JSC-18778

FLIGHT PROCEDURES HANDBOOK

HP-41 Computer

Mission Operations Directorate
Flight Design and Dynamics Division

BASIC, REV A
DECEMBER 7, 1984

National Aeronautics and
Space Administration

Lyndon B. Johnson Space Center
Houston, Texas

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HP-41 COMPUTER HANDBOOK

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MISSION OPERATIONS DIRECTORATE

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FLIGHT PROCEDURES HANDBOOK PUBLICATIONS

The following is a list of the Integrated Flight Procedures Handbooks of which this document is a part. These handbooks document integrated and/or flight procedural sequences covering major STS crew activity plan phases.

Title	JSC No.
ASCENT/ABORTS	10559
ENTRY	11542
RENDEZVOUS/ORBITAL NAVIGATION	10589
OMS/RCS	10588
ATTITUDE AND POINTING	10511
STS WORKDAY	10541
SPACELAB ACTIVATION	10545
SPACELAB DEACTIVATION	12803
CREW DATA MANAGEMENT	12985
PROXIMITY OPERATIONS	12802
IMU ALIGNMENT	12842
DEPLOYED PAYLOAD	16191
POSTINSERTION DEORBIT PREPARATION	16219
ASCENT/ORBIT/ENTRY POCKET CHECKLISTS	16873
PAYLOAD ASSIST MODULE-D (PAM-D)	17862
HP-41 COMPUTER	18778
SHUTTLE PORTABLE ON-BOARD COMPUTER (SPOC)	19574

TABLE OF CONTENTS

COMMENTS

It is requested that any organization having comments concerning this document contact R. A. Potter, Trajectory Operations Branch, DM6, telephone 483-3321.

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1. INTRODUCTION

This handbook explains the capabilities of the HP-41C hand-held computer and the programs available for crew use. This computer was provided to shuttle crews in order to give them increased computing flexibility in flight by way of an easy-to-program, easy-to-use computing tool. The computer uses the standard Hewlett-Packard programming language, and because of its compactness, storage in the spacecraft is not a problem. The HP-41C computer is used primarily to provide data storage and data manipulation capabilities that do not otherwise exist in the onboard computers because of core storage limitations. It also provides capabilities similar to existing ground computing capabilities in the event that the spacecraft and crew are in a no-communication situation.

In order to effectively use this book, it is important to have already read the HP-41C Familiarization Workbook prepared by the Crew Training Branch. The workbook provides basic information about the computer and digital cassette drive, which is essential to the proper use of the software described in this handbook. This handbook includes with each program description a program flow diagram which visually indicates keystrokes to be used in program operation. The flow diagrams are maintained in the Reference Data Flight Supplement section 6. The text of this handbook uses several symbols in conjunction with the flow diagrams for easy reference and ease of operation of the computer. In the text, an underlined symbol corresponds to a function key on the computer; on the flow diagrams, the same key would appear inside a box. For both the text and the flow diagrams, a symbol in quotes corresponds to a message that the computer displays on the liquid crystal. On the flow diagrams, straight lines with no arrow heads link program steps which do not require crew intervention; the program automatically proceeds to the indicated next step. Those lines with arrow heads link program steps that require crew intervention before the program can proceed. This is accomplished by pressing the R/S key.

This handbook has an appendix with diagrams of the basic keyboard layout and the keyboard overlays used to identify user-defined keys for the existing programs. In addition, this handbook assumes that the newer module HP41CV is being used with a standard configuration of extended functions module in port 1, extended memory modules in ports 2 and 3, and a time module in port 4. The Communications and the Alarm programs, however, may be used with a Tone Amp. A schematic showing the plug-in module configuration for each of these programs appears in the top lefthand corner of its program flow diagram included in this document.

There are currently eleven programs available in the HP-41C programming library: CG, AOS, Deorbit, Communications, Earth Observations, Orbit, Alarm, HEX, Landing, Proximity Operations, and Tail.

- The CG program allows the crew to track the current x and y cg as a function of MET, OMS and RCS propellant loadings, and whether the payloads are berthed or deployed.

- The AOS program supplies the crew with information concerning the next time the spacecraft will acquire a signal over a communications site.

- The Deorbit program provides the crew with the ability to calculate reliable deorbit targets in the event of a time-critical systems failure requiring an emergency deorbit or in the case of total loss of communications with the ground.

- The Communications program is identical to the AOS program, but it provides the crew with the ability to use the Tone Amp.

- The Earth Observations program provides observation pass information for any one of a set of stored earth observation sites.

- The Orbit program provides the crew with data concerning attitudes and rates involved in the star sighting function and with onorbit sunrise and sunset.

- The Alarm program gives the crew a mechanism by which they can be reminded of upcoming events of particular interest by having the computer sound a tone and display a pre-stored message.

- The HEX program performs a transformation from hexadecimal notation to decimal, and also gives the crew a decimal-to-octal, octal-to-decimal transformation capability.

- The Landing program computes data necessary for the approach and landing phase of flight and may be used in either the STA or the orbiter.

- The Proximity Operations program computes the direction in inertial space in which a payload's grapple fixture is pointed so that the orbiter can do an inertial flyaround to the optimum grapple orientation; it computes the grapple fixture rotation angle and time if the crew wishes to keep the orbiter on VBAR; and it will compute the orbiter range and range rate to the payload.

- The TAIL program computes the orbiter tail-to-sun attitude in the event that the crew needs to maneuver the spacecraft in order to reduce cooling due to the loss of a flash evaporator.

Of the existing programs, only the Alarm/HEX and Landing programs can be considered generic; all the others require flight specific initialization data to operate properly. In addition, though the Alarm program itself won't change, the pre-programmed alarms stored in the computer will change on a mission-by-mission basis. This document will be updated periodically as such data and changes become available.

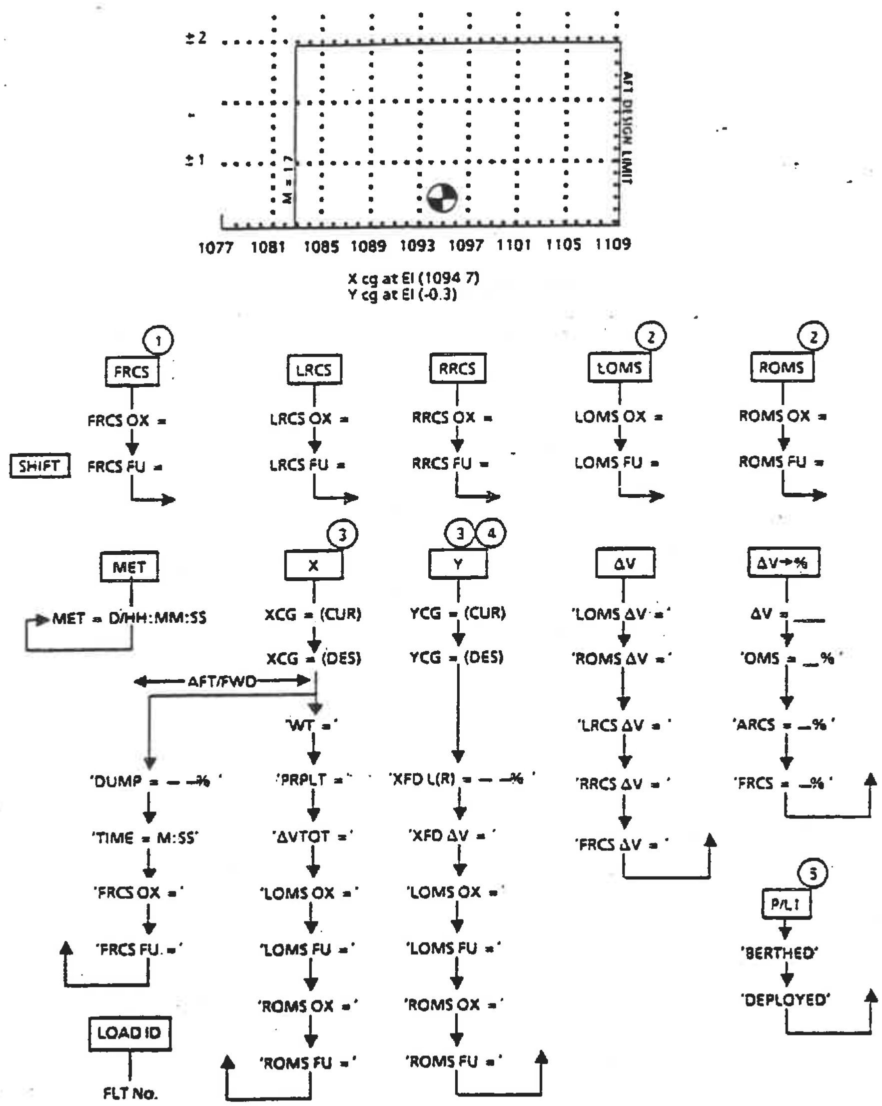
Of primary interest to users training in the SMS, a new capability has been added. All programs containing flight specific data now have a load identification (LOAD ID) key available for 51-DR and all subsequent flights. This key will allow the user to check which load is currently in the calculator's memory.

Additional programs are being developed, some for general flight usage, and others for flight specific payloads. As they become available, additional chapters to the handbook will be written and the document updated. As flights come closer together, more HP software is expected to become available to the community. In order to expedite the use of the HP-41C, it is imperative that timely and accurate user guide updates be provided to the handbook manager. It is the intent of the Flight Dynamics Division to keep this handbook up-to-date for the benefit of the general technical community and also for the purpose of streamlining the effort during the operational shuttle era.

CG PROGRAM

CG PROGRAM ('CG')

FLIGHT CONTROL



1. When a new value of OX is entered, that value will also be entered for the corresponding FU quantity.
2. He TK P may be entered in lieu of qty for LOMS and ROMS.
3. Flag 0 indicates that X or Y must be run to update the weights and moments for a newly entered prop value or payload status.
4. The OMS quantities last computed in X are adjusted in Y and 'XFD ΔV > ΔVTOT' will be displayed if the desired Y CG cannot be achieved.
5. Flags 1, 2, 3, and 4 indicate that the corresponding payload is berthed.

2. CG Program

The CG program allows the crew to calculate pertinent mass properties parameters based on the input requirements of OMS and RCS propellant loadings, time in MET, and whether any payloads are berthed or deployed. The parameters are as follows:

- the current x and y cg;
- the ΔV available in each pod;
- the propellant required for a given ΔV;
- the amount of forward RCS propellant to be dumped to obtain a desired x cg;
- the deorbit propellant weight to be burned for a desired x cg;
- the amount of OMS propellant to be burned while crossfeeding for a desired y cg.

The applicable cg envelope is shown in the figure at the top portion of the accompanying CG program flow diagram. This cg envelope complies with current mission rules and will be updated as required on a flight-by-flight basis. The x and y cg targets should occur at entry interface.

2.1 Initializing the Program

The top five keys of the computer are assigned in the USER mode to the five sets of prop tanks. Pressing one of them displays the oxidizer quantity of that tank, and pressing R/S displays the fuel quantity. Depressing R/S again moves to the next set of tanks. To change a tank quantity, key in the new percentage and press R/S. The new quantity will be displayed. Note that when the oxidizer quantity is changed, the fuel will also change to the same quantity. This feature shortens the time required to initialize the program. If the fuel quantity differs from the oxidizer, it can be changed independently.

