSTRUCTIONS FOR CMS/LMS

- 1) Check 'CTE SYNC'. A small green box located on A Computer control panel contains a split spril marked PCM VALID/CTE SYNC. If the 'CTE SYNC' is flashing, the CTE requires resetting. To reset the CTE call maintenance personnel or press the RESTART COUNT button located in Cab. 47 on the CTE PANEL. DO NOT PRESS THE SPRIL MARKED PCM VALID/CTE SYNC.
- 2) Place the mode switch located on the Interface Control Panel in the AMS/LMS position. If the CMS is not in the CMS/LMS mode at this time, the line printer will print out AMS DOWN.
- 3) When the CMS and LMS are both in the CMS/LMS mode, the READY/RUN, FREEZE and STORE buttons are wired together, i.e., either complex can initiate run, freeze or store. The RESET buttons are not tied together, so that a reset by LMS will not cause the CMS to reset.

After a reset the computers will not go into freeze until the minute pulse has occurred. When RUN has been initiated, the READY light will remain on until the minute pulse.

- 4) It is necessary to provide a communications loop between CMS and LMS to coordinate activities. Call EXT. 4810 and request a patch of the LMS LIL and the CMS CMIL comm. loops.
- 5) If for any reason the CMS/LMS mode is not operating properly, AMS DOWN will print on the line printer and the DATA FAIL light on the Interface Control Panel will be on. When this occurs;
a) the CMS and LMS are not transferring data; b) the CMS mode switch is not in the AMS/LMS position or c) the CMS is in reset. By checking the CMS/LMS analysis words (ANALY4 and ANALY5, next page), the CMS/LMS interface problem can be identified. Each complex should reset after the corrective action has been taken.
- 6) Each complex should use compatible reset tapes and reset points since a time check is required before data is accepted.
- 7) The LMS should reset after a patch has been loaded or the computers have halted for any reason.

1162

CMS/LMS ANALYSIS WORDS**

I. OPERATIONAL ANALYSIS

ANALY4

E	D	C	B	A	← DECIMAL READOUT WINDOW
---	---	---	---	---	--------------------------

A=0 LMS is not integrated
 A=1 LMS is integrated (CMS/LMS)
 *B=0 LMS is not receiving CMS data
 B=1 LMS is receiving CMS data
 *B=3 LMS and CMS TTAGTIME's do not agree
 *B=4 CMS data fails the checksum check.
 C=0 Real-Time I/O program indicates transfer OK
 *C=1 Real-Time I/O program indicates transfer failure
 D= SPARE
 E= SPARE

* DATA FAIL Light will be on, also

II. TIME ANALYSIS

ANALY5

--	--	--	--	--

ANALY5 = QTAGCMS - TTAGTIME

ANALY5 is the difference between the LMS and CMS TTAGTIME. If ANALY5 is greater than 1, (> 200 ms time difference) the CMS will be considered to be out of time with the LMS and the DATA FAIL light will be set. (ANALY4 B=3)

**ANALY4 and ANALY5 are in B-Upper. The Decimal Readout should be used to display the last 5 octal digits of the ANALYSIS words.

UNITED STATES GOVERNMENT

Memorandum

11M1

TO : CF332/Chief, IM Modification Section

DATE: DEC 30 1969

FROM : CF332/AST, IM Modification Section

In reply refer to:
CF332-9M-120

SUBJECT: IMS LTS (lunar terrain simulation)

With the installation of modification L-110,114, the capability of simulation of terrain deviations for the landing radar is greatly expanded. A 2-dimensional terrain is incorporated, and it provides realistic inputs to the landing radar. The LTS consists of a series of 25 line segments, serially connected, to form the surface under the flight path of the IM. The line segments are determined by a series of points defined by the altitude above and distance from the designated landing site. The points are defined in computer core by tables labeled GGALT and GRGLTS. The first point (i.e., last point passed by the IM) is determined by the first pair of elements from the tables.

The LTS can be selected or deselected by setting the discrete G900 to a one or zero. Normally, the LTS will be selected. The maximum range usable by the LTS is 240,000 feet. The profile used for Fra Mauro, Apollo XIII landing site, is in attachment one.

The location of the terms pertinent to the LTS for IMS load 78-01 are listed below, all in B-lower computer:

Term	Location	Scaling
GGALT	35616	B-23
GRGLTS	35564	B-18
G900	35704	N/A

Ben Fulbright
Ben Fulbright

Enclosure

cc:
FC63/C. Shelley
R. Koos
J. Honeycutt
G. Griffith
CF336/M. Brown
CFK/R. McCafferty
W. Busch

CF332:BFulbright:mlt 12-17-69 ✓



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Distance from landing
site (in feet)

Delta Elevation (in feet)

11 M 2

-29689	-66
0	0
6233	66
7217	56
11482	722
12794	689
13778	722
15254	656
17879	656
19683	590
21488	673
26572	230
32805	295
42975	-197
44943	-164
62330	-459
71188	-394
74140	-262
83818	-16
108258	66
128269	0
140571	230
147624	673
151889	755
157466	590
192568	919

Enclosure 1

Eftu

11M3



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
HOUSTON, TEXAS 77058

IN REPLY REFER TO: CF831-70M-54

MEMORANDUM TO: CF831/Chief, LM Modification Section

FROM : CF831/AST, LM Modification Section

SUBJECT : Operational techniques associated with LMS landing radar surface simulation

There are three options available in the LMS for lunar surface feature simulation for the landing radar: (1) Pseudo 3-Dimensional Lunar Terrain Simulation (3D-LTS), (2) Extended Lunar Terrain Simulation (ELTS), and (3) a cue-ball moon. Associated with the three options are two discreties, G909 and G900, both in B-Lower computer. The techniques of selecting the various options are listed below:

3D-LTS

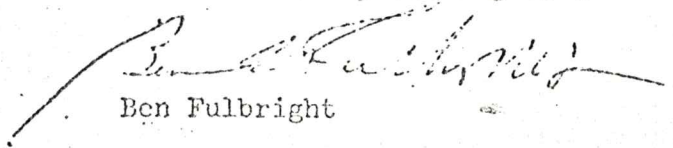
The option will normally be selected on the load tape. However, to verify its selection, check that the booleans G900 and G909 are "1" and "0," respectively. This will provide a near 3-dimensional simulation of the lunar surface for landing radar.

ELTS

This option will utilize only the 26-point, 2-dimensional surface as contained in record one, file one of the reset tape. The data extends from approximately forty miles downrange to five miles past the landing site. This data is read into core each time a reset is performed; therefore, in order to utilize any off-nominal ELTS profile, it will be necessary to read that data into core after resetting either from the Unitape or from cards. This option is selected by disallowing the real-time tape reading routing, or setting the boolean G909 to a "1."

Cue-ball moon

This option provides a smooth surface for radar use. To select this option, deselect ELTS by setting the boolean G900 to a "0." It should be noted that unless real-time tape read is deselected, the pseudo 3-dimensional data will be read; however, the radar will not use it. Therefore the real-time tape read should be disabled by setting G909 to a "1."


Ben Fulbright

cc: See attached list

SINGER-GENERAL PRECISION, INC.
LINK GROUP - SYSTEMS DIVISION
INTER-OFFICE CORRESPONDENCE

11N1

TO: G. J. Saccane
FROM: W. A. Ragsdale
SUBJECT: Action Memo L-4044
CSM IMU Gimbal Angles

DATE: 18 July 1969
FROM LOC: Houston
MEMO NO: Link/SIMCOM
WR-69-0923

An option has been added to EOM to compute the CSM IMU Gimbal Angles when the vehicles are docked. These angles are calculated assuming that both vehicles have the same REFSEMAT.

The procedure for using this option is as follows:

1. Set A501 = 1 on the IOS typewriter. (ML56-02 address for A501 is CCL 74530).
2. CSM IMU angles will be calculated and stored in the following locations; scaled at B09:

	<u>ML56-02 Address</u>	<u>Axis</u>	<u>Gimbal</u>
AUCMGA	57044 AU	Z	Middle
AUCIGA	57045 AU	Y	Inner
AUCOGA	57046 AU	X	Outer

3. This data can be displayed on the digital readout box, or printed on the real time print. Values will remain constant until they are recalculated by repeating this procedure.

W. A. Ragsdale
W. A. Ragsdale
IMS G & N Engineer

WAR:pb

cc: K. Altom
L. Butts
L. Hershey
R. Morris
P. Sivillo

RENDEZVOUS RADAR CDU BIAS PROCEDURES

11/25

In order to bias the LGC RR CDU (counters 35 and 36), the values of GABIAS and GEBIAS should be changed via typewriter. The address for GABIAS and GEBIAS will be found in the B-Upper Memory Map:

GABIAS is the trunnion bias, positive left.

GEBIAS is the shaft bias, positive up.

<u>89-04</u>	<u>10-01</u>	<u>1112B</u>
40316	36755	46633
40317	36756	39

The procedure is as follows:

1. Type: E (Carriage returns)
2. Type: XXXXXUB, where XXXXX is the address of GABIAS or GEBIAS (Typewriter prints out present value).
3. Type: Y0000ZZZ, where Y is zero for a positive bias and four for a negative bias, and ZZZ is the value from the following table.

For values not given in the table, the octal value can be found by the following equation: $VALUE = (91.2) \times (BIAS \text{ in degrees})$ converted to octal

<u>BIAS, deg.</u>	<u>VALUE</u>	<u>BIAS, deg.</u>	<u>VALUE</u>	<u>BIAS, deg.</u>	<u>VALUE</u>
0	000	1.1	144	2.1	277
0.1	011	1.2	155	2.2	310
0.2	022	1.3	166	2.3	322
0.3	033	1.4	177	2.4	333
0.4	044	1.5	211	2.5	344
0.5	055	1.6	222	2.6	355
0.6	067	1.7	233	2.7	366
0.7	100	1.8	244	2.8	377
0.8	111	1.9	255	2.9	410
0.9	122	2.0	266	3.0	421
1.0	133				

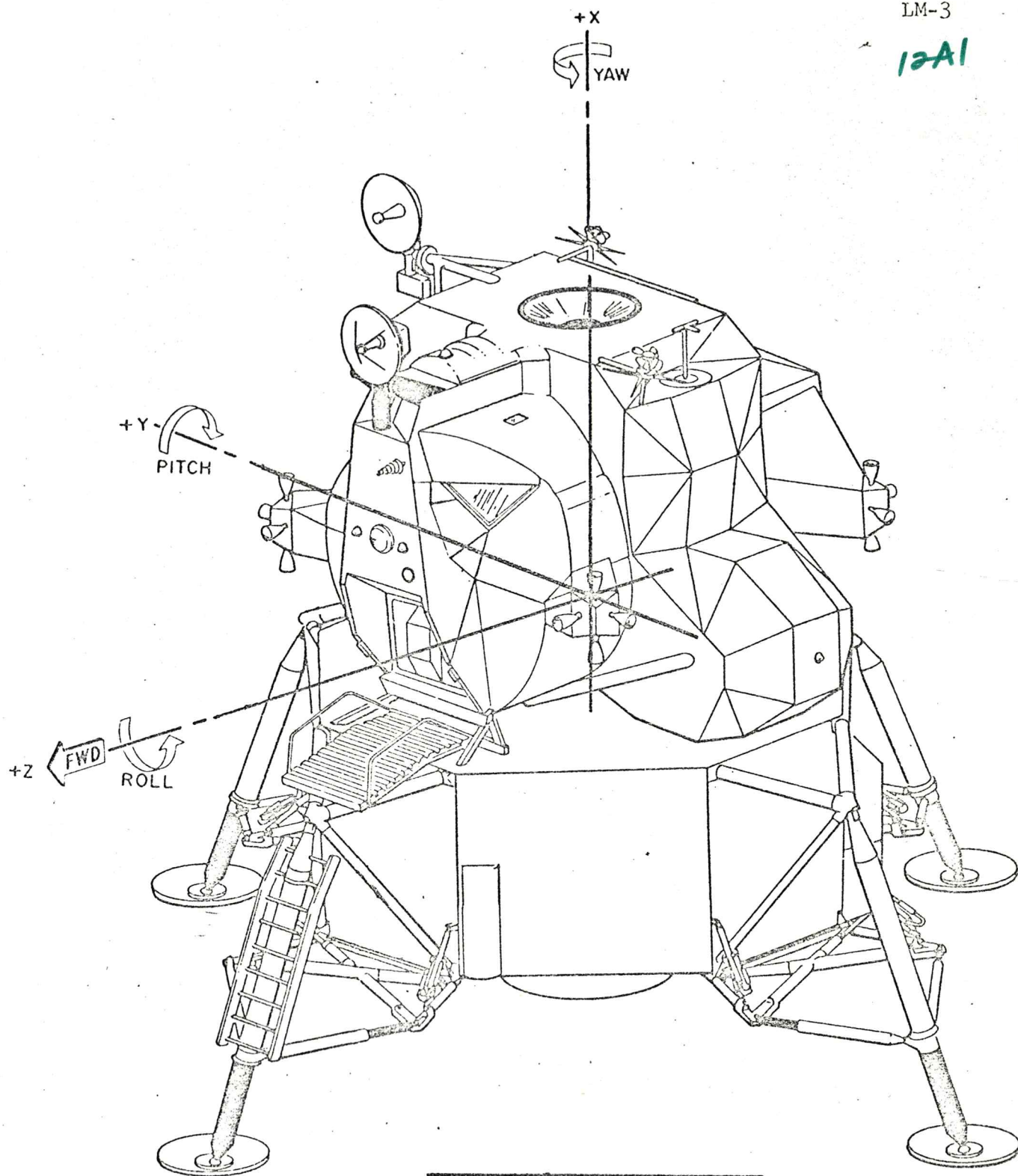
<u>BIAS, deg.</u>	<u>VALUE</u>	<u>BIAS, deg.</u>	<u>VALUE</u>
3.1	432	4.1	566
3.2	444	4.2	577
3.3	455	4.3	610
3.4	466	4.4	621
3.5	477	4.5	632
3.6	510	4.6	643
3.7	521	4.7	654
3.8	532	4.8	666
3.9	544	4.9	677
4.0	555	5.0	710

INSURING LUNAR CONTACT AT TOUCHDOWN

NASA training requires the L & A hardware to be on and to indicate the LM has landed only when the L & A physically comes within the range of fluidic switch lockup.

The only way to get software landing is if the L & A is turned off and is set to V063 = 1. V063 is defined in BU Data Pool. This boolean must be set after each reload.

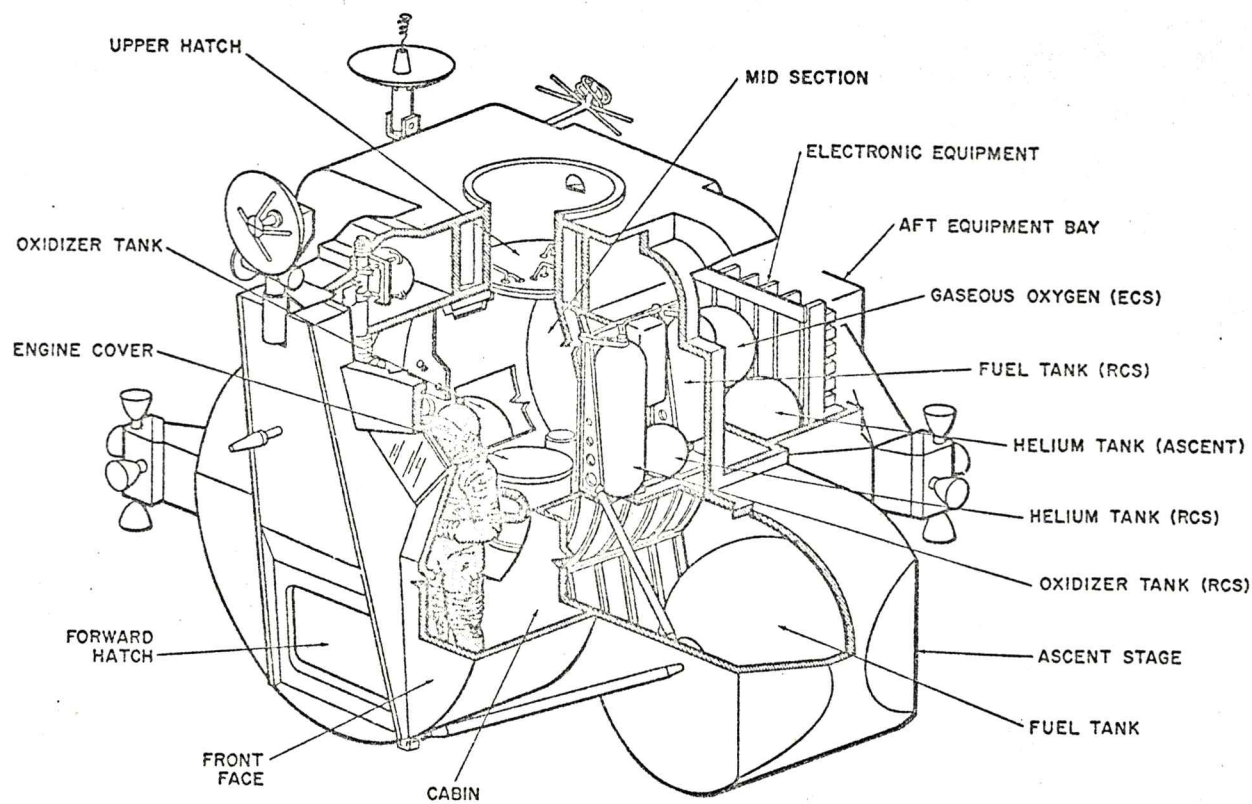
XII Real World



LUNAR MODULE

T30005-172.1

Date: November 1967

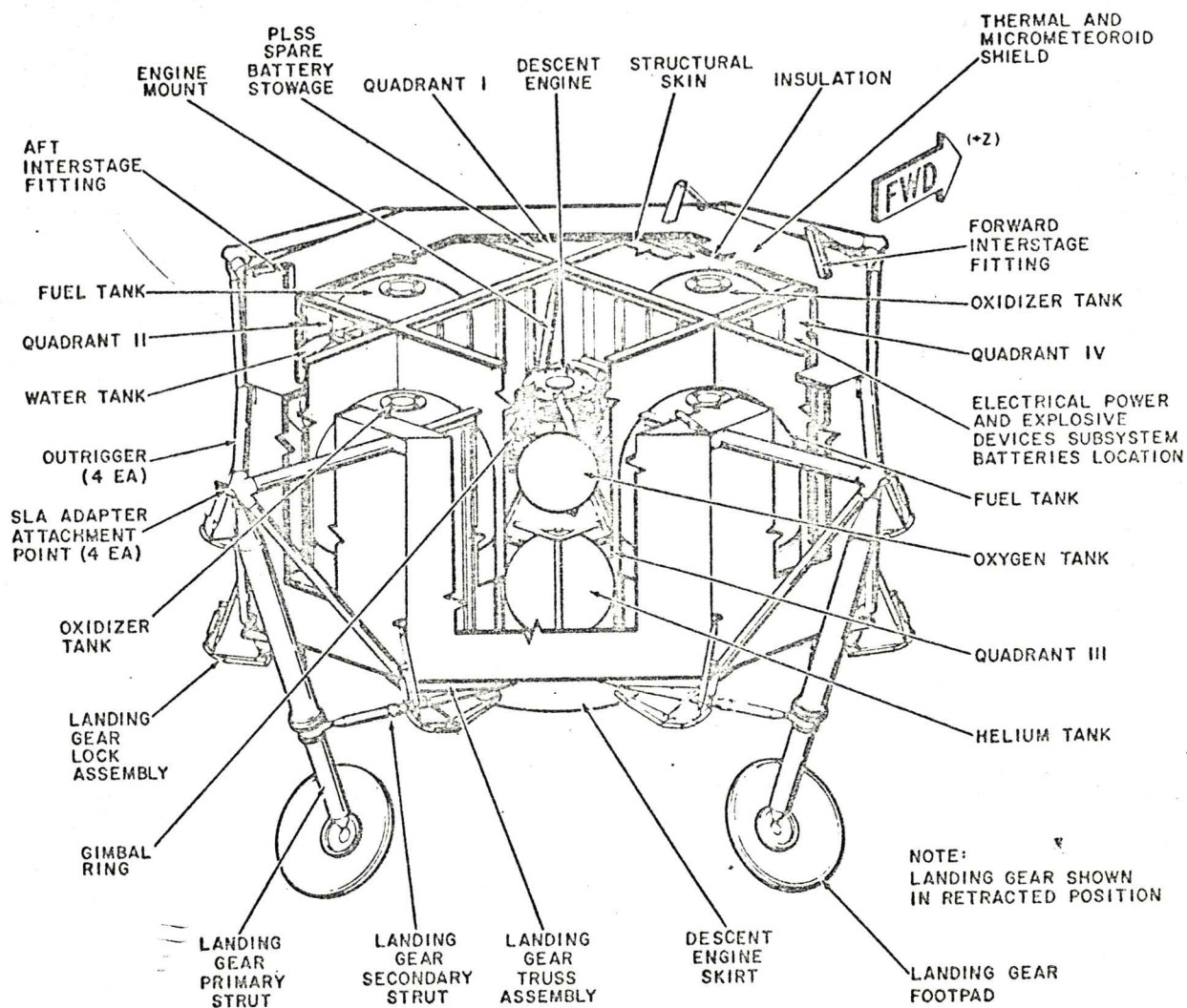


ASCENT STAGE

T30207-45.1

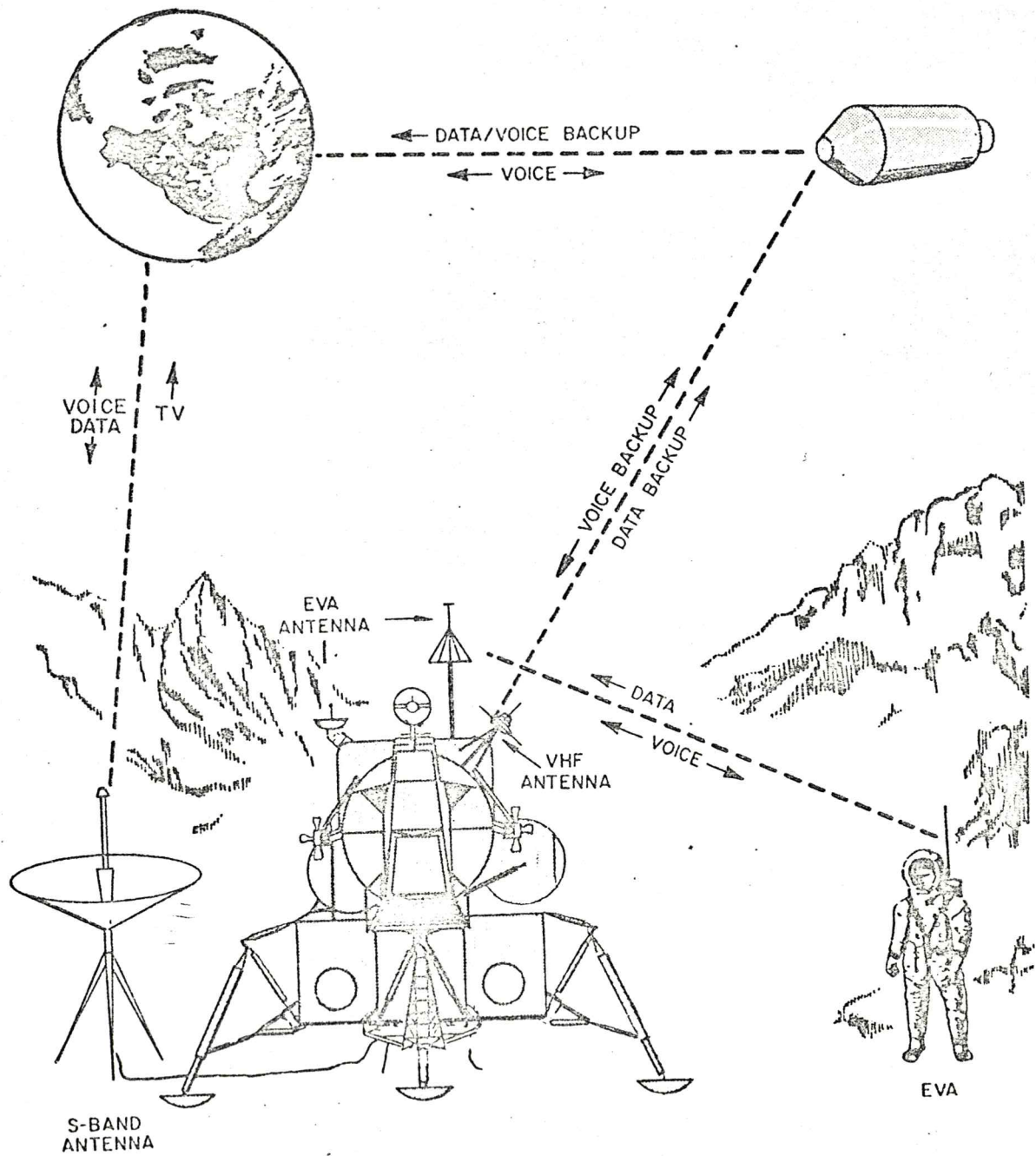
1287

1283



LM DESCENT STAGE

T30915-42.1



LUNAR SURFACE COMMUNICATIONS
CAPABILITY

T30005-40.1

XIII Math Tables

Table V. NATURAL TRIGONOMETRIC FUNCTIONS

0° (179°)	Sin	Tan	Ctn	Cos	1° (181°)	Sin	Tan	Ctn	Cos	(359°) 179°
0	.00000	.00000		1.00000	0	.01745	.01746	57.290	.99985	60
1	.00029	.00029	3437.7	1.00000	1	.01774	.01775	56.351	.99984	59
2	.00058	.00058	1718.9	1.00000	2	.01803	.01804	55.442	.99984	58
3	.00087	.00087	1145.9	1.00000	3	.01832	.01833	54.561	.99983	57
4	.00116	.00116	859.44	1.00000	4	.01862	.01862	53.709	.99983	56
5	.00145	.00145	687.55	1.00000	5	.01891	.01891	52.882	.99982	55
6	.00175	.00175	572.96	1.00000	6	.01920	.01920	52.081	.99982	54
7	.00204	.00204	491.11	1.00000	7	.01949	.01949	51.303	.99981	53
8	.00233	.00233	429.72	1.00000	8	.01978	.01978	50.549	.99980	52
9	.00262	.00262	381.97	1.00000	9	.02007	.02007	49.816	.99980	51
10	.00291	.00291	343.77	1.00000	10	.02036	.02036	49.104	.99979	50
11	.00320	.00320	312.52	.99999	11	.02065	.02065	48.412	.99979	49
12	.00349	.00349	286.48	.99999	12	.02094	.02095	47.740	.99978	48
13	.00378	.00378	264.44	.99999	13	.02123	.02124	47.085	.99977	47
14	.00407	.00407	245.55	.99999	14	.02152	.02153	46.449	.99977	46
15	.00436	.00436	229.18	.99999	15	.02181	.02182	45.829	.99976	45
16	.00465	.00465	214.85	.99999	16	.02211	.02211	45.226	.99976	44
17	.00495	.00495	202.22	.99999	17	.02240	.02240	44.639	.99975	43
18	.00524	.00524	190.98	.99999	18	.02269	.02269	44.066	.99974	42
19	.00553	.00553	180.93	.99998	19	.02298	.02298	43.508	.99974	41
20	.00582	.00582	171.89	.99998	20	.02327	.02328	42.964	.99973	40
21	.00611	.00611	163.70	.99998	21	.02356	.02357	42.433	.99972	39
22	.00640	.00640	156.26	.99998	22	.02385	.02386	41.916	.99972	38
23	.00669	.00669	149.47	.99998	23	.02414	.02415	41.411	.99971	37
24	.00698	.00698	143.24	.99998	24	.02443	.02444	40.917	.99970	36
25	.00727	.00727	137.51	.99997	25	.02472	.02473	40.436	.99969	35
26	.00756	.00756	132.22	.99997	26	.02501	.02502	39.965	.99969	34
27	.00785	.00785	127.32	.99997	27	.02530	.02531	39.506	.99968	33
28	.00814	.00815	122.77	.99997	28	.02559	.02560	39.057	.99967	32
29	.00844	.00844	118.54	.99996	29	.02588	.02589	38.618	.99966	31
30	.00873	.00873	114.59	.99996	30	.02618	.02619	38.188	.99966	30
31	.00902	.00902	110.89	.99996	31	.02647	.02648	37.769	.99965	29
32	.00931	.00931	107.43	.99996	32	.02676	.02677	37.358	.99964	28
33	.00960	.00960	104.17	.99995	33	.02705	.02706	36.956	.99963	27
34	.00989	.00989	101.11	.99995	34	.02734	.02735	36.563	.99963	26
35	.01018	.01018	98.218	.99995	35	.02763	.02764	36.178	.99962	25
36	.01047	.01047	95.489	.99995	36	.02792	.02793	35.801	.99961	24
37	.01076	.01076	92.908	.99994	37	.02821	.02822	35.431	.99960	23
38	.01105	.01105	90.463	.99994	38	.02850	.02851	35.070	.99959	22
39	.01134	.01135	88.144	.99994	39	.02879	.02881	34.715	.99959	21
40	.01164	.01164	85.940	.99993	40	.02908	.02910	34.368	.99958	20
41	.01193	.01193	83.844	.99993	41	.02938	.02939	34.027	.99957	19
42	.01222	.01222	81.847	.99993	42	.02967	.02968	33.694	.99956	18
43	.01251	.01251	79.943	.99992	43	.02996	.02997	33.366	.99955	17
44	.01280	.01280	78.126	.99992	44	.03025	.03026	33.045	.99954	16
45	.01309	.01309	76.390	.99991	45	.03054	.03055	32.730	.99953	15
46	.01338	.01338	74.729	.99991	46	.03083	.03084	32.421	.99952	14
47	.01367	.01367	73.139	.99991	47	.03112	.03114	32.118	.99952	13
48	.01396	.01396	71.615	.99990	48	.03141	.03143	31.821	.99951	12
49	.01425	.01425	70.153	.99990	49	.03170	.03172	31.528	.99950	11
50	.01454	.01455	68.750	.99989	50	.03199	.03201	31.242	.99949	10
51	.01483	.01484	67.402	.99989	51	.03228	.03230	30.960	.99948	9
52	.01513	.01513	66.105	.99989	52	.03257	.03259	30.683	.99947	8
53	.01542	.01542	64.858	.99988	53	.03286	.03288	30.412	.99946	7
54	.01571	.01571	63.657	.99988	54	.03316	.03317	30.145	.99945	6
55	.01600	.01600	62.499	.99987	55	.03345	.03346	29.882	.99944	5
56	.01629	.01629	61.383	.99987	56	.03374	.03376	29.624	.99943	4
57	.01658	.01658	60.306	.99986	57	.03403	.03405	29.371	.99942	3
58	.01687	.01687	59.266	.99986	58	.03432	.03434	29.122	.99941	2
59	.01716	.01716	58.261	.99985	59	.03461	.03463	28.877	.99940	1
60	.01745	.01746	57.290	.99985	60	.03490	.03492	28.636	.99939	0
	Cos	Ctn	Tan	Sin		Cos	Ctn	Tan	Sin	

