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MIT INSTRUMENTATION LABORATORY

DG MEMO NO. 88

DESCRIPTION AND STATUS OF AGC PROGRAMS

PRELIMINARY

Approved By: ______________________

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MIT INSTRUMENTATION LABORATORY

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FOREWORD

DG Memo 69 in its final form shall cover the G&N System to: 1) provide information for the Systems Assembly and Test group 2) provide definition of the Block I G& N System for engineering evaluation and 3) to provide a reference for the Block II design. This memo will serve as an interim document for DG 69. It is intended that the program description of this memo will be included in DG 69.

INTRODUCTION

It is difficult to organize the multitude of operations which must be performed by the AGC in the conduct of an Apollo mission into distinct categories which may be called programs. The organizational difficulty arises from the fact that many of the operations are performed during several of the mission phases and also because the computer operations run fairly continuously from one mission phase to the next. Several "lists" of computer programs have been written, and no two lists call the programs by the same names or strike the division between successive programs at the same point in the mission, even when written by the same author. Increased effort has been expended recently to produce a program organization. This organizational difficulty can be further appreciated from the following discussion.

One of the major differences between the AGC and a general purpose computer is that of operating in "real time", that is, of executing certain programs at a specified time. All of the mission requirements for the total mission could be written in a computer program and then this program executed in a chronological sequence from the time of liftoff. This could satisfy the requirement of executing certain programs at specified times. However, this would not permit the latitude of computer control that is desired. Asynchronous demands, such as a call to display information, a change of program, acceptance of uplink data, output of telemetry data, etc. are made on the computer and yet at the same time the computer is required to execute these other programs. In order to accomplish this end, it is the purpose of the executive programs (EXECUTIVE AND WAITLIST) to control all work to be done by the AGC. These programs have the capability of stacking up to seven program requests (in addition to the one being carried out) according to their assigned priorities, and of executing these jobs in the order of priority. The program priority is predetermined and included with the writing of the program. The executive programs are also able to stack up to six Tasks (these are time dependent operations to be initiated within the next two minutes) according to the time at which they have to be initiated, and of initiating these Tasks at those times. At the time of initiation, a Task causes the interruption of a less urgent Job and the execution of that Job. Thereafter, another Task, or the less urgent Job, or another Job of higher priority can be executed. The Task is by definition of higher priority than a Job and thus causes an interruption to the Job to enable its execution. A Task may be repeated at some later time by making a request to the WAITLIST during the interruption.

The AGC has eleven Basic instructions which are used to perform all computer programs. A Basic Instruction is defined as a sequence of control pulses generated by the Sequence Generator (SQG). These control pulses switch, trigger, enable, etc., various registers and gates of the AGC and some circuity within the SQG itself. One or more control pulses are generated to form a pulse set called an Action. An Action time is 0.977 μ sec. A Subinstruction consists of twelve Actions which makes up one memory cycle time (MCT). One MCT is 11.7 μ sec. A Basic Instruction may consist of one or more Sub-Instructions (one or more MCT's). Basic programs are composed of these

Basic Instructions. The AGC also has six Involuntary Instructions and four Miscellaneous Instructions, all of which are triggered by signals external to the AGC.

The set of eleven Basic Instructions which the AGC provides is rather restrictive and a more diverse set would be highly desirable. To satisfy this end, an AGC program has been prepared to interpret a set of pseudo-codes or Interpretive Instructions. These Interpretive Instructions when decoded by the Dispatcher section of the interpretive program generates a subroutine composed of a string of Basic Instructions and data. This permits a saving to both the programmer and program length and thus the amount of storage space in memory required because a subroutine consisting of many basic program instructions may be expressed by one Interpretive Instruction. The Interpretive Instructions include a variety of double-precision operations, a small number of triple-precision operations, and a set of double-precision vector operations. There is presently a total of seventy-two Interpretive Instructions available.

An AGC program can be written in basic language (Basic Instructions), in interpretive language (Interpretive Instructions), or in both languages. Basic programs work faster than interpretive programs because interpretive programs need extra time for interpreting instructions. Interpretive programs require less space for program storage than basic programs because of the subroutine character of Interpretive Instructions. Furthermore, the interpretive language considerably simplifies programming of complicated mathematical operations. Many of the control operations that the computer has to execute are written mainly in basic language. When computational time is not critical, a program can be written in the interpretive languages to save program storage. The interpretive language is used mainly for writing navigational programs, but Interpretive Instructions are also used frequently in control programs to simplify multiprecision and vector operations involved.

The main computer programs which are used for mission phases are generated from the basic building blocks of Basic Instructions and Interpretive Instructions. These blocks are used to make special programs or routines to perform specific Jobs or Tasks. A main computer program is a compilation of many Jobs and Tasks to perform the designated mission requirement.

00. PROGRAM ORGANIZATION

The present organization of computer programs and their component parts is defined in an informal document entitled "AGC PROGRAMS" dated 18 Sept. 63, which may be obtained from Tom Lawton. This document is used as the basis for organization in this discussion.

The programs listed by the above mentioned document are

01. Interpreter
02. Executive
03. Waitlister
04. Input/output control and processing
05. Prelaunch Platform Alignment
06. In-flight Platform Alignment
07. Midcourse and Orbital Navigation
08. Powered Flight Guidance and Navigation
09. Delta-V
10. Re-entry Guidance and Control
11. Boost Monitor
12. Test and Exercise

Following are collections of programs and their major sections:

ECLIPSE is the name of the collection of programs assembled by J. Rocchio for AGC 4 (and AGE 4). The major sections are:

EXECUTIVE

WAITLIST

INTERPRETER

GO PROG

DS RUPT

PINBALL

CDU DRIVING

LEFT BANK

SEINE is the name of the collection of programs assembled by D. Lambert and P. Harris for AGC 4. The major sections are:

EXECUTIVE

WAITLIST

INTERPRETER

GO PROG

DS RUPT

PINBALL

CDU DRIVING

LEFT BANK

RITE BANK

SUNRISE is the name of a collection of programs to be assembled by T. J. Lawton for AGE 4. The major sections will be:

EXECUTIVE

WAITLIST

SUNRISE version will include restart capability and ability for job to be suspended and late re-initiated without loss of Work Area.

INTERPRETER

DS RUPT

SUNRISE version will include New Downtelemetry program, and IMU/OPT mode sampling.

PINBALL

CDU DRIVING

SUNRISE version will include a new CDU driving program.

LEFT BANK

IMUMODES

Appropriate mode switching of IMU is accomplished by this program. In addition, error detection is included.

ERRUPT

Best current estimates of actions to be taken on receipt of error signals will be incorporated.

PRELAUNCH

Prelaunch vertical erection and gyrocompassing.

INFLIGHT

Inflight alignment of the IMU using star sightings. Will include maneuvering of S/C.

FREEFALL

Coasting phase position and velocity determination, including measurement incorporation.

MISCELLANEOUS ROUTINES

Included in this category are: Executive, Backup, Interrupt Lead-Ins, Executive and Waitlist Initialization, ERRUPT, Fixed- fixed routines and constants in general use.

SYSTEST

Short routines to fulfill special needs of System Test Group.

Following are short descriptions of the various programs and indications of their status.

01. INTERPRETER

The INTERPRETER is a program which decodes or transforms the Interpretive Instructions into a sequence of Basic Instructions to be executed by the computer. This program consists of approximately 1500 Basic Instructions. The INTERPRETER was written by Charles Muntz and documented in AGC MEMO#2, "A List Processing Interpreter for AGC 4." This is a highly technical and detailed description written for those with a penetrating knowledge of the AGC and its language. A comprehensive description of the program is contained in "Apollo Guidance Computer Information Series" Issue 6 published by Raytheon Sudbury.

The coding of this program is complete.

02 and 03. EXECUTIVE and WAITLIST

The purpose of the EXECUTIVE and WAITLIST programs was described in the INTRODUCTION and no further description will be included here. The coding of these programs is complete and they have been extensively simulated and checked out.

04. INPUT/OUTPUT CONTROL AND PROCESSING

This group includes many housekeeping subroutines. The areas included are timekeeping, interrupt processing, mode control, telemetry, uplink and keyboard data, transfer, engine sequencing, and computer start and recovery sequencing.

04-01 A. Computer Start-up Sequence

When AGC power is turned on, the Computer is forced to a hard-wired GOJAM sequence (GOJAM is also entered upon when restarting because of certain kinds of errors). This sequence automatically clears the output registers and the RUPT priority flip-flops. It also inhibits access to memory and generates a GO condition in the sequence generator. This GO condition initiates a program called GO PROG which initialize the following registers and tables for various programs:

1. NEW JOB
2. PRIORITY table
3. VAC(n) USE table
4. TIME 3
5. TIME 4
6. WAITLIST LST 1
7. WAITLIST LST 1

When the initialization is complete, control is transferred to the BACK-UP program. BACK-UP is the program executed when there are no other jobs requested and acts as an idling program. It is the lowest priority job.

The GOJAM signal is generated by the coincidence of a power-out-of-limits signal from the power supply and a time pulse twelve signal from the scalar. When the power is turned on the +3 volt supply starts at zero. The GOJAM signal will not be present until the voltage has risen to the point where the time counter starts to run and reaches time twelve. The GOJAM signal then holds the time counter to time twelve. During this time, the memory currents. This is accomplished by a Memory Clamp circuit which is activated when the +3 volt supply is lower than its alarm level of 1.8 v.