The helium tank pressure may be entered instead of a percentage quantity for LOMS and ROMS. If the entry is less than 1000, the program assumes a percentage; if it is greater than 1000, the program assumes a helium pressure and computes the corresponding quantity. As a guide, 1975 psi is about zero and 4000 psi is full (about 65 percent for STS-5).

The MET key should be used to sync the HP-41C Time Module with the onboard MET. The program uses this knowledge of MET to calculate the "dry" weight and cg which it knows as a function of MET. Once set, the MET will be updated by the Time Module for each subsequent computation of the cg. To sync the MET, key in the curent MET in a D.HHMMSS format and press R/S.

Pressing the key labeled for each deployable (P/L 1 key in the accompanying flow diagram) calls a display indicating whether the payload is "BERTHED" or "DEPLOYED". Once the function is called, pressing R/S will toggle the state for each deployable permitting crew selection of the appropriate payload state. In its current configuration, the CG program can handle up to four deployables. Note that the small numbers, "1 2 3 4", in the lower center of the display indicate which deployables are onboard: if the small number is on, the particular payload is berthed; if the number is off, the payload is deployed.

2.2 Calculating the Current CG

Once initialized, the program will calculate and display the x or y cg position when X or Y is pressed. When any of the prop quantities or deployables are changed, a small "0" will be present in the lower center of the display until the new cg has been calculated.

2.3 Calculating the ΔV Available in Each Pod

Press ΔV and the ΔV in feet per second that is available in the FRCS will be displayed based on the lesser of the two, either oxidizer or fuel loaded under FRCS. Press R/S and each of the other pod ΔV's will be displayed in turn.

2.4 Calculating the PRPLT Required for Any ΔV

Press ΔV % and key in a ΔV in feet per second. Press R/S and the amount of FRCS, ARCS, and OMS required for that ΔV will be displayed. In the case of ARCS and OMS, the percentage displayed is that required from either pod to attain the ΔV.

2.5 Dumping FRCS for a Desired X CG

Press X and the program displays the current x cg. Key in a desired x cg, about 1 inch greater than the current x cg, for example, and press R/S. Press R/S again after the desired cg is displayed and the program will calculate the quantity of FRCS to be dumped to achieve the desired x cg. Press R/S again and the time of the dump will be displayed in a M:SS format. Pressing R/S again will display the FRCS oxidizer and fuel quantities remaining after the dump. Note that this calculation does not affect the current prop quantities. They can be changed only by the top five keys.

2.6 Deorbit Burn of OMS for a Desired X CG

First, decide to what quantity the FRCS will be dumped after the deorbit burn and enter this quantity with the FRCS key. The more FRCS to dump, the more OMS will be wasted. Typically, FRCS is dumped to zero to minimize the landing weight. Then press X to display the x cg for no OMS burn and key in the desired x cg. A typical envelope of the allowable cg is attached (see pg. 2-2). Press R/S and the program will display the deorbit burn vehicle weight. Press R/S and the program will then calculate the PRPLT item entry of the deorbit maneuver display. This is the total weight of OMS to be burned on deorbit. Press R/S again and the program will display the equivalent ΔV which should agree with the deorbit burn ΔVTOT from guidance. If the guidance requires more ΔV for the inplane component of the burn than requested through the PRPLT entry, the ΔVTOT will be significantly larger than that given by the CG program. The result would be a more forward x cg than desired, and the only remedy is to dump more FRCS if it is available. Pressing R/S again will display the post-burn OMS quantities. Be aware that the program will solve for the desired x cg even if it has to use more OMS than is available, resulting in negative quantities remaining.

2.7 Crossfeeding OMS for a Desired Y CG

To determine the crossfeed cues for achieving a desired y cg, press Y and key in the desired y cg. Press R/S and the program will calculate the quantity of OMS to be burned from the heavy pod while in the crossfeed configuration. The corresponding ΔV is displayed, followed by the OMS quantities from the last burn computed in X adjusted for the crossfeed. If attempting to move the y cg farther than can be done if the entire X solution were to be burned from one pod, the program will display "XFD ΔV > ΔVTOT." In other words, the burn that was computed in X was not large enough to move the y cg as far as desired even if it were done entirely on one pod. The program will display the solution, which will add prop to the light side, if R/S is pressed.

AOS/DEORBIT PROGRAM SET

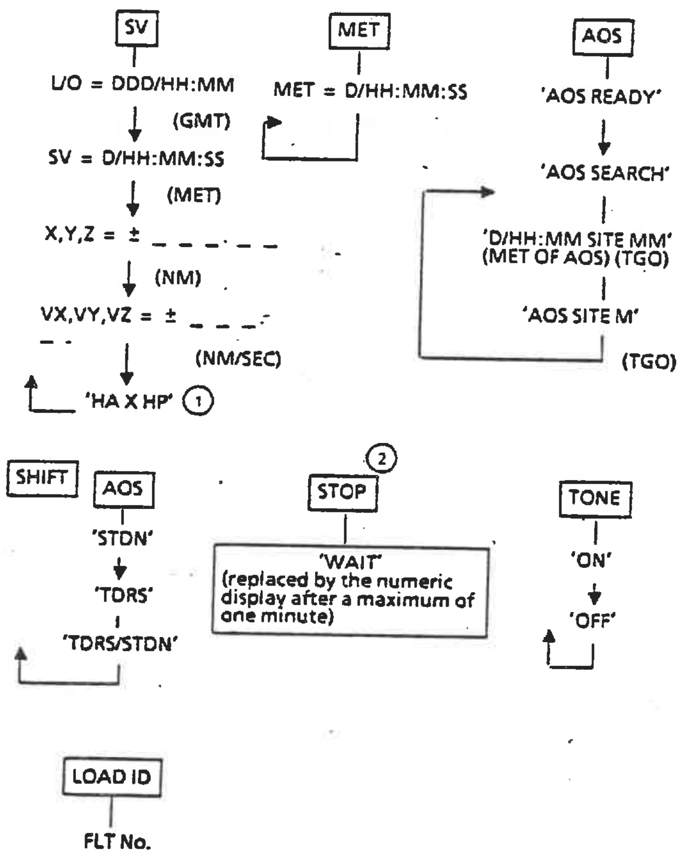
AOS PROGRAM ('AOS')

GNC 0 GPC MEMORY

ENG UNITS -
ITEM 26 + 2 0 1 EXEC

	OPS 2	OPS 8	OPS 3
X	BBF2 + +	C03C + +	C320 + +
Y	BBF6	C040	C324
Z	BBFA	C044	C328
VX	C032	BB06	C048
VY	C036	BB0A	C04A
VZ	C03A	BB0E	C04C

FREEZE DISPLAY USING SPEC KEY



1. The 'HA x HP' may differ by several miles from that displayed by the GPCs due to differences in the gravitational models.
2. Failure to use STOP and wait for 'WAIT' to disappear will result in a program interruption. 'NONEXISTENT' will be displayed and the new program must be recalled.
3. Flags: 0 - tone 'OFF'; 1 - 'SV'; 2 - 'AOS'; 3 - 'LAND'; 4 - 'DEO'.

3. AOS/Deorbit Program Set

This software set includes two separate programs that the crew can access: AOS and Deorbit. The AOS program provides the crew with communication site information. The Deorbit program allows the crew to calculate reliable deorbit targets onboard in the event of a time-critical or no-communications situation.

3.1 Initialization

The keys, SV and MET, are used to initialize the state vector and to set the MET. The state vector is obtained by a GMEM using the procedure which can be found in the upper portion of the accompanying AOS program flow diagram (Reference Data Book Flight Supplement, p. FS 6-6). Press the SV key and enter the state vector by keystroking the new data and pressing R/S. Press R/S again to proceed to the next entry. The CHS key is used to make an entry negative. The first entry is the Julian date and GMT of liftoff. This is not required for the AOS program, but is required for the Deorbit program to calculate the lighting conditions for landing.

After the last component of the state vector is entered, press R/S again and the program will calculate the orbital elements and display an approximate "HA x HP" in nautical miles. This may vary by a few miles from what the GPC's indicate because of differing assumptions in the earth's radius - it's only meant to show that there is no sign inversion or other gross error in the SV entry. Next, press MET and the computer will display its current MET in a "D/HH:MM:SS" format. To sync the computer with the onboard MET, key in an upcoming MET in a D.HHMMSS format and press R/S to enter it at the appropriate time.

A state vector will typically provide AOS/Deorbit solutions accurate to 1-2 minutes for at least 24 hours unless, of course, any significant translation maneuvers are performed. The MET clock is very accurate and will not require a new sync unless unplugged.

3.2 AOS Program

The AOS program provides the crew with the ability to determine when the spacecraft will pass over the next communications site, the site ID, the kind of communications available, and the length of the pass.

The AOS program can be run by depressing the AOS key. Once the computer has been initialized it will display "AOS READY". Press R/S; the display will show "AOS SEARCH" shortly after the program begins. The small "PRGM" in the lower right corner of the display is an indication that the program is running; the keyboard is locked out with the exception of the R/S key which can interrupt the program. Within 1 to 5 minutes the program should find the next AOS and display the following message:

"D/HH:MM	SITE	MM"
MET OF NEXT AOS	SITE AND COMM: S SBAND U UHF B BOTH	MINUTES TO AOS

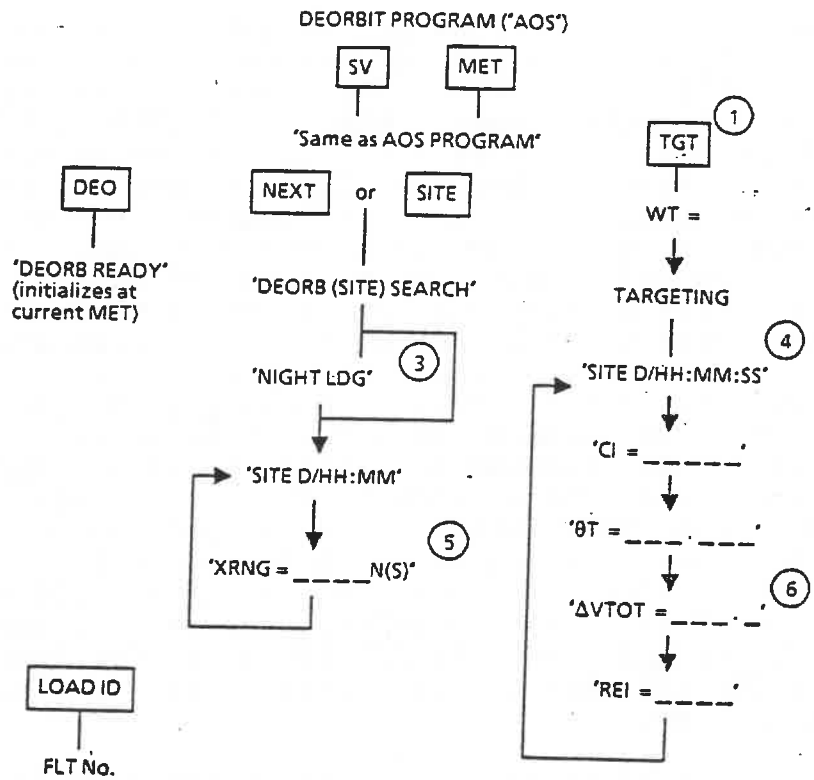
If more than 5 minutes go by, recheck the state vector for a bad component since the program has searched an entire rev without an AOS. If the minutes remaining to AOS are 10 or greater the display will scroll to the left and the "day" digit of the MET will disappear, leaving only the HH:MM. Every minute hereafter, the program will briefly run to decrement the minutes remaining to AOS. When AOS is reached, the computer will sound a series of tones and the display will change to:

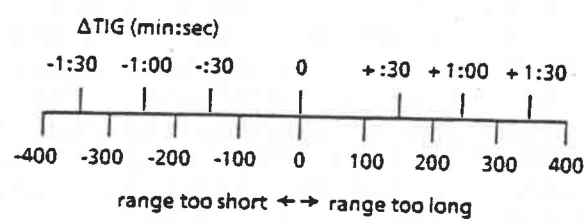
"AOS SITE M"

and the M will count down to LOS every minute. When LOS is reached, the display will show "AOS SEARCH" until the next AOS is calculated.