90° (270°) (269°) 89° 91° (271°) (268°) 88°

For degrees indicated at the top (bottom) of the page use the column headings at the top (bottom).
 With degrees at the left (right) of each block (top or bottom), use the minute column at the left (right).
 The correct sign (plus or minus) must be prefixed in accordance with paragraph 51, page 16.

Table F. NATURAL TRIGONOMETRIC FUNCTIONS

(182°)	Sin	Tan	Ctn	Cos	(357°) 177°	3° (183°)	Sin	Tan	Ctn	Cos	(356°) 176°
0	.03490	.03492	28.636	.99939	60	0	.05234	.05241	19.081	.99863	60
1	.03519	.03521	28.399	.99938	59	1	.05253	.05270	18.976	.99861	59
2	.03548	.03550	28.166	.99937	58	2	.05292	.05299	18.871	.99860	58
3	.03577	.03579	27.937	.99936	57	3	.05321	.05328	18.768	.99859	57
4	.03606	.03609	27.712	.99935	56	4	.05350	.05357	18.666	.99857	56
5	.03635	.03638	27.490	.99934	55	5	.05379	.05387	18.564	.99855	55
6	.03664	.03667	27.271	.99933	54	6	.05408	.05416	18.464	.99854	54
7	.03693	.03696	27.057	.99932	53	7	.05437	.05445	18.366	.99852	53
8	.03722	.03725	26.845	.99931	52	8	.05466	.05474	18.268	.99851	52
9	.03752	.03754	26.637	.99930	51	9	.05495	.05503	18.171	.99849	51
10	.03781	.03783	26.432	.99929	50	10	.05524	.05533	18.075	.99847	50
11	.03810	.03812	26.230	.99927	49	11	.05553	.05562	17.980	.99846	49
12	.03839	.03842	26.031	.99926	48	12	.05582	.05591	17.886	.99844	48
13	.03868	.03871	25.835	.99925	47	13	.05611	.05620	17.793	.99842	47
14	.03897	.03900	25.642	.99924	46	14	.05640	.05649	17.702	.99841	46
15	.03926	.03929	25.452	.99923	45	15	.05669	.05678	17.611	.99839	45
16	.03955	.03958	25.264	.99922	44	16	.05698	.05708	17.521	.99838	44
17	.03984	.03987	25.080	.99921	43	17	.05727	.05737	17.431	.99836	43
18	.04013	.04016	24.898	.99919	42	18	.05756	.05766	17.343	.99834	42
19	.04042	.04045	24.719	.99918	41	19	.05785	.05795	17.256	.99833	41
20	.04071	.04075	24.542	.99917	40	20	.05814	.05824	17.169	.99831	40
21	.04100	.04104	24.368	.99916	39	21	.05843	.05854	17.084	.99829	39
22	.04129	.04133	24.196	.99915	38	22	.05873	.05883	16.999	.99827	38
23	.04158	.04162	24.026	.99913	37	23	.05902	.05912	16.915	.99826	37
24	.04188	.04191	23.859	.99912	36	24	.05931	.05941	16.832	.99824	36
25	.04217	.04220	23.695	.99911	35	25	.05960	.05970	16.750	.99822	35
26	.04246	.04250	23.532	.99910	34	26	.05989	.05999	16.668	.99821	34
27	.04275	.04279	23.372	.99909	33	27	.06018	.06029	16.587	.99819	33
28	.04304	.04308	23.214	.99907	32	28	.06047	.06058	16.507	.99817	32
29	.04333	.04337	23.058	.99906	31	29	.06076	.06087	16.428	.99815	31
30	.04362	.04366	22.904	.99905	30	30	.06105	.06116	16.350	.99813	30
31	.04391	.04395	22.752	.99904	29	31	.06134	.06145	16.272	.99812	29
32	.04420	.04424	22.602	.99902	28	32	.06163	.06175	16.195	.99810	28
33	.04449	.04454	22.454	.99901	27	33	.06192	.06204	16.119	.99808	27
34	.04478	.04483	22.308	.99900	26	34	.06221	.06233	16.043	.99806	26
35	.04507	.04512	22.164	.99898	25	35	.06250	.06262	15.969	.99804	25
36	.04536	.04541	22.022	.99897	24	36	.06279	.06291	15.895	.99803	24
37	.04565	.04570	21.881	.99896	23	37	.06308	.06321	15.821	.99801	23
38	.04594	.04599	21.743	.99894	22	38	.06337	.06350	15.748	.99799	22
39	.04623	.04628	21.606	.99893	21	39	.06366	.06379	15.676	.99797	21
40	.04653	.04658	21.470	.99892	20	40	.06395	.06408	15.605	.99795	20
41	.04682	.04687	21.337	.99890	19	41	.06424	.06438	15.534	.99793	19
42	.04711	.04716	21.205	.99889	18	42	.06453	.06467	15.464	.99792	18
43	.04740	.04745	21.075	.99888	17	43	.06482	.06496	15.394	.99790	17
44	.04769	.04774	20.946	.99886	16	44	.06511	.06525	15.325	.99788	16
45	.04798	.04803	20.819	.99885	15	45	.06540	.06554	15.257	.99786	15
46	.04827	.04833	20.693	.99883	14	46	.06569	.06584	15.189	.99784	14
47	.04856	.04862	20.569	.99882	13	47	.06598	.06613	15.122	.99782	13
48	.04885	.04891	20.446	.99881	12	48	.06627	.06642	15.056	.99780	12
49	.04914	.04920	20.325	.99879	11	49	.06656	.06671	14.990	.99778	11
50	.04943	.04949	20.206	.99878	10	50	.06685	.06700	14.924	.99776	10
51	.04972	.04978	20.087	.99876	9	51	.06714	.06730	14.860	.99774	9
52	.05001	.05007	19.970	.99875	8	52	.06743	.06759	14.795	.99772	8
53	.05030	.05037	19.855	.99873	7	53	.06773	.06788	14.732	.99770	7
54	.05059	.05066	19.740	.99872	6	54	.06802	.06817	14.669	.99768	6
55	.05088	.05095	19.627	.99870	5	55	.06831	.06847	14.606	.99766	5
56	.05117	.05124	19.516	.99869	4	56	.06860	.06876	14.544	.99764	4
57	.05146	.05153	19.405	.99867	3	57	.06889	.06905	14.482	.99762	3
58	.05175	.05182	19.296	.99866	2	58	.06918	.06934	14.421	.99760	2
59	.05205	.05212	19.188	.99864	1	59	.06947	.06963	14.361	.99758	1
60	.05234	.05241	19.081	.99863	0	60	.06976	.06993	14.301	.99756	0
	Cos	Ctn	Tan	Sin			Cos	Ctn	Tan	Sin	

NATURAL TRIGONOMETRIC FUNCTIONS

(355°) 175°

5° (185°)

(351°) 179°

ble V

NATURAL TRIGONOMETRIC FUNCTIONS

(353°) 173°

7° (187°)

(355°) 175°

	Sin	Tan	Ctn	Cos	
0	.06976	.06993	14.301	.99756	60
1	.07005	.07022	14.241	.99754	59
2	.07034	.07051	14.182	.99752	58
3	.07063	.07080	14.124	.99750	57
4	.07092	.07110	14.065	.99748	56
5	.07121	.07139	14.008	.99746	55
6	.07150	.07168	13.951	.99744	54
7	.07179	.07197	13.894	.99742	53
8	.07208	.07227	13.838	.99740	52
9	.07237	.07256	13.782	.99738	51
10	.07266	.07285	13.727	.99736	50
11	.07295	.07314	13.672	.99734	49
12	.07324	.07344	13.617	.99732	48
13	.07353	.07373	13.563	.99729	47
14	.07382	.07402	13.510	.99727	46
15	.07411	.07431	13.457	.99725	45
16	.07440	.07461	13.404	.99723	44
17	.07469	.07490	13.352	.99721	43
18	.07498	.07519	13.300	.99719	42
19	.07527	.07548	13.248	.99716	41
20	.07556	.07578	13.197	.99714	40
21	.07585	.07607	13.146	.99712	39
22	.07614	.07636	13.096	.99710	38
23	.07643	.07665	13.046	.99708	37
24	.07672	.07695	12.996	.99705	36
25	.07701	.07724	12.947	.99703	35
26	.07730	.07753	12.898	.99701	34
27	.07759	.07782	12.850	.99699	33
28	.07788	.07812	12.801	.99696	32
29	.07817	.07841	12.754	.99694	31
30	.07846	.07870	12.705	.99692	30
31	.07875	.07899	12.659	.99689	29
32	.07904	.07929	12.612	.99687	28
33	.07933	.07958	12.566	.99685	27
34	.07962	.07987	12.520	.99683	26
35	.07991	.08017	12.474	.99680	25
36	.08020	.08046	12.429	.99678	24
37	.08049	.08075	12.384	.99676	23
38	.08078	.08104	12.339	.99673	22
39	.08107	.08134	12.295	.99671	21
40	.08136	.08163	12.251	.99668	20
41	.08165	.08192	12.207	.99666	19
42	.08194	.08221	12.163	.99664	18
43	.08223	.08251	12.120	.99661	17
44	.08252	.08280	12.077	.99659	16
45	.08281	.08309	12.035	.99657	15
46	.08310	.08339	11.992	.99654	14
47	.08339	.08368	11.950	.99652	13
48	.08368	.08397	11.909	.99649	12
49	.08397	.08427	11.867	.99647	11
50	.08426	.08456	11.826	.99644	10
51	.08455	.08485	11.785	.99642	9
52	.08484	.08514	11.745	.99639	8
53	.08513	.08544	11.705	.99637	7
54	.08542	.08573	11.664	.99635	6
55	.08571	.08602	11.625	.99632	5
56	.08600	.08632	11.585	.99630	4
57	.08629	.08661	11.546	.99627	3
58	.08658	.08690	11.507	.99625	2
59	.08687	.08720	11.468	.99622	1
60	.08716	.08749	11.430	.99619	0
	Cos	Ctn	Tan	Sin	

94° (274°)

(265°) 85°

95° (275°)

(264°) 84°

	Sin	Tan	Ctn	Cos	
0	.08716	.08749	11.430	.99619	60
1	.08745	.08778	11.392	.99617	59
2	.08774	.08807	11.354	.99614	58
3	.08803	.08837	11.316	.99612	57
4	.08831	.08866	11.279	.99609	56
5	.08860	.08895	11.242	.99607	55
6	.08889	.08925	11.205	.99604	54
7	.08918	.08954	11.168	.99602	53
8	.08947	.08983	11.132	.99599	52
9	.08976	.09013	11.095	.99596	51
10	.09005	.09042	11.059	.99594	50
11	.09034	.09071	11.024	.99591	49
12	.09063	.09101	10.988	.99588	48
13	.09092	.09130	10.953	.99586	47
14	.09121	.09159	10.918	.99583	46
15	.09150	.09189	10.883	.99580	45
16	.09179	.09218	10.848	.99578	44
17	.09208	.09247	10.814	.99575	43
18	.09237	.09277	10.780	.99572	42
19	.09266	.09306	10.746	.99570	41
20	.09295	.09335	10.712	.99567	40
21	.09324	.09365	10.678	.99564	39
22	.09353	.09394	10.645	.99562	38
23	.09382	.09423	10.612	.99559	37
24	.09411	.09453	10.579	.99556	36
25	.09440	.09482	10.546	.99553	35
26	.09469	.09511	10.514	.99551	34
27	.09498	.09541	10.481	.99548	33
28	.09527	.09570	10.449	.99545	32
29	.09556	.09600	10.417	.99542	31
30	.09585	.09629	10.385	.99540	30
31	.09614	.09658	10.354	.99537	29
32	.09642	.09688	10.322	.99534	28
33	.09671	.09717	10.291	.99531	27
34	.09700	.09746	10.260	.99528	26
35	.09729	.09776	10.229	.99526	25
36	.09758	.09805	10.199	.99523	24
37	.09787	.09834	10.168	.99520	23
38	.09816	.09864	10.138	.99517	22
39	.09845	.09893	10.108	.99514	21
40	.09874	.09923	10.078	.99511	20
41	.09903	.09952	10.048	.99508	19
42	.09932	.09981	10.019	.99506	18
43	.09961	.10011	9.9893	.99503	17
44	.09990	.10040	9.9601	.99500	16
45	.10019	.10069	9.9310	.99497	15
46	.10048	.10099	9.9021	.99494	14
47	.10077	.10128	9.8734	.99491	13
48	.10106	.10158	9.8448	.99488	12
49	.10135	.10187	9.8164	.99485	11
50	.10164	.10216	9.7882	.99482	10
51	.10192	.10246	9.7601	.99479	9
52	.10221	.10275	9.7322	.99476	8
53	.10250	.10305	9.7044	.99473	7
54	.10279	.10334	9.6768	.99470	6
55	.10308	.10363	9.6493	.99467	5
56	.10337	.10393	9.6220	.99464	4
57	.10366	.10422	9.5949	.99461	3
58	.10395	.10452	9.5679	.99458	2
59	.10424	.10481	9.5411	.99455	1
60	.10453	.10510	9.5144	.99452	0
	Cos	Ctn	Tan	Sin	

96° (276°)

(263°) 83°

97° (277°)

(262°) 82°

	Sin	Tan	Ctn	Cos	
0	.10453	.10510	9.5144	.99452	60
1	.10482	.10540	9.4878	.99449	59
2	.10511	.10569	9.4614	.99446	58
3	.10540	.10599	9.4352	.99443	57
4	.10569	.10628	9.4090	.99440	56
5	.10597	.10657	9.3831	.99437	55
6	.10626	.10687	9.3572	.99434	54
7	.10655	.10716	9.3315	.99431	53
8	.10684	.10746	9.3060	.99428	52
9	.10713	.10775	9.2806	.99424	51
10	.10742	.10805	9.2553	.99421	50
11	.10771	.10834	9.2302	.99418	49
12	.10800	.10863	9.2052	.99415	48
13	.10829	.10893	9.1803	.99412	47
14	.10858	.10922	9.1555	.99409	46
15	.10887	.10952	9.1309	.99406	45
16	.10916	.10981	9.1065	.99402	44
17	.10945	.11011	9.0821	.99399	43
18	.10973	.11040	9.0579	.99396	42
19	.11002	.11070	9.0338	.99393	41
20	.11031	.11099	9.0098	.99390	40
21	.11060	.11128	8.9860	.99386	39
22	.11089	.11158	8.9623	.99383	38
23	.11118	.11187	8.9387	.99380	37
24	.11147	.11217	8.9152	.99377	36
25	.11176	.11246	8.8919	.99374	35
26	.11205	.11276	8.8686	.99370	34
27	.11234	.11305	8.8455	.99367	33
28	.11263	.11335	8.8225	.99364	32
29	.11291	.11364	8.7996	.99360	31
30	.11320	.11394	8.7769	.99357	30
31	.11349	.11423	8.7542	.99354	29
32	.11378	.11452	8.7317	.99351	28
33	.11407	.11482	8.7093	.99347	27
34	.11436	.11511	8.6870	.99344	26
35	.11465	.11541	8.6648	.99341	25
36	.11494	.11570	8.6427	.99337	24
37	.11523	.11600	8.6208	.99334	23
38	.11552	.11629	8.5989	.99331	22
39	.11580	.11659	8.5772	.99327	21
40	.11609	.11688	8.5555	.99324	20
41	.11638	.11718	8.5340	.99320	19
42	.11667	.11747	8.5126	.99317	18
43	.11696	.11777	8.4913	.99314	17
44	.11725	.11806	8.4701	.99310	16
45	.11754	.11836	8.4490	.99307	15
46	.11783	.11865	8.4280	.99303	14
47	.11812	.11895	8.4071	.99300	13
48	.11840	.11924	8.3863	.99297	12
49	.11869	.11954	8.3656	.99293	11
50	.11898	.11983	8.3450	.99290	10
51	.11927	.12013	8.3245	.99286	9
52	.11956	.12042	8.3041	.99283	8
53	.11985	.12072	8.2838	.99279	7
54	.12014	.12101	8.2636	.99276	6
55	.12043	.12131	8.2434	.99272	5
56	.12071	.12160	8.2234	.99269	4
57	.12100	.12190	8.2035	.99265	3
58	.12129	.12219	8.1837	.99262	2
59	.12158	.12249	8.1640	.99258	1
60	.12187	.12278	8.1443	.99255	0
	Cos	Ctn	Tan	Sin	

97° (277°)

(262°) 82°

7° (187°)	Sin	Tan	Ctn	Cos	
0	.12187	.12278	8.1443	.99255	60
1	.12216	.12308	8.1248	.99251	59
2	.12245	.12338	8.1054	.99248	58
3	.12274	.12367	8.0860	.99244	57
4	.12302	.12397	8.0667	.99240	56
5	.12331	.12426	8.0476	.99237	55
6	.12360	.12456	8.0285	.99233	54
7	.12389	.12485	8.0095	.99230	53
8	.12418	.12515	7.9906	.99226	52
9	.12447	.12544	7.9718	.99222	51
10	.12476	.12574	7.9530	.99219	50
11	.12504	.12603	7.9344	.99215	49
12	.12533	.12633	7.9158	.99211	48
13	.12562	.12662	7.8973	.99208	47
14	.12591	.12692	7.8789	.99204	46
15	.12620	.12722	7.8606	.99200	45
16	.12649	.12751	7.8424	.99197	44
17	.12678	.12781	7.8243	.99193	43
18	.12706	.12810	7.8062	.99189	42
19	.12735	.12840	7.7882	.99186	41
20	.12764	.12869	7.7704	.99182	40
21	.12793	.12899	7.7525	.99178	39
22	.12822	.12929	7.7348	.99175	38
23	.12851	.12958	7.7171	.99171	37
24	.12880	.12988	7.6996	.99167	36
25	.12908	.13017	7.6821	.99163	35
26	.12937	.13047	7.6647	.99160	34
27	.12966	.13076	7.6473	.99156	33
28	.12995	.13106	7.6301	.99152	32
29	.13024	.13136	7.6129	.99148	31
30	.13053	.13165	7.5958	.99144	30
31	.13081	.13195	7.5787	.99141	29
32	.13110	.13224	7.5618	.99137	28
33	.13139	.13254	7.5449	.99133	27
34	.13168	.13284	7.5281	.99129	26
35	.13197	.13313	7.5113	.99125	25
36	.13226	.13343	7.4947	.99122	24
37	.13254	.13372	7.4781	.99118	23
38	.13283	.13402	7.4615	.99114	22
39	.13312	.13432	7.4451	.99110	21
40	.13341	.13461	7.4287	.99106	20
41	.13370	.13491	7.4124	.99102	19
42	.13399	.13521	7.3962	.99098	18
43	.13427	.13550	7.3800	.99094	17
44	.13456	.13580	7.3639	.99091	16
45	.13485	.13609	7.3479	.99087	15
46	.13514	.13639	7.3319	.99083	14
47	.13543	.13669	7.3160	.99079	13
48	.13572	.13698	7.3002	.99075	12
49	.13600	.13728	7.2844	.99071	11
50	.13629	.13758	7.2687	.99067	10
51	.13658	.13787	7.2531	.99063	9
52	.13687	.13817	7.2375	.99059	8
53	.13716	.13846	7.2220	.99055	7
54	.13744	.13876	7.2066	.99051	6
55	.13773	.13906	7.1912	.99047	5
56	.13802	.13935	7.1759	.99043	4
57	.13831	.13965	7.1607	.99039	3
58	.13860	.13995	7.1455	.99035	2
59	.13889	.14024	7.1304	.99031	1
60	.13917	.14054	7.1154	.99027	0
	Cos	Ctn	Tan	Sin	