B. Computer Turn-off Sequence

When the power is turned off, the computer will stop at time pulse twelve. It is assumed that the computer can still run when the power supply is sufficiently different from its nominal value to generate the out-of-limits signal. It is further assumed that the next twelve can be reached sooner than the voltages can decay from the limit point to the computer failure point. Thus the memory can always be restored to a proper state before the computer is stopped by GOJAM.

04-02 Computer Interrupts

The computer presently has five interrupts. When a program interrupt request is present, the Program Interrupt Priority Control produces the address of the appropriate RPT transfer routine and commands the Sequence Generator to execute the instruction RPT. When several program interrupt requests are present, the Program Interrupt Priority Control processes the requests one at a time in this order: WAITLIST, ERROR, DISPLAY, KEYBOARD (and MARK), and UPLINK.

A machine interrupt automatically saves the contents of the B and Z registers and inhibits further interrupts until a RESUME instruction is executed by the interrupting program.

Keyboard Interrupt Processor

The Keyboard is shown in Fig. 1 and the Display Panel in Fig. 2. When a key on either keyboard is depressed, an interrupt signal RP4 is produced within the computer by the Keyboard Trap. A "trap" consists of two flip-flops connected such that one side receives the set signal and the other side receives the reset or clear signal. The trap is used as a holding circuit to insure the recognition of the key signal as it is only sampled for 1 μs at Time 1. The depressed key also generates a 5-bit code or character which is applied to the low order bits of register IN 0. Each of the seventeen keys is wired to produce a separate 5 bit code. The code is indicated in Fig. 3.

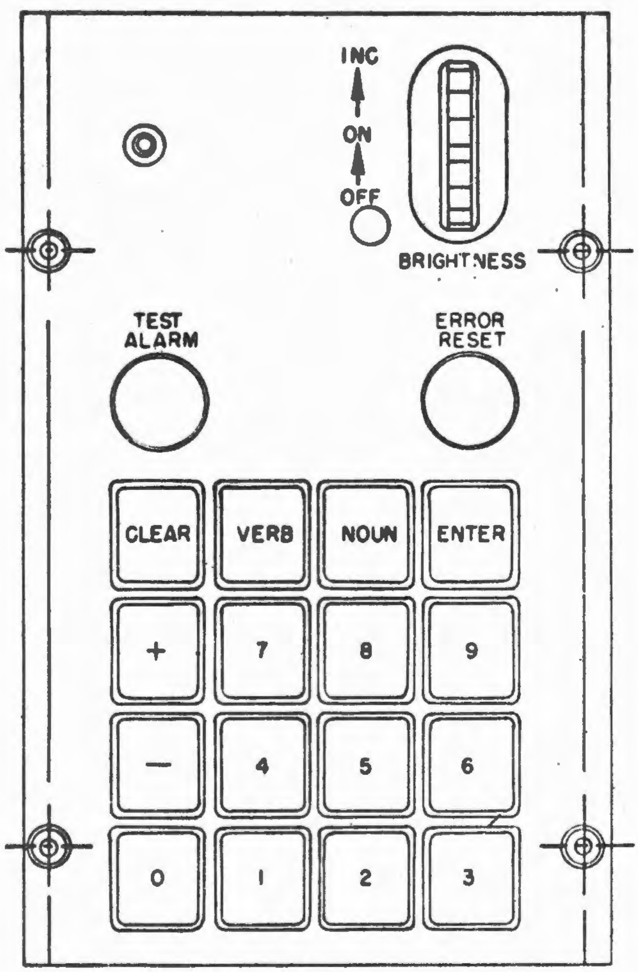


FIG. 1. KEYBOARD

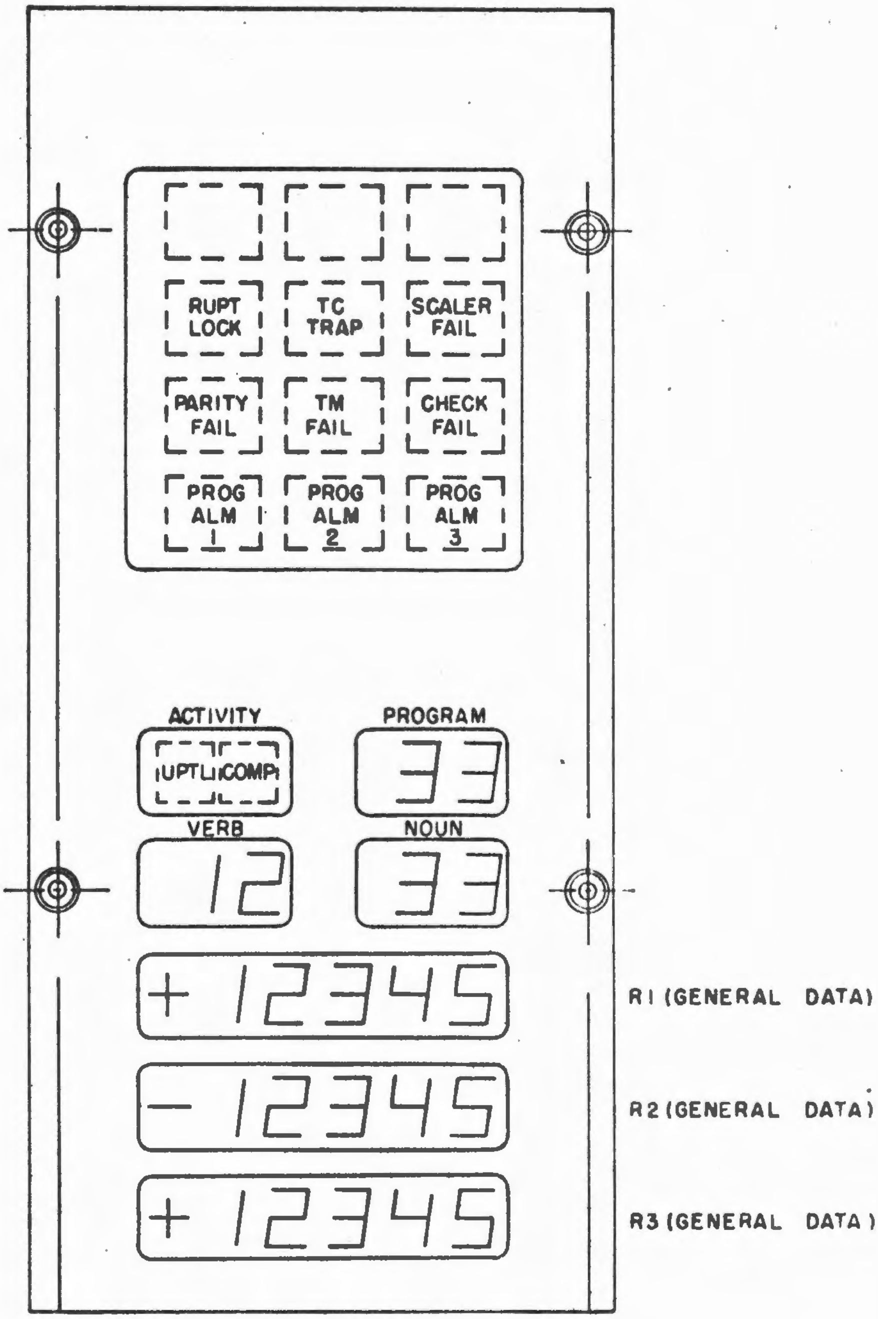


FIG. 2. DISPLAY PANEL

Keyboard Key	5 bit code
0	10000
1	00001
2	00010
3	00011
4	00100
5	00101
6	00110
7	00111
8	01000
9	01001
VERB	10001
ERROR LIGHT RESET	10010
+	11010
-	11011
ENTER	11100
CLEAR	11110
NOUN	11111

Figure 3. Keyboard Keys and Codes

The KEY RUPT program transfers the character from the IN O register and stores it in a buffer register which is used for assembling keyboard inputs. The program then requests execution of the CHARIN program via the Executive program.

04-03 Keyboard and Up-Tel Input Processor

There are Keyboard and Display Programs named PINBALL written for AGC 4 which are a part of the ECLIPSE Program. The names and descriptions of the sections of PINBALL pertaining to Keyboard and Up-Tel inputs are described below.

CHARIN	Examines the input character and decides whether it is numerical, VERB, NOUN, +, -, CLEAR, ENTER, ERROR RESET.
NUM	Accepts numerical data (octal or decimal) and builds up the proper octal data word.

Numerical data is assumed to be octal; all incoming decimal quantities are identified by a + or − sign, and are converted as decimal fractions (point at left). The scale factors, and types of scale factor routines are kept within the machine for each noun that is required to handle decimal data. For decimal displays, each noun that is required to display in decimal has the scale factors, types of scale factor routines, and component information within the machine. When a decimal display of a noun is requested, all components of the noun are displayed at once.

The Keyboard and Display Routines for AGE 4 are able to handle a limited amount of decimal/binary and binary/decimal scale factoring. The framework is included to handle many more scale factoring situations, but only the following are included at this time: fractional, whole, degrees (XXX.XX), seconds (up to 999.99 in decimal), hours (up to 999.99 in decimal). In all cases, a single precision (5 character) word is handled. There are no provisions for general double precision decimal conversions.

+, -	Sets machine to receive decimal data
VERB	Sets machine to interpret the next two numerical characters as the Verb Code.
NOUN	Sets machine to interpret next two numerical characters as the Noun Code.
CLEAR	Clears whichever display register is currently being used. Successive CLEARs will clear the register above the current one, until R1 is cleared.
ERROR RESET	Resets the Error Light and resets many internal switches. The Alarm light used by the Keyboard and Display routines is the Illegal Order Light.
ENTER	Performs a fan out of the Verb Code and selects the appropriate verb routine.