If no tone at AOS is desired, depress TONE and use the R/S key to toggle the tone OFF and ON. Note that flag "0" is set in the display when the tone is turned OFF. If the tone is changed when the program decrements the countdown clock, the display will revert to the proper AOS or LOS display and TONE must be depressed again. The same applies for doing arithmetic while the AOS program is counting down. The AOS program will interrupt every minute and calculations may have to be redone. If the display is canceled by doing some math, for example, depressing AOS at any time will regain it. Depressing the STOP key will cause the AOS program to stop when the next one minute countdown occurs. A "WAIT" will be present until that happens. The "WAIT" will then be replaced by a meaningless digit in the display, and calculations may be done without being interrupted. If another program is called while AOS is counting down, a "NONEXISTENT" message will be displayed when the one minute countdown occurs. Recall the desired program if this message if displayed.

The AOS program has the capability to search for STDN sites, TDRS EAST, or both, depending on crew selection. Pressing SHIFT AOS, and then using the R/S key to toggle the search options, the crew may select "STDN", "TDRS", or "TDRS/STDN" data to be displayed. Regardless of type of communications selected, the display will count down to AOS or LOS in the standard format. The HP-41CV with two X-MEMORY modules is required to run the AOS program now that this capability has been added.





1. The deorbit targeting assumes C2 = -.6000 and HT = 65.832.
2. 'NIGHT LDG' is displayed for any opportunities that will result in a sun elevation less than zero at landing time.
3. A TIG adjust is generally required to bring the actual REI to within 25 nm of the HP-41 solution.
4. Target XRNG limit is 1100 nm, but current flight rules do not recommend XRNGs in excess of 812 nm.
5. The ΔVTOT is an approximation of the inplane component of the deorbit burn.

3.3 Deorbit Program

The Deorbit (DEO) program gives the crew the ability to calculate reliable deorbit targets in the cockpit. This is similar to the ground computer's deorbit targeting function in the Mission Control Center; flightcrews would use the HP-41C program primarily in the event of a time-critical systems failure requiring an emergency deorbit or in the case of total loss of communications with the ground.

The Deorbit program can be called only by depressing the DEO key. When it begins execution and has read the current MET, "DEORB READY" will be displayed. To search for the next deorbit opportunity to any site, depress NEXT and "DEORB SEARCH" will be displayed while the program is running. To search for a particular site, depress that key, EDW for example, and "EDW SEARCH" will be displayed. When the program finds an opportunity that satisfies the crossrange (less than 1100 nm), it will sound a series of tones and display the site ID and an approximate TIG. Depressing R/S will display the crossrange north or south. The R/S key can be used to toggle between the two displays. "NIGHT LDG" will be displayed when a landing opportunity with sun elevation less than zero is found. Press R/S and the program will display the approximate TIG and XRNG as usual. Subsequent opportunities may be computed by depressing either NEXT or any of the single site keys. To go back to the current MET, you must depress DEO. When "DEORB READY" is displayed the current MET is being used for the initial search. A technique for finding a particular opportunity is to use the approximate TIG which is provided for each orbit in the teleprinter weather message as a guide for setting MET. Set the MET 15-30 minutes before the TIG, depress DEO and then the particular site key after "DEORB READY" is displayed.

When the desired deorbit opportunity has been found, depress TGT and the program will prompt for a crew input of the vehicle weight at deorbit TIG. Enter the weight, press R/S, and the computer will display "TARGETING" while the precise TIG and PEG 4 target are being computed. The program displays the landing site and TIG when the calculation is complete. The TIG format is "D/HH:MM:SS". Depress R/S to display the C1, 0T, ΔVTOT, and REI. Note that the C2 and HT are assumed to be the same for all deorbit burns as shown in the Reference Data Book Flight Supplement, p. FS 6-9. The weight to be input into the computer and recorded in the Reference Data Book Flight Supplement is the weight at deorbit TIG that comes from the CG program (see section 2.6). The TIG has been optimized for a thrust of 1.2 OMS engines. This allows for small TIG slips or engine failures without large ΔV penalties and is the same bias that is used by the ground processors. The ΔVTOT, however, is not biased and will generally be slightly smaller than the PEG 4 solution. Note also, that this ΔVTOT is the inplane component of the burn, and the PEG 4 solution may be considerably larger if a wasting angle has been generated for a PRPLT item entry.

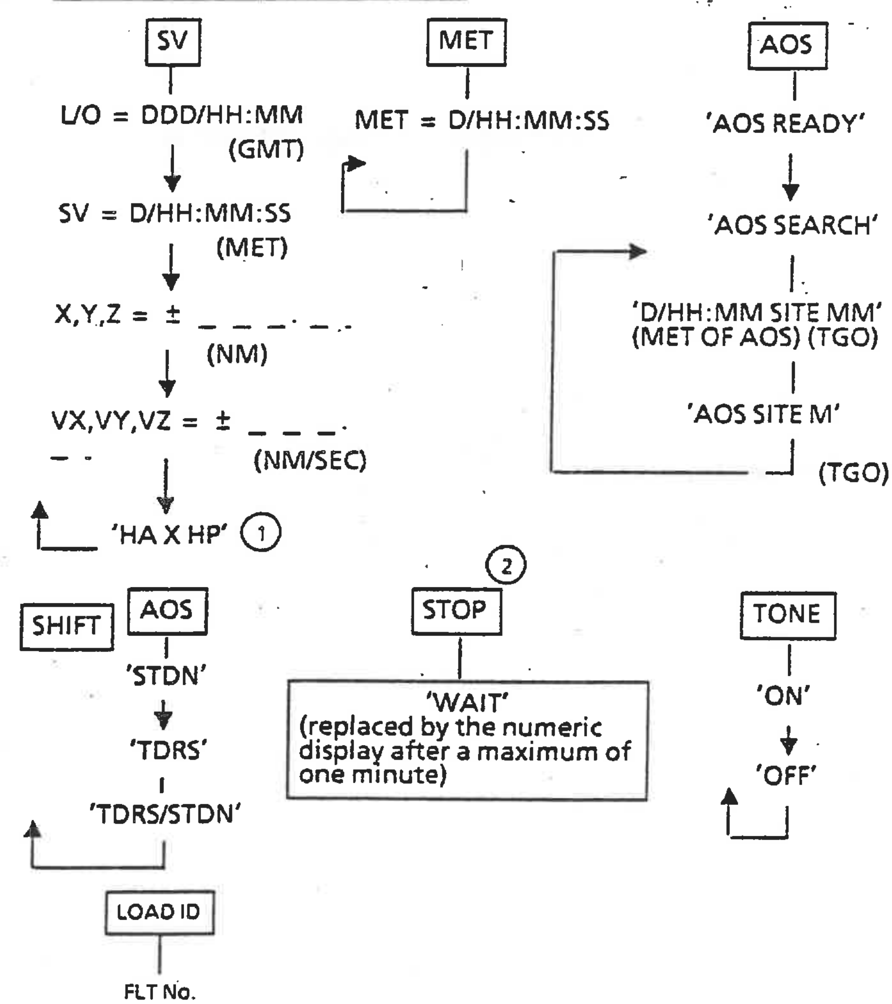
When the target is loaded into PEG 4, an actual REI will be computed and it will generally be different than the desired REI that has been specified by the HP-41C program. This is due to the fact that the HP-41C does not account for drag and oblateness effects between TIG and EI as does PEG 4. The difference may be as large as several hundred miles and a TIG adjust is required using the nomograph at the bottom of the cue card. Remember, the REI that is computed by the HP-41C <u>is</u> the desired range and the TIG should be adjusted until the PEG 4 REI is within 25 NM of this desired REI.

COMMUNICATIONS PROGRAM

COMMUNICATIONS PROGRAM ('COM')

X FUNCTIONS	X MEMORY
TIME MODULE	TONE AMP

PROCEDURE TO OBTAIN GPC READ/WRITE SAME AS AOS PROGRAM



1. Failure to use STOP and wait for 'WAIT' to disappear will result in a program interruption. 'NONEXISTENT' will be displayed and a new program must be recalled.

2. Flags: 0 - tone 'OFF'; 1 - 'SV'; 2 - 'AOS'.

4. Communications Program

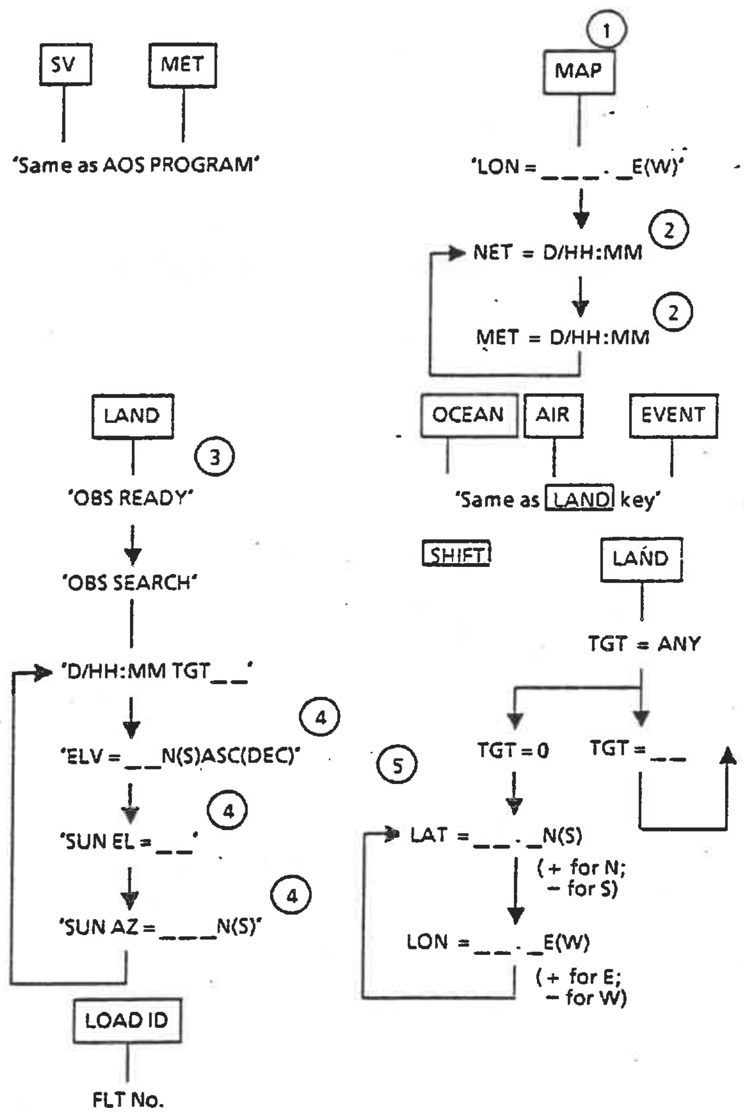
The Communications (COM) program is identical in function to the AOS program, except that it allows use of the Tone Amp to provide a series of tones loud enough to be heard in the noisy flight cabin environment.