NATURAL TRIGONOMETRIC FUNCTIONS

NATURAL TRIGONOMETRIC FUNCTIONS

8° (278°)	(351°) 171°	9° (189°)	(350°) 170°	10° (190°)	(349°) 169°	11° (191°)	(348°) 168°
0	1	2	3	4	5	6	7
8	9	10	11	12	13	14	15
16	17	18	19	20	21	22	23
24	25	26	27	28	29	30	31
32	33	34	35	36	37	38	39
40	41	42	43	44	45	46	47
48	49	50	51	52	53	54	55
56	57	58	59	60	61	62	63
64	65	66	67	68	69	70	71
72	73	74	75	76	77	78	79
80	81	82	83	84	85	86	87
88	89	90	91	92	93	94	95
96	97	98	99	100	101	102	103
104	105	106	107	108	109	110	111
112	113	114	115	116	117	118	119
120	121	122	123	124	125	126	127
128	129	130	131	132	133	134	135
136	137	138	139	140	141	142	143
144	145	146	147	148	149	150	151
152	153	154	155	156	157	158	159
160	161	162	163	164	165	166	167
168	169	170	171	172	173	174	175
176	177	178	179	180	181	182	183
184	185	186	187	188	189	190	191
192	193	194	195	196	197	198	199
200	201	202	203	204	205	206	207
208	209	210	211	212	213	214	215
216	217	218	219	220	221	222	223
224	225	226	227	228	229	230	231
232	233	234	235	236	237	238	239
240	241	242	243	244	245	246	247
248	249	250	251	252	253	254	255
256	257	258	259	260	261	262	263
264	265	266	267	268	269	270	271
272	273	274	275	276	277	278	279
280	281	282	283	284	285	286	287
288	289	290	291	292	293	294	295
296	297	298	299	300	301	302	303
304	305	306	307	308	309	310	311
312	313	314	315	316	317	318	319
320	321	322	323	324	325	326	327
328	329	330	331	332	333	334	335
336	337	338	339	340	341	342	343
344	345	346	347	348	349	350	351
352	353	354	355	356	357	358	359
360	361	362	363	364	365	366	367
368	369	370	371	372	373	374	375
376	377	378	379	380	381	382	383
384	385	386	387	388	389	390	391
392	393	394	395	396	397	398	399
400	401	402	403	404	405	406	407
408	409	410	411	412	413	414	415
416	417	418	419	420	421	422	423
424	425	426	427	428	429	430	431
432	433	434	435	436	437	438	439
440	441	442	443	444	445	446	447
448	449	450	451	452	453	454	455
456	457	458	459	460	461	462	463
464	465	466	467	468	469	470	471
472	473	474	475	476	477	478	479
480	481	482	483	484	485	486	487
488	489	490	491	492	493	494	495
496	497	498	499	500	501	502	503
504	505	506	507	508	509	510	511
512	513	514	515	516	517	518	519
520	521	522	523	524	525	526	527
528	529	530	531	532	533	534	535
536	537	538	539	540	541	542	543
544	545	546	547	548	549	550	551
552	553	554	555	556	557	558	559
560	561	562	563	564	565	566	567
568	569	570	571	572	573	574	575
576	577	578	579	580	581	582	583
584	585	586	587	588	589	590	591
592	593	594	595	596	597	598	599
600	601	602	603	604	605	606	607
608	609	610	611	612	613	614	615
616	617	618	619	620	621	622	623
624	625	626	627	628	629	630	631
632	633	634	635	636	637	638	639
640	641	642	643	644	645	646	647
648	649	650	651	652	653	654	655
656	657	658	659	660	661	662	663
664	665	666	667	668	669	670	671
672	673	674	675	676	677	678	679
680	681	682	683	684	685	686	687
688	689	690	691	692	693	694	695
696	697	698	699	700	701	702	703
704	705	706	707	708	709	710	711
712	713	714	715	716	717	718	719
720	721	722	723	724	725	726	727
728	729	730	731	732	733	734	735
736	737	738	739	740	741	742	743
744	745	746	747	748	749	750	751
752	753	754	755	756	757	758	759
760	761	762	763	764	765	766	767
768	769	770	771	772	773	774	775
776	777	778	779	780	781	782	783
784	785	786	787	788	789	790	791
792	793	794	795	796	797	798	799
800	801	802	803	804	805	806	807
808	809	810	811	812	813	814	815
816	817	818	819	820	821	822	823
824	825	826	827	828	829	830	831
832	833	834	835	836	837	838	839
840	841	842	843	844	845	846	847
848	849	850	851	852	853	854	855
856	857	858	859	860	861	862	863
864	865	866	867	868	869	870	871
872	873	874	875	876	877	878	879
880	881	882	883	884	885	886	887
888	889	890	891	892	893	894	895
896	897	898	899	900	901	902	903
904	905	906	907	908	909	910	911
912	913	914	915	916	917	918	919
920	921	922	923	924	925	926	927
928	929	930	931	932	933	934	935
936	937	938	939	940	941	942	943
944	945	946	947	948	949	950	951
952	953	954	955	956	957	958	959
960	961	962	963	964	965	966	967
968	969	970	971	972	973	974	975
976	977	978	979	980	981	982	983
984	985	986	987	988	989	990	991
992	993	994	995	996	997	998	999
1000	1001	1002	1003	1004	1005	1006	1007
1008	1009	1010	1011	1012	1013	1014	1015
1016	1017	1018	1019	1020	1021	1022	1023
1024	1025	1026	1027	1028	1029	1030	1031
1032	1033	1034	1035	1036	1037	1038	1039
1040	1041	1042	1043	1044	1045	1046	1047
1048	1049	1050	1051	1052	1053	1054	1055
1056	1057	1058	1059	1060	1061	1062	1063
1064	1065	1066	1067	1068	1069	1070	1071
1072	1073	1074	1075	1076	1077	1078	1079
1080	1081	1082	1083	1084	1085	1086	1087
1088	1089	1090	1091	1092	1093	1094	1095
1096	1097	1098	1099	1100	1101	1102	1103
1104	1105	1106	1107	1108	1109	1110	1111
1112	1113	1114	1115	1116	1117	1118	1119
1120	1121	1122	1123	1124	1125	1126	1127
1128	1129	1130	1131	1132	1133	1134	1135
1136	1137	1138	1139	1140	1141	1142	1143
1144	1145	1146	1147	1148	1149	1150	1151
1152	1153	1154	1155	1156	1157	1158	1159
1160	1161	1162	1163	1164	1165	1166	1167
1168	1169	1170	1171	1172	1173	1174	1175
1176	1177	1178	1179	1180	1181	1182	1183
1184	1185	1186	1187	1188	1189	1190	1191
1192	1193	1194	1195	1196	1197	1198	1199
1200	1201	1202	1203	1204	1205	1206	1207
1208	1209	1210	1211	1212	1213	1214	1215
1216	1217	1218	1219	1220	1221	1222	1223
1224	1225	1226	1227	1228	1229	1230	1231
1232	1233	1234	1235	1236	1237	1238	1239
1240	1241	1242	1243	1244	1245	1246	1247
1248	1249	1250	1251	1252	1253	1254	1255
1256	1257	1258	1259	1260	1261	1262	1263
1264	1265	1266	1267	1268	1269	1270	1271
1272	1273	1274	1275	1276	1277	1278	1279
1280	1281	1282	1283	1284	1285	1286	1287
1288	1289	1290	1291	1292	1293	1294	1295
1296	1297	1298	1299	1300	1301	1302	1303
1304	1305	1306	1307	1308	1309	1310	1311
1312	1313	1314	1315	1316	1317	1318	1319
1320	1321	1322	1323	1324	1325	1326	1327
1328	1329	1330	1331	1332	1333	1334	1335
1336	1337	1338	1339	1340	1341	1342	1343
1344	1345	1346	1347	1348	1349	1350	1351
1352	1353	1354	1355	1356	1357	1358	1359

NATURAL TRIGONOMETRIC FUNCTIONS

12° (282°)	(347°) 167°	13° (193°)	(346°) 166°	(194°)	(345°) 165°	15° (195°)	(344°)																
Sin	Tan	Ctn	Cos	Sin	Tan	Ctn	Cos																
0	.20791	.21256	4.7046	.97815	60	.22495	.23087	4.3315	.97437	60	.24192	.24933	4.0108	.97030	60	.25882	.26795	3.7321	.96593	60			
1	.20820	.21286	4.6979	.97809	59	1	.22523	.23117	4.3257	.97430	59	1	.24933	.24954	4.0058	.97023	59	1	.25910	.26826	3.7277	.96585	59
2	.20848	.21316	4.6912	.97803	58	2	.22552	.23148	4.3200	.97424	58	2	.24954	.24975	4.0009	.97015	58	2	.25938	.26857	3.7234	.96578	58
3	.20877	.21347	4.6845	.97797	57	3	.22580	.23179	4.3143	.97417	57	3	.24975	.24996	3.9959	.97008	57	3	.25965	.26888	3.7191	.96570	57
4	.20905	.21377	4.6779	.97791	56	4	.22608	.23209	4.3086	.97411	56	4	.24996	.25017	3.9910	.97001	56	4	.25994	.26920	3.7148	.96562	56
5	.20933	.21408	4.6712	.97784	55	5	.22637	.23240	4.3029	.97404	55	5	.25017	.25038	3.9861	.96994	55	5	.26022	.26951	3.7105	.96555	55
6	.20962	.21438	4.6646	.97778	54	6	.22665	.23271	4.2972	.97398	54	6	.25038	.25059	3.9812	.96987	54	6	.26050	.26982	3.7062	.96547	54
7	.20990	.21469	4.6580	.97772	53	7	.22693	.23301	4.2916	.97391	53	7	.25059	.25080	3.9763	.96980	53	7	.26079	.27013	3.7019	.96540	53
8	.21019	.21499	4.6514	.97766	52	8	.22722	.23332	4.2859	.97384	52	8	.25080	.25101	3.9714	.96973	52	8	.26107	.27044	3.6976	.96532	52
9	.21047	.21529	4.6448	.97760	51	9	.22750	.23363	4.2803	.97378	51	9	.25101	.25122	3.9665	.96966	51	9	.26135	.27076	3.6933	.96524	51
10	.21076	.21560	4.6382	.97754	50	10	.22778	.23393	4.2747	.97371	50	10	.25122	.25143	3.9617	.96959	50	10	.26163	.27107	3.6891	.96517	50
11	.21104	.21590	4.6317	.97748	49	11	.22807	.23424	4.2691	.97365	49	11	.25143	.25164	3.9568	.96952	49	11	.26191	.27138	3.6848	.96509	49
12	.21132	.21621	4.6252	.97742	48	12	.22835	.23455	4.2635	.97358	48	12	.25164	.25185	3.9520	.96945	48	12	.26219	.27169	3.6806	.96502	48
13	.21161	.21651	4.6187	.97735	47	13	.22863	.23485	4.2580	.97351	47	13	.25185	.25206	3.9471	.96937	47	13	.26247	.27201	3.6764	.96494	47
14	.21189	.21682	4.6122	.97729	46	14	.22892	.23516	4.2524	.97345	46	14	.25206	.25227	3.9423	.96930	46	14	.26275	.27232	3.6722	.96486	46
15	.21218	.21712	4.6057	.97723	45	15	.22920	.23547	4.2468	.97338	45	15	.25227	.25248	3.9375	.96923	45	15	.26303	.27263	3.6680	.96479	45
16	.21246	.21743	4.5993	.97717	44	16	.22948	.23578	4.2413	.97331	44	16	.25248	.25269	3.9327	.96916	44	16	.26331	.27294	3.6638	.96471	44
17	.21275	.21773	4.5928	.97711	43	17	.22977	.23608	4.2358	.97325	43	17	.25269	.25290	3.9279	.96909	43	17	.26359	.27326	3.6596	.96463	43
18	.21303	.21804	4.5864	.97705	42	18	.23005	.23639	4.2303	.97318	42	18	.25290	.25311	3.9232	.96902	42	18	.26387	.27357	3.6554	.96456	42
19	.21331	.21834	4.5800	.97698	41	19	.23033	.23670	4.2248	.97311	41	19	.25311	.25332	3.9184	.96894	41	19	.26415	.27388	3.6512	.96448	41
20	.21360	.21864	4.5736	.97692	40	20	.23062	.23700	4.2193	.97304	40	20	.25332	.25353	3.9136	.96887	40	20	.26443	.27419	3.6470	.96440	40
21	.21388	.21895	4.5673	.97686	39	21	.23090	.23731	4.2139	.97298	39	21	.25353	.25374	3.9089	.96880	39	21	.26471	.27451	3.6429	.96433	39
22	.21417	.21925	4.5609	.97680	38	22	.23118	.23762	4.2084	.97291	38	22	.25374	.25395	3.9042	.96873	38	22	.26500	.27482	3.6387	.96425	38
23	.21445	.21956	4.5546	.97673	37	23	.23146	.23793	4.2030	.97284	37	23	.25395	.25416	3.8995	.96866	37	23	.26528	.27513	3.6346	.96417	37
24	.21474	.21986	4.5483	.97667	36	24	.23175	.23823	4.1976	.97278	36	24	.25416	.25437	3.8947	.96858	36	24	.26556	.27545	3.6305	.96410	36
25	.21502	.22017	4.5420	.97661	35	25	.23203	.23854	4.1922	.97271	35	25	.25437	.25458	3.8900	.96851	35	25	.26584	.27576	3.6264	.96402	35
26	.21530	.22047	4.5357	.97655	34	26	.23231	.23885	4.1868	.97264	34	26	.25458	.25479	3.8854	.96844	34	26	.26612	.27607	3.6222	.96394	34
27	.21559	.22078	4.5294	.97648	33	27	.23260	.23916	4.1814	.97257	33	27	.25479	.25500	3.8807	.96837	33	27	.26640	.27638	3.6181	.96386	33
28	.21587	.22108	4.5232	.97642	32	28	.23288	.23946	4.1760	.97251	32	28	.25500	.25521	3.8760	.96830	32	28	.26668	.27670	3.6140	.96379	32
29	.21616	.22139	4.5169	.97636	31	29	.23316	.23977	4.1706	.97244	31	29	.25521	.25542	3.8714	.96822	31	29	.26696	.27701	3.6100	.96371	31
30	.21644	.22169	4.5107	.97630	30	30	.23345	.24008	4.1653	.97237	30	30	.25542	.25563	3.8667	.96815	30	30	.26724	.27732	3.6059	.96363	30
31	.21672	.22200	4.5045	.97623	29	31	.23373	.24039	4.1600	.97230	29	31	.25563	.25584	3.8621	.96807	29	31	.26752	.27764	3.6018	.96355	29
32	.21701	.22231	4.4983	.97617	28	32	.23401	.24069	4.1547	.97223	28	32	.25584	.25605	3.8575	.96800	28	32	.26780	.27795	3.5978	.96347	28
33	.21729	.22261	4.4922	.97611	27	33	.23429	.24100	4.1493	.97217	27	33	.25605	.25626	3.8528	.96793	27	33	.26808	.27826	3.5937	.96340	27
34	.21758	.22292	4.4860	.97604	26	34	.23458	.24131	4.1441	.97210	26	34	.25626	.25647	3.8482	.96786	26	34	.26836	.27858	3.5897	.96332	26
35	.21786	.22322	4.4799	.97598	25	35	.23485	.24162	4.1388	.97203	25	35	.25647	.25668	3.8436	.96778	25	35	.26864	.27889	3.5856	.96324	25
36	.21814	.22353	4.4737	.97592	24	36	.23514	.24193	4.1335	.97196	24	36	.25668	.25689	3.8391	.96771	24	36	.26892	.27921	3.5816	.96316	24
37	.21843	.22383	4.4676	.97585	23	37	.23542	.24223	4.1282	.97189	23	37	.25689	.25710	3.8345	.96764	23	37	.26920	.27952	3.5776	.96308	23
38	.21871	.22414	4.4615	.97579	22	38	.23571	.24254	4.1230	.97182	22	38	.25710	.25731	3.8299	.96756	22	38	.26948	.27983	3.5736	.96301	22
39	.21899	.22444	4.4555	.97573	21	39	.23599	.24285	4.1178	.97176	21	39	.25731	.25752	3.8254	.96749	21	39	.26976	.28015	3.5696	.96293	21
40	.21928	.22475	4.4494	.97566	20	40	.23627	.24316	4.1126	.97169	20	40	.25752	.25773	3.8208	.96742	20	40	.27004	.28046	3.5656	.96285	20
41	.21956	.22505	4.4434	.97560	19	41	.23655	.24347	4.1074	.97162	19	41	.25773	.25794	3.8163	.96734	19	41	.27032	.28077	3.5616	.96277	19
42	.21985	.22536	4.4373	.97553	18	42	.23684	.24377	4.1022	.97155	18	42	.25794	.25815	3.8118	.96727	18	42	.27060	.28109	3.5576	.96269	18
43	.22013	.22567	4.4313	.97547	17	43	.23712	.24408	4.0970	.97148	17	43	.25815	.25836	3.8073	.96719	17	43	.27088	.28140	3.5536	.96261	17
44	.22041	.22597	4.4253	.97541	16	44	.23740	.24439	4.0918	.97141	16	44	.25836	.25857	3.8028	.96712	16	44	.27116	.28172	3.5497	.96253	16
45	.22070	.22628	4.4194	.97534	15	45	.23769	.24470	4.0867	.97134	15	45	.25857	.25878	3.7983	.96705	15	45	.27144	.28203	3.5457	.96246	15
46	.22098	.22658	4.4134	.97528	14	46	.23797	.24501	4.0815	.97127	14	46	.25878	.25899	3.7938	.96697	14	46	.27172	.28234	3.5418	.96238	14
47	.22126	.22689	4.4075	.97521	13	47	.23825	.24532	4.0764	.97120	13	47	.25899	.25920	3.7893	.96690	13	47	.27200	.28266	3.5379	.96230	13
48	.22155	.22719	4.4015	.97515	12	48	.23853	.24562	4.0713	.97113	12	48	.25920	.25941	3.7848	.96682	12	48	.27228	.28297	3.5339	.96222	12
49	.22183	.22750	4.3956	.97508	11	49	.23882	.24593	4.0662	.97106	11	49	.25941	.25962	3.7804	.96675	11	49	.27256	.28329	3.5300	.96214	11
50	.22212	.22781	4.3897	.97502	10	50	.23910	.24624	4.0611	.97100	10	50	.25962	.25983	3.7759	.96667	10	50	.27284	.28360	3.5261	.96206	10
51	.22240	.22811	4.3838	.97496	9	51	.23938	.24655	4.0560	.97093	9	51	.25983	.26004	3.7715	.96660	9	51	.27312	.28391	3.5222	.96198	9
52	.22268	.22842	4.3779	.97489	8	52	.23966	.24686	4.0509	.97086	8	52	.26004	.26025	3.7671	.96653	8	52	.27340	.28423	3.5183	.96190	8
53	.22297	.22872	4.3721	.97483	7	53	.23995	.24717	4.0459	.97079	7	53	.26025	.26046	3.7627	.96645	7	53	.27368	.28454	3.5144	.96182	7
54	.22325	.22903	4.3662	.97476	6	54	.24																

NATURAL TRIGONOMETRIC FUNCTIONS

16° (196°)	(313°) 163°	17° (197°)	(342°) 162°
Sin Tan Ctn Cos	Sin Tan Ctn Cos	Sin Tan Ctn Cos	Sin Tan Ctn Cos
0 .27564 .28675 3.4874 .96126 60	0 .29237 .30573 3.2709 .95630 60	0 .29237 .30573 3.2709 .95630 60	0 .29237 .30573 3.2709 .95630 60
1 .27592 .28706 3.4836 .96118 59	1 .29265 .30605 3.2675 .95622 59	1 .29265 .30605 3.2675 .95622 59	1 .29265 .30605 3.2675 .95622 59
2 .27620 .28738 3.4798 .96110 58	2 .29293 .30637 3.2641 .95613 58	2 .29293 .30637 3.2641 .95613 58	2 .29293 .30637 3.2641 .95613 58
3 .27648 .28769 3.4760 .96102 57	3 .29321 .30669 3.2607 .95605 57	3 .29321 .30669 3.2607 .95605 57	3 .29321 .30669 3.2607 .95605 57
4 .27676 .28801 3.4722 .96094 56	4 .29348 .30700 3.2573 .95596 56	4 .29348 .30700 3.2573 .95596 56	4 .29348 .30700 3.2573 .95596 56
5 .27704 .28832 3.4684 .96086 55	5 .29376 .30732 3.2539 .95588 55	5 .29376 .30732 3.2539 .95588 55	5 .29376 .30732 3.2539 .95588 55
6 .27731 .28861 3.4646 .96078 54	6 .29404 .30764 3.2506 .95579 54	6 .29404 .30764 3.2506 .95579 54	6 .29404 .30764 3.2506 .95579 54
7 .27759 .28895 3.4608 .96070 53	7 .29432 .30796 3.2472 .95571 53	7 .29432 .30796 3.2472 .95571 53	7 .29432 .30796 3.2472 .95571 53
8 .27787 .28927 3.4570 .96062 52	8 .29460 .30828 3.2438 .95562 52	8 .29460 .30828 3.2438 .95562 52	8 .29460 .30828 3.2438 .95562 52
9 .27815 .28958 3.4533 .96054 51	9 .29487 .30860 3.2405 .95554 51	9 .29487 .30860 3.2405 .95554 51	9 .29487 .30860 3.2405 .95554 51
10 .27843 .28990 3.4495 .96046 50	10 .29515 .30891 3.2371 .95545 50	10 .29515 .30891 3.2371 .95545 50	10 .29515 .30891 3.2371 .95545 50
11 .27871 .29021 3.4458 .96037 49	11 .29543 .30923 3.2338 .95536 49	11 .29543 .30923 3.2338 .95536 49	11 .29543 .30923 3.2338 .95536 49
12 .27899 .29053 3.4420 .96029 48	12 .29571 .30955 3.2305 .95528 48	12 .29571 .30955 3.2305 .95528 48	12 .29571 .30955 3.2305 .95528 48
13 .27927 .29084 3.4383 .96021 47	13 .29599 .30987 3.2272 .95519 47	13 .29599 .30987 3.2272 .95519 47	13 .29599 .30987 3.2272 .95519 47
14 .27955 .29116 3.4346 .96013 46	14 .29626 .31019 3.2238 .95511 46	14 .29626 .31019 3.2238 .95511 46	14 .29626 .31019 3.2238 .95511 46
15 .27983 .29147 3.4308 .96005 45	15 .29654 .31051 3.2205 .95502 45	15 .29654 .31051 3.2205 .95502 45	15 .29654 .31051 3.2205 .95502 45
16 .28011 .29179 3.4271 .95997 44	16 .29682 .31083 3.2172 .95493 44	16 .29682 .31083 3.2172 .95493 44	16 .29682 .31083 3.2172 .95493 44
17 .28039 .29210 3.4234 .95989 43	17 .29710 .31115 3.2139 .95485 43	17 .29710 .31115 3.2139 .95485 43	17 .29710 .31115 3.2139 .95485 43
18 .28067 .29242 3.4197 .95981 42	18 .29737 .31147 3.2106 .95476 42	18 .29737 .31147 3.2106 .95476 42	18 .29737 .31147 3.2106 .95476 42
19 .28095 .29274 3.4160 .95972 41	19 .29765 .31178 3.2073 .95467 41	19 .29765 .31178 3.2073 .95467 41	19 .29765 .31178 3.2073 .95467 41
20 .28123 .29305 3.4124 .95964 40	20 .29793 .31210 3.2041 .95459 40	20 .29793 .31210 3.2041 .95459 40	20 .29793 .31210 3.2041 .95459 40
21 .28150 .29337 3.4087 .95956 39	21 .29821 .31242 3.2008 .95450 39	21 .29821 .31242 3.2008 .95450 39	21 .29821 .31242 3.2008 .95450 39
22 .28178 .29368 3.4050 .95948 38	22 .29849 .31274 3.1975 .95441 38	22 .29849 .31274 3.1975 .95441 38	22 .29849 .31274 3.1975 .95441 38
23 .28206 .29400 3.4014 .95940 37	23 .29876 .31306 3.1943 .95433 37	23 .29876 .31306 3.1943 .95433 37	23 .29876 .31306 3.1943 .95433 37
24 .28234 .29432 3.3977 .95931 36	24 .29904 .31338 3.1910 .95424 36	24 .29904 .31338 3.1910 .95424 36	24 .29904 .31338 3.1910 .95424 36
25 .28262 .29463 3.3941 .95923 35	25 .29932 .31370 3.1878 .95415 35	25 .29932 .31370 3.1878 .95415 35	25 .29932 .31370 3.1878 .95415 35
26 .28290 .29495 3.3904 .95915 34	26 .29960 .31402 3.1845 .95407 34	26 .29960 .31402 3.1845 .95407 34	26 .29960 .31402 3.1845 .95407 34
27 .28318 .29526 3.3868 .95907 33	27 .29987 .31434 3.1813 .95398 33	27 .29987 .31434 3.1813 .95398 33	27 .29987 .31434 3.1813 .95398 33
28 .28346 .29558 3.3832 .95899 32	28 .30015 .31466 3.1780 .95389 32	28 .30015 .31466 3.1780 .95389 32	28 .30015 .31466 3.1780 .95389 32
29 .28374 .29590 3.3796 .95890 31	29 .30043 .31498 3.1748 .95380 31	29 .30043 .31498 3.1748 .95380 31	29 .30043 .31498 3.1748 .95380 31
30 .28402 .29621 3.3759 .95882 30	30 .30071 .31530 3.1716 .95372 30	30 .30071 .31530 3.1716 .95372 30	30 .30071 .31530 3.1716 .95372 30
31 .28429 .29653 3.3723 .95874 29	31 .30099 .31562 3.1684 .95363 29	31 .30099 .31562 3.1684 .95363 29	31 .30099 .31562 3.1684 .95363 29
32 .28457 .29685 3.3687 .95865 28	32 .30126 .31594 3.1652 .95354 28	32 .30126 .31594 3.1652 .95354 28	32 .30126 .31594 3.1652 .95354 28
33 .28485 .29716 3.3652 .95857 27	33 .30154 .31626 3.1620 .95345 27	33 .30154 .31626 3.1620 .95345 27	33 .30154 .31626 3.1620 .95345 27
34 .28513 .29748 3.3616 .95849 26	34 .30182 .31658 3.1588 .95337 26	34 .30182 .31658 3.1588 .95337 26	34 .30182 .31658 3.1588 .95337 26
35 .28541 .29780 3.3580 .95841 25	35 .30209 .31690 3.1556 .95328 25	35 .30209 .31690 3.1556 .95328 25	35 .30209 .31690 3.1556 .95328 25
36 .28569 .29811 3.3544 .95832 24	36 .30237 .31722 3.1524 .95319 24	36 .30237 .31722 3.1524 .95319 24	36 .30237 .31722 3.1524 .95319 24
37 .28597 .29843 3.3509 .95824 23	37 .30265 .31754 3.1492 .95310 23	37 .30265 .31754 3.1492 .95310 23	37 .30265 .31754 3.1492 .95310 23
38 .28625 .29875 3.3473 .95816 22	38 .30292 .31786 3.1460 .95301 22	38 .30292 .31786 3.1460 .95301 22	38 .30292 .31786 3.1460 .95301 22
39 .28652 .29906 3.3438 .95807 21	39 .30320 .31818 3.1429 .95293 21	39 .30320 .31818 3.1429 .95293 21	39 .30320 .31818 3.1429 .95293 21
40 .28680 .29938 3.3402 .95799 20	40 .30348 .31850 3.1397 .95284 20	40 .30348 .31850 3.1397 .95284 20	40 .30348 .31850 3.1397 .95284 20
41 .28708 .29970 3.3367 .95791 19	41 .30376 .31882 3.1366 .95275 19	41 .30376 .31882 3.1366 .95275 19	41 .30376 .31882 3.1366 .95275 19
42 .28736 .30001 3.3332 .95782 18	42 .30403 .31914 3.1334 .95266 18	42 .30403 .31914 3.1334 .95266 18	42 .30403 .31914 3.1334 .95266 18
43 .28764 .30033 3.3297 .95774 17	43 .30431 .31946 3.1303 .95257 17	43 .30431 .31946 3.1303 .95257 17	43 .30431 .31946 3.1303 .95257 17
44 .28792 .30065 3.3261 .95766 16	44 .30459 .31978 3.1271 .95248 16	44 .30459 .31978 3.1271 .95248 16	44 .30459 .31978 3.1271 .95248 16
45 .28820 .30097 3.3226 .95757 15	45 .30486 .32010 3.1240 .95240 15	45 .30486 .32010 3.1240 .95240 15	45 .30486 .32010 3.1240 .95240 15
46 .28847 .30128 3.3191 .95749 14	46 .30514 .32042 3.1209 .95231 14	46 .30514 .32042 3.1209 .95231 14	46 .30514 .32042 3.1209 .95231 14
47 .28875 .30160 3.3156 .95740 13	47 .30542 .32074 3.1178 .95222 13	47 .30542 .32074 3.1178 .95222 13	47 .30542 .32074 3.1178 .95222 13
48 .28903 .30192 3.3122 .95732 12	48 .30570 .32106 3.1146 .95213 12	48 .30570 .32106 3.1146 .95213 12	48 .30570 .32106 3.1146 .95213 12
49 .28931 .30224 3.3087 .95724 11	49 .30597 .32139 3.1115 .95204 11	49 .30597 .32139 3.1115 .95204 11	49 .30597 .32139 3.1115 .95204 11
50 .28959 .30255 3.3052 .95715 10	50 .30625 .32171 3.1084 .95195 10	50 .30625 .32171 3.1084 .95195 10	50 .30625 .32171 3.1084 .95195 10
51 .28987 .30287 3.3017 .95707 9	51 .30653 .32203 3.1053 .95186 9	51 .30653 .32203 3.1053 .95186 9	51 .30653 .32203 3.1053 .95186 9
52 .29015 .30319 3.2983 .95698 8	52 .30680 .32235 3.1022 .95177 8	52 .30680 .32235 3.1022 .95177 8	52 .30680 .32235 3.1022 .95177 8
53 .29042 .30351 3.2948 .95690 7	53 .30708 .32267 3.0991 .95168 7	53 .30708 .32267 3.0991 .95168 7	53 .30708 .32267 3.0991 .95168 7
54 .29070 .30382 3.2914 .95681 6	54 .30736 .32299 3.0961 .95159 6	54 .30736 .32299 3.0961 .95159 6	54 .30736 .32299 3.0961 .95159 6
55 .29098 .30414 3.2879 .95673 5	55 .30763 .32331 3.0930 .95150 5	55 .30763 .32331 3.0930 .95150 5	55 .30763 .32331 3.0930 .95150 5
56 .29126 .30446 3.2845 .95664 4	56 .30791 .32363 3.0899 .95142 4	56 .30791 .32363 3.0899 .95142 4	56 .30791 .32363 3.0899 .95142 4
57 .29154 .30478 3.2811 .95656 3	57 .30819 .32395 3.0868 .95133 3	57 .30819 .32395 3.0868 .95133 3	57 .30819 .32395 3.0868 .95133 3
58 .29182 .30509 3.2777 .95647 2	58 .30846 .32428 3.0838 .95124 2	58 .30846 .32428 3.0838 .95124 2	58 .30846 .32428 3.0838 .95124 2
59 .29209 .30541 3.2743 .95639 1	59 .30874 .32460 3.0807 .95115 1	59 .30874 .32460 3.0807 .95115 1	59 .30874 .32460 3.0807 .95115 1
60 .29237 .30573 3.2709 .95630 0	60 .30902 .32492 3.0777 .95106 0	60 .30902 .32492 3.0777 .95106 0	60 .30902 .32492 3.0777 .95106 0
Cos Ctn Tan Sin	Cos Ctn Tan Sin	Cos Ctn Tan Sin	Cos Ctn Tan Sin