The general format of key operations is VERB V_1V_2, NOUN N_1N_2, and ENTER. V_1V_2 are the 2 digit code for the Verb number and are displayed in the Verb lights as entered. N_1N_2 are the 2 digit code for the Noun number and are displayed in the Noun lights as entered. The depression of the VERB key clears all Verb information. Thus, if an erroneous Verb number is detected before ENTER is pressed, merely press VERB again and the proper 2 digit code. Similarly for NOUN. The order of Noun/Verb load is immaterial. The ENTER key depression will take the action appropriate to the contents of the Verb/Noun lights at the time the ENTER is pressed, regardless of the history or sequence of Noun/Verb loading.

If data is to be punched in, the Verb/Noun lights will flash indicating that the operator should begin punching data. The data will be displayed in either R1, R2, or R3, depending on the nature of the data.

If an erroneous number is detected in the data loading, the CLEAR button will erase it. Successive CLEAR depressions will result in clearing the register above the current one, until R_1 is cleared. This feature should prove useful for multi-component loads. Obviously, this works only before the last ENTER of a set of data is pressed. (A Set being 2 for double precision; 3 for triple precision.)

Data is considered octal, unless each word is preceded by a + or - sign, in which case it is considered decimal.

In general, R1 is for the 1st component of data; R2, for the 2nd, if applicable; R3, for the 3rd, if applicable.

04-04 Up-Tel Interrupt Processor

Information is entered serially into the AGC via UPLINK. A serial-to-parallel conversion is made by the uplink counters. A word is entered by sending a string of 16 bits, the first of which is a "1". The "1" bit causes an overflow upon receipt of the 16th bit which in turn causes an interrupt signal RP 5 to be produced by the Uplink Gate. This signal initiates the uplink interrupt program UPRUPT. The program transfers the assembled data in the counters into storage and then requests execution of the CHARIN program via the Executive program.

04-05 Up-Tel Processor

The Up-Tel input processing is presently accomplished by the same programs as the Keyboard inputs.

04-06 Display and Down-Tel

An AGC DOWNLINK program has been written for AGC 4. The program appears in ECLIPSE. The DOWN LINK program is functioning all the time the AGC is operating and will output AGC information to the Inflight Telemetry equipment at the rate of 1 word every 20 msec.

The DOWN LINK format consists of five words in a group (100 msec) and 10 groups in a frame (1 sec). Each 5 word group contains 1 Identification word (ID WORD) to identify the particular word group and 4 data words. Each frame therefore consists of 10 ID WORDS and 40 true data words.

The 40 data words are selected from erasable memory as they normally exist. Their selection is controlled by a 40 word DOWNLIST in fixed memory which contains the addresses of the erasable locations. The IDWORDS are synthesized by the program itself.

The 40 word DOWNLIST presently consists of the following locations:

DOWNLIST

1.	ADRES	BANK REG		
2.	ADRES	TIME	1	
3.	ADRES	TIME	2	
4.	ADRES	PIPA	X	
5.	ADRES	PIPA	Y	
6.	ADRES	PIPA	Z	
7.	ADRES	ICDU	X	
8.	ADRES	ICDU	Y	
9.	ADRES	ICDU	Z	
10.	ADRES	OCDU	X	
11.	ADRES	ODCU	Y	
12.	ADRES	TRKR	X	
13.	ADRES	TRKR	Y	
14.	ADRES	TRKR	R	
15.	ADRES	PRIORITY		
16.	ADRES	PRIORITY		+8 D
17.	ADRES	PRIORITY		+16 D
18.	ADRES	PRIORITY		+32 D
19.	ADRES	PRIORITY		+40 D

DOWNLIST (Cont.)

20.	ADRES	PRIORITY	+48 D
21.	ADRES	PRIORITY	+56 D
22.	ADRES	PRIORITY	+64 D
23.	ADRES	VAC 1 USE	
24.	ADRES	VAC 2 USE	
25.	ADRES	VAC 3 USE	
26.	ADRES	VAC 4 USE	
27.	ADRES	VAC 5 USE	
28.	ADRES	LOC	
29.	ADRES	LST 2	
30.	ADRES	LST 2 + 1	
31.	ADRES	LST 2 + 2	
32.	ADRES	LST 2 + 3	
33.	ADRES	LST 2 + 4	
34.	ADRES	LST 2 + 5	
35.	ADRES	FLAG W D	
36.	ADRES	MK TIME 1	
37.	ADRES	MK TIME 2	
38.	ADRES	OUT 1	
39.	ADRES	N OUT	
40.	ADRES	DSPCNT	

The T/M word format is as follows:

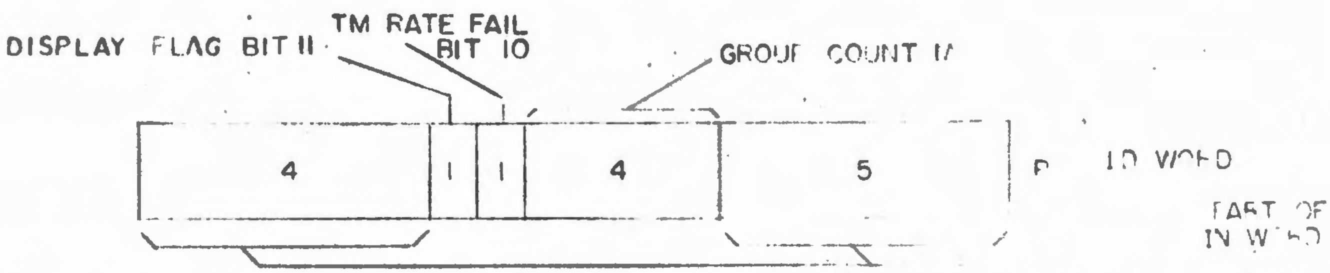
AGC WORD 2nd transmission	AGC WORD 1st transmission	T/M word order
last 16 bits	next 16 bits	1st 8 bits

Each 15-bit AGC word will appear on the operational telemetry link as a string of 40 bits. The same AGC word is transmitted twice for reliability. The T/M

Word Order in the above format will consist of all zero's for an IDWORD and all one's for a Data Word.

The IDWORD is the first word of a group. It's format appears as:

ID WORD FORMAT



Four bits of the IDWORD contains the group count M(0,1,2,3,4,5,6,7,8,9) , one bit is used as a flag which tells if the T/M timing source has failed, and amother bit is to flag if one of the words in the current group is a "display" word, that is, a word which was currently displayed on the astronauts display panel. Five bits of the IDWORD will contain whatever requests to the AGC have currently been entered through the keyboard or through uplink.

The DOWNLINK program was originally intended to have the sole function of assembling selected AGC data for downlink transmission. This program has the property of being a good timing device, and as such the program has been adopted to perform the additional functions of initiating the AGC Display programs, the ISS Mode Switching programs, and the ISS CDU Control programs. The program normally gets its timing reference from the telemetry END pulse. In the event the telemetry malfunctions, an alternate source of timing will be used which will permit the continued execution of these additional functions.

Display and Down-Tel Interrupt Processor

When an END pulse from the Telemetry program is received or when the T4 counter overflows (every 20 msec) an interrupt signal RP3 is produced by the Display Gate. This signal causes the display interrupt program DSRUPT to be initiated. The DSRUPT program performs a series of five functions on a cyclic basis. The functions are controlled by a counter called N DEX (N = 4,3,2,1,0) .

This counter is incremented every 20 msec. The five functions are:

1) N = 4, REGROUP, (a) load DWNTAB with the next 4 words specified by the 40 word DWN LIST (DWNTAB is a four word buffer table for the TM data. Data is entered every 100 msec by the REGROUP routine and pulled out a word at a time at successive 20 msec intervals). (b) synthesize the IDWORD and transfer it to Output Register OUT 4 for telemetry transmission. (c) Set word order bits to "zero". (d) Reset Displays.

2) N = 3 (a) load OUT 4 with Data Word from DWNTAB. (b) Set word order bits to "one". (c) If required, perform the CDU Driving Routine CDU PROG B (see 04-14).

3) N = 2 (a) load OUT 4 with Data Word from DWNTAB.

4) N = 1 (a) load OUT 4 with Data Word from DWNTAB. (b) If required, perform the CDU Driving Routine CDU PROG A (see 04-14).

5) N = 0 (a) load OUT 4 with Data Word from DWNTAB. (b) If required, perform ISS MODE Switching Routine CDRVE (see 04-12). (c) If ISS MODE Switching was not required and if a display is required, perform the Display Routine DISPOUT (see 04-07). During CDRVE or DISPOUT, the word that is sent to OUT 0 to change the ISS MODE or the Display is also put in DWNTAB + 3. A flag is set in the IDWORD which indicates the current group will contain as the first data word following the IDWORD, the ISS MODE or Display Word. This word will actually replace one of the 40 data words which would normally have been transmitted. This replaced data word will be skipped during this 40 word frame and will be picked up again during the next frame if a display word does not again replace it. Prior to the execution of any of the five functions, the DSRUPT program makes a test on the telemetry END pulses.