State vector initialization, program operation, and keystrokes are the same as in the AOS portion of the AOS/Deorbit program set. The difference is the Tone Amp. The Tone Amp is accommodated by removing the X MEMORY module from port 3, shifting the time module from port 4 to port 3, and inserting the Tone Amp into port 4, as shown in the figure at the top of the accompanying program flow diagram (Reference Data Flight Supplement, p. FS 6-12).

To operate the HP-41C/Tone Amp combination, first turn on the Tone Amp, then the computer. Depress SHIFT, then BEEP to produce a tone from the computer. Set the volume control on the Tone Amp to the desired gain. Then, commence normal Communications program execution in the same manner as would be done with the AOS program in a computer without a Tone Amp.

Earth Observations Program

EARTH OBSERVATIONS PROGRAM ('OBS')



1. MAP computes the longitude of the ascending node of the current orbit.
2. Changing NET and MET while in MAP does not change the current MET.
3. The first calling of LAND initializes the search at the current MET.
4. Elevations are relative to the target; sun azimuth is relative to the velocity vector.
5. TGT = 0 only available with the EVENT key.
6. Flags: 0 - SV initialization; 1 - LAND geology sites; 2 - OCEAN oceanography sites; 3 - AIR meterorology sites; 4 - EVENT special event sites of interest.

5. Earth Observations Program

The Earth Observations (OBS) program provides the crew with a variety of information that supports earth observations of specific locations. The locations are of geologic, oceanographic, meteorological and special interest and have been selected preflight. However, the crew can enter any latitude and longitude of their choice while on-orbit and receive the same information. The program is initialized with the same on-board state vector that is used for the AOS program and calculates the MET at which the next site of opportunity will be abeam the spacecraft, the elevation of the site, the azimuth to the site either north or south of the groundtrack, and the elevation and azimuth of the sun.

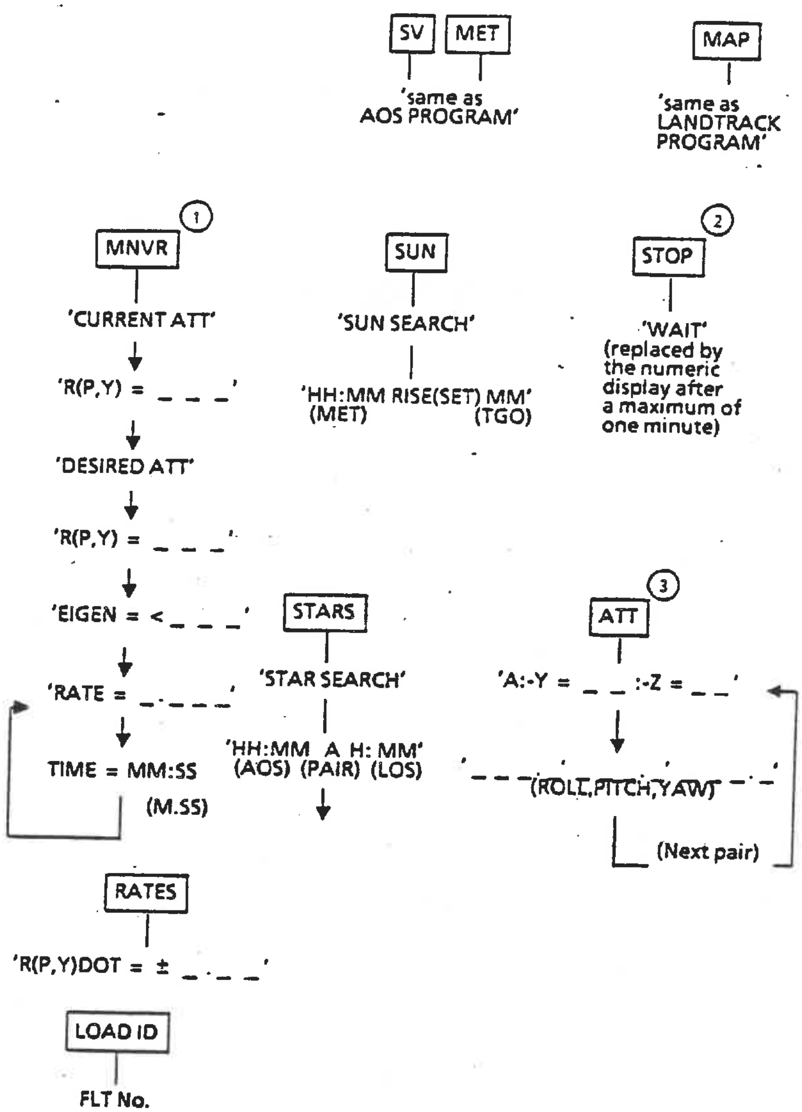
Depress LAND to read the program into main memory; once ready the computer will display "OBS READY". At this point, the available data in the computer are the geologic sites. If the oceanographic, meteoroligical, or special event sites are desired, press OCEAN, AIR, or EVENT, respectively. To search for a particular site, press SHIFT LAND, and the program will display "TGT=ANY". Enter the desired ID number found in the list of sites in the Reference Data Flight Supplement, p. FS 6-11, and depress R/S. The program will acknowledge the site ID. Now, depressing LAND, or one of the other site type keys if that is the case, will cause the program to search for that specific site. To input a site that is not one of the pre-loaded sites, when the display shows "TGT=ANY", enter zero and press R/S. Then the program will ask for latitude and longitude. North and east are entered as positive degrees and south and west as negatives using the CHS key. This scratch line capability is only available under the EVENT key; if a zero is entered as the site ID for any of the other keys, the program will not acknowledge the input, but will redisplay "TGT=ANY". Note that the only way to get back to "TGT=ANY" is to depress the SHIFT LAND keys. The R/S key allows the review of entered data.

The computer will find the target site as it searches at a rate of one orbit every 10 minutes. The MET in the display is the time at which that site will be abeam the spacecraft. Depress R/S and the display shows the elevation of the spacecraft above the horizon from the site (or the site below the horizon from the spacecraft). The minimum elevation for an acceptable pass is 40 deg. The "N" or "S" following the elevation indicates that the site is north or south of the groundtrack and the "ASC" or "DEC" means the groundtrack is ascending (northbound) passing the site or descending (southbound). Depress R/S again and the sun elevation is displayed. Depressing it again displays the sun azimuth in degrees from the velocity vector either north or south of the groundtrack. The displays can be reviewed with the R/S key. If the sun is below the horizon, "NITE" will be displayed.

The MAP key is used to support the Orbit Map that is carried on-board. The overlay of this map is set by aligning an index to the longitude of the ascending node of this current orbit. Depress the MAP key and the display shows the longitude of the ascending node. The Orbit Map is graduated in minutes to show the elapsed time from the ascending node for the next three orbits. Depressing R/S again will show the current node elapsed time or NET, and depressing it once more will show the current MET of the program. By keystroking in a new time at either of these displays, both will change to the new time, but will not update the program's MET. This allows the use of the Orbit Map to determine at what MET the spacecraft will be at a specific location or where the spacecraft will be at a specific time. The MAP key will function properly only for an MET that is after the SV MET.

ORBIT PROGRAM

ORBIT PROGRAM ('ORB')



1. Euler sequence is PYR and assumes: $0 \leq P < 360$, $270 \leq Y \leq 90$, and $0 \leq R < 360$.

2. Failure to use STOP and wait for 'WAIT' to disappear will result in a program interruption.

3. ATT will load the displayed star pair attitude into the 'DESIRED ATT' of MNVR.

6. Orbit Program

The Orbit program provides the crew with information concerning Startracker star pairs, vehicle maneuver information pertinent to the Startracker sighting, and has the ability to predict onorbit sunrise and sunset. The Orbit program is initialized by entering a state vector and an MET using the same format as in the AOS program (see section 3.1). In addition, the Orbit program has a MAP key which functions in the same way as the MAP key in the Earth Observations program (see section 5.).

Once the Orbit program has been initialized, press the key labeled STARS. The computer will display "STAR SEARCH" and then the following:

"HH:MM	A	HH:MM"
(AOS)	(star pair index)	(LOS)

where the first time displayed is the time of acquisition of the star pair for observation, the second time is when the star pair will be lost over the horizon, and in the middle of the display is the index letter that catalogs a particular star pair. If R/S is pressed, the program will calculate what the next star pair will be and display that index along with the time of acquisition and loss of the star pair for sighting purposes.

For a particular star pair of interest, if the ATT key is pressed, the computer will first display the star ID's for the star pair in the format "A : -Y = : -Z = ," where A is the star pair index, -Y is the star ID for the -Y Startracker port, and -Z is the star ID for the -Z Startracker port. If R/S is pressed, the computer will then calculate and display the roll, pitch, yaw attitude in the M50 system corresponding to that star pair. Pressing R/S will then switch the stars in the same pair and repeat the process by displaying the other attitude for that pair. Press R/S again, and the computer will cycle through to the next star pair and display those star ID's. When the ATT key is used, the roll, pitch, yaw attitude is automatically loaded into the "DESIRED ATT" addresses under the MNVR key.

To compute the rates and time required for any three-axis maneuver press MNVR. The program will prompt for the current vehicle attitude with the display "CURRENT ATT". Enter the current roll, pitch, yaw sequence; when all components are entered, press R/S again and the computer will ask for "DESIRED ATT". At this point the desired vehicle attitude may be keyed in or the user may default to those stored from the ATT function key. When the desired attitude has been completely entered into the computer, the HP-41C will compute and display an eigen angle, in the format "EIGEN = ". Press R/S and the computer will request an angular rate to perform the maneuver (the default value is 0.2 deg/sec). Press R/S again and it will display the length of time it takes to perform the Startracker maneuver in "MM:SS" at the rate that was input. Changing either the rate or the time (MM.SS) will cause the program to recompute the other. To obtain the vehicle rates in the roll, pitch, and yaw channels, press the RATES key and use the R/S key to toggle through the displays. The RATES key can be used only in conjunction with the MNVR key; using it at any other time will result in meaningless data.

To obtain the time of the next sunrise or sunset, press the SUN key. The computer will display "SUN SEARCH" and then the following:

"HH:MM	RISE (SET)	MM"
(MET)		(TGO)

where the time displayed is the MET of the event, next a label indicating whether the event is sunrise or sunset, and a decrementing counter which shows how many minutes from the current MET until the event.