106° (286°)

(253°) 73°

107° (287°)

(252°) 72°

Table V

NATURAL TRIGONOMETRIC FUNCTIONS

183

18° (198°)					(341°) 161°					19° (199°)					(340°) 160°				
	Sin	Tan	Ctn	Cos			Sin	Tan	Ctn	Cos			Sin	Tan	Ctn	Cos			
0	.30902	.32492	3.0777	.95106	60	0	.32557	.34433	2.9042	.94552	60	0	.32557	.34433	2.9042	.94552	60		
1	.30929	.32524	3.0746	.95097	59	1	.32584	.34465	2.9015	.94542	59	1	.32584	.34465	2.9015	.94542	59		
2	.30957	.32556	3.0716	.95088	58	2	.32612	.34498	2.8987	.94533	58	2	.32612	.34498	2.8987	.94533	58		
3	.30985	.32588	3.0686	.95079	57	3	.32639	.34530	2.8960	.94523	57	3	.32639	.34530	2.8960	.94523	57		
4	.31012	.32621	3.0655	.95070	56	4	.32667	.34563	2.8933	.94514	56	4	.32667	.34563	2.8933	.94514	56		
5	.31040	.32653	3.0625	.95061	55	5	.32694	.34596	2.8905	.94504	55	5	.32694	.34596	2.8905	.94504	55		
6	.31068	.32685	3.0595	.95052	54	6	.32722	.34628	2.8878	.94495	54	6	.32722	.34628	2.8878	.94495	54		
7	.31095	.32717	3.0565	.95043	53	7	.32749	.34661	2.8851	.94485	53	7	.32749	.34661	2.8851	.94485	53		
8	.31123	.32749	3.0535	.95033	52	8	.32777	.34693	2.8824	.94476	52	8	.32777	.34693	2.8824	.94476	52		
9	.31151	.32782	3.0505	.95024	51	9	.32804	.34726	2.8797	.94466	51	9	.32804	.34726	2.8797	.94466	51		
10	.31178	.32814	3.0475	.95015	50	10	.32832	.34758	2.8770	.94457	50	10	.32832	.34758	2.8770	.94457	50		
11	.31206	.32846	3.0445	.95006	49	11	.32859	.34791	2.8743	.94447	49	11	.32859	.34791	2.8743	.94447	49		
12	.31233	.32878	3.0415	.94997	48	12	.32887	.34824	2.8716	.94438	48	12	.32887	.34824	2.8716	.94438	48		
13	.31261	.32911	3.0385	.94988	47	13	.32914	.34856	2.8689	.94428	47	13	.32914	.34856	2.8689	.94428	47		
14	.31289	.32943	3.0356	.94979	46	14	.32942	.34889	2.8662	.94418	46	14	.32942	.34889	2.8662	.94418	46		
15	.31316	.32975	3.0326	.94970	45	15	.32969	.34922	2.8636	.94409	45	15	.32969	.34922	2.8636	.94409	45		
16	.31344	.33007	3.0296	.94961	44	16	.32997	.34954	2.8609	.94399	44	16	.32997	.34954	2.8609	.94399	44		
17	.31372	.33040	3.0267	.94952	43	17	.33024	.34987	2.8582	.94390	43	17	.33024	.34987	2.8582	.94390	43		
18	.31399	.33072	3.0237	.94943	42	18	.33051	.35020	2.8556	.94380	42	18	.33051	.35020	2.8556	.94380	42		
19	.31427	.33104	3.0208	.94933	41	19	.33079	.35052	2.8529	.94370	41	19	.33079	.35052	2.8529	.94370	41		
20	.31454	.33136	3.0178	.94924	40	20	.33106	.35085	2.8502	.94361	40	20	.33106	.35085	2.8502	.94361	40		
21	.31482	.33169	3.0149	.94915	39	21	.33134	.35118	2.8476	.94351	39	21	.33134	.35118	2.8476	.94351	39		
22	.31510	.33201	3.0120	.94906	38	22	.33161	.35150	2.8449	.94342	38	22	.33161	.35150	2.8449	.94342	38		
23	.31537	.33233	3.0090	.94897	37	23	.33189	.35183	2.8423	.94332	37	23	.33189	.35183	2.8423	.94332	37		
24	.31565	.33266	3.0061	.94888	36	24	.33216	.35216	2.8397	.94322	36	24	.33216	.35216	2.8397	.94322	36		
25	.31593	.33298	3.0032	.94878	35	25	.33244	.35248	2.8370	.94313	35	25	.33244	.35248	2.8370	.94313	35		
26	.31620	.33330	3.0003	.94869	34	26	.33271	.35281	2.8344	.94303	34	26	.33271	.35281	2.8344	.94303	34		
27	.31648	.33363	2.9974	.94860	33	27	.33298	.35314	2.8318	.94293	33	27	.33298	.35314	2.8318	.94293	33		
28	.31675	.33395	2.9945	.94851	32	28	.33326	.35346	2.8291	.94284	32	28	.33326	.35346	2.8291	.94284	32		
29	.31703	.33427	2.9916	.94842	31	29	.33353	.35379	2.8265	.94274	31	29	.33353	.35379	2.8265	.94274	31		
30	.31730	.33460	2.9887	.94832	30	30	.33381	.35412	2.8239	.94264	30	30	.33381	.35412	2.8239	.94264	30		
31	.31758	.33492	2.9858	.94823	29	31	.33408	.35445	2.8213	.94254	29	31	.33408	.35445	2.8213	.94254	29		
32	.31786	.33524	2.9829	.94814	28	32	.33436	.35477	2.8187	.94245	28	32	.33436	.35477	2.8187	.94245	28		
33	.31813	.33557	2.9800	.94805	27	33	.33463	.35510	2.8161	.94235	27	33	.33463	.35510	2.8161	.94235	27		
34	.31841	.33589	2.9772	.94795	26	34	.33490	.35543	2.8135	.94225	26	34	.33490	.35543	2.8135	.94225	26		
35	.31868	.33621	2.9743	.94786	25	35	.33518	.35576	2.8109	.94215	25	35	.33518	.35576	2.8109	.94215	25		
36	.31896	.33654	2.9714	.94777	24	36	.33545	.35608	2.8083	.94206	24	36	.33545	.35608	2.8083	.94206	24		
37	.31923	.33686	2.9686	.94768	23	37	.33573	.35641	2.8057	.94196	23	37	.33573	.35641	2.8057	.94196	23		
38	.31951	.33718	2.9657	.94758	22	38	.33600	.35674	2.8032	.94186	22	38	.33600	.35674	2.8032	.94186	22		
39	.31979	.33751	2.9629	.94749	21	39	.33627	.35707	2.8006	.94176	21	39	.33627	.35707	2.8006	.94176	21		
40	.32006	.33783	2.9600	.94740	20	40	.33655	.35740	2.7980	.94167	20	40	.33655	.35740	2.7980	.94167	20		
41	.32034	.33816	2.9572	.94730	19	41	.33682	.35772	2.7955	.94157	19	41	.33682	.35772	2.7955	.94157	19		
42	.32061	.33848	2.9544	.94721	18	42	.33710	.35805	2.7929	.94147	18	42	.33710	.35805	2.7929	.94147	18		
43	.32089	.33881	2.9515	.94712	17	43	.33737	.35838	2.7903	.94137	17	43	.33737	.35838	2.7903	.94137	17		
44	.32116	.33913	2.9487	.94702	16	44	.33764	.35871	2.7878	.94127	16	44	.33764	.35871	2.7878	.94127	16		
45	.32144	.33945	2.9459	.94693	15	45	.33792	.35904	2.7852	.94118	15	45	.33792	.35904	2.7852	.94118	15		
46	.32171	.33978	2.9431	.94684	14	46	.33819	.35937	2.7827	.94108	14	46	.33819	.35937	2.7827	.94108	14		
47	.32199	.34010	2.9403	.94674	13	47	.33846	.35969	2.7801	.94098	13	47	.33846	.35969	2.7801	.94098	13		
48	.32227	.34043	2.9375	.94665	12	48	.33874	.36002	2.7776	.94088	12	48	.33874	.36002	2.7776	.94088	12		
49	.32254	.34075	2.9347	.94656	11	49	.33901	.36035	2.7751	.94078	11	49	.33901	.36035	2.7751	.94078	11		
50	.32282	.34108	2.9319	.94646	10	50	.33929	.36068	2.7725	.94068	10	50	.33929	.36068	2.7725	.94068	10		
51	.32309	.34140	2.9291	.94637	9	51	.33956	.36101	2.7700	.94058	9	51	.33956	.36101	2.7700	.94058	9		
52	.32337	.34173	2.9263	.94627	8	52	.33983	.36134	2.7675	.94049	8	52	.33983	.36134	2.7675	.94049	8		
53	.32364	.34205	2.9235	.94618	7	53	.34011	.36167	2.7650	.94039	7	53	.34011	.36167	2.7650	.94039	7		
54	.32392	.34238	2.9208	.94609	6	54	.34038	.36199	2.7625	.94029	6	54	.34038	.36199	2.7625	.94029	6		
55	.32419	.34270	2.9180	.94599	5	55	.34065	.36232	2.7600	.94019	5	55	.34065	.36232	2.7600	.94019	5		
56	.32447	.34303	2.9152	.94590	4	56	.34093	.36265	2.7575	.94009	4	56	.34093	.36265	2.7575	.94009	4		
57	.32474	.34335	2.9125	.94580	3	57	.34120	.36298	2.7550	.93999	3	57	.34120	.36298	2.7550	.93999	3		
58	.32502	.34368	2.9097	.94571	2	58	.34147	.36331	2.7525	.93989	2	58	.34147	.36331	2.7525	.93989	2		
59	.32529	.34400	2.9070	.94561	1	59	.34175	.36364	2.7500	.93979	1	59	.34175	.36364	2.7500	.93979	1		
60	.32557	.34433	2.9042	.94552	0	60	.34202	.36397	2.7475	.93969	0	60	.34202	.36397	2.7475	.93969	0		
/	Cos	Ctn	Tan	Sin	/	/	Cos	Ctn	Tan	Sin	/	/	Cos	Ctn	Tan	Sin	/		

NATURAL TRIGONOMETRIC FUNCTIONS

20° (20°)	(339°) 159°	21° (201°)			
Sin	Tan	Ctn	Cos		
0	.34202	.36397	2.7475	.93969	60
1	.34229	.36430	2.7450	.93959	59
2	.34257	.36463	2.7425	.93949	58
3	.34284	.36496	2.7400	.93939	57
4	.34311	.36529	2.7376	.93929	56
5	.34339	.36562	2.7351	.93919	55
6	.34366	.36595	2.7326	.93909	54
7	.34393	.36628	2.7302	.93899	53
8	.34421	.36661	2.7277	.93889	52
9	.34448	.36694	2.7253	.93879	51
10	.34475	.36727	2.7228	.93869	50
11	.34503	.36760	2.7204	.93859	49
12	.34530	.36793	2.7179	.93849	48
13	.34557	.36826	2.7155	.93839	47
14	.34584	.36859	2.7130	.93829	46
15	.34612	.36892	2.7106	.93819	45
16	.34639	.36925	2.7082	.93809	44
17	.34666	.36958	2.7058	.93799	43
18	.34694	.36991	2.7034	.93789	42
19	.34721	.37024	2.7009	.93779	41
20	.34748	.37057	2.6985	.93769	40
21	.34775	.37090	2.6961	.93759	39
22	.34803	.37123	2.6937	.93748	38
23	.34830	.37157	2.6913	.93738	37
24	.34857	.37190	2.6889	.93728	36
25	.34884	.37223	2.6865	.93718	35
26	.34912	.37256	2.6841	.93708	34
27	.34939	.37289	2.6818	.93698	33
28	.34966	.37322	2.6794	.93688	32
29	.34993	.37355	2.6770	.93677	31
30	.35021	.37388	2.6746	.93667	30
31	.35048	.37422	2.6723	.93657	29
32	.35075	.37455	2.6699	.93647	28
33	.35102	.37488	2.6675	.93637	27
34	.35130	.37521	2.6652	.93626	26
35	.35157	.37554	2.6628	.93616	25
36	.35184	.37588	2.6605	.93606	24
37	.35211	.37621	2.6581	.93596	23
38	.35239	.37654	2.6558	.93585	22
39	.35266	.37687	2.6534	.93575	21
40	.35293	.37720	2.6511	.93565	20
41	.35320	.37754	2.6488	.93555	19
42	.35347	.37787	2.6464	.93544	18
43	.35375	.37820	2.6441	.93534	17
44	.35402	.37853	2.6418	.93524	16
45	.35429	.37887	2.6395	.93514	15
46	.35456	.37920	2.6371	.93503	14
47	.35484	.37953	2.6348	.93493	13
48	.35511	.37986	2.6325	.93483	12
49	.35538	.38020	2.6302	.93472	11
50	.35565	.38053	2.6279	.93462	10
51	.35592	.38086	2.6256	.93452	9
52	.35619	.38120	2.6233	.93441	8
53	.35647	.38153	2.6210	.93431	7
54	.35674	.38186	2.6187	.93420	6
55	.35701	.38220	2.6165	.93410	5
56	.35728	.38253	2.6142	.93400	4
57	.35755	.38286	2.6119	.93389	3
58	.35782	.38320	2.6096	.93379	2
59	.35810	.38353	2.6074	.93368	1
60	.35837	.38386	2.6051	.93358	0
Cos	Ctn	Tan	Sin		

110° (290°)

(249°) 69°

111° (291°)

(248°) 67°

Table V

NATURAL TRIGONOMETRIC FUNCTIONS

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22° (202°)	(337°) 157°	23° (203°)			
Sin	Tan	Ctn	Cos		
0	.37461	.40403	2.4751	.92718	60
1	.37488	.40436	2.4730	.92707	59
2	.37515	.40470	2.4709	.92697	58
3	.37542	.40504	2.4689	.92686	57
4	.37569	.40538	2.4668	.92675	56
5	.37595	.40572	2.4648	.92664	55
6	.37622	.40606	2.4627	.92653	54
7	.37649	.40640	2.4606	.92642	53
8	.37676	.40674	2.4586	.92631	52
9	.37703	.40707	2.4566	.92620	51
10	.37730	.40741	2.4545	.92609	50
11	.37757	.40775	2.4525	.92598	49
12	.37784	.40809	2.4504	.92587	48
13	.37811	.40843	2.4484	.92576	47
14	.37838	.40877	2.4464	.92565	46
15	.37865	.40911	2.4443	.92554	45
16	.37892	.40945	2.4423	.92543	44
17	.37919	.40979	2.4403	.92532	43
18	.37946	.41013	2.4383	.92521	42
19	.37973	.41047	2.4362	.92510	41
20	.37999	.41081	2.4342	.92499	40
21	.38026	.41115	2.4322	.92488	39
22	.38053	.41149	2.4302	.92477	38
23	.38080	.41183	2.4282	.92466	37
24	.38107	.41217	2.4262	.92455	36
25	.38134	.41251	2.4242	.92444	35
26	.38161	.41285	2.4222	.92432	34
27	.38188	.41319	2.4202	.92421	33
28	.38215	.41353	2.4182	.92410	32
29	.38241	.41387	2.4162	.92399	31
30	.38268	.41421	2.4142	.92388	30
31	.38295	.41455	2.4122	.92377	29
32	.38322	.41490	2.4102	.92366	28
33	.38349	.41524	2.4083	.92355	27
34	.38376	.41558	2.4063	.92343	26
35	.38403	.41592	2.4043	.92332	25
36	.38430	.41626	2.4023	.92321	24
37	.38456	.41660	2.4004	.92310	23
38	.38483	.41694	2.3984	.92299	22
39	.38510	.41728	2.3964	.92287	21
40	.38537	.41763	2.3945	.92276	20
41	.38564	.41797	2.3925	.92265	19
42	.38591	.41831	2.3905	.92254	18
43	.38617	.41865	2.3886	.92243	17
44	.38644	.41899	2.3867	.92231	16
45	.38671	.41933	2.3847	.92220	15
46	.38698	.41968	2.3828	.92209	14
47	.38725	.42002	2.3808	.92198	13
48	.38752	.42036	2.3789	.92186	12
49	.38778	.42070	2.3770	.92175	11
50	.38805	.42105	2.3750	.92164	10
51	.38832	.42139	2.3731	.92152	9
52	.38859	.42173	2.3712	.92141	8
53	.38886	.42207	2.3693	.92130	7
54	.38912	.42242	2.3673	.92119	6
55	.38939	.42276	2.3654	.92107	5
56	.38966	.42310	2.3635	.92096	4
57	.38993	.42345	2.3616	.92085	3
58	.39020	.42379	2.3597	.92073	2
59	.39046	.42413	2.3578	.92062	1
60	.39073	.42447	2.3559	.92050	0
Cos	Ctn	Tan	Sin		

112° (292°)

(247°) 67°

113° (293°)

(246°) 66°

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NATURAL TRIGONOMETRIC FUNCTIONS

Table V

NATURAL TRIGONOMETRIC FUNCTIONS

187

(335°) 155°					25° (205°)					(334°) 26° (206°)					(333°) 153°					27° (207°)					(332°) 152°					
Sin	Tan	Ctn	Cos	'	Sin	Tan	Ctn	Cos	'	Sin	Tan	Ctn	Cos	'	Sin	Tan	Ctn	Cos	'	Sin	Tan	Ctn	Cos	'	Sin	Tan	Ctn	Cos	'	
0	.40674	.44523	2.2460	.91355	60	.42262	.46631	2.1445	.90631	0	.43837	.48773	2.0503	.89879	60	.45399	.50953	1.9626	.89101	60	.45399	.50953	1.9626	.89101	60	.45399	.50953	1.9626	.89101	60
1	.40700	.44558	2.2443	.91343	59	.42288	.46666	2.1429	.90618	1	.43863	.48809	2.0488	.89867	59	.45425	.50989	1.9612	.89087	59	.45425	.50989	1.9612	.89087	59	.45425	.50989	1.9612	.89087	59
2	.40727	.44593	2.2425	.91331	58	.42315	.46702	2.1413	.90605	2	.43889	.48845	2.0473	.89854	58	.45451	.51026	1.9598	.89067	58	.45451	.51026	1.9598	.89067	58	.45451	.51026	1.9598	.89067	58
3	.40753	.44627	2.2408	.91319	57	.42341	.46737	2.1396	.90594	3	.43916	.48881	2.0458	.89841	57	.45477	.51063	1.9584	.89051	57	.45477	.51063	1.9584	.89051	57	.45477	.51063	1.9584	.89051	57
4	.40780	.44662	2.2390	.91307	56	.42367	.46772	2.1380	.90582	4	.43942	.48917	2.0443	.89828	56	.45503	.51099	1.9570	.89048	56	.45503	.51099	1.9570	.89048	56	.45503	.51099	1.9570	.89048	56
5	.40806	.44697	2.2373	.91295	55	.42394	.46808	2.1364	.90569	5	.43968	.48953	2.0428	.89816	55	.45529	.51136	1.9556	.89035	55	.45529	.51136	1.9556	.89035	55	.45529	.51136	1.9556	.89035	55
6	.40833	.44732	2.2355	.91283	54	.42420	.46843	2.1348	.90557	6	.43994	.48989	2.0413	.89803	54	.45554	.51173	1.9542	.89021	54	.45554	.51173	1.9542	.89021	54	.45554	.51173	1.9542	.89021	54
7	.40860	.44767	2.2338	.91272	53	.42446	.46879	2.1332	.90545	7	.44020	.49026	2.0398	.89790	53	.45580	.51209	1.9528	.89008	53	.45580	.51209	1.9528	.89008	53	.45580	.51209	1.9528	.89008	53
8	.40886	.44802	2.2320	.91260	52	.42473	.46914	2.1315	.90532	8	.44046	.49062	2.0383	.89777	52	.45606	.51246	1.9514	.88995	52	.45606	.51246	1.9514	.88995	52	.45606	.51246	1.9514	.88995	52
9	.40913	.44837	2.2303	.91248	51	.42499	.46950	2.1299	.90520	9	.44072	.49098	2.0368	.89764	51	.45632	.51283	1.9500	.88981	51	.45632	.51283	1.9500	.88981	51	.45632	.51283	1.9500	.88981	51
10	.40939	.44872	2.2286	.91236	50	.42525	.46985	2.1283	.90507	10	.44098	.49134	2.0353	.89752	50	.45658	.51319	1.9486	.88968	50	.45658	.51319	1.9486	.88968	50	.45658	.51319	1.9486	.88968	50
11	.40966	.44907	2.2268	.91224	49	.42552	.47021	2.1267	.90495	11	.44124	.49170	2.0338	.89739	49	.45684	.51356	1.9472	.88955	49	.45684	.51356	1.9472	.88955	49	.45684	.51356	1.9472	.88955	49
12	.40992	.44942	2.2251	.91212	48	.42578	.47056	2.1251	.90483	12	.44151	.49206	2.0323	.89726	48	.45710	.51393	1.9458	.88942	48	.45710	.51393	1.9458	.88942	48	.45710	.51393	1.9458	.88942	48
13	.41019	.44977	2.2234	.91200	47	.42604	.47092	2.1235	.90470	13	.44177	.49242	2.0308	.89713	47	.45736	.51430	1.9444	.88929	47	.45736	.51430	1.9444	.88929	47	.45736	.51430	1.9444	.88929	47
14	.41045	.45012	2.2216	.91188	46	.42631	.47128	2.1219	.90458	14	.44203	.49278	2.0293	.89700	46	.45762	.51467	1.9430	.88915	46	.45762	.51467	1.9430	.88915	46	.45762	.51467	1.9430	.88915	46
15	.41072	.45047	2.2199	.91176	45	.42657	.47163	2.1203	.90446	15	.44229	.49315	2.0278	.89687	45	.45787	.51503	1.9416	.88902	45	.45787	.51503	1.9416	.88902	45	.45787	.51503	1.9416	.88902	45
16	.41098	.45082	2.2182	.91164	44	.42683	.47199	2.1187	.90433	16	.44255	.49351	2.0263	.89674	44	.45813	.51540	1.9402	.88888	44	.45813	.51540	1.9402	.88888	44	.45813	.51540	1.9402	.88888	44
17	.41125	.45117	2.2165	.91152	43	.42709	.47234	2.1171	.90421	17	.44281	.49387	2.0248	.89662	43	.45839	.51577	1.9388	.88875	43	.45839	.51577	1.9388	.88875	43	.45839	.51577	1.9388	.88875	43
18	.41151	.45152	2.2148	.91140	42	.42736	.47270	2.1155	.90408	18	.44307	.49423	2.0233	.89649	42	.45865	.51614	1.9375	.88862	42	.45865	.51614	1.9375	.88862	42	.45865	.51614	1.9375	.88862	42
19	.41178	.45187	2.2130	.91128	41	.42762	.47305	2.1139	.90396	19	.44333	.49459	2.0219	.89636	41	.45891	.51651	1.9361	.88848	41	.45891	.51651	1.9361	.88848	41	.45891	.51651	1.9361	.88848	41
20	.41204	.45222	2.2113	.91116	40	.42788	.47341	2.1123	.90383	20	.44359	.49495	2.0204	.89623	40	.45917	.51688	1.9347	.88835	40	.45917	.51688	1.9347	.88835	40	.45917	.51688	1.9347	.88835	40
21	.41231	.45257	2.2096	.91104	39	.42815	.47377	2.1107	.90371	21	.44385	.49532	2.0189	.89610	39	.45942	.51724	1.9333	.88822	39	.45942	.51724	1.9333	.88822	39	.45942	.51724	1.9333	.88822	39
22	.41257	.45292	2.2079	.91092	38	.42841	.47412	2.1092	.90358	22	.44411	.49568	2.0174	.89597	38	.45968	.51761	1.9319	.88809	38	.45968	.51761	1.9319	.88809	38	.45968	.51761	1.9319	.88809	38
23	.41284	.45327	2.2062	.91080	37	.42867	.47448	2.1076	.90346	23	.44437	.49604	2.0160	.89584	37	.45994	.51798	1.9306	.88795	37	.45994	.51798	1.9306	.88795	37	.45994	.51798	1.9306	.88795	37
24	.41310	.45362	2.2045	.91068	36	.42894	.47483	2.1060	.90334	24	.44464	.49640	2.0145	.89571	36	.46020	.51835	1.9292	.88782	36	.46020	.51835	1.9292	.88782	36	.46020	.51835	1.9292	.88782	36
25	.41337	.45397	2.2028	.91056	35	.42920	.47519	2.1044	.90321	25	.44490	.49677	2.0130	.89558	35	.46046	.51872	1.9278	.88768	35	.46046	.51872	1.9278	.88768	35	.46046	.51872	1.9278	.88768	35
26	.41363	.45432	2.2011	.91044	34	.42946	.47555	2.1028	.90309	26	.44516	.49713	2.0115	.89545	34	.46072	.51909	1.9265	.88755	34	.46072	.51909	1.9265	.88755	34	.46072	.51909	1.9265	.88755	34
27	.41390	.45467	2.1994	.91032	33	.42972	.47590	2.1013	.90296	27	.44542	.49749	2.0101	.89532	33	.46098	.51946	1.9251	.88742	33	.46098	.51946	1.9251	.88742	33	.46098	.51946	1.9251	.88742	33
28	.41416	.45502	2.1977	.91020	32	.42998	.47626	2.0997	.90284	28	.44568	.49785	2.0086	.89519	32	.46123	.51983	1.9237	.88728	32	.46123	.51983	1.9237	.88728	32	.46123	.51983	1.9237	.88728	32
29	.41443	.45538	2.1960	.91008	31	.43025	.47662	2.0981	.90271	29	.44594	.49822	2.0072	.89506	31	.46149	.52020	1.9223	.88715	31	.46149	.52020	1.9223	.88715	31	.46149	.52020	1.9223	.88715	31
30	.41469	.45573	2.1943	.90996	30	.43051	.47698	2.0965	.90259	30	.44620	.49858	2.0057	.89493	30	.46175	.52057	1.9210	.88701	30	.46175	.52057	1.9210	.88701	30	.46175	.52057	1.9210	.88701	30
31	.41496	.45608	2.1926	.90984	29	.43077	.47733	2.0950	.90246	31	.44646	.49894	2.0042	.89480	29	.46201	.52094	1.9196	.88688	29	.46201	.52094	1.9196	.88688	29	.46201	.52094	1.9196	.88688	29
32	.41522	.45643	2.1909	.90972	28	.43104	.47769	2.0934	.90233	32	.44672	.49931	2.0028	.89467	28	.46226	.52131	1.9182	.88674	28	.46226	.52131	1.9182	.88674	28	.46226	.52131	1.9182	.88674	28
33	.41549	.45678	2.1892	.90960	27	.43130	.47805	2.0918</																						