The telemetry END pulses are used as the means of initiating the DSRUPT program as long as they are "good"; whenever they are missing or are coming too fast, the program is initiated by the output of the T4 Counter. Under these conditions, the TM FAIL light on the M & DV is turned on. As long as the Display program is receiving its timing from the T4 counter, it "blocks" telemetry END pulses from causing a DSRUPT and therby initiating the Display program at the wrong time. Every 20 msec. the Display program looks at the telemetry END pulses again to see if the telemetry timing troubles have disappeared - if so, the Display program takes its timing from telemetry and turns off the TM FAIL light; if not, it continues to get its timing from T4.

04-07 Display Output Processor

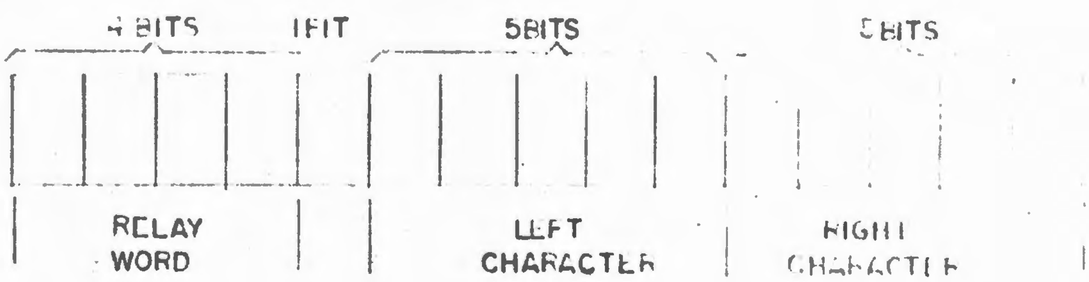
A display output program called DSPOUT has been written for AGC 4. This program appears in ECLIPSE. The display output initiation is generated at time N = 0 of the DSRUPT program.

Energizing of the electroluminescent displays on the DSKY is controlled by the R relays of the DSKY. The R relays are in turn controlled by relay drivers which are energized as a result of the bit configuration of OUT 0.

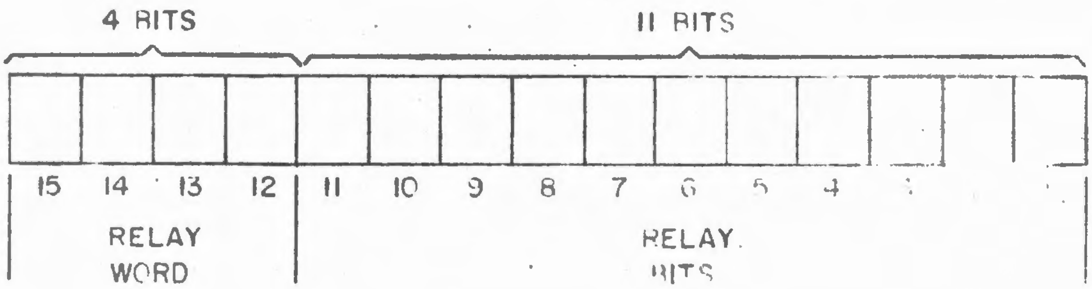
Display of data can be initiated by either Keyboard entrance of the appropriate List 1 Noun-Verb routine or by internal computer program action.

Display of data by a program is accomplished by a request through the NVSUB routine of the appropriate List No. 1 Noun-Verb routine. NVSUB is a routine for calling any Noun-Verb combination from within the computer. The Noun-Verb routines in turn use either of two routines to display the data. 1) DSPOCTWD breaks up an octal data word into 5 octal characters and presents them one at a time to DSPIN, 2) DSPECWD breaks up an octal data word and converts it as a decimal fraction into 5 decimal characters (plus sign) and presents them one at a time to DSPIN. DSPIN is a routine which places the octal or decimal character into the display table, DSPTAB.

DSPTAB is a group of 13 consecutive memory locations in erasable memory used to list the desired DSKY relay changes. The data stored in this list is the complement of the required word which in OUT 0 will change the proper relays. The first 10 locations are for the R relays which control the EL display. The word format is:

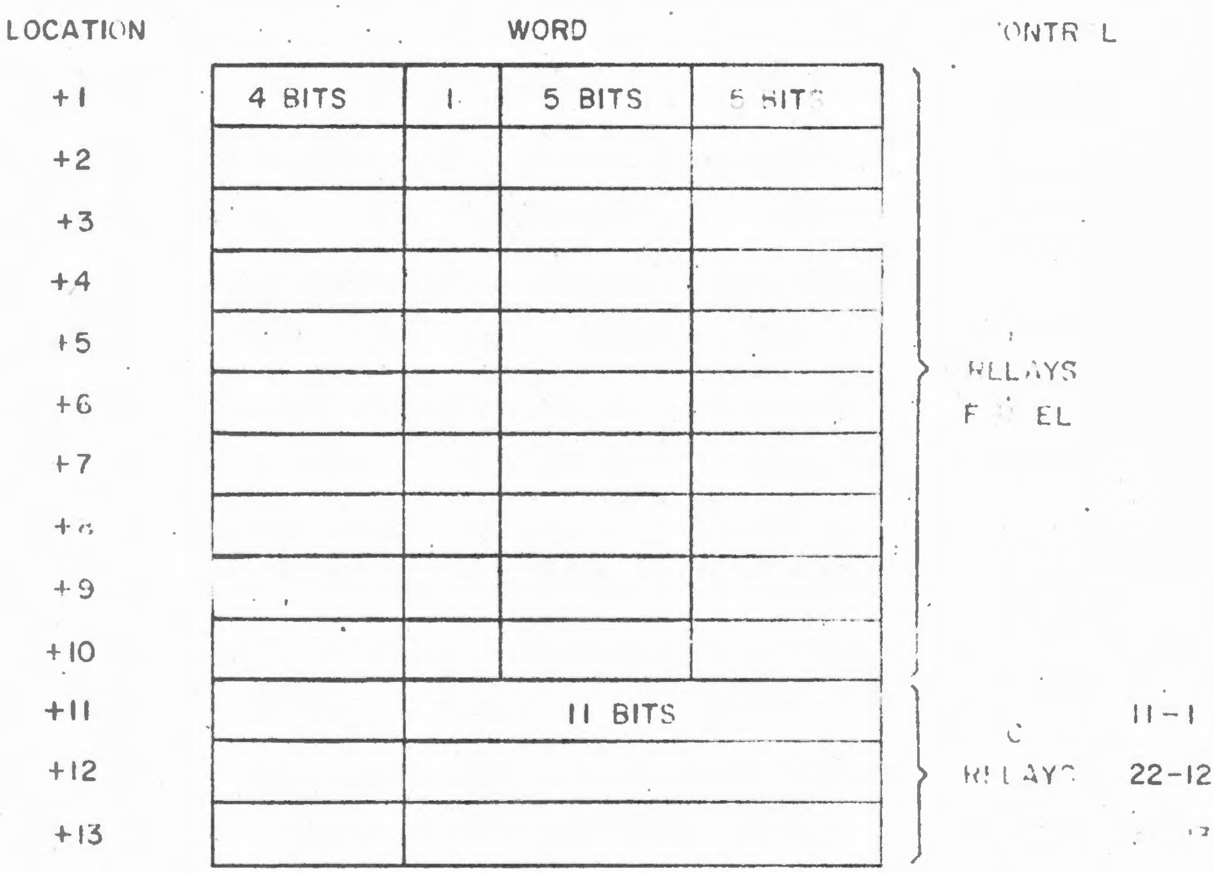


The last 3 locations are for the C relays. The word format is:



(see 04-12).

DSPTAB appears as follows:



During N = 0 of the DSPRUPT program and after the completion of the load of OUT 4 with the T/M word, the program examines FLAGWORD to determine if a "c" relay has to be changed. If "yes", the program transfers control to the CDRVE routine (see 04-12). If "no", the program transfers control to the DSPOUT routine. In view that the words put into DSPTAB are negative (complement of requirement for OUT 0), the DSPOUT routine examines sequentially the contents of DSPTAB to see if any words are negative. If a negative word is found, it is complemented and transferred to OUT 0 (this word is also transferred to DWNTAB + 3 and IDWORD bit 11 is set for the T/M display). When the word is put in OUT 0 the "R" relays are set and thus the EL display is energized. The complemented word is also put back in the same location of DSPTAB and thus DSPTAB reflects the present status of the Display program, that is, the present state of the Display Panel and what changes are to be made.

04-08 Error Interrupt Processor

When any of the following errors are produced, an interrupt signal RP2 is produced by the Error Trap.

1. LIFT OFF (ENG ENABLE)
2. SIVB BACKUP (G/N CONTROL)
3. ABORT
4. IMU FAIL
5. PIPA FAIL
6. CDU FAIL
7. OPTICS FAIL
8. LANDING RADAR FAIL
9. THRUST (ULLAGE)

These error signals which are produced by sensors external to the AGC, are applied to input register IN2 as indicated below:

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
IN 2	ENG ENABLE	G/N CONTROL	ABORT	IMU FAIL	PIPA FAIL	CDU FAIL	OPT FAIL	LRDR FAIL	THRUST	X	X	X	X	X	X

The interrupt program scans the 9 bits to determine which one or several caused the interrupt and then branches to the appropriate program.

04-09 Error Processor

When an Error Interrupt occurs, the interrupt program branches to the respective program.

1. LIFT OFF — This program performs the following four functions:
   a) save time of day
   b) inhibit gyrocompassing
   c) zero PIPA counters
   d) call Boost Monitor program.