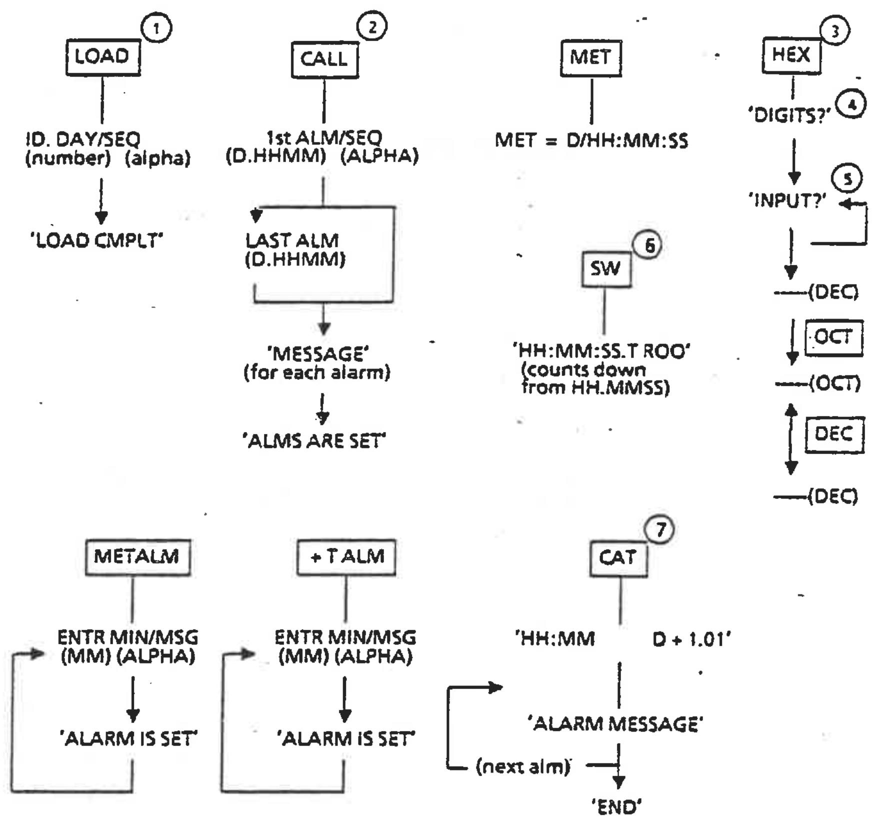
To exit the Orbit program, there is a STOP key similar in function to the STOP key for the AOS program. When the STOP key is depressed, the display will show "WAIT" for approximately one minute. When the "WAIT" disappears, it is then acceptable to proceed with other computer functions.

ALARM/HEX PROGRAM SET

ALARM-HEX PROGRAM ('ALM')

HP-41CV

X FUNCTIONS	X MEMORY
TIME MODULE	TONE AMP



1. Remove the tone amp and insert the cassette drive prior to pressing LOAD. For METALMs, key in ID (CDR = 1 PLT = 2) and flight day. For + T ALM sequences, key in the ALPHA name of the sequence.
2. Enter a D.HHMM to call a series of METALMs. To call a + T ALM sequence, enter the ALPHA name and the D.HHMM for the sequence initiation (default at current MET).
3. The hexadecimal number to be converted should not exceed 11 digits in length.
4. Enter total number of digits in the hexadecimal number.
5. Input digits one at a time from left to right.
6. R/S will stop and restart SW, and ENTER will store lap times in R00, R01, etc. Use SHIFT ← to exit SW.
7. Use R/S to stop CAT and SST or SHIFT SST to step or backstep. SHIFT 'C' WILL CLEAR AN ALARM. Use ← to exit CAT.

7.1 Alarm Program

The Alarm program allows crews the flexibility of having the HP-41C computer serve as a mechanism to remind them of upcoming events of particular interest. A message and a time in MET may be input into the computer. Then, taking advantage of the computer's time module capability, a tone will sound at the correct time and the message will be displayed for crew inspection and acknowledgement.

7.2 The LOAD Function

As many as 120 preprogrammed alarm messages can be stored in the Extended Memory. Alarms are stored in blocks of similar function or by proximity in time, and may be labeled for use by a specific flight crew member on a specific day. The format for the label for such a block of alarms would be crew ID.day, where the crew ID is a number assigned to a designated crew member, such as 1 for the commander, 2 for the pilot, etc. Following the period in the label, the day would indicate which day of flight, such as fight day 3. The LOAD function allows these alarms to be loaded from a cassette using the digital cassette drive. The CALL function then permits the selective calling of one or more of these alarms into active memory.

To load a day's alarms, turn off the computer, remove the Tone Amp and insert the HP-IL module attached to the cassette drive. Turn the computer on and press LOAD. The user then has the option of loading alarms as follows:

(1) Key in a crew ID.day, such as 1.1 for the commander on day one of the mission, for a particular set of alarms.

(2) Toggle into ALPHA mode, and key in a particular sequence name to retrieve a block of alarms, then toggle out of ALPHA.

When the computer has retrieved the desired block of alarms, it will display "LOAD CMPLT". At this point, turn off the computer, remove the HP-IL module, reinsert the Tone Amp, and turn the computer back on.

7.3 The CALL Function

To activate any one of these alarms or block of alarms, press CALL and the program will prompt for an input. This prompt can be answered in one of two ways:

(1) Key in the MET of the first desired alarm in the block and press R/S; then key in the MET of the last alarm in the block or an MET after the last alarm and press R/S again.

(2) Select ALPHA and key in the sequence name for the particular block of alarms of interest, deselect ALPHA, then key in the reference MET for the sequence to begin, and press R/S. (There is no preferred order; the user may key in the reference time first, then toggle to ALPHA and key in the sequence name, if desired.)

The program will flash each alarm message as it is set and prompt with "ALMS ARE SET" when done. Press CAT to review or edit the alarms that were just set.

7.4 Program Operation

Depressing either the MET ALM or +T ALM keys will call the Alarm program. The MET ALM will prompt with the following display:

"ENTR MET/MSG"

Enter an MET in the D.HHMMSS format and a message by selecting ALPHA and typing the blue letters. Depress R/S after entering both the MET and message (in either order) and the display will confirm "ALARM IS SET." Don't forget to toggle out of ALPHA. If only the MET is entered, the default message will be "D.HHMM ALARM". The +T ALM function is similar except that the delta time to the alarm is entered in minutes and the default message is "MM ALARM", where MM is the number of minutes. To review the alarms that are currently stored in memory, depress CAT for alarm catalog. A series of displays will flash starting with the next due alarm and proceeding to the most distant. There are two lines displayed for each alarm. The first is the time for the alarm

"HH.MM D+1.01"

and the second is the message that was entered

"ALARM MESSAGE"

When the catalog is complete, "END" will appear in the display. To review the alarms more leisurely depress R/S while the catalog is being displayed. This will stop the catalog at the current display and the SST key can be used to single step through the alarms. To go backwards through the alarms, depress SHIFT (yellow key) then SST. To exit the catalog depress <--. Any alarms that come due while in the catalog will be announced upon exiting it.

When an alarm comes due, two tones will sound and the message will flash on the display. Acknowledge the alarm by depressing any key on the keyboard and the message will clear after about 3 seconds. If not acknowledged, another series of 16 tones will sound and the message will remain in the display.

Alarms that are not acknowledged will remain in the memory and will be announced again if the computer is turned off. If it is then acknowledged it will be cleared. Alarms that are acknowledged by depressing STO will be retained as past due alarms. The presence of a past due alarm will cause two tones to sound when exiting catalog or turning on the computer. To clear an alarm before it comes due, enter the catalog and stop at the alarm to be cleared. Then depress SHIFT and "C" to clear the alarm. The catalog will move to the next alarm and exit by depressing <--.

Another feature of the Alarm program is the stopwatch function. It provides a precise clock display that can be used to count up or down and sound a tone. To count up, enter zero into the display and depress SW. The display will begin counting from zero in a HH:MM:SS.S format. The R/S key can be used to stop and restart the stopwatch. The only way to exit the stopwatch mode is by depressing SHIFT and <-- or by turning off the computer. Any alarms that come due while in the stopwatch mode will become past due without being displayed. When exiting the stopwatch mode two tones will sound if an alarm has come due. To count down and sound a tone upon reaching zero, enter the start time in HH.MMSS and depress SW. The display will count down to zero, sound a tone, and continue counting up from zero. The display also indicates which register the time data will be stored in if the user wishes to take splits. Press ENTER to store the time in the register indicated. The display will then show the next available storage register. Use SHIFT <-- to exit. If exiting the stopwatch mode while it is counting down, an alarm will be announced when the stopwatch reaches zero. A "TIMER ALARM" message will be displayed and can be acknowledged with any key.

7.5 Program Memory

Each of the various programs called from Extended Memory into the main memory use various amounts of the availale space. Since each alarm message requires some program memory, the number of alarms that can be stored in a particular memory configuration varies. If attempting to set one too many alarms, the display will show "PACKING" and then "TRY AGAIN". If attempting to call a program when too many alarms are already set, the display will shown "NO ROOM" and some alarms must be deleted to run that program.

7.6 HEX Program

The HEX program allows the crew to perform simple numerical transformations between different bases. The program provides the capability to transform a hexadecimal number to decimal notation. This was the primary reason for constructing this program in support of the CFES project or STS 41-D, through it has flown subsequently. This program can also perform decimal-to-octal and octal-to-decimal transformations.

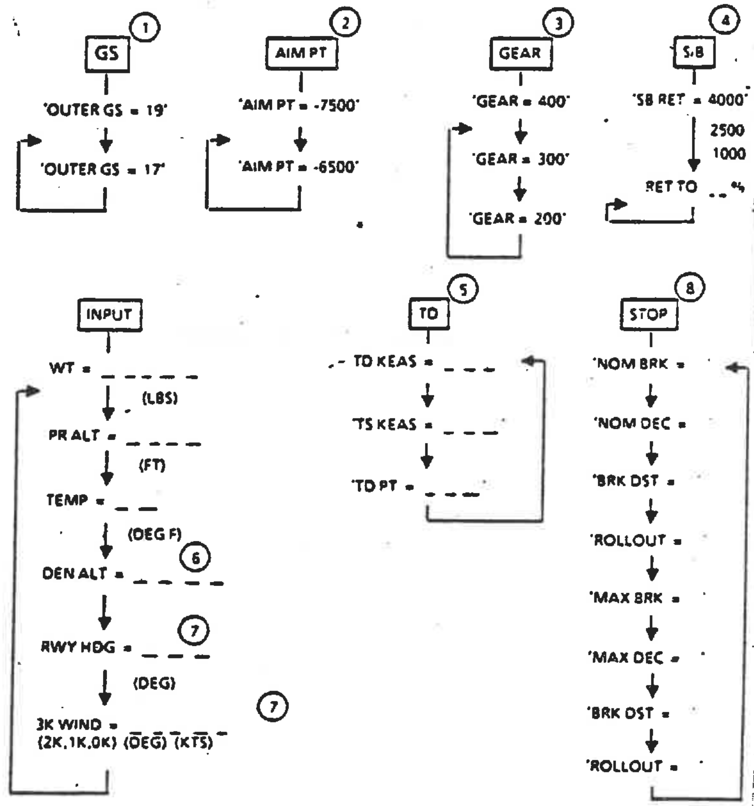
Depress the HEX key and the computer will dispay a "DIGITS?" message. Enter the number of digits in the hexadecimal number and press R/S. The computer will display "INPUT?". Enter the first digit, press R/S, then repeat until all the digits have been keyed in. For alphabetic characters, be sure to press the ALPHA key before entering this digit, and again before pressing R/S. Do not use the ALPHA key when entering numerical characters. Once the first digit has been entered, upon pressing R/S, the computer will process the hexadecimal number and display the equivalent decimal value.