NATURAL TRIGONOMETRIC FUNCTIONS

	Sin	Tan	Ctn	Cos	
0	.46947	.53171	1.8807	.88295	60
1	.46973	.53208	1.8794	.88281	59
2	.46999	.53246	1.8781	.88267	58
3	.47024	.53283	1.8768	.88254	57
4	.47050	.53320	1.8755	.88240	56
5	.47076	.53358	1.8741	.88226	55
6	.47101	.53395	1.8728	.88213	54
7	.47127	.53432	1.8715	.88199	53
8	.47153	.53470	1.8702	.88185	52
9	.47178	.53507	1.8689	.88172	51
10	.47204	.53545	1.8676	.88158	50
11	.47229	.53582	1.8663	.88144	49
12	.47255	.53620	1.8650	.88130	48
13	.47281	.53657	1.8637	.88117	47
14	.47306	.53694	1.8624	.88103	46
15	.47332	.53732	1.8611	.88089	45
16	.47358	.53769	1.8598	.88075	44
17	.47383	.53807	1.8585	.88062	43
18	.47409	.53844	1.8572	.88048	42
19	.47434	.53882	1.8559	.88034	41
20	.47460	.53920	1.8546	.88020	40
21	.47486	.53957	1.8533	.88006	39
22	.47511	.53995	1.8520	.87993	38
23	.47537	.54032	1.8507	.87979	37
24	.47562	.54070	1.8495	.87965	36
25	.47588	.54107	1.8482	.87951	35
26	.47614	.54145	1.8469	.87937	34
27	.47639	.54183	1.8456	.87923	33
28	.47665	.54220	1.8443	.87909	32
29	.47690	.54258	1.8430	.87896	31
30	.47716	.54296	1.8418	.87882	30
31	.47741	.54333	1.8405	.87868	29
32	.47767	.54371	1.8392	.87854	28
33	.47793	.54409	1.8379	.87840	27
34	.47818	.54446	1.8367	.87826	26
35	.47844	.54484	1.8354	.87812	25
36	.47869	.54522	1.8341	.87798	24
37	.47895	.54560	1.8329	.87784	23
38	.47920	.54597	1.8316	.87770	22
39	.47946	.54635	1.8303	.87756	21
40	.47971	.54673	1.8291	.87743	20
41	.47997	.54711	1.8278	.87729	19
42	.48022	.54748	1.8265	.87715	18
43	.48048	.54786	1.8253	.87701	17
44	.48073	.54824	1.8240	.87687	16
45	.48099	.54862	1.8228	.87673	15
46	.48124	.54900	1.8215	.87659	14
47	.48150	.54938	1.8202	.87645	13
48	.48175	.54975	1.8190	.87631	12
49	.48201	.55013	1.8177	.87617	11
50	.48226	.55051	1.8165	.87603	10
51	.48252	.55089	1.8152	.87589	9
52	.48277	.55127	1.8140	.87575	8
53	.48303	.55165	1.8127	.87561	7
54	.48328	.55203	1.8115	.87546	6
55	.48354	.55241	1.8103	.87532	5
56	.48379	.55279	1.8090	.87518	4
57	.48405	.55317	1.8078	.87504	3
58	.48430	.55355	1.8065	.87490	2
59	.48456	.55393	1.8053	.87476	1
60	.48481	.55431	1.8040	.87462	0
	Cos	Ctn	Tan	Sin	

118° (298°)

(241°) 61°

	Sin	Tan	Ctn	Cos	
0	.48481	.55431	1.8040	.87462	60
1	.48506	.55469	1.8028	.87448	59
2	.48532	.55507	1.8016	.87434	58
3	.48557	.55545	1.8003	.87420	57
4	.48583	.55583	1.7991	.87406	56
5	.48608	.55621	1.7979	.87391	55
6	.48634	.55659	1.7966	.87377	54
7	.48659	.55697	1.7954	.87363	53
8	.48684	.55736	1.7942	.87349	52
9	.48710	.55774	1.7930	.87335	51
10	.48735	.55812	1.7917	.87321	50
11	.48761	.55850	1.7905	.87306	49
12	.48786	.55888	1.7893	.87292	48
13	.48811	.55926	1.7881	.87278	47
14	.48837	.55964	1.7868	.87264	46
15	.48862	.56003	1.7856	.87250	45
16	.48888	.56041	1.7844	.87235	44
17	.48913	.56079	1.7832	.87221	43
18	.48938	.56117	1.7820	.87207	42
19	.48964	.56156	1.7808	.87193	41
20	.48989	.56194	1.7796	.87178	40
21	.49014	.56232	1.7783	.87164	39
22	.49040	.56270	1.7771	.87150	38
23	.49065	.56309	1.7759	.87136	37
24	.49090	.56347	1.7747	.87121	36
25	.49116	.56385	1.7735	.87107	35
26	.49141	.56424	1.7723	.87093	34
27	.49166	.56462	1.7711	.87079	33
28	.49192	.56501	1.7699	.87064	32
29	.49217	.56539	1.7687	.87050	31
30	.49242	.56577	1.7675	.87036	30
31	.49268	.56616	1.7663	.87021	29
32	.49293	.56654	1.7651	.87007	28
33	.49318	.56693	1.7639	.86993	27
34	.49344	.56731	1.7627	.86978	26
35	.49369	.56769	1.7615	.86964	25
36	.49394	.56808	1.7603	.86949	24
37	.49419	.56846	1.7591	.86935	23
38	.49445	.56885	1.7579	.86921	22
39	.49470	.56923	1.7567	.86906	21
40	.49495	.56962	1.7555	.86892	20
41	.49521	.57000	1.7544	.86878	19
42	.49546	.57039	1.7532	.86863	18
43	.49571	.57078	1.7520	.86849	17
44	.49596	.57116	1.7508	.86834	16
45	.49622	.57155	1.7496	.86820	15
46	.49647	.57193	1.7485	.86805	14
47	.49672	.57232	1.7473	.86791	13
48	.49697	.57271	1.7461	.86777	12
49	.49723	.57309	1.7449	.86762	11
50	.49748	.57348	1.7437	.86748	10
51	.49773	.57386	1.7426	.86733	9
52	.49798	.57425	1.7414	.86719	8
53	.49824	.57464	1.7402	.86704	7
54	.49849	.57503	1.7391	.86690	6
55	.49874	.57541	1.7379	.86675	5
56	.49899	.57580	1.7367	.86661	4
57	.49924	.57619	1.7355	.86646	3
58	.49950	.57657	1.7344	.86632	2
59	.49975	.57696	1.7332	.86617	1
60	.50000	.57735	1.7321	.86603	0
	Cos	Ctn	Tan	Sin	

119° (299°)

(240°) 50°

Table V

NATURAL TRIGONOMETRIC FUNCTIONS

	Sin	Tan	Ctn	Cos	
0	.50000	.57735	1.7321	.86603	60
1	.50025	.57774	1.7309	.86588	59
2	.50050	.57813	1.7297	.86573	58
3	.50076	.57851	1.7286	.86559	57
4	.50101	.57890	1.7274	.86544	56
5	.50126	.57929	1.7262	.86530	55
6	.50151	.57968	1.7251	.86515	54
7	.50176	.58007	1.7239	.86501	53
8	.50201	.58046	1.7228	.86486	52
9	.50227	.58085	1.7216	.86471	51
10	.50252	.58124	1.7205	.86457	50
11	.50277	.58162	1.7193	.86442	49
12	.50302	.58201	1.7182	.86427	48
13	.50327	.58240	1.7170	.86413	47
14	.50352	.58279	1.7159	.86398	46
15	.50377	.58318	1.7147	.86384	45
16	.50403	.58357	1.7136	.86369	44
17	.50428	.58396	1.7124	.86354	43
18	.50453	.58435	1.7113	.86340	42
19	.50478	.58474	1.7102	.86325	41
20	.50503	.58513	1.7090	.86310	40
21	.50528	.58552	1.7079	.86295	39
22	.50553	.58591	1.7067	.86281	38
23	.50578	.58631	1.7056	.86266	37
24	.50603	.58670	1.7045	.86251	36
25	.50628	.58709	1.7033	.86237	35
26	.50654	.58748	1.7022	.86222	34
27	.50679	.58787	1.7011	.86207	33
28	.50704	.58826	1.6999	.86192	32
29	.50729	.58865	1.6988	.86178	31
30	.50754	.58905	1.6977	.86163	30
31	.50779	.58944	1.6965	.86148	29
32	.50804	.58983	1.6954	.86133	28
33	.50829	.59022	1.6943	.86119	27
34	.50854	.59061	1.6932	.86104	26
35	.50879	.59101	1.6920	.86089	25
36	.50904	.59140	1.6909	.86074	24
37	.50929	.59179	1.6898	.86059	23
38	.50954	.59218	1.6887	.86044	22
39	.50979	.59258	1.6875	.86030	21
40	.51004	.59297	1.6864	.86015	20
41	.51029	.59336	1.6853	.86000	19
42	.51054	.59376	1.6842	.85985	18
43	.51079	.59415	1.6831	.85970	17
44	.51104	.59454	1.6820	.85956	16
45	.51129	.59494	1.6808	.85941	15
46	.51154	.59533	1.6797	.85926	14
47	.51179	.59573	1.6786	.85911	13
48	.51204	.59612	1.6775	.85896	12
49	.51229	.59651	1.6764	.85881	11
50	.51254	.59691	1.6753	.85866	10
51	.51279	.59730	1.6742	.85851	9
52	.51304	.59770	1.6731	.85836	8
53	.51329	.59809	1.6720	.85821	7
54	.51354	.59849	1.6709	.85806	6
55	.51379	.59888	1.6698	.85792	5
56	.51404	.59928	1.6687	.85777	4
57	.51429	.59967	1.6676	.85762	3
58	.51454	.60007	1.6665	.85747	2
59	.51479	.60046	1.6654	.85732	1
60	.51504	.60086	1.6643	.85717	0
	Cos	Ctn	Tan	Sin	

120° (300°)

(239°) 59°

31° (211°)				(321°)	
°	Sin	Tan	Ctn	Cos	°
0	.51504	.60086	1.6643	.85717	60
1	.51529	.60126	1.6632	.85702	59
2	.51554	.60165	1.6621	.85687	58
3	.51579	.60205	1.6610	.85672	57
4	.51604	.60245	1.6599	.85657	56
5	.51628	.60284	1.6588	.85642	55
6	.51653	.60324	1.6577	.85627	54
7	.51678	.60364	1.6566	.85612	53
8	.51703	.60403	1.6555	.85597	52
9	.51728	.60443	1.6545	.85582	51
10	.51753	.60483	1.6534	.85567	50
11	.51778	.60522	1.6523	.85551	49
12	.51803	.60562	1.6512	.85536	48
13	.51828	.60602	1.6501	.85521	47
14	.51852	.60642	1.6490	.85506	46
15	.51877	.60681	1.6479	.85491	45
16	.51902	.60721	1.6469	.85476	44
17	.51927	.60761	1.6458	.85461	43
18	.51952	.60801	1.6447	.85446	42
19	.51977	.60841	1.6436	.85431	41
20	.52002	.60881	1.6426	.85416	40
21	.52026	.60921	1.6415	.85401	39
22	.52051	.60960	1.6404	.85386	38
23	.52076	.61000	1.6393	.85370	37
24	.52101	.61040	1.6383	.85355	36
25	.52126	.61080	1.6372	.85340	35
26	.52151	.61120	1.6361	.85325	34
27	.52175	.61160	1.6351	.85310	33
28	.52200	.61200	1.6340	.85294	32
29	.52225	.61240	1.6329	.85279	31
30	.52250	.61280	1.6319	.85264	30
31	.52275	.61320	1.6308	.85249	29
32	.52299	.61360	1.6297	.85234	28
33	.52324	.61400	1.6287	.85218	27
34	.52349	.61440	1.6276	.85203	26
35	.52374	.61480	1.6265	.85188	25
36	.52399	.61520	1.6255	.85173	24
37	.52423	.61561	1.6244	.85157	23
38	.52448	.61601	1.6234	.85142	22
39	.52473	.61641	1.6223	.85127	21
40	.52498	.61681	1.6212	.85112	20
41	.52522	.61721	1.6202	.85096	19
42	.52547	.61761	1.6191	.85081	18
43	.52572	.61801	1.6181	.85066	17
44	.52597	.61842	1.6170	.85051	16
45	.52621	.61882	1.6160	.85035	15
46	.52646	.61922	1.6149	.85020	14
47	.52671	.61962	1.6139	.85005	13
48	.52696	.62003	1.6128	.84989	12
49	.52720	.62043	1.6118	.84974	11
50	.52745	.62083	1.6107	.84959	10
51	.52770	.62124	1.6097	.84943	9
52	.52794	.62164	1.6087	.84928	8
53	.52819	.62204	1.6076	.84913	7
54	.52844	.62245	1.6066	.84897	6
55	.52869	.62285	1.6055	.84882	5
56	.52893	.62325	1.6045	.84866	4
57	.52918	.62366	1.6034	.84851	3
58	.52943	.62406	1.6024	.84836	2
59	.52967	.62446	1.6014	.84820	1
60	.52992	.62487	1.6003	.84805	0
°	Cos	Ctn	Tan	Sin	°

NATURAL TRIGONOMETRIC FUNCTIONS

NATURAL TRIGONOMETRIC FUNCTIONS

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32° (327°) 147°	33° (213°)	34° (214°)	35° (215°)	36° (216°)
Sin Tan Ctn Cos	Sin Tan Ctn Cos	Sin Tan Ctn Cos	Sin Tan Ctn Cos	Sin Tan Ctn Cos
0 .52992 .62487 1.6003 .84805 60	0 .54464 .64941 1.5399 .83867 60	0 .55919 .67451 1.4826 .82904 60	0 .57358 .70021 1.4281 .81915 60	0 .58800 .72727 1.3764 .80902 60
1 .53017 .62527 1.5993 .84739 59	1 .54488 .64982 1.5389 .83851 59	1 .55943 .67493 1.4816 .82887 59	1 .57381 .70064 1.4273 .81899 59	1 .58823 .72770 1.3756 .80880 59
2 .53041 .62568 1.5983 .84674 58	2 .54513 .65024 1.5379 .83835 58	2 .55968 .67536 1.4807 .82871 58	2 .57405 .70107 1.4264 .81882 58	2 .58845 .72811 1.3748 .80863 58
3 .53066 .62608 1.5972 .84610 57	3 .54537 .65065 1.5369 .83819 57	3 .55992 .67578 1.4798 .82855 57	3 .57429 .70151 1.4255 .81865 57	3 .58869 .72857 1.3740 .80845 57
4 .53091 .62649 1.5962 .84545 56	4 .54561 .65106 1.5359 .83804 56	4 .56016 .67620 1.4788 .82839 56	4 .57453 .70194 1.4246 .81848 56	4 .58893 .72900 1.3732 .80826 56
5 .53115 .62689 1.5952 .84478 55	5 .54586 .65148 1.5350 .83788 55	5 .56040 .67663 1.4779 .82822 55	5 .57477 .70238 1.4237 .81832 55	5 .58913 .72947 1.3724 .80804 55
6 .53140 .62730 1.5941 .84412 54	6 .54610 .65189 1.5340 .83772 54	6 .56064 .67705 1.4770 .82805 54	6 .57501 .70281 1.4229 .81815 54	6 .58937 .72990 1.3716 .80786 54
7 .53164 .62770 1.5931 .84346 53	7 .54635 .65231 1.5330 .83756 53	7 .56088 .67748 1.4761 .82789 53	7 .57524 .70325 1.4220 .81798 53	7 .58963 .73039 1.3708 .80757 53
8 .53189 .62811 1.5921 .84280 52	8 .54659 .65272 1.5320 .83740 52	8 .56112 .67790 1.4751 .82773 52	8 .57548 .70368 1.4211 .81782 52	8 .58989 .73088 1.3700 .80737 52
9 .53214 .62852 1.5911 .84214 51	9 .54683 .65314 1.5311 .83724 51	9 .56136 .67832 1.4742 .82757 51	9 .57572 .70412 1.4202 .81765 51	9 .59015 .73133 1.3692 .80712 51
10 .53238 .62892 1.5900 .84148 50	10 .54708 .65355 1.5301 .83708 50	10 .56160 .67875 1.4733 .82741 50	10 .57596 .70455 1.4193 .81748 50	10 .59039 .73183 1.3684 .80688 50
11 .53263 .62933 1.5890 .84082 49	11 .54732 .65397 1.5291 .83692 49	11 .56184 .67917 1.4724 .82724 49	11 .57619 .70499 1.4185 .81731 49	11 .59063 .73233 1.3676 .80663 49
12 .53288 .62973 1.5880 .84016 48	12 .54756 .65438 1.5282 .83676 48	12 .56208 .67960 1.4715 .82708 48	12 .57643 .70542 1.4176 .81714 48	12 .59087 .73283 1.3668 .80638 48
13 .53312 .63014 1.5869 .83950 47	13 .54781 .65480 1.5272 .83660 47	13 .56232 .68002 1.4705 .82692 47	13 .57667 .70585 1.4167 .81698 47	13 .59111 .73333 1.3660 .80613 47
14 .53337 .63055 1.5859 .83884 46	14 .54805 .65521 1.5262 .83644 46	14 .56256 .68045 1.4696 .82675 46	14 .57691 .70629 1.4158 .81681 46	14 .59135 .73383 1.3652 .80588 46
15 .53361 .63095 1.5849 .83818 45	15 .54829 .65563 1.5253 .83629 45	15 .56280 .68088 1.4687 .82659 45	15 .57715 .70673 1.4150 .81664 45	15 .59159 .73433 1.3644 .80563 45
16 .53386 .63136 1.5839 .83752 44	16 .54854 .65604 1.5243 .83613 44	16 .56305 .68130 1.4678 .82643 44	16 .57739 .70717 1.4141 .81647 44	16 .59183 .73483 1.3636 .80538 44
17 .53411 .63177 1.5829 .83686 43	17 .54878 .65646 1.5233 .83597 43	17 .56329 .68173 1.4669 .82626 43	17 .57763 .70760 1.4132 .81630 43	17 .59207 .73533 1.3628 .80513 43
18 .53435 .63217 1.5818 .83620 42	18 .54902 .65688 1.5224 .83581 42	18 .56353 .68215 1.4659 .82610 42	18 .57787 .70804 1.4124 .81614 42	18 .59231 .73583 1.3620 .80488 42
19 .53460 .63258 1.5808 .83554 41	19 .54927 .65729 1.5214 .83565 41	19 .56377 .68258 1.4650 .82593 41	19 .57811 .70848 1.4115 .81597 41	19 .59255 .73633 1.3612 .80463 41
20 .53484 .63299 1.5798 .83488 40	20 .54951 .65771 1.5204 .83549 40	20 .56401 .68301 1.4641 .82577 40	20 .57835 .70891 1.4106 .81580 40	20 .59279 .73683 1.3604 .80438 40
21 .53509 .63340 1.5788 .83422 39	21 .54975 .65813 1.5195 .83533 39	21 .56425 .68343 1.4632 .82561 39	21 .57859 .70935 1.4097 .81563 39	21 .59303 .73733 1.3596 .80413 39
22 .53534 .63380 1.5778 .83356 38	22 .54999 .65854 1.5185 .83517 38	22 .56449 .68385 1.4623 .82544 38	22 .57883 .70979 1.4089 .81546 38	22 .59327 .73783 1.3588 .80388 38
23 .53558 .63421 1.5768 .83290 37	23 .55024 .65896 1.5175 .83501 37	23 .56473 .68429 1.4614 .82528 37	23 .57907 .71023 1.4080 .81529 37	23 .59351 .73833 1.3580 .80363 37
24 .53583 .63462 1.5757 .83224 36	24 .55048 .65938 1.5166 .83485 36	24 .56497 .68471 1.4605 .82511 36	24 .57931 .71066 1.4071 .81513 36	24 .59375 .73883 1.3572 .80338 36
25 .53607 .63503 1.5747 .83158 35	25 .55072 .65980 1.5156 .83469 35	25 .56521 .68514 1.4596 .82495 35	25 .57955 .71110 1.4063 .81496 35	25 .59400 .73933 1.3564 .80313 35
26 .53632 .63544 1.5737 .83092 34	26 .55097 .66021 1.5147 .83453 34	26 .56545 .68557 1.4586 .82478 34	26 .57979 .71154 1.4054 .81479 34	26 .59424 .73983 1.3556 .80288 34
27 .53656 .63584 1.5727 .83026 33	27 .55121 .66063 1.5137 .83437 33	27 .56569 .68600 1.4577 .82462 33	27 .58003 .71198 1.4045 .81462 33	27 .59448 .74033 1.3548 .80263 33
28 .53681 .63625 1.5717 .82960 32	28 .55145 .66105 1.5127 .83421 32	28 .56593 .68642 1.4568 .82446 32	28 .58027 .71242 1.4037 .81445 32	28 .59472 .74083 1.3540 .80238 32
29 .53705 .63666 1.5707 .82894 31	29 .55169 .66147 1.5118 .83405 31	29 .56617 .68685 1.4559 .82429 31	29 .58051 .71285 1.4028 .81428 31	29 .59496 .74133 1.3532 .80213 31
30 .53730 .63707 1.5697 .82828 30	30 .55194 .66189 1.5108 .83389 30	30 .56641 .68728 1.4550 .82413 30	30 .58075 .71329 1.4019 .81412 30	30 .59520 .74183 1.3524 .80188 30
31 .53754 .63748 1.5687 .82762 29	31 .55218 .66230 1.5099 .83373 29	31 .56665 .68771 1.4541 .82396 29	31 .58099 .71373 1.4011 .81395 29	31 .59544 .74233 1.3516 .80163 29
32 .53779 .63789 1.5677 .82696 28	32 .55242 .66272 1.5089 .83356 28	32 .56689 .68814 1.4532 .82380 28	32 .58123 .71417 1.4002 .81378 28	32 .59568 .74283 1.3508 .80138 28
33 .53804 .63830 1.5667 .82630 27	33 .55266 .66314 1.5080 .83340 27	33 .56713 .68857 1.4523 .82363 27	33 .58147 .71461 1.3994 .81361 27	33 .59592 .74333 1.3500 .80113 27
34 .53828 .63871 1.5657 .82564 26	34 .55291 .66356 1.5070 .83324 26	34 .56737 .68900 1.4514 .82347 26	34 .58171 .71505 1.3985 .81344 26	34 .59616 .74383 1.3492 .80088 26
35 .53853 .63912 1.5647 .82498 25	35 .55315 .66398 1.5061 .83308 25	35 .56761 .68942 1.4505 .82330 25	35 .58195 .71549 1.3976 .81327 25	35 .59640 .74433 1.3484 .80063 25
36 .53877 .63953 1.5637 .82432 24	36 .55339 .66440 1.5051 .83292 24	36 .56785 .68985 1.4496 .82314 24	36 .58219 .71593 1.3967 .81310 24	36 .59664 .74483 1.3476 .80038 24
37 .53902 .63994 1.5627 .82366 23	37 .55363 .66482 1.5042 .83276 23	37 .56809 .69028 1.4487 .82297 23	37 .58243 .71637 1.3959 .81293 23	37 .59688 .74533 1.3468 .80013 23
38 .53926 .64035 1.5617 .82300 22	38 .55388 .66524 1.5032 .83260 22	38 .56833 .69071 1.4478 .82281 22	38 .58267 .71681 1.3951 .81276 22	38 .59712 .74583 1.3460 .79988 22
39 .53951 .64076 1.5607 .82234 21	39 .55412 .66566 1.5023 .83244 21	39 .56857 .69114 1.4469 .82264 21	39 .58291 .71725 1.3942 .81259 21	39 .59736 .74633 1.3452 .79963 21
40 .53975 .64117 1.5597 .82168 20	40 .55436 .66608 1.5013 .83228 20	40 .56881 .69157 1.4460 .82248 20	40 .58315 .71769 1.3934 .81242 20	40 .59760 .74683 1.3444 .79938 20
41 .54000 .64158 1.5587 .82102 19	41 .55460 .66650 1.5004 .83212 19	41 .56905 .69200 1.4451 .82231 19	41 .58339 .71813 1.3925 .81225 19	41 .59784 .74733 1.3436 .79913 19
42 .54024 .64199 1.5577 .82036 18	42 .55484 .66692 1.4994 .83196 18	42 .56929 .69243 1.4442 .82214 18	42 .58363 .71857 1.3917 .81208 18	42 .59808 .74783 1.3428 .79888 18
43 .54049 .64240 1.5567 .81970 17	43 .55509 .66734 1.4985 .83179 17	43 .56953 .69286 1.4433 .82198 17	43 .58387 .71901 1.3908 .81191 17	43 .59832 .74833 1.3420 .79863 17
44 .54073 .64281 1.5557 .81904 16	44 .55533 .66776 1.4975 .83163 16	44 .56977 .69329 1.4424 .82181 16	44 .58411 .71945 1.3899 .81174 16	44 .59856 .74883 1.3412 .79838 16
45 .54097 .64322 1.5547 .81838 15	45 .55557 .66818 1.4966 .83147 15	45 .57001 .69372 1.4415 .82165 15	45 .58435 .71989 1.3891 .81157 15	45 .59880 .74933 1.3404 .79813 15
46 .54122 .64363 1.5537 .81772 14	46 .55581 .66860 1.4957 .83131 14	46 .57025 .69416 1.4406 .82148 14	46 .58459 .72033 1.3882 .81140 14	46 .59904 .74983 1.3396 .79788 14
47 .54146 .64404 1.5527 .81706 13	47 .55605 .66902 1.4947 .83115 13	47 .57049 .69459 1.4397 .82132 13	47 .58483 .72077 1.3874 .81123 13	47 .59928 .75033 1.3388 .79763 13
48 .54171 .64446 1.5517 .81640 12	48 .55630 .66944 1.4938 .83098 12	48 .57073 .69502 1.4388 .82115 12	48 .58507 .72121 1.3865 .81106 12	48 .59952 .75083 1.3380 .79738 12
49 .54195 .64487 1.5507 .81574 11	49 .55654 .66986 1.4928 .83082 11	49 .57097 .69545 1.4379 .82098 11	49 .58531 .72165 1.3857 .81089 11	49 .59976 .75133 1.3372 .79713 11
50 .54220 .64528 1.5497 .81508 10	50 .55678 .67028 1.4919 .83066 10	50 .57121 .69588 1.4370 .82082 10	50 .58555 .72209 1.3848 .81072 10	50 .60000 .75183 1.3364 .79688 10
51 .54244 .64569 1.5487 .81442 9	51 .55702 .67071 1.4910 .83050 9	51 .57145 .69631 1.4361 .82065 9	51 .58579 .72253 1.3840 .81055 9	51 .60024 .75233 1.3356 .79663 9
52 .54269 .64610 1.5477 .81376 8	52 .55726 .67113 1.4900 .83034 8	52 .57169 .69673 1.4352 .82048 8	52 .58603 .72297 1.3832 .81038 8	52 .60048 .75283 1.3348 .79638 8
53 .54293 .64652 1.5468 .81310 7	53 .55750 .67155 1.4891 .83017 7	53 .57193 .69716 1.4344 .82032 7	53 .58627 .72341 1.3824 .81021 7	53 .60072 .75333 1.3340 .79613 7
54 .54317 .64693 1.5458 .81244 6	54 .55775 .67197 1.4882 .83001 6	54 .57217 .69759 1.4335 .82015 6	54 .58651 .72385 1.3816 .81004 6	54 .60096 .75383 1.3332 .79588 6
55 .54342 .64734 1.5448 .81178 5	55 .55799 .67239 1.4872 .82985 5	55 .57241 .69802 1.4326 .81999 5	55 .58675 .72429 1.3808 .80987 5	55 .60120 .75433 1.3324 .79563 5
56 .54366 .64775 1.5438 .81112 4	56 .55823 .67282 1.4863 .82969 4	56 .57265 .69845 1.4317 .81982 4	56 .58699 .72473 1.3800 .80970 4	56 .60144 .75483 1.3316 .79538 4
57 .54391 .64817 1.5428 .81046 3	57 .55847 .67324 1.4854 .82953 3	57 .57289 .69888 1.4308 .81965 3	57 .58723 .72517 1.3792 .80953 3	57 .60168 .75533 1.3308 .79513 3
58 .54415 .64858 1.5418 .80980 2	58 .55871 .67366 1.4845 .82937 2	58 .57313 .69931 1.4299 .81949 2	58 .58747 .72561 1.3784 .80936 2	58 .60192 .75583 1.3300 .79488 2
59 .54440 .64899 1.5408 .80914 1	59 .55895 .67409 1.4835 .82921 1	59 .57337 .69974 1.4290 .81932 1	59 .58771 .72605 1.3776 .80919 1	59 .60216 .75633 1.3292 .79463 1
60 .54464 .64941 1.5399 .80848 0	60 .55919 .67451 1.4826 .82904 0	60 .57361 .70017 1.4281 .81915 0	60 .58795 .72649 1.3768 .80902 0	60 .60240 .75683 1.3284 .79438 0
Cos Ctn Tan Sin	Cos Ctn Tan Sin	Cos Ctn Tan Sin	Cos Ctn Tan Sin	Cos Ctn Tan Sin