2. BACKUP — This program has not been defined.

3. ABORT — This program has not been defined.

4. IMU FAIL — This program will first check to see if system is in the COARSE ALIGN mode. If not, the program will turn on the IMU FAIL lamp on the M and DV and switch the system to COARSE ALIGN which will inhibit the SCS signals. If the system is in the COARSE ALIGN mode, the program will wait for x seconds and then test for the presence of the FAIL. If the FAIL is off, the program will have the computer RESUME. If it is still on the program will turn on the IMU FAIL lamp and then RESUME.

5. PIPA FAIL — This program turns on the IMU FAIL lamp on the M & DV and then RESUMES.

6. CDU FAIL — This program will first check to see if the system is in the ZERO ENCODE or FINE ALIGN mode. If not, the program will turn on the CDU FAIL lamp on the M & DV and switch the system to COARSE ALIGN. If the system is in either of these modes, the program will wait for x seconds and then test the presence of the FAIL. If the FAIL is off, the program will

have the computer RESUME. If the FAIL is still on the program will turn on the CDU FAIL lamp and then RESUME.

7. & 8. OPT and LRDR FAIL — This programs turns on the respective FAIL lamp on the M & DV and then RESUMES.

9. THRUST — This program requests the appropriate routine through the Executive program.

After an Error Interrupt has occurred, an error sampling program is initiated every second. This program determines if an error is still present. If not, the program turns off all error lights and exits. If yes, the program then determines if it is the same error. If it is the same, the program exits. If it is not the same, the program then reinitiates the Interrupt Program and the 1 second call for the error sampling program and exits.

The Error Interrupt program appears in ECLIPSE; the Error processor will appear in SUNRISE.

04-10 List 1 Noun-Verb Routines

These programs allow the computer operator to display, monitor and load certain data, and to terminate and select various programs. With each program there is a corresponding octal number representing the particular Verb with which to select the program. In some instances, particular Nouns must be selected in order to identify the particular G & N component or parameter(s) to be investigated in conjunction with the Verb's task. In others, there are no associated Nouns required by the program.

Any noun/verb combination can be called as a subroutine within the computer. Most requests will be to display a quantity, monitor a quantity, or request a load through the keyboard. Such subroutine calls will be accepted only when the keyboard is not using the noun/verb routines and the display panel, or utter chaos would result.

In all cases the action is requested by means of the appropriate noun and verb code combination.

The noun/verb system is considered busy and NVSUB is locked out by depression of either the NOUN key or VERB key. It is released by a "verb = release noun/verb system".

The following is a list of the present Verbs 00 to 37 and their description:

VERB	FUNCTION	DISPLAY LOCATION
00	Illegal	
01	Display (in octal) 1st component of:	R1
02	Display (in octal) 2nd component of:	R1
03	Display (in octal) 3rd component of:	R1
04	Display (in octal) 1st and 2nd components of:	R1, R2
05	Display (in octal) 1st, 2nd, and 3rd components of:	R1, R2, R3
	Verbs 01-05 Perform octal displays of data.	

VERB	FUNCTION	DISPLAY LOCATION
06	Display (in decimal) all component(s) of: Performs decimal display of data. The scale factors, types of scale factor routines, and component information are stored within the machine for each noun which is required to display in decimal.	As appropriate
07	Enter Request to Executive. Enters request to executive routine for any address with any priority (probably not needed in operational versions).	
10	Enter Request to Waitlist. Enters request to waitlist routine for any routine for any address with any delay (probably not needed for operational versions).	
11	Monitor (in octal) 1st component of:	R1
12	Monitor (in octal) 2nd component of:	R1
13	Monitor (in octal) 3rd component of:	R1
14	Monitor (in octal) 1st and 2nd components of:	R1, R2
15	Monitor (in octal) 1st, 2nd, and 3rd components of:	R1, R2, R3
16	Monitor (in decimal) all component(s) of:	As appropriate
17	Spare	
20	Spare	
21	Write 1st component into:	R1
22	Write 2nd component into:	R2

VERB	FUNCTION	DISPLAY LOCATION
23	Write 3rd component into:	R3
24	Write 1st and 2nd components into:	R1, R2
25	Write 1st, 2nd, and 3rd components into: Verbs 21 - 25 – Perform data load. Octal quantities are unsigned. Decimal quantities are preceded by a + or - sign.	R1, R2, R3
26	Spare	
27	Spare	
30	Spare	
31	Bank Display This verb is included to permit displaying the contents of fixed memory in any bank. Its intended use is for checking program ropes and the BANK position of program ropes.	
32	Bump displays [c(R2) into R3, c(R1) into R2] Display Shift. Useful for preserving an existing display of a quantity while displaying another quantity.	
33	Proceed Without Data Informs routine requesting data to be loaded that the operator chooses not to load fresh data, but wishes the routine to continue as best it can with old data. Final decision for what action should be taken is left to requesting routine.	

VERB	FUNCTION	DISPLAY LOCATION
34	Terminate Load Request	

Informs routine requesting data to be loaded that the operator chooses not to load fresh data, and wishes the routine to terminate. Final decision for what action should be taken is left to requesting routine.

35	Release Display Panel	

Releases display system for internally initiated use.

36	Fresh Start	

This verb calls in exactly the same program that machine initiated Automatic Restart does. In particular, the Executive Routine and Waitlist Routine are cleared, TIME 3 is initialized, the C relays are zeroed, the display system is released for internal use, the "release display system" light is turned off, the display output table is checked for proper format and corrected if necessary, the Backup Routine is entered.

37	Change Major Mode to:	

Changes to New Major Mode. The potentially new Major Mode number, as punched in, will be displayed temporarily for verification (probably in the Noun lights). After verification, the operator presses ENTER. Only then is the number transferred to the Major Mode lights and is the appropriate action taken. Thus, the old Major Mode number is not disturbed until it is actually replaced by the desired and verhified new value.

The following is a list of the present Nouns 00 to 77 and their description:

NOUN #	NORMAL NOUNS
00	Not in Use
01	Specify Machine Address (Fractional)
02	Specify Machine Address (Whole)
03	Specify Machine Address (Degrees)
04	Specify Machine Address (Hours)
05	Specify Machine Address (Seconds)
Nouns 01-05	The machine address for these nouns is not stored within the machine, but is supplied by the operator. This allows any address to be loaded, displayed, or monitored. When ENTER is pressed with one of these nouns, the Flash is activated, but the Verb is left unchanged. This indicates to the operator that he should type in the 5 character OCTAL address, followed by an ENTER. It is displayed in R3, and the flash is turned off. Thereafter, the execution of the Verb continues, just as in the case of any other noun. Five different "Machine Address to be Specified" nouns are provided so that any of the decimal scale factors may be applied to the contents of any machine address.
06	Increment Machine Address This is used to increment the machine address already specified. It is useful for loading or displaying a group of consecutive addresses. OCTAL only.
07	Time Seconds
10	Time Hours Refer to the time counters TIME 1, TIME 2, and are not normally loaded. If decimal is desired, Noun 07 gives

seconds modulo 1000 (maximum 999.99 sec.); Noun 10 gives hours up to a machine maximum of 745.65 hours. (See Note 1.)

11 ICDU

12 OCDU

Refer to the 5 CDU counters. They are not normally loaded. If decimal is desired, the form is XXX.XX degrees (maximum of 359.99). (See Note 1.)

13 PIPAS

Refers to the 3 PIPA counters, and is not normally loaded. In decimal, register contents are presented as whole decimal, representing the number of PIPA counts. (See Note 1.)

14 New Angle I

Primarily for loading ICDU absolute angular commands. In decimal, the scale is XXX.XX degrees. This noun refers to a 3 register temporary buffer.

15 New Angle 0

Same as 14, but for OCDU's.

16 Delta Angle

Primarily for loading a single change in angle. In decimal, the regular degrees scale is used.

17 Delta Angle I

Primarily for loading ICDU angular change commands (3 components). Refers to temporary buffer. Normal decimal degree scale.

Note 1. Since this noun refers to counter registers, it is not normally loaded. However, the capability exists and loading may be useful in special applications.

20 Delta Angle 0

Same as 17, but for OCDU angular change commands (2 components).

21 Delta Time (Sec)

22 Sample Time (Sec)

Nouns 21 & 22 Each of these nouns is primarily for loading a single quantity scaled as time in seconds (XXX.XX).

23 Time to Fire (Sec)

Primarily for display of time with seconds scale.

24 MARK Time (Seconds)

25 MARK Time (Hours)

Primarily used for displaying Time of MARK. Either seconds or hours scale. (See Note 2.)

26 MARK Angle I

27 MARK Angle 0

Nouns 26-27 Primarily for display of either ICDU or OCDU angles as of MARK. If decimal is desired, standard degrees scale is used. (See Note 2.)

30 Star Number

Refers to a 3 register buffer. The scale on each is whole, if decimal is desired. Intended for star identification numbers.

31 Fail Reg

Intended for the identification of certain failure conditions in programmed tests. OCTAL only.

Note 2. Since this noun refers to registers which are loaded by MARK, loading by keyboard action is not normal. However, the capability exists, and loading may be useful in special applications.

32	Pass Reg
	Intended for the identification of certain acceptable conditions in programmed tests. OCTAL only.
33	Prio/Delay
	This noun is to be preloaded with the desired PRIORITY for use with VERB = 07 (REQUEST EXECUTIVE); with the desired DELAY, when used with VERB = 10 (REQUEST WAITLIST). OCTAL is to be used for the PRIORITY, decimal whole scaling is provided for the DELAY.
34	CADR Reg
	This register is to be loaded with the address of the starting location of a desired test routine list for the test routine linkage program (so called English Interpreter).
35	IMU
36	C Relays
37	AGC
Nouns 35-37	Are label nouns. They refer to no particular machine address, nor any decimal scale. Their function is one of identification only.
40	Delta Velocity
41	Radar 1
42	Radar 2
Nouns 40-42	Are reserved for future use, but specific addresses and scales have not yet been assigned.