To go from decimal to octal notation, press the OCT key. The computer will take the decimal number in the current display, process it, and then display its octal equivalent. To go from octal back to decimal notation, press the DEC key, and the computer will display the number in decimal notation.

The only limitation to the HEX program is that the hexadecimal number to be converted should not exceed eleven (11) digits. Otherwise, it will cause an overflow condition when processing the hex-to-decimal transformation.

LANDING PROGRAM

LANDING PROGRAM ('LDG')



1. For WT ≥ 220000, the recommended glideslope of 17 will be displayed first

2. For large headwind components, the recommended aim point of -6500 must be crew selected.

3. The recommended gear deploy altitude is 400 feet, and is the displayed value. Crew may also select either 300 or 200 feet for the gear deploy attitude.

4. Speed brake retraction altitude is predicted as a function of winds, weight, and glideslope. The speed brakes are initialized to retract to 15% at that attitude. If a value other than 15% is entered, the TD will be computed assuming that the entered value of S/B extension will be held to touchdown

5. Initial answer is based on a design TD speed of 195 knots for lightweight vehicle, 200 knots for heavyweight vehicle. By inputting a desired TD KEAS, the TD PT will be recomputed

6. DEN ALT computed from PR ALT and temp, and will be displayed. The crew may enter a different value if desired

7. Runway heading and wind direction should both be either true or magnetic

8. Nominal braking begins at 140 KGS with a deceleration rate of 7.5 fps^2. Maximum braking begins at 160 KGS with a deceleration rate of 9.0 fps^2. The crew may enter a different brake initiation speed if desired. The rollout distance is referenced from the runway threshold

8. Landing Program

The Landing Program can provide the flight crews with basic landing data, such as touchdown speed, touchdown point, and rollout distance based upon vehicle weight, landing site characteristics, and winds direction and velocity. First, press INPUT and the computer will prompt for the orbiter weight. Enter the landing weight of the orbiter and press R/S. Next the computer will ask for the runway altitude. Once entered, it will ask for a temperature at the landing site in deg F. With these last two entries, the computer calculates and displays a density altitude for the landing site. The crew may enter a new density altitude into the computer at this point. The computer then prompts for a runway heading in degrees. Press R/S, and then enter the winds at 3000 ft, 2000 ft, 1000 ft, and at the surface in the format DEG.KTS. The user must be careful to enter the runway heading and the wind direction in either all true or all magnetic, but not in a mixed mode. A five-knot wind from the north would be entered as 360.05.

Next, press the GS key in order to initialize the glide slope. The program allows the user to toggle between 19 and 17 degrees. Normally the program will display a 19-deg glide slope to the crews. However, if the vehicle weight is over 220,000 pounds, it will first display 17 degrees.

Press the AIM PT key to select the runway aim point. The program allows the user to toggle between -7500 ft and -6500 ft by means of the R/S key. When the AIM PT key is pressed, it will always initially display -7500 ft.

The GEAR key allows the crew to choose among three different gear deploy altitudes: 400 ft, 300 ft, or 200 ft. The R/S key allows the crew to toggle among the three altitudes. The nominal gear deploy altitude is 300 ft, and that is the value first displayed by the computer when the GEAR key is selected.

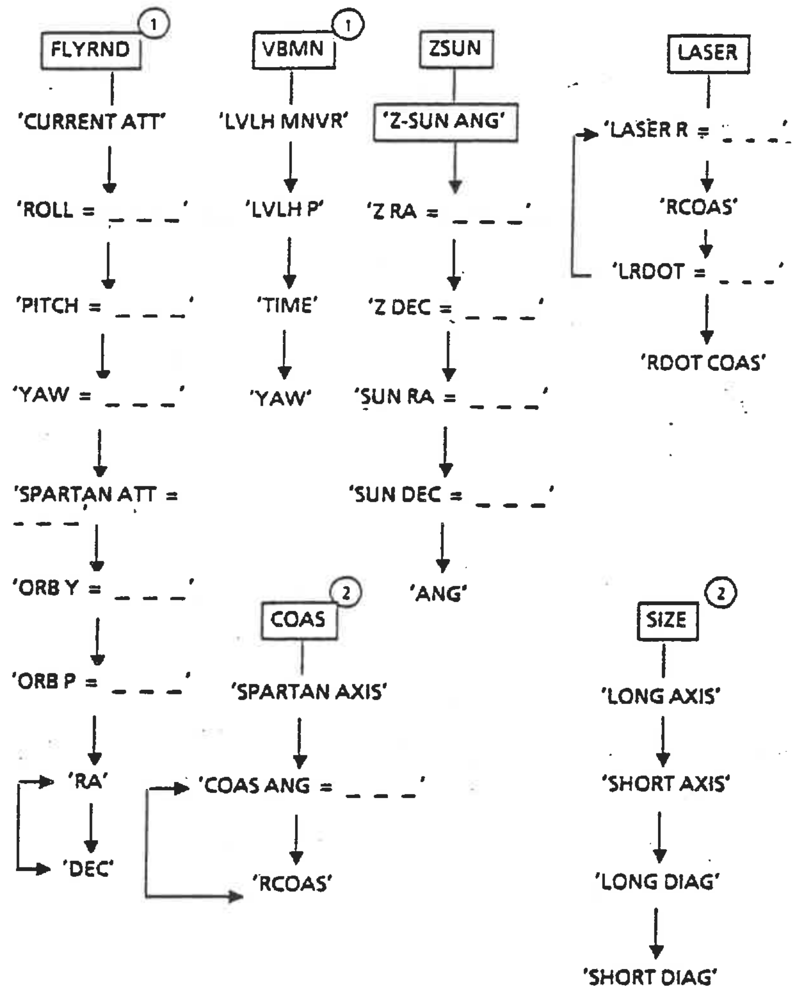
Once weight and wind data have been entered and glide slope, aim point, and gear have been initialized, the program is ready. Press the S/B key, and the program will compute and display the altitude at which the speed brake will retract to 15%. The computer will calculate whether that will be at an altitude of 4000, 2500, or 1000 feet, based on the headwind component at 3000 feet. The crew also has the option of entering a speed brake setting. The computer will hold any crew-selected setting to touchdown, thus affecting the position of the touchdown point.

Press the TD key and the computer will display the touchdown speed in knots as predicted by entry flight procedures: 195 kts for lightweight vehicle and 200 kts for heavyweight vehicle. Press R/S and it will display the tail scrape speed for that orbiter weight. Press R/S again, and it will display the touchdown point from the runway threshold. Since most landings are done manually, the crew has the option to input a manual touchdown speed. When the touchdown speed is displayed, enter the desired touchdown speed and the touchdown point will be adjusted accordingly. If the touchdown point is less than 1000 feet from the runway threshold, the crew should press the AIM PT key and reinitialize the aim point to -6500 feet by means of the R/S key toggling capability. Then, the entire speedbrake and touchdown procedure should be repeated.

The STOP key allows the crew to compute a braking and total rollout distance based on brake application groundspeed and brake deceleration rate. Press the STOP key and the computer will display the nominal brake application ground speed of 140 KGS. The crew has the option of entering another brake application speed if they so desire. Press R/S and the computer will display the nominal deceleration rate of 7.5 fps^2. This value may also be input by the crew. Press R/S and the program will compute the braking distance for the input conditions, and pressing R/S again, the computer will display the total rollout distance from runway threshold. By pressing R/S at this point, the crew can recompute these values for maximum braking conditions: brake application at 160 KGS with a deceleration rate of 9 fps^2. Again, the crew may key in other values for these initial conditions, if desired. The computer will then calculate braking distance and total rollout distance for these maximum conditions.

PROXIMITY OPERATIONS PROGRAM

PROXIMITY OPERATIONS PROGRAM ('PRX')



1. Always execute |FLYRND| prior to |VBMN|. The |FLYRND| logic is used to initialize the |VBMN| logic.
2. Execute |SIZE| prior to first execution of |COAS| in order to ensure proper initialization of |COAS| logic.

9. Proximity Operations Program

The Proximity Operations (PROX) program provides the crew with useful information concerning vehicle flyaround and stationkeeping with a target satellite, sun angle data pertinent to rendezvous operations, and range-range rate data for closing on the target. This program was developed by J. A. Hoffman/CB specifically to be used with the SPARTAN spacecraft. However, it can be adapted to provide useful data for any rendezvous target spacecraft.

9.1 Stationkeeping and Proximity Operations

The first portion of the program deals with placing the orbiter in the optimum orientation to grapple the target satellite. The inputs include the current orbiter attitude and an out-the-window, observed estimate of the grapple fixture orientation of the target satellite.

Press FLYRND; the computer will display the message "CURRENT ATT." Press R/S, and the computer will call for the current orbiter attitude; first roll, then pitch, and finally yaw. Press R/S after each entry, and the computer will display "SPARTAN ATT." These are the yaw and pitch angles that the orbiter would have to fly through to point the orbiter +X axis (nose) in the same direction as the Spartan grapple fixture, based on the crew's out-the-window estimate of the observed grapple fixture orientation of the target vehicle. Simulations in the SES have demonstrated that there is sufficient accuracy if these angles can be estimated to within 10-15 deg. of the actual position, which the crews have been able to do consistently. Enter the yaw angle, press R/S, then enter the pitch angle.

Once all the inputs have been made, press R/S, and the computer will output the right ascension ("RA"). Press R/S and then the declination ("DEC") will be displayed. These are the M50 coordinates of the direction in which the Spartan grapple fixture is pointed. To orient the orbiter in an optimum grapple attitude (grapple fixture pointed toward the orbiter's -y axis), the crew must execute a universal pointing track option to the displayed RA, DEC using the orbiter's -y axis (P=0, Y=270) as the body vector (ITEM 5). This, then, defines the orbiter inertial flyaround maneuver to the optimum grapple orientation.

If the crew prefers to keep the orbiter on VBAR instead of doing an inertial flyaround, they may execute the VBMN key. This option computes the angle that the grapple fixture will rotate in order to be in a plane perpendicular to VBAR, how long this rotation will take, and also the orbiter yaw angle to place the satellite grapple fixture at the optimum grapple orientation. Please note, this key should only be used after the FLYRND key has been pressed, and the program properly initialized.

After the VBMN key has been depressed, the computer will display the message "LVLH MNVR." Once the crew acknowledges this by pressing R/S, the computer will display "LVLH P." This is the angle through which the grapple fixture must pitch relative to the orbiter in a standard VBAR, nose up, station - keeping position, to move into the orbiter's Y-Z plane. Press R/S again, and the computer will display "TIME", the length of time required for the grapple fixture to move into the orbiter's Y-Z plane (the plane perpendicular to VBAR) at the relative pitch rate caused by the orbiter being in LVLH and the Spartan being in inertial hold. At the end of this time interval, the orbiter must go into inertial hold to keep the grapple fixture in the orbiter Y-Z plane. Press R/S once more, and the computer will display "YAW", the angle and direction through which the orbiter must yaw to get the grapple fixture (assumed to be in the orbiter Y-Z plane now) pointed towards the -Y axis. This yaw maneuver may be performed during the time of waiting for the target to pitch into the proper orientation, as previously mentioned.