122° (302°) (237°) 57° 123° (303°) (236°) 56° 124° (304°) (235°) 55° 125° (305°) (234°) 54°

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NATURAL TRIGONOMETRIC FUNCTIONS

(323°) 143°					37° (217°)				
	Tan	Ctn	Cos			Sin	Tan	Ctn	Cos
0	.58779	.72654	1.3764	.80902	60	.60182	.75355	1.3270	.79864
1	.58802	.72699	1.3755	.80885	59	.60205	.75401	1.3262	.79846
2	.58826	.72743	1.3747	.80867	58	.60228	.75447	1.3254	.79829
3	.58849	.72788	1.3739	.80850	57	.60251	.75492	1.3246	.79811
4	.58873	.72832	1.3730	.80833	56	.60274	.75538	1.3238	.79793
5	.58896	.72877	1.3722	.80816	55	.60298	.75584	1.3230	.79776
6	.58920	.72921	1.3713	.80799	54	.60321	.75629	1.3222	.79758
7	.58943	.72966	1.3705	.80782	53	.60344	.75675	1.3214	.79741
8	.58967	.73010	1.3697	.80765	52	.60367	.75721	1.3206	.79723
9	.58990	.73055	1.3688	.80748	51	.60390	.75767	1.3198	.79706
10	.59014	.73100	1.3680	.80730	50	.60414	.75812	1.3190	.79688
11	.59037	.73144	1.3672	.80713	49	.60437	.75858	1.3182	.79671
12	.59061	.73189	1.3663	.80696	48	.60460	.75904	1.3175	.79653
13	.59084	.73234	1.3655	.80679	47	.60483	.75950	1.3167	.79635
14	.59108	.73278	1.3647	.80662	46	.60506	.75996	1.3159	.79618
15	.59131	.73323	1.3638	.80644	45	.60529	.76042	1.3151	.79600
16	.59154	.73368	1.3630	.80627	44	.60553	.76088	1.3143	.79583
17	.59178	.73413	1.3622	.80610	43	.60576	.76134	1.3135	.79565
18	.59201	.73457	1.3613	.80593	42	.60599	.76180	1.3127	.79547
19	.59225	.73502	1.3605	.80576	41	.60622	.76226	1.3119	.79530
20	.59248	.73547	1.3597	.80558	40	.60645	.76272	1.3111	.79512
21	.59272	.73592	1.3588	.80541	39	.60668	.76318	1.3103	.79494
22	.59295	.73637	1.3580	.80524	38	.60691	.76364	1.3095	.79477
23	.59318	.73681	1.3572	.80507	37	.60714	.76410	1.3087	.79459
24	.59342	.73726	1.3564	.80489	36	.60738	.76456	1.3079	.79441
25	.59365	.73771	1.3555	.80472	35	.60761	.76502	1.3072	.79424
26	.59389	.73816	1.3547	.80455	34	.60784	.76548	1.3064	.79406
27	.59412	.73861	1.3539	.80438	33	.60807	.76594	1.3056	.79388
28	.59436	.73906	1.3531	.80420	32	.60830	.76640	1.3048	.79371
29	.59459	.73951	1.3522	.80403	31	.60853	.76686	1.3040	.79353
30	.59482	.73996	1.3514	.80386	30	.60876	.76733	1.3032	.79335
31	.59506	.74041	1.3506	.80368	29	.60899	.76779	1.3024	.79318
32	.59529	.74086	1.3498	.80351	28	.60922	.76825	1.3017	.79300
33	.59552	.74131	1.3490	.80334	27	.60945	.76871	1.3009	.79282
34	.59576	.74176	1.3481	.80316	26	.60968	.76918	1.3001	.79264
35	.59599	.74221	1.3473	.80299	25	.60991	.76964	1.2993	.79247
36	.59622	.74267	1.3465	.80282	24	.61015	.77010	1.2985	.79229
37	.59646	.74312	1.3457	.80264	23	.61038	.77057	1.2977	.79211
38	.59669	.74357	1.3449	.80247	22	.61061	.77103	1.2970	.79193
39	.59693	.74402	1.3440	.80230	21	.61084	.77149	1.2962	.79176
40	.59716	.74447	1.3432	.80212	20	.61107	.77196	1.2954	.79158
41	.59739	.74492	1.3424	.80195	19	.61130	.77242	1.2946	.79140
42	.59763	.74538	1.3416	.80178	18	.61153	.77289	1.2938	.79122
43	.59786	.74583	1.3408	.80160	17	.61176	.77335	1.2931	.79105
44	.59809	.74628	1.3400	.80143	16	.61199	.77382	1.2923	.79087
45	.59832	.74674	1.3392	.80125	15	.61222	.77428	1.2915	.79069
46	.59855	.74719	1.3384	.80108	14	.61245	.77475	1.2907	.79051
47	.59879	.74764	1.3375	.80091	13	.61268	.77521	1.2900	.79033
48	.59902	.74810	1.3367	.80073	12	.61291	.77568	1.2892	.79016
49	.59926	.74855	1.3359	.80056	11	.61314	.77615	1.2884	.78998
50	.59949	.74900	1.3351	.80038	10	.61337	.77661	1.2876	.78980
51	.59972	.74946	1.3343	.80021	9	.61360	.77707	1.2869	.78962
52	.59995	.74991	1.3335	.80003	8	.61383	.77754	1.2861	.78944
53	.60019	.75037	1.3327	.79986	7	.61406	.77801	1.2853	.78926
54	.60042	.75082	1.3319	.79968	6	.61429	.77848	1.2846	.78908
55	.60065	.75128	1.3311	.79951	5	.61451	.77895	1.2838	.78891
56	.60089	.75173	1.3303	.79934	4	.61474	.77941	1.2830	.78873
57	.60112	.75219	1.3295	.79916	3	.61497	.77988	1.2822	.78855
58	.60135	.75264	1.3287	.79899	2	.61520	.78035	1.2815	.78837
59	.60158	.75310	1.3278	.79881	1	.61543	.78082	1.2807	.78819
60	.60182	.75355	1.3270	.79864	0	.61566	.78129	1.2799	.78801
	Cos	Ctn	Tan	Sin		Cos	Ctn	Tan	Sin

126° (306°)

(233°) 53°

127° (307°)

(232°) 52°

Table V

NATURAL TRIGONOMETRIC FUNCTIONS

193

33° (218°)					(321°) 141°					39° (219°)					(329°) 140°				
	Sin	Tan	Ctn	Cos			Sin	Tan	Ctn	Cos			Sin	Tan	Ctn	Cos			Sin
0	.61566	.78129	1.2799	.78801	60	.62932	.80978	1.2349	.77715	0	.64279	.83910	1.1918	.76604	0	.64279	.83910	1.1918	.76604
1	.61589	.78175	1.2792	.78783	59	.62955	.81027	1.2342	.77696	59	.64299	.83955	1.1910	.76584	59	.64319	.83999	1.1902	.76564
2	.61612	.78222	1.2784	.78765	58	.62977	.81075	1.2334	.77678	58	.64319	.83999	1.1902	.76564	58	.64339	.84043	1.1894	.76544
3	.61635	.78269	1.2776	.78747	57	.63000	.81123	1.2327	.77660	57	.64339	.84043	1.1894	.76544	57	.64359	.84087	1.1886	.76524
4	.61658	.78316	1.2769	.78729	56	.63022	.81171	1.2320	.77641	56	.64359	.84087	1.1886	.76544	56	.64379	.84131	1.1878	.76504
5	.61681	.78363	1.2761	.78711	55	.63045	.81219	1.2312	.77623	55	.64379	.84131	1.1878	.76544	55	.64399	.84175	1.1870	.76484
6	.61704	.78410	1.2753	.78694	54	.63068	.81268	1.2305	.77605	54	.64399	.84175	1.1870	.76544	54	.64419	.84219	1.1862	.76464
7	.61726	.78457	1.2746	.78676	53	.63090	.81316	1.2298	.77587	53	.64419	.84219	1.1862	.76544	53	.64439	.84263	1.1854	.76444
8	.61749	.78504	1.2738	.78658	52	.63113	.81364	1.2290	.77568	52	.64439	.84263	1.1854	.76544	52	.64459	.84307	1.1846	.76424
9	.61772	.78551	1.2731	.78640	51	.63135	.81413	1.2283	.77550	51	.64459	.84307	1.1846	.76544	51	.64479	.84351	1.1838	.76404
10	.61795	.78598	1.2723	.78622	50	.63158	.81461	1.2276	.77531	50	.64479	.84351	1.1838	.76544	50	.64499	.84395	1.1830	.76384
11	.61818	.78645	1.2715	.78604	49	.63180	.81510	1.2268	.77513	49	.64499	.84395	1.1830	.76544	49	.64519	.84439	1.1822	.76364
12	.61841	.78692	1.2708	.78586	48	.63203	.81558	1.2261	.77494	48	.64519	.84439	1.1822	.76544	48	.64539	.84483	1.1814	.76344
13	.61864	.78739	1.2700	.78568	47	.63225	.81606	1.2254	.77476	47	.64539	.84483	1.1814	.76544	47	.64559	.84527	1.1806	.76324
14	.61887	.78786	1.2693	.78550	46	.63248	.81655	1.2247	.77458	46	.64559	.84527	1.1806	.76544	46	.64579	.84571	1.1798	.76304
15	.61909	.78834	1.2685	.78532	45	.63271	.81703	1.2239	.77439	45	.64579	.84571	1.1798	.76544	45	.64599	.84615	1.1790	.76284
16	.61932	.78881	1.2677	.78514	44	.63293	.81752	1.2232	.77421	44	.64599	.84615	1.1790	.76544	44	.64619	.84659	1.1782	.76264
17	.61955	.78928	1.2670	.78496	43	.63316	.81800	1.2225	.77402	43	.64619	.84659	1.1782	.76544	43	.64639	.84703	1.1774	.76244
18	.61978	.78975	1.2662	.78478	42	.63338	.81849	1.2218	.77384	42	.64639	.84703	1.1774	.76544	42	.64659	.84747	1.1766	.76224
19	.62001	.79022	1.2655	.78460	41	.63361	.81898	1.2210	.77366	41	.64659	.84747	1.1766	.76544	41	.64679	.84791	1.1758	.76204
20	.62024	.79070	1.2647	.78442	40	.63383	.81946	1.2203	.77347	40	.64679	.84791	1.1758	.76544	40	.64699	.84835	1.1750	.76184
21	.62046	.79117	1.2640	.78424	39	.63406	.81995	1.2196	.77329	39	.64699	.84835	1.1750	.76544	39	.64719	.84879	1.1742	.76164
22	.62069	.79164	1.2632	.78406	38	.63428	.82044	1.2189	.77310	38	.64719	.84879	1.1742	.76544	38	.64739	.84923	1.1734	.76144
23	.62092	.79212	1.2624	.78388	37	.63451	.82092	1.2181	.77292	37	.64739	.84923	1.1734	.76544	37	.64759	.84967	1.1726	.76124
24	.62115	.79259	1.2617	.78369	36	.63473	.82141	1.2174	.77273	36	.64759	.84967	1.1726	.76544	36	.64779	.85011	1.1718	.76104
25	.62138	.79306	1.2609	.78351	35	.63496	.82190	1.2167	.77255	35	.64779	.85011	1.1718	.76544	35	.64799	.85055	1.1710	.76084
26	.62160	.79354	1.2602	.78333	34	.63518	.82238	1.2160	.77236	34	.64799	.85055	1.1710	.76544	34	.64819	.85099	1.1702	.7606

NATURAL TRIGONOMETRIC FUNCTIONS

Table V

NATURAL TRIGONOMETRIC FUNCTIONS

195

136°

(319°) 139°					41° (221°)					(318°)					42° (222°)					(317°) 137°					43° (223°)					136°					
	Sin	Tan	Ctn	Cos		Sin	Tan	Ctn	Cos		Sin	Tan	Ctn	Cos		Sin	Tan	Ctn	Cos		Sin	Tan	Ctn	Cos		Sin	Tan	Ctn	Cos		Sin	Tan	Ctn	Cos	
0	.64279	.83910	1.1918	.76504	60	.65606	.86929	1.1504	.75471	60	.66913	.90040	1.1106	.74314	60	.68200	.93252	1.0724	.73135	60	.69466	.96569	1.0355	.71934	60	.70719	.99925	1.0000	.70719	60	.71934	.99925	1.0000	.70719	60
1	.64301	.83960	1.1910	.76586	59	.65628	.86980	1.1497	.75452	59	.66935	.90093	1.1100	.74295	59	.68221	.93306	1.0717	.73116	59	.69487	.96616	1.0347	.71894	59	.70739	.99936	1.0000	.70739	59	.71950	.99936	1.0000	.70739	59
2	.64323	.84009	1.1903	.76667	58	.65650	.87031	1.1490	.75433	58	.66956	.90146	1.1093	.74276	58	.68242	.93360	1.0711	.73096	58	.69508	.96667	1.0339	.71873	58	.70760	.99947	1.0000	.70760	58	.71971	.99947	1.0000	.70760	58
3	.64346	.84059	1.1896	.76748	57	.65672	.87082	1.1483	.75414	57	.66978	.90199	1.1087	.74257	57	.68264	.93415	1.0705	.73076	57	.69529	.96714	1.0331	.71852	57	.70781	.99958	1.0000	.70781	57	.71992	.99958	1.0000	.70781	57
4	.64368	.84108	1.1889	.76830	56	.65694	.87133	1.1477	.75395	56	.66999	.90251	1.1080	.74237	56	.68285	.93469	1.0699	.73056	56	.69550	.96763	1.0323	.71831	56	.70792	.99969	1.0000	.70792	56	.72003	.99969	1.0000	.70792	56
5	.64390	.84158	1.1882	.76911	55	.65716	.87184	1.1470	.75375	55	.67021	.90304	1.1074	.74217	55	.68306	.93524	1.0692	.73036	55	.69571	.96810	1.0315	.71792	55	.70803	.99980	1.0000	.70803	55	.72014	.99980	1.0000	.70803	55
6	.64412	.84208	1.1875	.76992	54	.65738	.87236	1.1463	.75356	54	.67043	.90357	1.1067	.74198	54	.68327	.93578	1.0685	.73016	54	.69592	.96857	1.0307	.71768	54	.70814	.99991	1.0000	.70814	54	.72025	.99991	1.0000	.70814	54
7	.64435	.84258	1.1868	.77073	53	.65759	.87287	1.1456	.75337	53	.67064	.90410	1.1061	.74178	53	.68348	.93633	1.0678	.72996	53	.69613	.96903	1.0299	.71744	53	.70825	.99992	1.0000	.70825	53	.72036	.99992	1.0000	.70825	53
8	.64457	.84307	1.1861	.77154	52	.65781	.87338	1.1450	.75318	52	.67086	.90463	1.1054	.74159	52	.68369	.93688	1.0670	.72976	52	.69634	.96942	1.0291	.71720	52	.70836	.99993	1.0000	.70836	52	.72047	.99993	1.0000	.70836	52
9	.64479	.84357	1.1854	.77235	51	.65803	.87389	1.1443	.75299	51	.67107	.90516	1.1048	.74139	51	.68391	.93742	1.0668	.72957	51	.69655	.96991	1.0283	.71696	51	.70847	.99994	1.0000	.70847	51	.72058	.99994	1.0000	.70847	51
10	.64501	.84407	1.1847	.77316	50	.65825	.87441	1.1436	.75280	50	.67129	.90569	1.1041	.74120	50	.68412	.93797	1.0661	.72937	50	.69676	.97039	1.0275	.71672	50	.70858	.99995	1.0000	.70858	50	.72069	.99995	1.0000	.70858	50
11	.64524	.84457	1.1840	.77397	49	.65847	.87492	1.1430	.75261	49	.67151	.90621	1.1035	.74100	49	.68434	.93852	1.0655	.72917	49	.69697	.97080	1.0267	.71648	49	.70869	.99996	1.0000	.70869	49	.72080	.99996	1.0000	.70869	49
12	.64546	.84507	1.1833	.77478	48	.65869	.87543	1.1423	.75242	48	.67172	.90674	1.1028	.74080	48	.68455	.93906	1.0649	.72897	48	.69718	.97121	1.0259	.71624	48	.70880	.99997	1.0000	.70880	48	.72091	.99997	1.0000	.70880	48
13	.64568	.84556	1.1826	.77559	47	.65891	.87595	1.1416	.75222	47	.67194	.90727	1.1022	.74061	47	.68476	.93961	1.0643	.72877	47	.69739	.97162	1.0251	.71600	47	.70891	.99998	1.0000	.70891	47	.72102	.99998	1.0000	.70891	47
14	.64590	.84606	1.1819	.77640	46	.65913	.87646	1.1410	.75203	46	.67215	.90781	1.1016	.74041	46	.68497	.94016	1.0637	.72857	46	.69760	.97203	1.0243	.71576	46	.70902	.99999	1.0000	.70902	46	.72113	.99999	1.0000	.70902	46
15	.64612	.84656	1.1812	.77721	45	.65935	.87698	1.1403	.75184	45	.67237	.90834	1.1009	.74022	45	.68518	.94071	1.0630	.72837	45	.69781	.97244	1.0235	.71552	45	.70913	.99999	1.0000	.70913	45	.72124	.99999	1.0000	.70913	45
16	.64635	.84706	1.1805	.77802	44	.65957	.87749	1.1396	.75165	44	.67258	.90887	1.1003	.74002	44	.68539	.94125	1.0624	.72817	44	.69802	.97285	1.0227	.71528	44	.70924	.99999	1.0000	.70924	44	.72135	.99999	1.0000	.70924	44
17	.64657	.84756	1.1799	.77883	43	.65978	.87801	1.1389	.75146	43	.67280	.90940	1.0996	.73983	43	.68560	.94180	1.0618	.72797	43	.69823	.97326	1.0219	.71504	43	.70935	.99999	1.0000	.70935	43	.72146	.99999	1.0000	.70935	43
18	.64679	.84806	1.1792	.77964	42	.66000	.87852	1.1383	.75127	42	.67301	.90993	1.0990	.73963	42	.68582	.94235	1.0612	.72777	42	.69844	.97367	1.0211	.71480	42	.70946	.99999	1.0000	.70946	42	.72157	.99999	1.0000	.70946	42
19	.64701	.84856	1.1785	.78045	41	.66022	.87904	1.1376	.75107	41	.67323	.91046	1.0983	.73944	41	.68603	.94290	1.0606	.72757	41	.69865	.97408	1.0203	.71456	41	.70957	.99999	1.0000	.70957	41	.72168	.99999	1.0000	.70957	41
20	.64723	.84906	1.1778	.78126	40	.66044	.87955	1.1369	.75088	40	.67344	.91099	1.0977	.73924	40	.68624	.94345	1.0599	.72737	40	.69886	.97449	1.0195	.71432	40	.70968	.99999	1.0000	.70968	40	.72179	.99999	1.0000	.70968	40
21	.64746	.84956	1.1771	.78207	39	.66066	.88007	1.1363	.75069	39	.67366	.91153	1.0971	.73904	39	.68645	.94400	1.0593	.72717	39	.69907	.97490	1.0187	.71408	39	.70979	.99999	1.0000	.70979	39	.72190	.99999	1.0000	.70979	39
22	.64768	.85006	1.1764	.78288	38	.66088	.88059	1.1356	.75050	38	.67387	.91206	1.0964	.73885	38	.68666	.94455	1.0587	.72697	38	.69928	.97531	1.0179	.71384	38	.70990	.99999	1.0000	.70990	38	.72201	.99999	1.0000	.70990	38
23	.64790	.85057	1.1757	.78369	37	.66110	.88110	1.1350	.75030	37	.67409	.91259	1.0958	.73865	37	.68688	.94510	1.0581	.72677	37	.69949	.97572	1.0171	.71360	37	.71001	.99999	1.0000	.71001	37	.72212	.99999	1.0000	.71001	37
24	.64812	.85107	1.1750	.78450	36	.66131	.88162	1.1343	.75011	36	.67430	.91313	1.0951	.73846	36	.68709	.94565	1.0575	.72657	36	.69970	.97613	1.0163	.71336	36	.71012	.99999	1.0000	.71012	36	.72223	.99999	1.0000	.71012	36
25	.64834	.85157	1.1743	.78531	35	.66153	.88214	1.1336	.74992	35	.67452	.91366	1.0945	.73826	35	.68730	.94620	1.0569	.72637	35	.70001	.97654	1.0155	.71312	35	.71023	.99999	1.0000	.71023	35	.72234	.99999	1.0000	.71023	35
26	.64856	.85207	1.1736	.78612	34	.66175	.88265	1.1329	.74973	34	.67473	.91419	1.0939	.73806	34	.68751	.94675	1.0562	.72617	34	.70022	.97695	1.0147	.71288	34	.71034	.99999	1.0000	.71034	34	.72245	.99999	1.0000	.71034	34
27	.64878	.85257	1.1729	.78693	33	.66197	.88317	1.1323	.74953	33	.67495	.91473	1.0932	.73787	33	.68772	.94731	1.0556	.72597	33	.70043	.97736	1.0139	.71264	33	.71045	.99999	1.0000	.71045	33	.72256	.99999	1.0000	.71045	33
28	.64901	.85308	1.1722	.78774	32	.66218	.88369	1.1316	.74934	32	.67516	.91526	1.0926	.73767	32	.68793	.94786	1.0550	.72577	32	.70064	.97777	1.0131	.71240	32	.71056	.99999	1.0000	.71056	32	.72267	.99999	1.0000	.71056	32
29	.649																																		

NATURAL TRIGONOMETRIC FUNCTIONS

44° (224°)

(315°) 135°

	Sin	Tan	Ctn	Cos	
0	.69466	.96569	1.0355	.71934	60
1	.69487	.96625	1.0349	.71914	59
2	.69508	.96681	1.0343	.71894	58
3	.69529	.96738	1.0337	.71873	57
4	.69549	.96794	1.0331	.71853	56
5	.69570	.96850	1.0325	.71833	55
6	.69591	.96907	1.0319	.71813	54
7	.69612	.96963	1.0313	.71792	53
8	.69633	.97020	1.0307	.71772	52
9	.69654	.97076	1.0301	.71752	51
10	.69675	.97133	1.0295	.71732	50
11	.69696	.97189	1.0289	.71711	49
12	.69717	.97246	1.0283	.71691	48
13	.69737	.97302	1.0277	.71671	47
14	.69758	.97359	1.0271	.71650	46
15	.69779	.97416	1.0265	.71630	45
16	.69800	.97472	1.0259	.71610	44
17	.69821	.97529	1.0253	.71590	43
18	.69842	.97585	1.0247	.71569	42
19	.69862	.97643	1.0241	.71549	41
20	.69883	.97700	1.0235	.71529	40
21	.69904	.97756	1.0230	.71508	39
22	.69925	.97813	1.0224	.71488	38
23	.69946	.97870	1.0218	.71468	37
24	.69966	.97927	1.0212	.71447	36
25	.69987	.97984	1.0206	.71427	35
26	.70008	.98041	1.0200	.71407	34
27	.70029	.98098	1.0194	.71386	33
28	.70049	.98155	1.0188	.71366	32
29	.70070	.98213	1.0182	.71345	31
30	.70091	.98270	1.0176	.71325	30
31	.70112	.98327	1.0170	.71305	29
32	.70132	.98384	1.0164	.71284	28
33	.70153	.98441	1.0158	.71264	27
34	.70174	.98499	1.0152	.71243	26
35	.70195	.98556	1.0147	.71223	25
36	.70215	.98613	1.0141	.71203	24
37	.70236	.98671	1.0135	.71182	23
38	.70257	.98728	1.0129	.71162	22
39	.70277	.98786	1.0123	.71141	21
40	.70298	.98843	1.0117	.71121	20
41	.70319	.98901	1.0111	.71100	19
42	.70339	.98958	1.0105	.71080	18
43	.70360	.99016	1.0099	.71059	17
44	.70381	.99073	1.0094	.71039	16
45	.70401	.99131	1.0088	.71019	15
46	.70422	.99189	1.0082	.70998	14
47	.70443	.99247	1.0076	.70978	13
48	.70463	.99304	1.0070	.70957	12
49	.70484	.99362	1.0064	.70937	11
50	.70505	.99420	1.0058	.70916	10
51	.70525	.99478	1.0052	.70896	9
52	.70546	.99536	1.0047	.70875	8
53	.70567	.99594	1.0041	.70855	7
54	.70587	.99652	1.0035	.70834	6
55	.70608	.99710	1.0029	.70813	5
56	.70628	.99768	1.0023	.70793	4
57	.70649	.99826	1.0017	.70772	3
58	.70670	.99884	1.0012	.70752	2
59	.70690	.99942	1.0006	.70731	1
60	.70711	1.0000	1.0000	.70711	0
	Cos	Ctn	Tan	Sin	

134° (314°)

(225°) 45°

12/12

12B1

TABLE OF POWERS OF TWO AND EIGHT

	2^N	N	2^{-N}	
$8^0 =$	1	0	1.0	8^0
	2	1	0.5	
8^1	4	2	0.25	
	8	3	0.125	$1/8 = 8^{-1}$
	16	4	0.062 5	
8^2	32	5	0.031 25	
	64	6	0.015 625	$1/64 = 8^{-2}$
	128	7	0.007 812 5	
8^3	256	8	0.003 906 25	
	512	9	0.001 953 125	$1/512 = 8^{-3}$
	1 024	10	0.000 976 562 5	
8^4	2 048	11	0.000 488 281 25	
	4 096	12	0.000 244 140 625	$1/4096 = 8^{-4}$
	8 192	13	0.000 122 070 312 5	
8^5	16 384	14	0.000 061 035 156 25	
	32 768	15	0.000 030 517 578 125	$1/32768 = 8^{-5}$
	65 536	16	0.000 015 258 789 062 5	
8^6	131 072	17	0.000 007 629 394 531 25	
	262 144	18	0.000 003 814 697 265 625	8^{-6}
	524 288	19	0.000 001 907 348 632 812 5	
8^7	1 048 576	20	0.000 000 953 674 316 406 25	
	2 097 152	21	0.000 000 476 837 158 203 125	8^{-7}
	4 194 304	22	0.000 000 238 418 579 101 562 5	
8^8	8 388 608	23	0.000 000 119 209 289 550 781 25	
	16 777 216	24	0.000 000 059 604 644 775 390 625	8^{-8}
	33 554 432	25	0.000 000 029 802 322 387 695 312 5	
8^9	67 108 864	26	0.000 000 014 901 161 193 847 656 25	
	134 217 728	27	0.000 000 007 450 580 596 923 828 125	8^{-9}
	268 435 456	28	0.000 000 003 725 290 298 461 914 062 5	
8^{10}	536 870 912	29	0.000 000 001 862 645 149 230 957 031 25	
	1 073 741 824	30	0.000 000 000 931 322 574 615 478 515 625	8^{-10}
	2 147 483 648	31	0.000 000 000 465 661 287 307 739 257 812 5	
8^{11}	4 294 967 296	32	0.000 000 000 232 830 643 653 869 628 906 25	
	8 589 934 592	33	0.000 000 000 116 415 321 826 934 814 453 125	8^{-11}
	17 179 869 184	34	0.000 000 000 058 207 660 913 467 407 226 562 5	
8^{12}	34 359 738 368	35	0.000 000 000 029 103 830 456 733 703 613 281 25	
	68 719 476 736	36	0.000 000 000 014 551 915 228 366 851 806 640 625	8^{-12}
	137 438 953 472	37	0.000 000 000 007 275 957 614 183 425 903 320 312 5	
8^{13}	274 877 906 944	38	0.000 000 000 003 637 978 807 091 712 951 660 156 25	
	549 765 813 888	39	0.000 000 000 001 818 989 403 545 856 475 830 078 125	8^{-13}

to: DISTRIBUTION
from: C. Latady
subject: Programmers Manual Update #33

LINK DIVISION
refer to: CL-71-342
date: October 12, 1971

Please replace or add the following to your Programmer's On-Line Manual:

1. Cover page - showing Update #33.
2. Replace PREFACE (1 page).
3. Replace TABLE OF CONTENTS (4 pages).

COMPUTER COMPLEX AREA

4. Replace pages 1 and 3 of your HARDWARE LAYOUT.
5. Replace pages 1 and 2 of your CORE LAYOUT. (3)
6. Replace your 5 pages of COMPUTER FAILURE with the attached 3 pages. (6)
7. Replace your Maintenance Test Fixture with SPECIAL HARDWARE FEATURES (2 pages).
8. Replace the 2 pages of Timing Study Procedure with 2 pages of TIMING.