This ends the list of nouns that are intended for operational use beyond AGE 4. The following nouns (43-77) are included solely as conveniences for early computer testing and program checkout. Also, it seems wise to include a few typical Mixed Nouns to demonstrate their operation and feasibility.

43	Waitlist 1 Group A
44	Waitlist 1 Group B
45	Waitlist 2 Group A
46	Waitlist 2 Group B
Nouns 43-46	Refer to the two lists used by the Waitlist Program. The first keeps addresses; the second, delays. They are to be used in OCTAL only. (See Note 3.)
47	Spare
50	Spare
51	Spare
52	Spare
53	Spare
54	Spare

MIXED NOUNS are those whose components refer to non-consecutive addresses or have different scale factors.

NOUN #	MIXED NOUNS
55	Time (Sec), ICDUX, OCDUX Primarily for display. Gives time, the X component of ICDU, and the X component of OCDU. If decimal is desired, the scales are seconds, degrees, degrees. (See Note 1.)
56	Time (Sec), ICDUY, OCDUY Same as Noun 55, but for Y components. (See Note 1.)
57	Time (Sec), ICDUZ Similar to Nouns 55 and 56, but this is a 2 component noun. Time and Z component of ICDU. (See Note 1.)

Note 3. Since this noun refers to registers used for control data by the Executive or Waitlist Routine, loading by keyboard action is not normal. However, the capability exists, and loading may be useful in special applications.

60	MARK Time (Sec), (Hours), ICDUX
61	MARK Time (Sec), (Hours), ICDUY
62	MARK Time (Sec), (Hours), ICDUZ
63	MARK Time (Sec), (Hours), OCDUX
64	MARK Time (Sec), (Hours), OCDUY
Nouns 60-64	Primarily for display. Give time of MARK, together with a CDU counter. In decimal, they give Time of MARK in seconds, Time of MARK in hours, and the appropriate CDU counter in degrees. (See Notes 1 and 2.)
65	New Angle X, Time (Sec)
66	New Angle Y, Time (Sec)
67	New Angle Z, Time (Sec)
Nouns 65-67	Primarily for loading an angle and time. These are 2 component nouns. In decimal, the scales are degrees, and seconds. (See Note 1.)
70	Priority Group 1
71	Priority Group 2
Nouns 70-71	Refer to the Priority registers used by the Executive Routine. OCTAL only. (See Note 3.)
72	VAC Use Group 1
73	VAC Use Group 2
Nouns 72-73	Refer to the Vector Accumulator Use registers of the Executive Routine. (See Note 3.)
74	Spare
75	Spare
76	Spare
77	Spare

Some examples of Noun/Verb use are as follows:

1. To load device "N1" (a 1 component device)

VERB	21	NOUN	N1	ENTER

Verb and Noun lights flash, requesting 1 component to be punched in.

XXXXX displayed in R1. ENTER End of flash.

2. To load device "N3" (a 3 compenent device)

VERB	25	NOUN	N3	ENTER

Verb changes to 21. Verb and Noun flash, requesting 1st component to be punched in.

XXXXX displayed in R1. ENTER

Verb changes to 22. Flash, requesting 2nd component to be punched in.

XXXXX displayed in R2. ENTER

Verb changes to 23. Flash, requesting 3rd component to be punched in.

XXXXX displayed in R3. ENTER End of flash.

3. To load 2nd component <u>only</u> of device "N3" (a 3 component device)

VERB	22	NOUN	N3	ENTER

Verb and Noun lights flash, requesting 2nd component to be punched in.

XXXXX displayed in R2. ENTER End of flash.

4. To display (in octal) both components of device "N2" (a 2 component device)

VERB	04	NOUN	N2	ENTER

1st component of "N2" is displayed in R1.

2nd component of "N2" is displayed in R2.

5. To display (in octal) 2nd component only of device "N2" (a 2 component device)

VERB 02 NOUN N2 ENTER

2nd component of "N2" is displayed in R1.

6. To change Major Mode

VERB 37 ENTER

Verb light flashes, requesting Major Mode number to be punched in (2 char). XX displayed temporarily in Noun lights. ENTER End of flash. Major Mode number is now placed in Major Mode lights and mode change is carried out. (Note that old Major Mode number is preserved in Major Mode lights until visual observation of Noun lights confirms proper new Major Mode number. It is second ENTER that performs action and changes Major Mode display.)

The LIST 1 VERB - NOUNS are a part of PINBALL which appears in ECLIPSE

04-11 ISS Mode Switching

The ISS Modes may be controlled by the computer. This is accomplished by routines written for AGC 4 which appear in ECLIPSE.

The ISS Modes are controlled through the "C" relays of the DSKY. These relays, like the "R" relays (see 04-07), are controlled by the computer through OUT 0. If a "C" relay is to be changed by a program, the complement of the required bit configuration for OUT 0 is entered into DSPTAB + 11 and a 1 is set in FLAGWORD bit 11 by that program. During N = 0 of the DSPRUPT program, FLAGWORD is examined to see if a "C" relay is to be changed. If yes, the contents of DSPTAB + 11 is transferred (complemented) to OUT 0 by the routine CDRIVE and the "C" relay is changed (the same word that is transferred to OUT 0 is also transferred to DWNTAB + 3 and bit 11 of IDWORD is set for the T/M display). If no, the routine DSPOUT is initiated (see 04-07).

Fig. 4

DISPTAB + 11_D — BITS 11 → 1 MUST CONTAIN THE COMPLEMENT OF THE DESIRED C RELAY CONFIGURATION

1	1	1	1											

FLAG WD — MASK & PRESERVE

X	X	X	X	X	X	X	X	X	X	X	X	X	X	1

OUT 0 REGISTER IS SET BY DISRUPT ROUTINE AS PER DISPTAB + 11_D

	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1
	0	0	0	0											
DSKY RELAYS FROM AGC RELAYS					C11	C10	C9	C8	C7	C6	C5	C4	C3	C2	C1
ISS RELAYS					K5	K12						K4	K3	K2	K1
M & DV LITES							AGC FAIL	IMU FAIL	PIPA FAIL	CDU FAIL	ENCODER ZEROING				
IMU CONTROL PANEL LITES					ENTRY	ATT CONTROL						FINE ALIGN	CDU MANUAL	COARSE ALIGN	ZERO ENCODE
IN 3 BIT RETURN					BIT 7	BIT 5						BIT 4	BIT 3	BIT 2	BIT 1
ZERO ICDU (ZERO ENCODER)					0	0	(0 → 30 SEC)				1	1	0	0	1
					0	0	(> 30 SEC)				0	1	0	0	1
FOLLOW ICDU (COARSE ALIGN)					0	0					0	0	0	1	0
FOLLOW IMU (FINE ALIGN)					0	0					0	1	0	0	0
FREE IMU (ATTITUDE CONTROL)					0	1					0	0	0	0	0
FREE IMU ENTRY (ENTRY)					1	0					0	0	0	0	0

The only programs thus far written which load DSPTAB + 11 are the List No. 2 Verb-Nouns. The OUT 0, "C" relay, ISS "K" relay correspondence is indicated in Fig. 4.

04-12 ISS Mode Sampling

The ISS Mode Sampling routine will be initiated by the DSPRUPT program. Fig. 5 indicates a flowgram of the routine that is intended to appear in SUNRISE. The routine is not programed at this time.

