MASSACHUSETTS INSTITUTE OF TECHNOLOGY

APOLLO

GUIDANCE, NAVIGATION AND CONTROL

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R-577

GUIDANCE SYSTEM OPERATIONS PLAN FOR MANNED CM EARTH ORBITAL AND LUNAR MISSIONS USING PROGRAM COLOSSUS I (REV. 237) AND PROGRAM COLOSSUS IA (REV. 249)

SECTION 4 GNCS OPERATIONS (Rev. 6)

DECEMBER 1968

MIT INSTRUMENTATION LABORATORY

CAMBRIDGE 39, MASSACHUSETTS

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R-577

GUIDANCE SYSTEM OPERATIONS PLAN FOR MANNED CM EARTH ORBITAL OR LUNAR MISSIONS USING PROGRAM COLOSSUS

SECTION 4 OPERATIONAL MODES

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REVISION INDEX COVER SHEET

GUIDANCE SYSTEM OPERATION PLAN

GSOP #R-577 Title: For Manned CM Earth Orbital and Lunar Missions Using Program COLOSSUS

Section #4 Title: GNCS Operational Modes (through Rev. 2, see next page for Rev. 3)

Date	Rev.	
April 1968	1	Revision 1 incorporated the following NASA/MSC approved changes, and was published as a complete new document:

MIT No.	NASA PCR		
15.3	146.3	*	Emergency Termination of Integration
27.3	80.3	*	State Vector Synch
29	108	*	P37 Description
32	87	*	Initiation of Average-G
33	84	*	Astronaut Request of CISLUNAR Tracking Attitude Maneuver
34	109	*	Clarify Use of ECSTEER
35	150	*	Provide Attitude Set for Mode III not Mode II
38	110	*	Preferred Orientation Flag
41	111	*	Re-Insert N61 in P62
42	112	*	Re-Locate N61 in P61
45	113	*	Typographical Error-Delete "New Data Option"
50.1	148.1	*	IMU-on Check P51-P53
54	147	*	Update GSOP Section 4
62	123		R03 Ascent Stage Only
66	198	*	UPDATE GSOP for Typographical Errors and Coding Reconciliation
67	167	*	Terminate Flag in R53
72.3	121.3		ΔV Monitor and New Engine Fail Routine
80			Deleted by MIT PCN 98
93	151		Restore RCS Deadband
98	193	*	Low Thrust Detection and New Engine Fail Routine
99.	170	*	Change Recycle Location in P52, P54
	3		Attitude Error Display During First 10 Seconds of Launch
	9		Simplify Crew Procedures in R60
	50		Logic Flow Change P61-~~P67~~
	63		Delete Program P15
	64		Add VI, H, $\dot{H}$ Display to P47
	79		Flag bit Update Verb

13 May 1968	2	Revision 2 incorporated the following NASA/MSC approved changes.				
		MIT No.	NASA PCR		Remove:	Add:
	(Page rev.)	116	194		P22, Rev. 7	P22, Rev. 8
		83	169	*	P22, Rev. 7	P22, Rev. 8
		149	200	*	P61, Rev. 11	P61, Rev. 12
		152	201	*	P62, Rev. 9	P62, Rev. 10
			155		P66, Rev. 6	P66, Rev. 7
		116	194	*	R35, Rev. 7	R35, Rev. 8
		103.1	173.1	*		V67, Rev. 1
					Section 4.4.1	Section 4.4.1, May 1968
		87	136		Section 4.5	Section 4.5, May 1968 (V47 added)
					Section 4.6	Section 4.6, May 1968

* Indicates an MIT Program Change Notice (PCN)

Date: 22 July 1968

REVISION INDEX COVER SHEET

GUIDANCE SYSTEM OPERATION PLAN

GSOP # R-577 Title: For Manned CM Earth Orbital and Lunar Missions Using Program COLOSSUS

Section #4 Title: GNCS Operational Modes (Rev 3)

Date	Rev.	
22 July 1968	3	Revision 3 incorporates the following NASA/MSC approved changes

MIT No.	NASA PCR	Description
	439	Downgrade the authority of the preferred attitude flag P52
481		Termination of N69 in P65
	206	To update Colossus GSOP Sec. 4 delete assumption (3) from R03,
401.1		Correction of IMU WARM UP TIME P40, 41, 47
440		Prevent mark incorporation during R32-R22
435		Compatibility with other "Please Mark" displays P03
436		Correct R36 Sect. 4 GSOP (description of R36)
463		Display missing in P40 V06N40
464		Incorrect Gimbal Angle Test value in R-50
465		Resetting of VHFR FLAG, and STIK FLAG in R00. P20, R22
423		Clarification of NO-DAP and Saturn Configuration Bits R03
447		Describe R00 operation during TVC.
487		New Noun for Back-up Optics in R23
490		New Noun for Option Code in Extended Verbs. R30
491		Provide longer computer wait periods during R22
492		Stop tracking in R00
	225	Inhibit of Auto Maneuver in P20
448		Elimination of V01N71 display in R53 when P23 is operating
493		FIX terminate response to V51 during P03
495		Use of V16 in R31 and R34
	468.1	Change R32 into a program: P76
474		Delete assumption (3) from R03
	226	Change priority display from 5 sec. to 2 sec.
503		Disable optics Tracking when Update Flag is Reset