ON-LINE UTILIZATION (7)

9. Replace your 9 pages on PRIMARY OS FUNCTION with the attached 5 pages.
10. Replace your 3 pages on TYPEWRITER CODES with the attached 2 pages.
11. Replace all 4 pages on COMPUTER-STORE/SAFE-STORE LOGGING & WRITE-RESET.
12. Replace pages 1 and 2 of your RESIDENT UTILITIES.
13. Throw away PROCEDURE FOR TYPING IN MALFUNCTION LEAKAGE RATES (1 page).
14. Replace your PERCENTAGE MALFUNCTION pages (6 pages).

LOADING PROCEDURES


15. Replace the UNIFIED SIMULATION SYSTEM: Phase 2 (USS 2) (15 pages).
16. Replace your three pages on HEADER CARD FORMATS.
17. Replace your OCTLB00T page (1 page).

DATA OUTPUTS


18. Replace your 4 pages on REAL TIME PRINT.
19. Replace your DEP (DEDA ENTER PRINT) (1 page).
20. Replace your page on DATA RECORDING (1 page).
21. Replace your GSSC RECORD/READ page.

SOURCE DECKS

22. Replace your entire LMS INDEX (8 pages).


C. H. Latady
LMS OBS Programmer/Analyst

Concurrence:


K. R. Altom
Senior Supervisor - LMS Programming

CHL/mmm

Dist.

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Memorandum

SINGER
EDUCATION & TRAINING PRODUCTS

to: Distribution
from: K. R. Altom
subject: LMS User's Manual Update #34

LINK DIVISION
refer to: KRA-71-354
date: October 22, 1971

Please change the following in your Programmer's Manual:

1. Replace the cover page showing the latest update, Update #34.
2. Replace IOS DOCKING AND UPDOCKING PROCEDURES in "Special On-Line Operating Procedures", section C. (1 page)


K. R. Altom
Senior Supervisor - LMS Programming

KRA/mm

Memorandum

SINGER
EDUCATION & TRAINING PRODUCTS

to: Distribution
from: L. Owens
subject: LMS User's Manual Update #38

LINK DIVISION
refer to: L0-71-414
date: December 22, 1971

Please make the following changes to your LMS User's Manual:

1. Replace your cover page showing the latest update.
2. Replace page 3 of your Table Of Contents.
3. Replace page 1 and 2 on PRIMARY FUNCTIONS in the Operating System section of your manual.
4. Add the page titled PCM FORMAT LOADER to the back of the section labeled Other Utilities.

Larry Owens

L. Owens

LMS Flight Mechanics Programmer/Analyst

L0/mm

Concurrence:

K. R. Altom

K. R. Altom

Senior Supervisor - LMS Programming

December 22, 1971

UPDATE #38

LMS USER'S MANUAL

VOLUME I

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11.1 BIASING THE LUNAR TERRAIN BY A SLOPE

11.2 IØS CSM CONTROL PANEL OPTIONS

11.3 IØS DOCKING AND UNDOCKING PROCEDURES

PRIMARY FUNCTIONS

1. Initial Startup:

- 1.1 P-Register: '100:SIM mode - all three computers or A&B computer only.
'101:SYS mode - all three computers or A&B computer only.
'102:Interactive Initialization (DCE setup, A&B Log, EØF, Safe-Store/Write Reset Initialization) - All three computers or A&B computer only. (After all responses are made will go to SYS mode.)
- 1.2 A-Register: Set to '1 to wait on minute pulse before transferring to SIM mode - A computer only
- 1.3 Index Registers: X1: Set to '1nn (where nn is reset point desired) to cause an automatic reset on transfer to SIM mode. - All three computers or A&B computer only.
X2: Set to '1 to set Q775 for GSSC Logging (must set X3 to '0) - A computer only.
X3: Set to '1 to set Q776 for GSSC Log Playback (must set X2 to '0) - A computer only.

2. Sense Switch Options (SIM Mode):

2.1 A & B Computers Only:

- 2.1.1 SSW1: spare
2.1.2 SSW2: spare
2.1.3 SSW4: forces the complex to clear-and-halt at end of current major cycle (16 frames).

2.2 A Computer Only:

- 2.2.1 SSW3: Real Time Print
2.2.2 SSW5: To load PCM buffer in real-time

1. Neither Q775 or Q776 are set,
2. Computers are in SIM mode,
3. Mount PCM format tape on Drive 4,
4. Push PCM INVALID button on the PCM buffer box located next to the A-Computer CPU,
5. Raise SSW5,
6. One minute later, the PCM format tape is read and PCM INVALID light goes out. Lower SSW5.

To load PCM buffer in non real-time see the Other Utilities section.

2.2.3 SSW6: Real Time I/O bypass.

2.3 B Computer Only:

2.3.1 SSW3: A & B Log.

2.3.2 SSW6: Line Printer activity bypass for entire complex.

3. Executive Philosophy

3.1 The programs are divided into three classes: high priority (those programs with a function of time), low priority (those not using Delta T), and Data Displays (X-Y/X-T/Event, Digital Readout, and Parameter Display).

3.2 There are two options for calling these three groups of programs. Either option may be selected at any time. The sequence in calling priority is shown below for both options.

WSELECT = 1 : High Priority
 Data Displays
 Low Priority

WSELECT = 2 : High Priority
 Low Priority
 Data Displays

3.3 There are two different call table executors for high priority and low priority programs similar to the following instructions:

LOOP	IRX	CALLPNTR, 1
	LDA	CALLTABL, 1
	STA	CALL
	XEC	CALL
	SKS	'40700
	NOP	
	NOP	
	JMP	LOOP

3.4 The high priority programs should be completed every frame. Should they fail for any reason to be completed the executive will set a flag which will type out the data associated with the interrupt (see RTI typeout). The executive will then complete the interrupted high priority program and all remaining high priority programs in the interrupted frame. The executive will then do the next frame's High Priority Programs. This means that the execution of the Data Display Programs in the interrupted frame will be omitted. The necessary controls, however, will be set such that the Low Priority Programs remaining in the interrupted frame will, time permitting, catch up with the High Priority Programs.

3.5 If WSELECT = 1, the Data Display programs should be completed in every frame. Should they fail for any reason to be completed the executive will set a flag which will type out the data associated with the interrupt. The executive will then do the next frame's high priority programs. This means that the interrupted Data Display program as well as the remaining Data Display programs in the interrupted frame will not be executed. The necessary controls, however, will be set such that the Low Priority Programs remaining in the interrupted frame will, time permitting, catch up with the High Priority Programs.

PCM FORMAT LOADER

1. Mount PCM format tape on Drive 1.
2. Fill input deck at 50K in A-Computer.
3. Master clear.
4. Push PCM INVALID button on PCM buffer box.
5. Start at 50K.
6. Computer halts with A-Reg. = '77777770.
7. Press START.
8. Computer halts with A-Reg. = B-Reg. = '22222222.
9. PCM format tape loaded. Reload On-Line load.

Memorandum

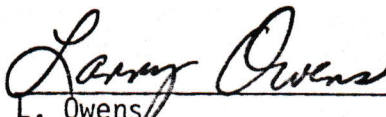
SINGER
EDUCATION & TRAINING PRODUCTS

to: Distribution
from: L. Owens
subject: LMS User's Manual Update #39

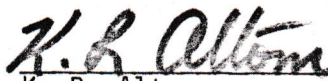
LINK DIVISION
refer to: LO-72-006
date: January 5, 1972

Please make the following changes to your LMS User's Manual:

1. Replace your cover page to show the latest update.
2. Replace page 1 of PRIMARY FUNCTIONS located in the Operating System section of your manual.


L. Owens
LMS Flight Mechanics Programmer/Analyst

LO/mm

Concurrence: 
K. R. Altom
Senior Supervisor - LMS Programming

January 4, 1971

UPDATE #39

LMS USER'S MANUAL

VOLUME I

PRIMARY FUNCTIONS

1. Initial Startup:

- 1.1 P-Register: '100:SIM mode - all three computers or A&B Computer only.
'101:SIM mode - all three computers or A&B Computer only.
'102:Interactive Initialization (DCE setup, A&B Log, EOF, Safe-Store/Write Reset Initialization) - all three computers or A&B Computer only. (After all responses are made will go to SYS mode.)
- 1.2 A-Register: Set to '1 to wait on minute pulse before transferring to SIM mode - A Computer only.
- 1.3 Index Register: X1: Set to '1nn (where nn is reset point desired) to cause an automatic reset on transfer to SIM mode. - All three computers or A&B Computer only.
X2: Set to '1 to set Q775 for GSSC Logging (must set X3 to '0) - A Computer only.
X3: Set to '1 to set Q776 for GSSC Log Playback (must set X2 to '0) - A Computer only.

2. Sense Switch Options (SIM Mode):

2.1 A & B Computers Only:

- 2.1.1 SSW1: Spare
2.1.2 SSW2: Spare
2.1.3 SSW4: Forces the complex to clear-and-halt at end of current major cycle (16 frames).

2.2 A Computer Only:

- 2.2.1 SSW3: Real Time Print
2.2.2 SSW5: To load PCM buffer in real-time:
1. Neither Q775 or Q776 are set,
2. Computers are in SIM mode,
3. Mount PCM format tape on Drive 4,
4. Push PCM INVALID button on the PCM buffer box located next to the A-Computer CPU,
5. Raise SSW5,
6. One minute later, the PCM format tape is read and PCM INVALID light goes out. Lower SSW5.

To load PCM buffer in non real-time see the OTHER UTILITIES section.

GSSC inputs are logged on drive 4 when Q775 is set and the LMS mode switch is in LMS/GSSC or LMS/CMS/GSSC positions.

GSSC data stored on drive 4 is read to simulate GSSC inputs when Q776 is set and the LMS mode switch is in LMS ONLY or LMS/CMS positions.

Memorandum

SINGER
EDUCATION & TRAINING PRODUCTS

LINK DIVISION

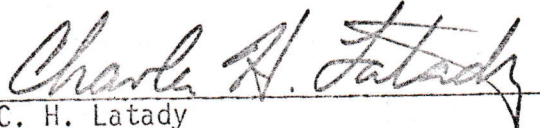
to: Distribution
from: C. Latady
subject: LMS User's Manual Update #40

refer to: CL-72-012


date: January 14, 1972

Please make the following changes to your manual:

1. Replace cover page to show the latest update.
2. Replace pages 1 and 3 of your TABLE OF CONTENTS.
3. Add SIMULATOR I/O FAILURES behind Computer Failures in the LMS COMPLEX section.
4. OTHER UTILITIES SECTION
 - 4.1 Take out SYSTEM TAPE UPDATE.
 - 4.2 Take out ASSEMBLY PROCEDURES.
 - 4.3 Tape out FILL DECK PROCEDURES. (2 pages)
 - 4.4 Replace ABSLOAD - PDUMP Operating Procedures with ABSLOAD. (1 page)
 - 4.5 Add 1 page on PDUMP.
 - 4.6 Take out 2 pages on Search and Dump and replace with 1 page on SEARCH & DUMP.
 - 4.7 Take out 1 page on UT 101(VLRTCC).
 - 4.8 Replace 1 page on C-LOG DELOG
5. LGC SECTION
 - 5.1 Take out the 6 pages on C-COMPUTER and replace it with 5 pages on ISLGC.


C. H. Latady
OBS Programmer/Analyst

Concurrence:


K. R. Altom
Senior Supervisor - LMS Programming

CHL/mm

January 13, 1972

UPDATE #40

LMS USER'S MANUAL

VOLUME I: ON-LINE

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10.4 OPERATION OF CLOCKS

10.5 ISLGC CORE LAYOUT

11. SPECIAL ONLINE OPERATING PROCEDURES

11.1 BIASING THE LUNAR TERRAIN BY A SLOPE

11.2 IØS CSM CONTROL PANEL OPTIONS

11.3 IØS DOCKING AND UNDOCKING PROCEDURES

SIMULATOR I/O FAILURES

These failures are annunciated by one of the following messages being printed on the line printer, together with a count (nnnn below) of how many failures have occurred since the last annunciation.

PCM FAILED	nnnn	PCM Telemetry
GTL FAILED	nnnn	GSSC-to-LMS
LTG FAILED	nnnn	LMS-to-GSSC
SCS FAILED	nnnn	Special S&C hardware
A/D FAILED	nnnn	Analog-to-digital
DBI FAILED	nnnn	Discrete bit input
DWI FAILED	nnnn	Digital word input
DWR FAILED	nnnn	Digital word output (relay)
DBØ FAILED	nnnn	Discrete bit output
D/A FAILED	nnnn	Digital to analog
FBC FAILED	nnnn	Fully Buffered Channel

ABSLØAD

ABSLØAD is used to load an absolute binary (tape or deck) produced by ASM:

Operating Instructions:

1. Fill ABSLØAD at address specified on fill deck.
2. Set the first three bits of the A-Register to the tape drive to be used or to zero if the absolute binary deck is to be read instead of the tape.
3. Set P09 if loading into upper bank.
4. Start at address specified on fill deck.
5. 'LØADING CØMPLETE' and the last address used +1 will be typed out when the process has finished.

PDUMP

PDUMP is used to dump core to the line printer in several different formats:

Operating Instructions:

1. Fill PDUMP at address specified on fill deck.
2. Set the A-Register to the starting address for the dump.
3. Set the B-Register to the ending address for the dump.
4. Set Index Register 1 to one of the following formats:
 - 4.1 '1 for octal,
 - 4.2 '2 for DAP,
 - 4.3 '3 for BCD,
 - 4.4 '4 for numeric (decimal, B23).
5. Start at address specified on fill deck.

SEARCH AND DUMP

SEARCH AND DUMP is used for two purposes:

1. Search core for words with certain bit patterns and output these words and their absolute addresses to the line printer in octal format.
2. Dump core to the line printer in octal format.

Operating Instructions:

1. Fill SEARCH AND DUMP at address specified on fill deck.
2. Set the A-Register to the bit pattern to be searched for or set to '0 for dump.
3. Set the B-Register to the mask to be used in the search or set to '0 for dump.
4. Set Index Register 1 to the starting address for the search or dump.
5. Set Index Register 2 to the ending address for the search or dump.
6. Start at address specified on fill deck.

Example of Mask:

Set each bit of the B-Register to "1" for each bit of the A-Register that you want checked.

If I want to determine which instructions store into location '62071, I could perform two (2) Searches:

SEARCH 1	A-Register = '00562071
	B-Register = '77777777
SEARCH 2	A-Register = '00362071
	B-Register = '77777777

or I could perform one (1) Search operation if I set up the register accordingly:

A-Register = '00062071
B-Register = '77077777

Thus, all STA (OP CODE = '05) and STB (OP CODE = '03) would be determined in one (1) Search as well as STC (OP CODE = '04) and STD (OP CODE = '06).

C-LØG DELØG

1. Mount system tape on drive 1, delog tape on drive 2, initialize system.
2. Load job control deck in card reader.
3. When computer goes to I/Ø hold, type "\$, tab, CØN, tab, CARDS", carriage return.
4. The delog program types a message at each end of file. Press start each time to delog the number of files desired.

ISLGC DELOG JOB CONTROL DECK

1 6

\$ JØB

1 6 12

\$ CALL PØSTPRØC,2,,,,,,,,,1

1 5 12 15

JØB 00000 3 99999

DELOG DECK

1

END

1 6

\$ EØJ

ISLGC

1. Special Operating Procedures

1.1 Special Switch Checklist

- 1.1.1 C Enable - on.
- 1.1.2 Common core lockout - disabled.
- 1.1.3 DDP/SGC configuration - SGC
- 1.1.4 All special SGC switches - normal

1.2 Special Start-Up Procedures

1.2.1 Clear E-Memory on Start-Up

- 1.2.1.1 Of questionable value since overridden by reset
- 1.2.1.2 Start at '103

1.2.2 Calculate Banksum

- 1.2.2.1 Seldom used option to recalculate banksums when F-Memory patch made.
- 1.2.2.2 Start at '105.

2. Octal Dump

- 2.1 The purpose of octal dump is to allow a line printer dump of any selectable ~~consecutive~~ core area in C-Lower (0-'57777) or common ('60000-'77777). Eight words per line are dumped.

2.2 Operating Instructions

- 2.2.1 Put LMS Simulator in FREEZE.
- 2.2.2 Raise SSW2 on C (C will halt).
- 2.2.3 A-Reg and B-Reg may be changed to lower and upper dump limits. ('53700-'57777 which include LGC channels and E-Memory are standard dump limits.)
- 2.2.4 To avoid suppressing lines of all zero, raise SSW1.
- 2.2.5 Put SSW2 down.
- 2.2.6 Press START (after print completion, C will return to FREEZE).

3. C-Log

3.1 Description

C-Log is the counterpart of A/B Log. Up to 100 variables may be logged at rates up to 20 times/sec. Fifty-seven of the variables to be logged are selectable. Channels and counters are always selected. Processing of the tape produced On-Line is accomplished via the ISAGC post-processor.

3.2 Manual Log Initialization

- 3.2.1 Place LMS in FREEZE.
- 3.2.2 Raise SSW4 on C (C will halt).
- 3.2.3 Index Register 1 identifies the selectable log variable (1-'71).
- 3.2.4 The B-Reg contains the address of the variable presently to be logged.
- 3.2.5 To select a different variable for logging, key address into A-Reg.
- 3.2.6 Push START.
- 3.2.7 Continue 3.2.3 through 3.2.6 until all desired variables (up to '71) have been keyed in.
- 3.2.8 Mount log tapes.
- 3.2.9 Lower SSW4, set bit 1 of A-Reg, push START.
- 3.2.10 Set A-Reg as follows on halt.
 - 3.2.10.1 Bit = 1 rewind 1st log tape.
 - 3.2.10.2 Bits 2-9 log interval (50 millisec per bit) i.e., 1 sec = 20 X 50 millisec., set 2-9 = '024 (20 decimal).
 - 3.2.10.3 Bits 13-24 (in groups of 3) represent log drives 1, 2, 3, & 4.
- 3.2.11 If log header print is desired put SSW1 up.
- 3.2.12 Push START, first log tape will be initialized, C will return to FREEZE.

3.3 Standard DSKY Log

- 3.3.1 Mount log tape on Drive 4.
- 3.3.2 If log header print is desired, raise SSW1.
- 3.3.3 Raise and then immediately lower SSW6.

3.4 Log Initialization Card Format (See "Loading Procedures" for instructions).

3.4.1 First Card

Columns	1 - 3	LØG
Column	6	Blank or R for rewind
Columns	7 - 13	Log tape drive specifications starting with the first through the last. 4, 2 would specify Drive 4 as the 1st and Drive 2 as the 2nd tape drive.
Columns	15 - 18	Log interval specified in seconds and hundredths of seconds. I.E. 1.01 would request a log every 1.01 seconds.
Columns	21 - 80	Comments for tape identification.

3.4.2 Selection Cards

Columns	1 - 3	S01 through S57 (logging location assignment must be in sequence with no omissions).
Columns	5 - 12	Name of parameter.
Column	14	Successive locations (DP = 2, TP = 3, etc.)
Columns	16 - 20	Address

3.4.2 Last Card

Columns	1 - 3	END
---------	-------	-----

3.5 Operating Procedures for Log

3.5.1 Turn On initialized log with SSW5 up or C-Log enable.

3.5.2 Data separation is effected by writing an EOF on the log tape upon reset if C-Log is on (SSW5 or C-Log enable).

3.5.3 Upon terminating, run several EOF's should be written on the log tape. Should the log tape be on unit 4, raising and lowering SSW6 will accomplish this.

4. Operation of C-Computer Clocks and Interrupts

When the LMS is operated with the Central Timing Equipment, CTE, switched to "half-time" the A, B, and C-Computer interrupts and clocks function as follows:

4.1 A, B, and C-Computers

4.1.1 The minute pulse is not affected by changing the CTE timing.

4.1.2 The 50 millisecond pulse is extended to 100 milliseconds.

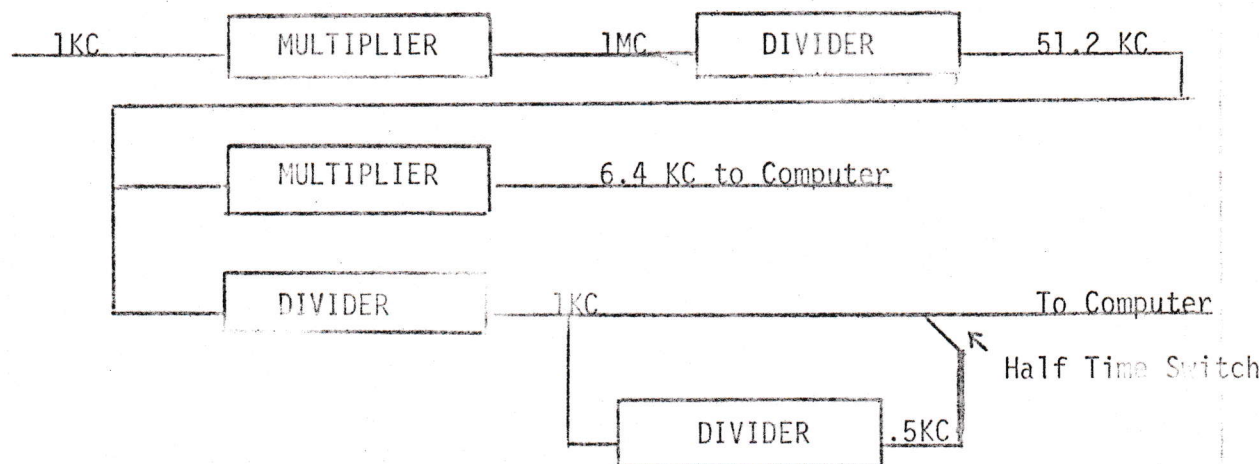
4.2 C-Computer

4.2.1 The 10 millisecond pulse which is used to increment the T1, T2, T3, T4, and T5 readable/programmable clocks is extended to 20 milliseconds.

4.2 The 20 millisecond interrupt is extended to 40 millisecond.

4.3 The T6 clock which counts at 6.4. KC is not affected by the CTE.

A functional diagram of the hardware used to develop the timing clocks follows:



5. ISLGC CORE LAYOUT

0 1		PFI
2 17		UNUSED
20 ↓ 60		INTERRUPT TRAP/TRANSFER
	61 77	<u>UNUSED</u>
100 ↓ 12300		PART IV
	12301 ↓ 13577	<u>UNUSED</u>
13600 ↓ 13677		MALFUNCTION TABLE PART IV
13700 ↓ 17777		SAFE STORE BUFFER IV
20000 ↓ 23777		PART I
24000 ↓ 30007		PART II
30010 ↓ 30077		SPECIAL DATA POOL
30100 ↓ 31777		PART II
32000 ↓ 33311		PART III
33340 ↓ 33360		JET TIMES
33400 ↓ 35777		PART III
36000 ↓ 37777		PART I (good sized gaps)
40000 ↓ 47777		FIXED
50000 ↓ 53277		MTP LOADER
53000 ↓ 53777		TM PARITY TABLE IV
53700 ↓ 57777		PRIVATE CHANNELS E-MEMORY

Memorandum

SINGER
EDUCATION & TRAINING PRODUCTS

LINK DIVISION

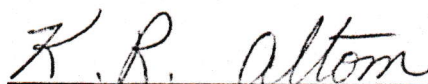
to: Distribution
from: K. R. Altom
subject: LMS User's Manual Update #41

refer to: KRA-72-019

date: January 24, 1972

Please make the following changes to your LMS User's Manual:

1. Change your cover page to show the latest update.
2. Replace pages 3 and 4 of the Pre-Programmed Data Outputs in the DATA ACQUISITION SYSTEM section of your manual.
3. Add 2 pages, LMS UP-DATA LINK CHECKOUT directly behind "Up-Data-Link (UDL) Via Communication Link" in your Special On-Line Operating Procedures section of your User's Manual.