9.2 Sun Angle

It is highly desirable to avoid sun interference while performing out-the-window tasks during payload proximity operations. Therefore, it is valuable to know the angle between the sun and the -Z axis of the orbiter. The ZSUN portion of the program computes axis information.

Depress ZSUN and the computer will display the message "Z-SUN ANG". Press R/S, and the program will prompt for the right assension and declination of the orbiter Z axis. These inputs may be computed with the FLYRND program using the current orbiter attitudes and a "SPARTAN ATT" of y=0, p=90. The right ascension and declination of the sun can be obtained by executing ITEM 8 + 4 on universal pointing and reading off the data beside items 9 and 10. Thus, once "Z RA," "Z DEC," "SUN RA," and "SUN DEC" have been entered into the computer, following each data entry with R/S, the computer will compute and display the angle between the orbiter Z axis and the sun.

9.3 Range-Range Rate

The PRX program provides two different methods of calculating orbiter range from the target vehicle. In addition, one of these methods also provides the range rate, or the rate at which the orbiter closes on its rendezvous target.

The first method is with LASER. The crew inputs the range and range rate as read off the laser range-finders on TV cameras B and C. The computer then outputs the line-of-sight range and range rate parallel to the Z-axis for a payload near the center of the COAS field of view. Depress LASER, and the computer will prompt for the laser range with the message "LASER R= ". Enter the value, press R/S, and the computer will display the COAS range, "RCOAS". Press R/S again; the computer will prompt for the laser range rate with the message "LRDOT =   ". Enter the data, press R/S, and the computer will display the COAS range rate, "RDOT COAS". If R/S is pressed again, the computer will return to the top of the program flow, and ask for a new laser range.

The second method takes the angle subtended in the COAS by the target satellite and computes the line-of-sight range. First, the SIZE key should be pressed, and the axis that the pilot is measuring through the COAS should be selected. Using the R/S key, the crew should select among "LONG AXIS," "SHORT AXIS," "LONG DIAG," or "SHORT DIAG". The SIZE key should be pressed and the axis selection made before pressing the COAS key, since the program under the COAS key is initialized using the axis data.

Once axis selection has been completed and all is properly initialized, press the COAS key. The program will display the label of the axis that was selected by the SIZE key, and represents the data stored in the computer to be used in the program calculation. Press R/S, and the program prompts "COAS ANG =   "; the crew should enter the angle subtended by the target satellite in the COAS, and press R/S. The computer will calculate and display the "RCOAS," the line-of-sight range to the target satellite.

9.4 General Comments on PRX Program Use

The PRX was originally developed for use in conjunction with the SPARTAN satellite. Since SPARTAN will fly on several missions, there is a high probability that the PRX program will be reused. It can even be adapted for use with any general rendezvous target by changing the axis dimensions of the satellite to be flown on a mission-by-mission basis. Currently the capability doesn't exist, but if satellite dimensions became readily available, the PRX program could be updated, and then regularly used in conjunction with any rendezvous missions.

TAIL PROGRAM

TAIL-TO-SUN PROGRAM ('TAIL')

Σ+ ①

↓

'ENT DAY L/O GMT = ______'

↓

'ENT HR L/O GMT = ______'

↓

'MET DAY ? ______'

↓

'MET HR ? ______'

↓

'PITCH ='

↓

'YAW ='

↓ ②

'ROLL ='

1. The TAIL Program is loaded into the [Σ+] key on the calculator, no overlay is needed.
2. Once the required pitch and yaw maneuvers are executed, the roll maneuver is not necessary, the orbiter will already be in a tail-to-sun attitude.

10. TAIL Program

The TAIL program provides the crew with the ability to compute the orbiter tail-to-sun attitude, in order to reduce the vehicle cooling requirements in the event of losing a flash evaporator. This procedure is only required during OPS 3; onorbit, the crew may obtain this data from the GPC's. This, then, is very specialized use for the HP-41C computer. In addition, software only resides under one key, the Σ+ key. Therefore, there is no accompanying overlay. Once the program has been loaded from the cassette, all the crew need do is depress the Σ+ key, the key in the upper left-hand corner of the computer keyboard (keyboard location 11), in order to execute the program.

Depress Σ+ and the computer will display the message "ENT DAY L/O GMT" to the crew. The crew should enter the day of liftoff in GMT and press R/S. The computer will prompt for the next input with the message, "ENT HR L/O GMT." The hour of liftoff in GMT should be entered; then, depress R/S. The computer will ask "MET DAY?" The crew should enter the day of mission elapsed time and press R/S. Finally, the computer will prompt with "MET HR?", and the crew sould enter the hour of mission elapsed time and press R/S.

Once these four values have been entered into the computer, the computer will calculate the correct orbiter tail-to-sun attitude for the given time of liftoff in GMT and the orbiter MET. Firstly, the computer wil display "PITCH = ". This is the desired pitch angle for the tail-to-sun attitude. Press R/S, and the computer will display "YAW = ", the desired yaw angle. Press R/S again, and the computer will display "ROLL OK", indicating that any roll angle is acceptable. If the crew presses R/S again, the computer will cycle to the top of the program and prompt for a new input time of liftoff in GMT.

HP-41C KEYBOARD & PROGRAM OVERLAYS

Normal Mode Keyboard

Pressing a key executes the function shown on the face of that key.

■ pressed before another key executes the function shown above that key.

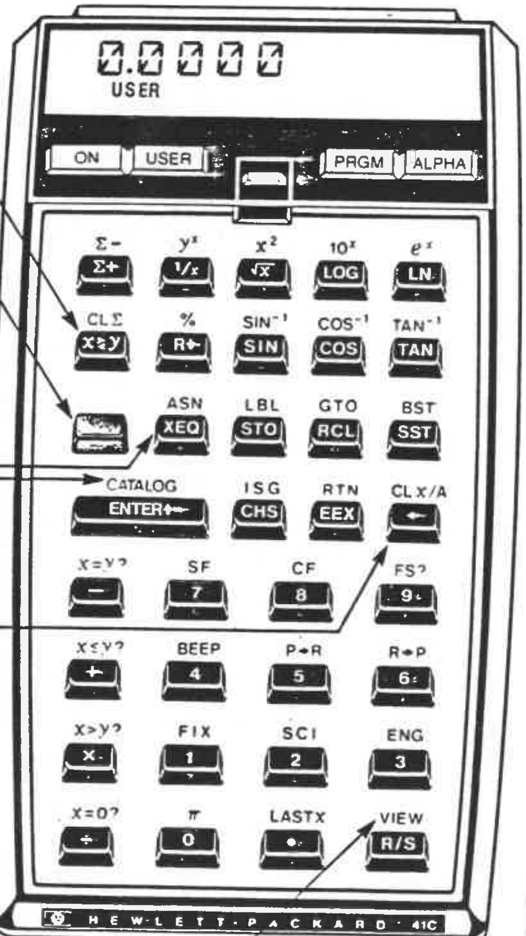
XEQ (execute) is used to execute functions and programs from the display. To execute and standard function, or a program that is stored in program memory:

1. Press XEQ.
2. Press ALPHA and the program or function name. Press ALPHA.

The named function or program will be executed. If the function expects parameters, then the calculator prompts for them.

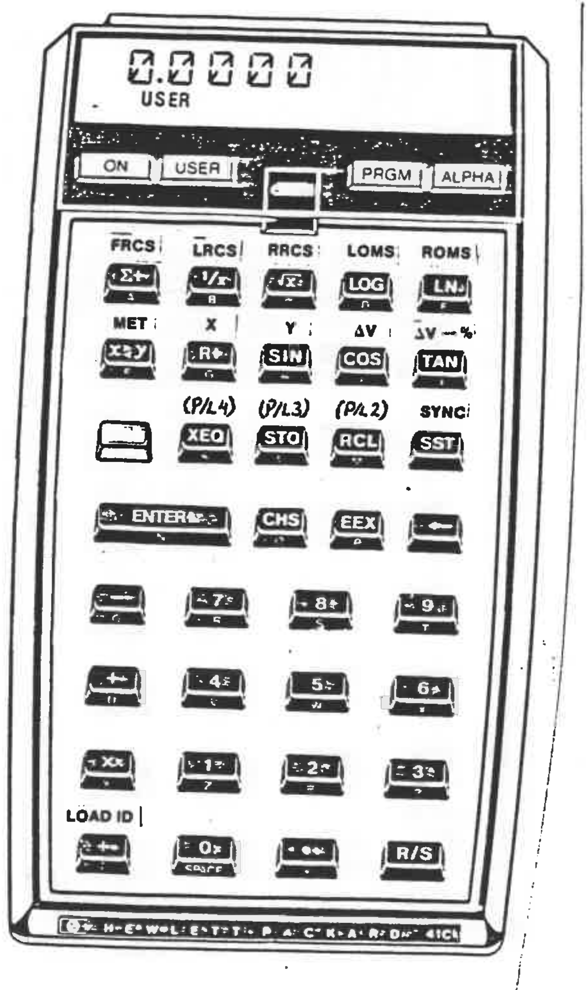
CATALOG lists the contents of the function and program catalogs. Catalog 1 is the user catalog and it contains the global (ALPHA) labels and END instructions of programs stored in program memory. The catalog is positioned in memory to the displayed program labels during the listing of catalog 1. Catalog 2 lists all functions contained in currently plugged-in application modules and peripherals. Catalog 3 lists all standard HP-41C functions. Press any key (other than ON or R/S) to slow the listing down. Press R/S and any other key to terminate a running listing. Press R/S to stop the listing (use SST and BST to step through the catalog manually).

Deletes the right-most digit during digit or parameter entry. If digit entry has been terminated, clears entire displayed X-register. Also clears messages from the display. Press ■ CLX to clear the displayed X-register. If ← is held down while HP-41C is turned on, does master clear.

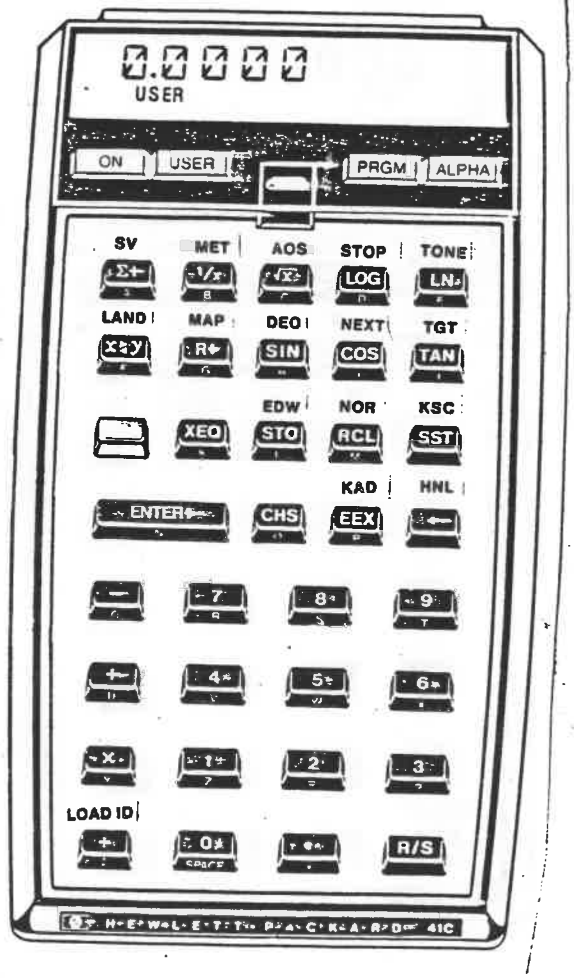


Views the contents of any register without disturbing the stack. To clear viewed data and return to the contents of the X-register, press ←.