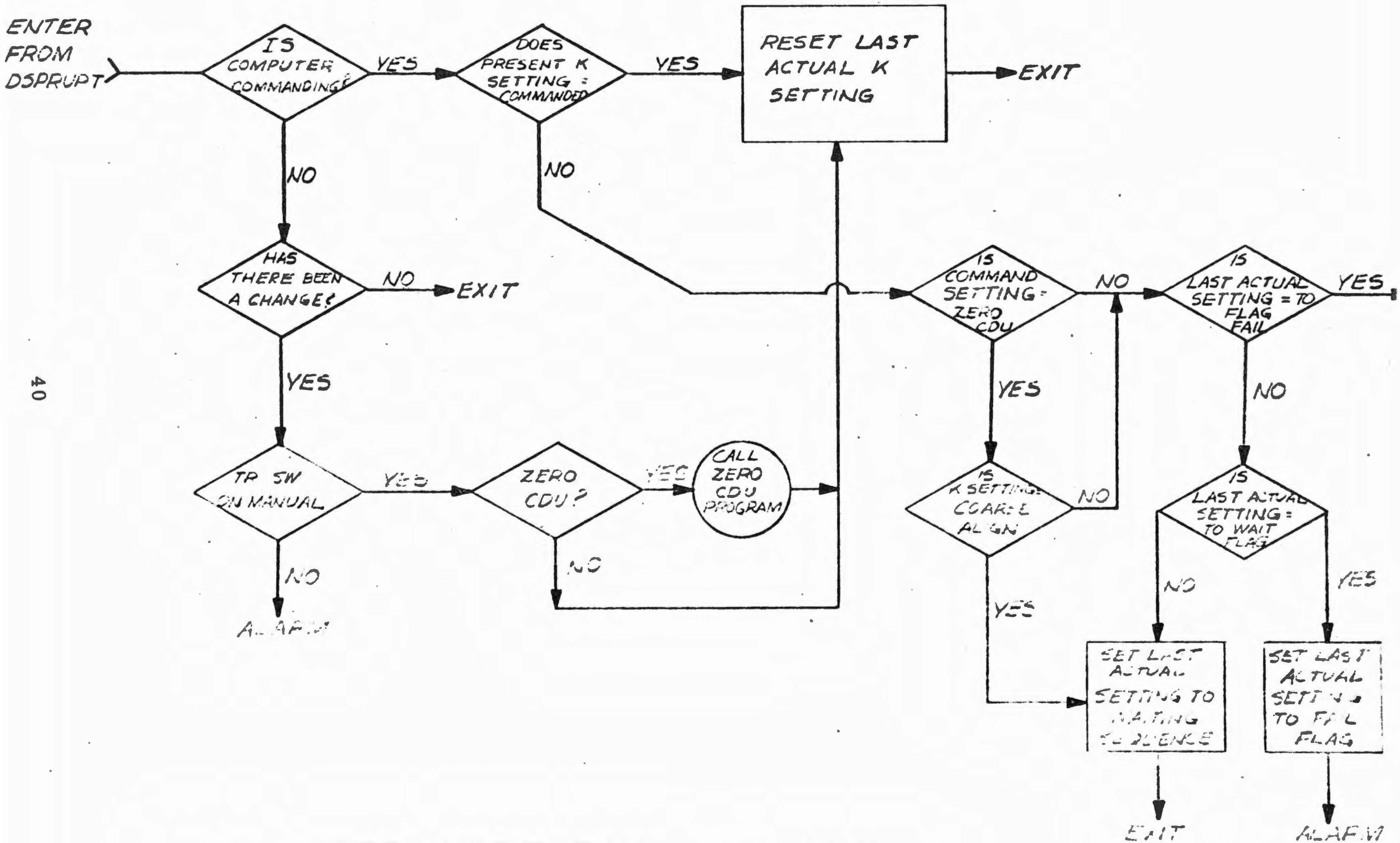


FIG 5 ISS MODE SAMPLING ROUTINE

04-13 ISS CDU Control

CDU driving routines have been written by Ramon Alonso for AGC 4. These routines appear in ECLIPSE. Another routine has been written by Charles Muntz.

CDU driving is accomplished by sending pulses to the Digital-to-Analog Converters of the ISS. The transmission of these pulses is controlled by the upper seven bit configuration of output register OUT 2, as indicated:

	15	14	13	12	11	10	9	
OUT 2	−	+	CDU	GYRO	X	Y	Z	[illegible]

These bits control the logic circuits which enable the 3μs, 3200 pps pulses.

The present DSPRUPT program provides for initiation of the CDU driving routine during the N = 3 and N = 1 cycles. The DSPRUPT program in this instance is used as a timing device. To permit the selection of two different routines and also two different loop sampling rates for these routines, the calling program will set the desired request into a temporary storage area called FLAGWORD as indicated:

	15	14	13	12
FLAGWORD	SHAFT I .15	SHAFT I .3	ECDU .1[illegible]	ECDU .[illegible]

During N = 3, CDUPROG B is initiated which examines bits 15 and 13 to determine if either driving routine SHAFTI or ECDU should be executed. The routine SHAFTI makes the contents of the CDU counters in the AGC match the contents of three registers called ANGIX, ANGIY, and ANGIZ by enabling the pulse transmission. These three registers contain the desired angle. The gain of the loop is 1-G, where G is a constant either positive or negative. It is stored in erasable memory. The CDU's are driven sequentially and always in the direction which involves the smallest angle between the two values. The routine ECDU has not been written.

During N = 1, CDU PROG A is initiated which examines bits 15 through 12 of FLAGWORD to again determine if the driving routines are to be initiated. By examining only bits 15 and 13 during N = 3 and all four bits when N = 1, the loop sample rate can be controlled to be 0.15 seconds or 0.3 seconds.

The routine by Charles Muntz differs from SHAFTI in that it provides for an additional gain change which could compensate for such things as different SCS scale factors. This routine will appear in SUNRISE.

04-14 ISS IRIG Pulse Control

An ISS IRIG Pulse Control routine has been written for AGC 4. This routine will appear in SUNRISE. The routine sends the demands on the gyro's from the internal program and will end by sending out 2 negative followed by 2 positive pulses to the gyro.

04-15 ISS PIPA Snapshot

This program will be used to read the PIPA counters for the prelaunch, boost, powered flight, and entry programs. This program is written and will appear in the SUNRISE package.

This program reads the PIPA counters, transfers the data to the appropriate program, resets the PIPA counters, requests the program to be reinitiated in 0.5 seconds and calls the appropriate program to be executed via the Executive.

04-16 OPT Mode Switching

There is no provision in Block I for OPT Mode Switching by the computer.

04-17 OPT Mode Sampling

There are no programs written for OPT Mode Sampling.

04-18 OPTICS CDU Control

There are no programs written for computer control of the optics CDU's.

04-19 MARK Routine

The MARK routine, in conjunction with the MARK button on the G and N Control Panel, will be used during navigational sightings. The routine will record the following set of values when the MARK button is pressed:

1. TIMER 1 } double precision time
2. TIMER 2 }
3. ICDU X
4. ICDU Y
5. ICDU Z
6. OCDU X
7. OCDU Y

When the MARK button is pressed a discrete signal is generated which is applied to the computer Mark Trap and INO bit 15. The Mark Trap generates a RUPT signal, RP4, which is similar to the KEYRUPT signal (see 04.02). This RUPT signal initiates the RUPT routine and in turn the KEYRUPT program. The KEYRUPT program tests bit 15 of INO and then branches to the MARK routine.

The MARK routine has a 20 second timer associated with its operation which is initiated when the MARK button is first pressed. After the MARK button is pressed and the seven values recorded, the astronaut may choose to better the recording by again pressing the MARK button. This will replace the previous values with the seven new values. This option may be exercised repeatedly during the 20 second interval. Normally there will be two sightings made; after the 20 seconds, the program will make preparation for recording the seven pieces of data in a second set of seven locations when the MARK button is again pressed.

If the astronaut later decides to change the values set in during either of the two 20 second intervals, this will require Keyboard entrance.

The MARK interrupt routine is a part of the KEYRUPT program and appears in ECLIPSE. The MARK routine as described is the current planning and is not programmed.

04-20 RDR Control

No programs have been written for RDR control. Interface has not been fully defined.

04-21 RDR Processor

No programs have been written for RDR Processing. Interface has not been fully defined.

04-22 Engine Sequencing

Programs for engine sequencing are presently in the planning stage. The constraint to this progress is lack of interface definition.

05. PRELAUNCH PLATFORM ALIGNMENT

Prior to launch the platform must be erected with the outer gimbal axis directed along the local vertical and the middle gimbal axis in the direction of the launch azimuth. This means that the inner gimbal axis is directed approximately north-south.

Vertical sensing is accomplished by Y and Z PIPAs. The computer adjusts the inner and middle gimbal angles such as to null the outputs of these accelerometers. Azimuth orientation is achieved by gyro compassing.

This program has been coded and is in the process of being checked out.

06. IN-FLIGHT PLATFORM ALIGNMENT

In-flight platform alignment is performed prior to any powered flight phase. The spacecraft must initially be in the SCS attitude hold mode with a 1/2 degree deadband, and the required velocity increment vector must be in computer memory. The previous plan to have the computer determine when to make midcourse corrections has been dropped, and it is now planned to make the maneuvers at predecided discrete times during the transit. Likewise the times at which injection maneuvers are to be performed is known approximately prior to launch.

A complete description of the lengthy process of in-flight platform alignment will be included later.

The in-flight platform alignment program is in programming.

07. MIDCOURSE AND ORBITAL NAVIGATION

Midcourse and Orbital Navigation includes all of those functions necessary to determine the spacial location of the spacecraft and the corrections required. It includes computation of the state (position and velocity) vector, the error and uncertainties in the spacecraft "state", and the corrections required to reach the desired terminal point. The theoretical basis for the Midcourse and Orbital Navigation program is contained in R-341 by Battin, and other pertinent documents are R-382, and SGA Memos #12 and 40.

The Midcourse and Orbital Navigation program is very extensive, expected to require 1500 to 2000 words, and is in the process of being programmed.

08. POWERED FLIGHT GUIDANCE AND NAVIGATION PROGRAM

This program is used to compute the velocity to be gained and to control the spacecraft attitude during mission phases other than midcourse correction. It is not expected that this program will be used for midcourse corrections because of the small time duration (one or two seconds) of the midcourse corrections as compared to the rise time of the Guidance and Navigation loop (on the order of ten seconds)

The scope of the Powered Flight G&N Program includes iterative computation of the velocity to be gained vector according to the previously computed and stored destination aim point, and it includes all functions necessary to initiate thrust, to control the direction of the thrust vector, and to terminate thrust.

This program is in process of being coded.

09. DELTA-V

The Delta-V program is similar to the Powered Flight Guidance and Navigation Program except that it is used for control of the spacecraft attitude during engine thrusting for the midcourse corrections only. The Delta-V program is entered at a termination of the Midcourse and Orbital Navigation Program. Inputs to the Delta-V program are the quantities computed by the Midcourse and Orbital Navigation program. The primary input of concern here is the state vector (position and velocity) of the spacecraft extrapolated to the time at which the midcourse correction will be applied. This is the extrapolated initial velocity for the midcourse correction.