K. R. Altom
Senior Supervisor - LMS Programming

KRA/mm

UPDATE #41
January 24, 1972

LMS USER'S MANUAL
VOLUME I - ONLINE

LMS UP-DATA LINK CHECKOUT

Checkout of the LMS Up-Data Link (UDL) interface can be accomplished with one of the following procedures:

1. Complete command interface must be checked but GSSC isn't available.
 - 1.1 Set Mode Select Switch to LMS/MCC.
 - 1.2 Set Q750 to "1" by typewriter entry.
 - 1.3 S-Band communication equipment in normal up-data mode (Panel 12).
 - 1.3.1 All power and communication circuit breakers closed.
 - 1.3.2 UPDATA LINK switch -- DATA position.
 - 1.3.3 XMTR/RCVR switch -- PRIM or SEC (requires 16 second warm-up).
 - 1.3.4 S-Band antenna switch -- FWD or AFT, whichever position gives best signal strength. If signal strength is approximately .5 volts in either position, the LM is occulted, or Q750 (Earth station transmitting) is zero. Verify that Q750 is "1". Set T067 (A-Upper) to "1" to cancel occulting effects. Or, set SNOCHECK TO "1" and bypass all on-board configuration requirements for communication.
 - 1.4 APCU (support complex in building 30) can complete the loop and send commands and receive MAP's (message accepted pulses) as appropriate.
2. Up-Link feature is to be tested but GSSC is not available.
 - 2.1 Set Mode Select Switch to LMS/MCC.
 - 2.2 Set SNOCHECK to "1" by typewriter entry.
 - 2.3 APCU can send commands; however, no valid MAP's will be sent by LMS.
3. GSSC is available for test and can assist:
 - 3.1 Set Mode Select Switch to LMS/MCC.
 - 3.2 Sync LMS with GSSC.
 - 3.3 S-Band communication equipment in normal up-date mode. (Reference 1.3).
 - 3.4 GSSC can turn-on a ground station by MED to set GSSC-to-LMS word 31, bit 24 to a "1".
 - 3.5 APCU can complete the loop and send commands and receive MAP's as appropriate.

4. GSSC is available for the test, but for some reason is unable to assist.
 - 4.1 Set Mode Select Switch to LMS/MCC.
 - 4.2 Sync LMS with GSSC.
 - 4.3 GSSC cannot turn-on a ground station. Using the Daisy Chain Monitor, LMS cabinet 50, dial 05 into device digiswitches to select CCBI, dial 031 into number digiswitches to select CCBI word 31, set bit 24 of selected I/O display register to "1", and depress dump. This bypasses GSSC's inability to select a ground station.
5. S-Band Communication equipment to normal up-data mode. (Reference 1.3)
6. APCU can complete loop and send commands and receive MAP's as appropriate.

NOTES:

Auto Up-Link SPRIL on the Instructors Console must be in the Auto Up-Link state.

The aforementioned procedures checks the hardware up-link. It does not check the simulated Auto Up-Link simulation.

Message Accepted Pulses (MAP's) are generated by OCP '3212 and cause a pulse of 70 ms duration to be sent to building 30 via TM.

Setting S160 to "1" causes the commands from APCU to be displayed on the line printer in Real Time.

<u>XT Channel No.</u>	<u>Symbol</u>	<u>Range Recorded</u>	<u>Description</u>
<u>Table B (Rendezvous)</u>			
17	PROTECTED		
18	VARCDIST	± 500	ORB. ARC DIST WTO CSM (NAUT.MI.)
19	PROTECTED		
20	VRADIFF	± 150	RAD. VEC. DIFF WTO CSM (NAUT.MI.)
21	PROTECTED		
22	VXRELH	± 300	RANGE ALONG ORBIT AXIS (NAUT. MILES)
23	PROTECTED		
24	VZRELH	± 300	RANGE-VERTICAL AXIS (NAUT. MILES)

The following parameters have been programmed for the EVENT RECORDERS:

<u>Channel No.</u>	<u>Symbol</u>	<u>Description</u>
25	R950	RCS THRUSTER NO. 1 (4U)
26	R951	RCS THRUSTER NO. 2 (4D)
27	R952	RCS THRUSTER NO. 3 (4F)
28	R953	RCS THRUSTER NO. 4 (4S)
29	R954	RCS THRUSTER NO. 5 (3U)
30	R955	RCS THRUSTER NO. 6 (3D)
31	R956	RCS THRUSTER NO. 7 (3F)
32	R957	RCS THRUSTER NO. 8 (3S)
33	R958	RCS THRUSTER NO. 9 (2U)
34	R959	RCS THRUSTER NO. 10 (2D)
35	R960	RCS THRUSTER NO. 11 (2F)
36	R961	RCS THRUSTER NO. 12 (2S)
37	R962	RCS THRUSTER NO. 13 (1U)
38	R963	RCS THRUSTER NO. 14 (1D)
39	R964	RCS THRUSTER NO. 15 (1F)

<u>Channel No.</u>	<u>Symbol</u>	<u>Description</u>
40	R965	RCS THRUSTER NO. 16 (1S)
41	M011	IOS MARK DISCRETE

The Parameter Display Initialization Routine has been programmed to display the following variables when the corresponding number is dialed:

<u>Parameter No.</u>	<u>Symbol</u>	<u>Description</u>
01	VARHOLS	RANGE LM TO CSM (LESS THAN 128,000 FT)
02	ARHODLS	RANGE RATE, FT/SEC.
03	ARHONM	RANGE, NAUTICAL MILES
04	AUHP1	LM PERIGEE, N. MI.
05	AUHA1	LM APOGEE, N. MI.
06	AULAT	LM LATITUDE
07	GEDELE	ELEVATION ANGLE BETWEEN LOS & X AXIS
08	TPPC	PITCH ANGLE FOR S-BAND ANTENNA
09	AURTRM	PITCH CG IN TRIM GIMBAL COORDINATES
10	AUWLM	WEIGHT OF LM ONLY
11	VHNLTEMP	ALTITUDE ABOVE L.S.
12	ARDNL	ALTITUDE RATE, FT/SEC.
13	SPARE	
14	AUHP	CSM PERIGEE, N. MI.
15	AUHA	CSM APOGEE, N. MI.
16	AULON	LM LONGITUDE
17	GEDELA	AZIMUTH ANGLE BETWEEN LOS & X AXIS
18	TYPC	YAW ANGLE FOR S-BAND ANTENNA
19	AURTRM	ROLL CB IN TRIM GIMBAL COORDINATES
20	AUWCM	WEIGHT OF CSM
21	AUROL	LM LOC. HORIZ. ROLL, DEG.
22	AUPIT	LM LOC. HORIZ. PITCH, DEG.
23	AUYAW	LM LOC. HORIZ. YAW, DEG.
24	AUAV1	LM ANGULAR VELOCITY, DEG/MIN
25	AUW1	LM ARG. OF PERIGEE, DEG.
26	AUNU1	LM TRUE ANOMALY, DEG.
27	AUI1	LM INCLINATION, DEG.

Memorandum

SINGER
EDUCATION & TRAINING PRODUCTS

to: Distribution
from: K. R. Altom
subject: Programmers User Manual Update #42

LINK DIVISION

refer to: KRA-72-031

date: March 6, 1972

Please make the following changes to your User's Manual:

1. Change the cover page to show the latest update.
2. Replace page 4 of your TABLE OF CONTENTS.

OPERATING SYSTEMS

3. Replace page 2 of your TYPEWRITER CODES.

DATA OUTPUTS/DATA ACQUISITION

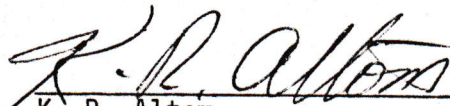
4. Replace 1 page of DEP(DEDA ENTER PRINT) with 2 new pages on DEP(DEDA ENTER PRINT).
5. Replace page 2 of your PRE-PROGRAMMED DATA OUTPUTS.

RESET POINTS

6. Replace Revision G with Revision J for LMS RESET POINT DEFINITION. (4 pages)

SPECIAL ONLINE OPERATING PROCEDURES

7. Add 4 pages on EXCESS CURRENT USAGE MALFUNCTION to the back of this section.


K. R. Altom
Senior Supervisor - LMS Programming

KRA/mm

UPDATE #42
February 3, 1972

LMS USER'S MANUAL
VOLUME I - ONLINE

- 11.4 POST LANDING DYNAMICS
- 11.5 AUTO-UPLINK
- 11.6 LGC ASCENT/DESCENT PROCEDURES
- 11.7 AOT MARK ERROR ROUTINE
- 11.8 LMS MANUAL LANDINGS
- 11.9 STATE VECTOR DISPERSIONS
- 11.10 OPERATING OF LGC DOWNLINK MONITOR CONSOLE
- 11.11 LMS COMMUNICATIONS UTILIZATION
- 11.12 OPERATING INSTRUCTIONS FOR THE CMS/LMS INTERFACE
- 11.13 LUNAR TERRAIN SOFTWARE SIMULATION
- 11.14 CSM IMU GIMBAL ANGLE
- 11.15 RENDEZVOUS RADAR CDU BIAS PROCEDURES
- 11.16 INSURING LUNAR CONTACT AT TOUCHDOWN
- 11.17 EXCESS CURRENT USAGE MALFUNCTION
- 12. REAL WORLD
 - 12.1 LM PICTURE
 - 12.2 ASCENT/DESCENT STAGES
 - 12.3 COMMUNICATION LINKAGE
- 13. MATHEMATICAL TABLES
 - 13.1 NATURAL TRIGONOMETRIC FUNCTIONS
 - 13.2 POWERS OF 2 TABLE

2.1.5 F = RCS refuel command (no \) LMS\

2.1.6 \$ - See Loading Procedures (no \ at this point)

2.2 Freeze Only

2.2.1 S\ = Step Ahead Time HHH/MMSS\

H = Hours, 3 decimal digits

M = Minutes, 2 decimal digits. Limits are 00-59.

S = Seconds, 2 decimal digits. Limits are 00-59.

NOTE: Step Ahead time is limited as follows: 0 Hours \leq STEP AHEAD TIME \leq 10 Hours

3. C Computer Only: (No \ required)

3.1 Freeze only

3.1.1 L = Look AAAAAB . . . (display)

3.1.2 E = Enter AAAAAB . . . (display) . . . 00000000

A = Address, 5 octal digits

B = Bank (L or U)

0 = Data, 8 octal digits

DEP (DEDA ENTER PRINT)

PURPOSE: To allow preprogrammed or initialized outputs to be displayed via Real Time Print upon command from the Abort Guidance System. There are presently two (2) conditions which command this print, an "ENTRY" on the AGS DEDA, and the completion of a Rendezvous Radar to AGS update. This mode has no effect when it is required that there be normal RTP utilization.

RESTRICTIONS: The DEP and RTP are functionally the same Hence, one must be in print control but not both. The DEP is presently the controlling function; however, selection of R.T.P. via Sense Switch 3 on A-Computer of the IOS RTP button causes R.T.P. to be in print control. While in DEP mode "RTP TOP OF FORM LOGIC" and "NASA VARIABLE PRINT RATE LOGIC" is inhibited.

INITIALIZATION: The DEP mode is presently preprogrammed to display 18 parameter values plus R.T.P. formatted mission time. As many as 36, however, may be displayed using the DEP Initialization cards. The following Parameters are presently preprogrammed for DEP display:

	<u>VARIABLE</u>	<u>SCALE FACTOR</u>	<u>DEFINITION</u>
	IPUT1	OCT	DEDA ADDRESS ENTERED
	IPUT2	B+23	DEDA DATE ENTERED
L	IVG	B+15	MAG OF INCRT IN VEL REQ FOR TRI + SEL XFER ORB
I	I1J28	B+15	X COMP OF MANUAL CHANGE IN LM VEL
N	I2J28	B+15	Y COMP OF MANUAL CHANGE IN LM VEL
E	I3J28	B+15	Z COMP OF MANUAL CHANGE IN LM VEL
#	IVPY	B+15	MAG OF VEL ALONG LM Y-AXIS AFTER CDH OR CSI
1	IMU19	B+17	RADAR UPDATE COUNTER (XXOYY) XX=#RNG UPDATES, YY=RNG-RT UPDATES
	HLDZ2LS	B+8	ELEVATION ANGLE BETWEEN LM AND CMS AT TIME OF DEDA ENTRY

	<u>VARIABLE</u>	<u>SCALE FACTOR</u>	<u>DEFINITION</u>
	EMAAPO	B+14	EOM APOGEE MINUS AGS CALCULATED APOGEE
	EMAPERI	B+14	EOM PERIGEE MINUS AGS CALCULATED PERIGEE
L	EMARNGE	B+14	EOM RANGE MINUS AGS CALCULATED RANGE
I	EMARNGRT	B+15	EOM RANGE-RATE MINUS AGS CALCULATED RANGE-RATE
N	EMAALT	B+23	EOM ALTITUDE MINUS AGS CALCULATED ALT.
E	EMAALTRT	B+15	EOM ALTITUDE-RATE MINUS AGS CALCULATED ALTITUDE-RATE
#	ARHONM	B+15	CSM/LM RANGE IN NAUTICAL MILES
	ARHODLS	B+16	CSM/LM RATE OF CHANGE OF LINE OF SIGHT DISTANCE
2	IEOMART	B+16	EOM ALTITUDE RATE AT TIME OF DEDA ENTRY

The following parameters represent the standard pre-programmed X-Y plotter outputs and are effective only if Option A or B have not previously been selected:

<u>Channel No.</u>	<u>Symbol</u>	<u>Range Recorded</u>	<u>Description</u>
17	VXRELHNM	<u>+500</u>	RANGE-ALONG ORBIT AXIS (NAUT. MILES)
18	VXRELHNM	<u>+500</u>	
19	VZRELHNM	<u>+250</u>	RANGE-VERTICAL AXIS (NAUT. MILES)
20	VZRELHNM	<u>+250</u>	
21	VXRELH	<u>+100</u>	RANGE-ALONG ORBIT AXIS (NAUT. MILES)
22	VXRELH	<u>+100</u>	
23	VZRELH	<u>+100</u>	RANGE-VERTICAL AXIS (NAUT. MILES)
24	VZRELH	<u>+100</u>	

The following options (A or B) overlay the standard X-Y table. See X-Y/X-T/Event Recorders write-up for information on the selection of these options.

<u>XT Channel No.</u>	<u>Symbol</u>	<u>Range Recorded</u>	<u>Description</u>
<u>Table A (Descent)</u>			
17	VHNLTEMP	0 to +70,000	ALTITUDE (FT)
18	GALTBIAS	<u>+2,000</u> / <u>+5,000</u>	LUNAR TERRAIN WRT LANDING SITE (FT)
19	ARDNL	<u>+300</u>	ALTITUDE RATE (FT/SEC)
20	VLONGPLT	0/+400,000	RANGE WRT NOM. TRAJECTORY (FT)
21	VLONGPLT	-5,000/+70,000	RANGE WRT NOM. TRAJECTORY (FT)
22	VLONGPLT	-25,000/+50,000	RANGE WRT NOM. TRAJECTORY (FT)
23	VCROSPLT	+25,000	CROSS RANGE WRT NOM. TRAJECTORY (FT)
24	VHNLTEMP	0/+10,000	ALTITUDE (FT)

LINK GROUP - SYSTEMS DIVISION
GENERAL PRECISION, INC.
BINGHAMTON, N.Y.

LMS RESET POINT DEFINITION

LMS-DS-001

REV. J

REVISIONS	PREPARED BY	DATE	PREPARED BY	DATE	CHECKED BY	DATE	APPROVED	DATE
ORIGINAL	Larry Wright	10/17/68						
J	John Bennett	2/7/72						

DATE 3-8-72

SINGER-GENERAL PRECISION, INC.
LINK DIVISION

PAGE NO. 1

REV. J

BINGHAMTON, NEW YORK

REP. NO.

The following changes have been made to LMS-DS-001 Rev. I to update it to Rev. J configuration.

- 1) Launch time and date on page 2 was updated.
- 2) References on page 2 were updated.
- 3) Event times on pages 2 and 3 were updated for each Reset Point.
- 4) Page 3 was deleted.
- 5) New title page was added.

DATE 3-8-72

SINGER-GENERAL PRECISION, INC.
LINK DIVISION

PAGE NO. 2

REV. J

BINGHAMTON, NEW YORK

REP. NO.

APOLLO 16 MISSION

Apollo 16, AS-510/CSM-112/LM-10 is a lunar landing mission to be launched April 16, 1972, at 1154:00.0 C.S.T.

Rev: 1) Operational Trajectory Simulator Data Package for Apollo 16 (Mission J-2) for April 16, 1972 Launch, dated March 1, 1972, MSC Int Note #72-FM-61.

RESET NUMBER	EVENT GET	EVENT
1	74:09:00	LØI - 20 min.
3	78:16:00	DØI - 20 min.
5	93:44:00	Separation - 2.5 hrs.
7	95:54:00	Separation - 20 min.
10	96:15:00	Separation + 1. min.
11	97:22:00	CSM Circularization - 20 min.
12	97:43:00	CSM Circularization Burnout + 1. min.
15	98:15:00	PDI - 20 min.
16	98:30:00	PDI - 5. min.
20	100:17:00	Landing + 1.5 hrs.
24	167:45:00	Ascent - 4.0 hrs.
25	170:30:00	Ascent - 1.25 hrs.
26	171:10:00	Ascent - 35. min.
27	171:35:00	Ascent - 10. min.
31	171:40:00	Ascent - 5. min.
30	171:53:00	Insertion Burnout + 1. min.
40	172:19:00	TPI - 20. min.
42	172:40:00	TPI Burnout + 1. min.
45	173:10:00	MCC - 2 Burnout
50	173:42:00	Docking + 1. min.

EXCESS CURRENT USAGE MALFUNCTION
By Any System on CD's & SE's Buss

Go to any nominal powered up R.P.(ex: R.P. 16) go to run.

For LMP's Buss:

1. Using "U" routine, enter desired percentage or percentages into any or all of the following:

LPR1:	.55360	} See Note	NOTE: See remarks
LPR2:	55361		
LPR3:	55362		

EXAMPLE:

C/R

U

C/R

XXXXX BL

XXXXX: Core location of LPR1, 2, or 3.

will get printout of contents

Enter desired percent, (e.x., 13% would be: .13 B1)

C/R

2. Enter desired CKT BKR or CKT BKRS location (s) into the following:

SECB1:	55344	} See Note
SECB2:	55345	
SECB3:	55346	

EXAMPLE:

C/R

E

C/R

XXXXX BL

XXXXX: Core location of SECB1, 2, or 3.

C/R

typewriter will type out 00070032 (See Note)

Type in: 000YYYYY

YYYYY: Core location of desired CKT BKR.

C/R

3. Note Schematic at right:

This circuit configuration must be used
to increase the current thru the switch
location simulating excess current from
specific equipment.

CKT BKR

SWITCH

Enter desired switch location or locations into
the following:

LOAD

SESW1:	55347	} See Note
SESW2:	55350	
SESW3:	55351	

EXAMPLE:

C/R

E

C/R

XXXXX BL

XXXXX: Core location of SESW1, 2, or 3.

C/R

Typewriter will type out 00070032 (See Note)

Type in: 000YYYYY

YYYYY: Core location of desired switch

C/R

NOTE: If no switch is involved, then 00070001 must be typed into
SESW1, 2, or 3 location.

4. LMP Bus Current should increase by approximately the percentage called for. Monitor this current on the bit box CBIFDSE, 52300 BL @ B12.
5. To remove enter 00070032 into Step 2 or 3 or set percentage location, LPR1, 2, or 3 to zero.
6. The same procedure holds for commanders buss using the allotted commander terms.

CDR'S %'S

CPR1: 55363
CPR2: 55364
CPR3: 55365

} See Note

CDR'S CB'S

CRCB1: 55352
CRCB2: 55353
CRCB3: 55354

} See Note

CDR'S SW'S

CRSW1: 55355
CRSW2: 55356
CRSW3: 55357

} See Note

Monitor this buss current: CBIFDCDR: 52301 B12 BL

REMARKS:

- A. When entering percentages into the "U" routine, the percentages are normalized. Therefore,

100% = 1.0 B1
50% = .5 B1
5% = .05 B1

- B. Use the following equation to determine %:

$$\% = (.0625)(I)$$

Where: I = desired amount of current increase

NOTE: 100% increase in current = approximately 15 AMPS. DO NOT EXCEED.

- C. The EPS system is not designed to allow the circuit breakers to "POP" if their current limitations are exceeded. Refer to systems handbood, DWG. 5.5 for circuit breaker limitations. Operators must exercise CAUTION when using this mod in order to maintain a "REALISTIC" circuit configuration. Refer to the Equate List for core location of CKT BKR's and switches.

NOTE: Addresses will change with each Load.

Memorandum

SINGER
EDUCATION & TRAINING PRODUCTS

to: LMS Programmers
from: M. Dunnam
subject: Programmer's User Manual Update #43

LINK DIVISION

refer to: MD-72-062

date: March 17, 1972

Please make the following changes to your LMS User's Manual:

1. Replace cover page showing the latest update.
2. Replace 1 page on Parameter Display in the Data Acquisition System section of your manual.
3. Replace Examples IV and VI in the DDP-224 Summary Section of your manual. (2 pages).



M. Dunnam
LMS Flight Mechanics Supervisor



Concurrence:

K. R. Altom
Senior Supervisor - LMS Programming

MD/imm

Distribution

UPDATE #43

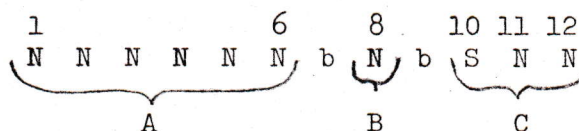
March 17, 1972

LMS USER'S MANUAL

VOLUME I - ONLINE

PARAMETER DISPLAY

I. Card Format for Pre-Mission Initialization



The order in which the cards are read will correspond to the value of the parameter display thumbwheel.

- A. Columns 1-6: The absolute address of the parameter to be displayed (with leading zeros if necessary) is punched in columns 2-6. If the parameter is in upper core, 1 is punched in column 1. If the parameter is in lower core, zero is punched in column 1.
- B. Column 8: The computer in which the parameter is located where 1 = Computer A
2 = Computer B
3 = Common Core
- C. Columns 10-12: The scaling in decimal of the parameter (with leading zero if necessary). The sign must be punched in Column 10. For B0 one must use +00.

II. Loading of Cards;

- A. The initialization deck consists of a header card as described in the Unified Simulation System under "Loading Procedures", up to 50 initialization cards, a blank card, and an *END card.
- B. The deck is loaded in the same fashion as all other card inputs described in the Unified Simulation System.

IV. Honoring 50ms. Interrupt

Problem: Increment X1 by 1 every 50 ms.

```

      ORG      '2
      PZE                      50 ms. TRAP LOC. A & B COMPUTERS ONLY
      JMP      INTRUP
      *
      ORG      '100
START  ENB      ENABLE INTERRUPT
      OCP      '5040
      JMP      *              SIMULATED NORMAL FRAME
      HLT
INTRUP STX      SAVEX1, 1    SAVE ALL NECESSARY REGISTERS
      IRX      0, 1         INCREMENT X1
SAVEX1 LDX      **, 1
      JRT      '2          RETURN TO NEXT INSTRUCTION TO BE EXECUTED WHEN
                           INTERRUPTED.
      END

```


LEM DCE I/O

VI. DCE input/output is accomplished through the address and range register enabled through the FBC. Although the complete range of the desired device need not be transferred, to ensure a complete transmission of all words needed, one will normally input/output the maximum number of words possible.

	OCP	'26145	Connect FBC to DCE
	OCP	'6010	Select FBC
	OTM	X	Address of data
	OTM	Y	Range of data
	OCP	'XXXX	Select device
	SKS	'26010	Is Transmission complete?
	JMP	* - 1	No, wait
X	MZE	ADDR	Address of data (for output)
or			
X	PZE	ADDR	Address of data (for input)
Y	DEC	NUM	.

For example, to output D/A values:

	OCP	'2614	
	OCP	'6010	
	OTM	X	
	OTM	Y	
	OCP	'3026	
	SKS	'26010	
	JMP	* - 1	
		;	
		.	
		.	
X	X	MZE	DATABAB + 1
Y	I	DEC	320
DATABAB		REFN	
		END	

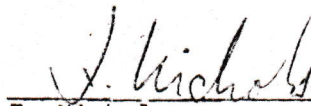
to: Distribution
from: F. Nichols
subject: LMS User's Manual #44

LINK DIVISION
refer to: FN-72-67
date: March 29, 1972

Please make the following changes to your LMS User's Manual:

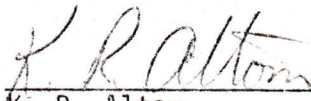
1. Replace cover page showing the latest update.
2. Replace pages 3 and 4 in Real Time Print in the DATA ACQUISITION SYSTEM section of your manual.

NOTE: Update #44 clears DR L-0655



F. Nichols
LMS OBS Programmer

Concurrence:



K. R. Altom
Senior Supervisor, LMS Programming

FN/mm

LMS USER'S MANUAL

VOLUME I - ONLINE

- 1) Address - same as DEC, see 1.c.1
- 2) Bank - same as DEC, see 1.c.2.
- 3) Scaling - not applicable.
- 4) Print - same as DEC, see 1.c.4.

TYPE OF CONTROL CARDS

1. PDT - optional - specifies the data print rate in Run mode.
2. PFDT - optional - specifies the data print rate in Freeze mode.

The print rate is defined as being the time increment between output. If a print rate control card is not used, the default rate value will assume a maximum rate.

When both print rate control cards are used, their order of sequence is not relevant. It is important however, that if one or the other is used, or if they are used together, they must precede the first parameter card.

The time variable field on each print rate control card begins in C.C.16 and they are in the following identical format:

HH/MM/SS/TT

Where: HH - is an integer denoting hours
MM - is an integer denoting minutes
SS - is an integer denoting seconds
TT - is an integer denoting 20's of seconds

All time components smaller than the major time component present must be delimited.

EXAMPLES:

<u>Time</u>	<u>Variable Field</u>
1 second	1/
1 minute	1//
1.5 seconds	1/10
1.5 minutes	1/30/

2. ENDx - required - x defines computer from which the preceding parameter cards were for
3. EOF - required - defines the physical end of the initialization cards.

OPERATING PROCEDURES

1. Loading of cards:

- A. The initialization deck consists of a (Link) header card as described in the Unified Simulation System under "Loading Procedures", an initialization card deck as just described, and an *END card.
- B. The deck is loaded in the same fashion as all other card inputs described in the Unified Simulation System.
- C. RTP may be initiated by SSW3 on A-Computer or by depressing the "RTP" spril on the I/S.

OPTIONAL PROCEDURES FOR VARIED OUTPUT FREQUENCY

(1/10 second in powered flight; 1/minute in coasting flight)

1. See above 1., but use a NRT header card.
2. NRT may be initiated by SSW3 on A-Computer or by depressing the "RTP" spril on the I/S.

NOTE: It is possible to use only one of these RTP procedures at a given time and whenever going from one to the other it will be necessary to reinitialize.