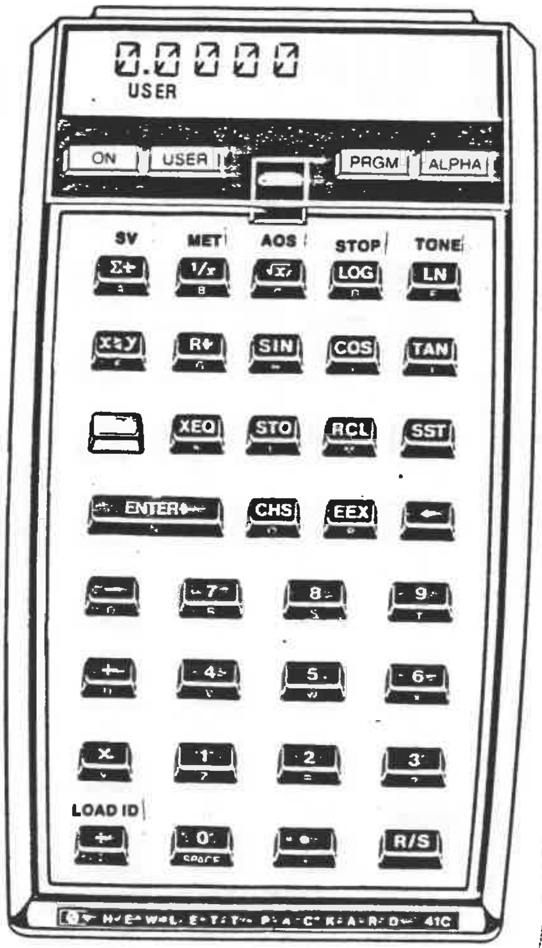
CG Program Overlay



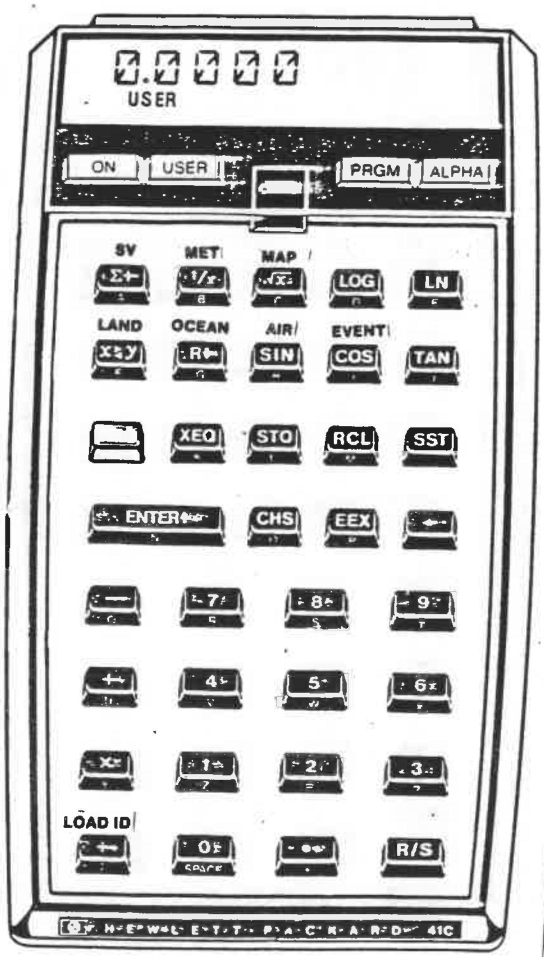
AOS/Deorbit Program Set Overlay



Communications Program Overlay



Earth Observations Program Overlay



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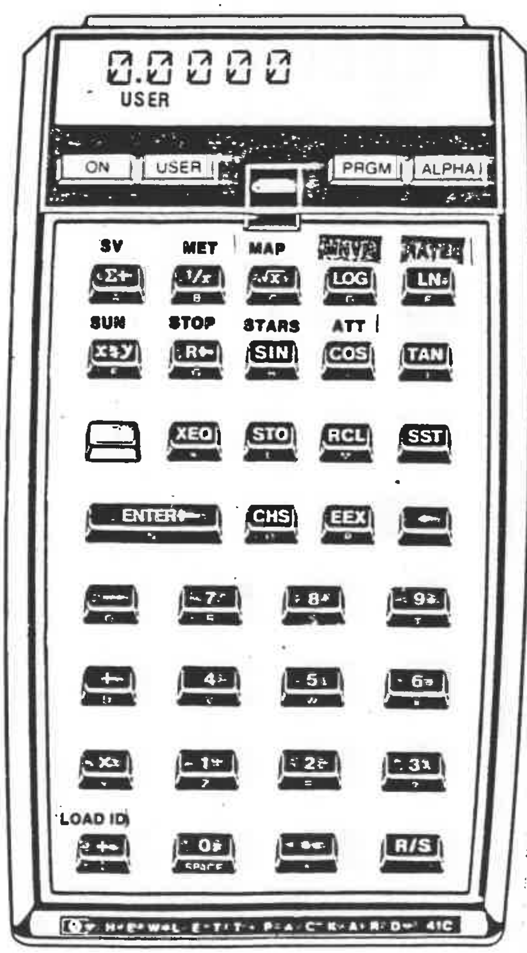
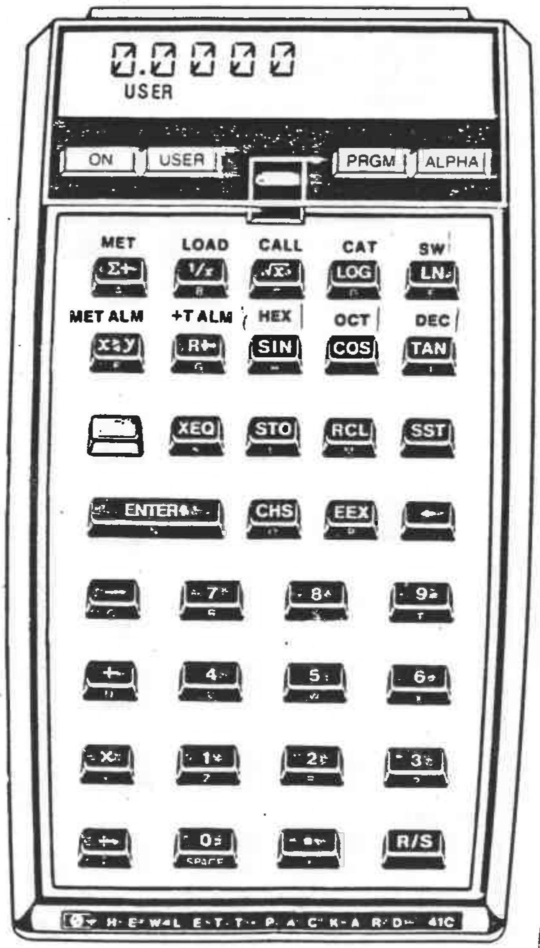
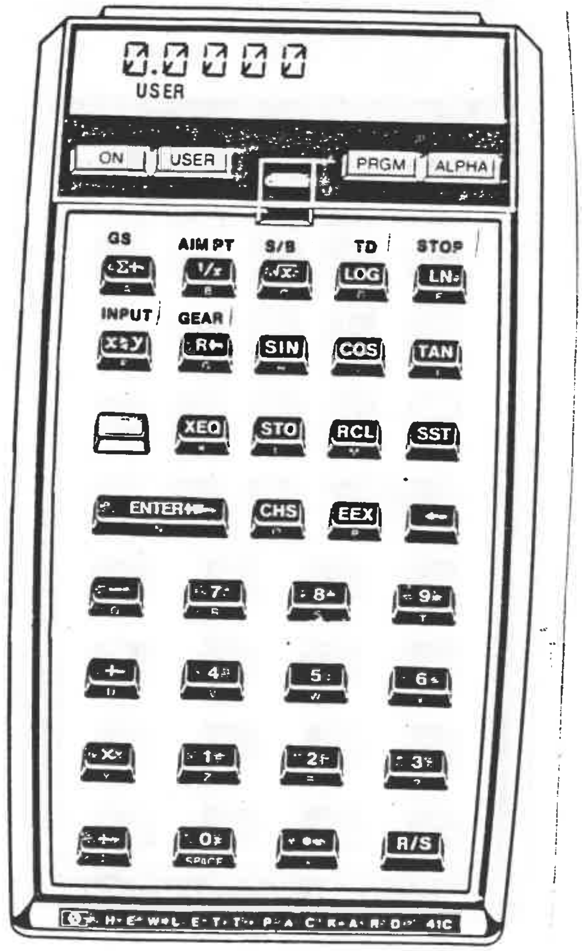
Orbit Program Overlay



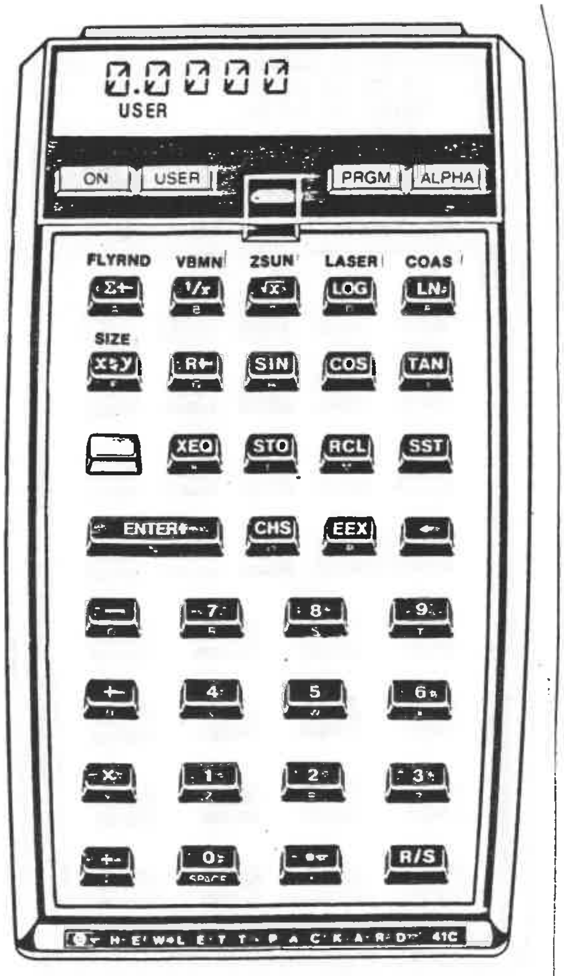
Alarm/HEX Program Set Overlay



Landing Program Overlay



Proximity Operations Program Overlay



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