To compute Delta-V, the program fits a conic between the intended correction point at the intended time of correction, and the desired destination aim point at the desired arrival time. This is a two body problem known as Lambert's problem. The perturbing effects of the other bodies are accounted for by a correction which is contained in the location of the aim point. Only one conic will span between the correction and aim points and also yield the desired flight time. This conic requires a certain velocity at the termination of the correction. The difference between this required terminal velocity and the extrapolated initial velocity mentioned previously is the velocity to be added, Delta-V.

The duration of thrusting for midcourse corrections will be so short that it will not be possible to control the thrust direction using AGC processing of the PIPA outputs. Thus control of the spacecraft during operation of the Delta-V program is similar to that of the Powered Flight G&N program except that the loop through the computer is not closed. The spacecraft attitude is controlled by the error signals from theCDUs, and the CDU reference angles are fixed.

10. RE-ENTRY GUIDANCE AND CONTROL

This program is in the planning stage.

11. BOOST MONITOR

The Boost Monitor program will be used to monitor the path of the spacecraft from liftoff to earth orbit, and to take remedial action if an anomaly is detected. The program is in the planning stage.

12. TEST AND EXERCISE

This program is being designed to perform introspective diagnosis on the computer and also on other system components when there is no higher priority task for the computer.

Some of these programs will not be a part of airborne equipment. Programs written to date on Test and Exercise are LEFT BANK and RITE BANK.

LEFT BANK is an assembly of interface and self tests for the AGC. It has two major sections; IOTEST and FOUR CHEK. LEFT BANK appears in ECLIPSE.

IOTEST is the name given to the IN-OUT testing program for the AGC. IOTEST automatically verifies the circuitry associated with the transformer coupled AGC interfaces. The program is grouped into an AGC-S/C test and an AGC-PSA test. Test stimuli are provided by programming commands into output registers. These stimuli are coupled back to the input by means of a special passive adapter to replace the AGC junction box. Response to the programmed stimuli is checked by inspection of input registers and counters.

AGC S/C is called by LIST 2 VERB-NOUN TEST 2 AGC. AGC-PSA is called by TEST 3 AGC. Failures and successes will be displayed by the Display Panel.

FOUR CHEK These are AGC self tests for checking the correct execution of each instruction, and of proper functioning of memory. FOUR CHEK contains over one hundred small subprograms normally of less than ten words each. Each subprogram consists of a discrete test of some phase of the microprogram. FOUR CHEK does not attempt to tell what is wrong but rather only that which is right. However, by always knowing what is functioning correctly and being able to pinpoint a malfunction to a small section of the program, this should normally give an excellent indication as to exactly where the trouble lies.

RITE BANK is the assembly of the LIST 2 VERB-NOUNS and the associated routines. RITE BANK appears in SEINE.

The LIST 2 VERB-NOUNS and a brief description of their operation is as follows:

Align 1 (x, y, z All) ICDU VERB 40,41, 42, 43 NOUN 11

Align the specified CDUs to a given angle. Upon entering this command, the AGC requests a load by flashing "Load (All, x, y, z) ANGI". The noun ANGI is the full angle to which a particular CDU, specified by the verb, is to be aligned to.

Align 1 Time VERB 40-42 NOUN 21

Take a snapshot of Time 1, Time 2, and IN 1 to be held while in Standby.

Align 1 IMU VERB 40-47 NOUN 35

Align the IMU to the angles specified by the CDUs. This action differs from Coarse Alignment, in that it does the following:

1. Test 3 ICDU; i.e., check the zero reference
2. Follow IMU; i.e., seek the platform angles.
3. Without the platform following, Align 2 ICDU; i.e., drive the CDUs off null sufficiently to avoid false nulls (stick off).
4. Follow IMU; again, seek the platform angles.
5. Follow ICDU; set to the Coarse Align mode. Since the ICDUs are at the platform angles, there will be no motion.
6. Align 2 ICDU; with the platform following the CDUs, align the CDUs to their original position.

Align 2 (x, y, z All) ICDU VERB 44, 45,46, 47 NOUN 11

As in Align 1 ICDU, except that the CDUs are aligned to their present angles plus an increment. The loading request made by the AGC reads "Load (All, x, y, z) DELTANGI," where DELTANGI is the angular increment to be loaded.

<u>Align 2</u>	<u>Time</u>	VERB 44, 45	NOUN 21

Increment, or decrement, the AGC time counters by an desired amount.

This is accomplished by:

1. Request load DELTIME
2. Add DELTIME TO TIME 1 and TIME 2
3. Request monitor time.

<u>Zero</u>	<u>ICDU</u>	VERB 50	NOUN 11

Set K relays to zeroing mode (or check that they are so set); after 30 seconds, zero CDU counters.

<u>Follow</u>	<u>ICDU</u>	VERB 51	NOUN 11

This is the Coarse Align mode.

<u>Follow</u>	<u>IMU</u>	VERB 51	NOUN 35

This is the Fine Align mode.

Free ICDU VERB 52 NOUN 11

Turn off the AGC program for closing the CDU position loop. This function is for drifting, or testing drift.

Free IMU VERB 52 NOUN 35

This is the Attitude Control mode.

Free IMU ENTRY VERB 52 NOUN 57

This is the Entry mode.

Test 1 AGC VERB 54 NOUN 37

A program (FOUR CHEK) that tests the central portions of the AGC. Located in LEFT BANK.

Test 2 AGC VERB 55 NOUN 37

For testing the AGC S2C interfaces. Requires a special test plug. Located in LEFT BANK.

Test 3 ICDU (Zero Test of CDUs) VERB 56 NOUN 11

Set K relays to zeroing mode; check that CDU counters read zero after 30 seconds. If they do, return CDUs to original position. If they don't, alarm.

Test 3 PIPAS VERB 56 NOUN 13

Count the velocity increments accumulated in each PIPA counter in time interval, as specified by the operator. Calculate the square root of the sum of the squares of the PIPA counters x, y, z after 81.92 sec. and compares to that expected at the earths surface. This is referred to as the RMS Test.

Test 3 C-RELAYS VERB 56 NOUN 36

The C relays are thosed used by the AGC for driving the K relays, and other display and control relays as well. This program tests each of the 33 C relays.

Test 3 — AGC — VERB 56 — NOUN 37

For testing the AGC-PSA interfaces. Located in LEFT BANK.

Torque (x, y, z) — ICDU — VERB 60, 61, 62 — NOUN 11

For step testing the CDUs. The AGC calls for a Loadx DELTANGI (if the command was Torquex), and then a Loadx SAMPTIME and a Loady SAMPTIME. The noun SAMPTIME refer to times, as measured from the start of the command pulses; the first and second sampling times are identified by Loadx SAMPTIME and Loady SAMPTIME respectively. The sampled positions are displayed.

Tourque (x, y, z) — IMU — VERB 60, 61, 62 — NOUN 35

Torque the specified gyro (x, y, z). The AGC calls for a "Load (x, y, z) DELTANG". The pulses are delivered to the gyros in such a way that the last pulse sent is always positive.

Linkage of List 2 Verb-Nouns

ENGLISH is a utility program for linkage of List 2 Verb-Nouns. It is initially entered by a change to major mode 02 or 03 and remains on the Executive list with priority BACKUP plus one. The verb-nouns to be linked must be of higher priority than ENGLISH.

The mechanism for initiating the ENGLISH linkage routine is as follows:

1. The operator types in the request for the major mode change (MMCHANG) routine. This routine requests the operator to load the new mode.

2. The operator types in 02 for semi-automatic linkage, or 03 for automatic linkage.

3. The MMCHANG routine enters a request to Executive for MJMODE02 (or MJMODE03).

4. MJMODE02 (or MJMODE03) requests the operator to load the CADR of the first VN in the sequence.

5. The operator types in the desired CADR. Control is transferred to NEWVN to call up the first VN in the sequence.

The specific means for (and meanings of) automatic, semi-automatic, and manual operation are as follows:

1. Manual

The verb-nouns (VN) are entered by way of the keyboard. In this mode, further loading instructions are given to the operator by way of the displays. Tolerances would probably not be entered when the VN are called manually; part of the VN's function is to display the quantities of interest, and the operator would do the comparison.

As a rule a List 2 VN action in progress is indicated by the "PROGRAM ACTIVITY" light being on. The end of the action is signaled by turning that light off. Failures, as discussed in DD Memo #96, are indicated by a flashing VN "Display Failreg," with the failure number displayed in R1 of DSKY. Upon a failure, the operator may Terminate, which ends that VN's action; or he may Proceed, which continues the VN's action as if the test had succeeded (underlined words are verbs or nouns). He may also request any display before instructing Terminate or Proceed, including Display Specified Address.

2. Semi-Automatic

Entered by changing the Major Mode to 02. The AGC then requests the complete address (CADR) of the sequence of VN's and associated data. These may be in fixed or in erasable, and there may be more than one such sequence.

The VN are each executed without operator intervention as to date, but operator action is required to proceed to the next calculation within the VN, or to the next VN. As before, the "PROGRAM ACTIVITY" light indicates the end of a VN action by going off. The operator procedure in the event of an alarm is the same as in manual operation. Note that there is no particular Major Mode associated with singly commanded VN's (Manual operation), but there is with semi or automatic operation.

3. Automatic

Entered by changing the Major Mode to 03. The AGC then requests the CADR of the desired sequence of VN's. The same sequence may be called in either automatic and semi-automatic modes. In the automatic mode there is no operator intervention from start to finish, except for the case of alarms.

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