Date: Aug. 28, 1968

REVISION INDEX COVER SHEET
GUIDANCE SYSTEM OPERATION PLAN

GSOP #R-577 Title: For Manned CM Earth Orbital and Lunar Mission Using Program COLOSSUS

Section # 4 Title: GNCS Operational Modes (Rev. 4 Aug. 1968)

Date	Rev.	Revision incorporates the following NASA/MSC approved changes		
8/28/68	1	NASA PCR	Remove	Add
		538*		P77 Rev. 03
		468.2	R 32 Rev. 00	
			Title Page	Title Page (Rev. 4)
			NASA Signature Sheet page iii	NASA Signature Sheet page iii (Rev. 4)
			Preface page vii	Preface page vii (Rev. 4)
				Revision Index Cover Sheet page v (Rev. 4)

* Indicates an MIT Program Change Notice (PCN)

Date: 3 December 1968

REVISION INDEX COVER SHEET
GUIDANCE SYSTEM OPERATION PLAN

GSOP # R-577 Title: For Manned CM Earth Orbital and Lunar Missions Using Program COLOSSUS

Section #4 Title: GNCS Operation Modes (Rev 5)

Date	Rev.	Revision 5 incorporates the following NASA/MSC approved changes.	
3 Dec 1968	5	PCR/PCN*	Description
		206	PCR 206 Editorial Changes
		507	Termination of Integration
		509	Eliminate P11 Interlock In R30
		511*	Eliminate 0.5 sec wait aften N54 in R31 and R34
		515*	Update Extended Verbs
		519*	Calculation of o in R34 is Incorrect
		520*	Define LOS Axis in P23
		521	Change C-Steering Constant in P37
		524	Provide Maximum Display for Perigee and Apogee in P30, P31, and R30
		528	Display Change in P67
		531	Add 1 Minute in R63 Extrapolation
		552*	Limitation of First Mark in P22.
			Editorial Changes
		570*	Pick Up REFSMMAT flag test in R22
		571*	Update V94 Description and Usage
		578*	P38/P78 Correction
		579*	Update Assumption 5 in P20
		580*	Resetting RENDWFLG in P22
		581*	Setting of R61 Counter in R61
		582*	P34/P74 GSOP Error
		586*	Other Extended Verb Activity Check
		594*	Advanced Orbit Correction in P22 and R52
		595*	Altitude for Landing Site Option in P52
		620*	Update GSOP Alarm Codes
		651*	Innaccuracies in GSOP Description of R41

* Indicates an MIT Program Change Notice (PCN)

1A

Date: December 1968

REVISION INDEX COVER SHEET
GUIDANCE SYSTEM OPERATION PLAN

GSOP # R-577 Title: For Manned CM Earth Orbital and Lunar Missions Using Program Colossus 1 (Rev. 237) and Program Colossus 1A (Rev. 249)

Section #4 Title: GNCS Operations (Rev. 6)

This revision (Rev. 6) incorporates the following NASA/MSC approved changes from the previous revision.

Date	Rev.	Remove	Add	PCR Ref.
Dec. 1968	6	P20 Rev. 21	P20 Rev. 22	606
		P35 Rev. 12	P35 Rev. 13	Edit
		P38 Rev. 13	P38 Rev. 14	577
		P39 Rev. 12	P39 Rev. 13	Edit
		P52 Rev. 15	P52 Rev. 15	Edit
		P54 Rev. 15	P54 Rev. 16	Edit
		P78 Rev. 6	P78 Rev. 7	577
		R53 Rev. 8	R53 Rev. 9	Edit
		R56 Rev. 9	R56 Rev. 10	Edit
		R61 Rev. 15	R61 Rev. 16	606
		Program Alarm Codes Rev. 2	Program Alarm Codes Rev. 3	588
		Revision Index Cover Sheet Page viii	Revision Index Cover Sheet Page viii Rev 6	
			Revision Index Cover Sheet Page ix Rev 6	

Preface

The Guidance System Operations Plan is published as six separate volumes (sections) as follows:

Section 1	Pre-Launch
Section 2	Data Links
Section 3	Digital Autopilots
Section 4	Operational Modes
Section 5	Guidance Equations
Section 6	Control Data

This volume, Revision 5 of Section 4 of the Guidance System Operations Plan for Manned CM Earth Orbital and Lunar Missions using Program COLOSSUS describes the operational modes of the missions.

It constitutes a Control Document to govern the structure of these missions, including GNCS interfaces with the flight crew and MCC.

Revisions to this plan require NASA approval.

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NOTE: The reproduction of IBM print-outs in Sections 4.4.1 through 4.9 inclusive are deliberately not paginated. Reference to the material on these pages is accomplished by using title and line numbers of Sections 4.5 through 4.9.

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4. GNCS OPERATIONAL MODES

4.0 Introduction

Preparation of the GNCS for any mission involves the generation of computer programs, flight and ground crew procedures, and the provision of hardware to meet interface, accuracy, and instrumentation requirements. All of these mission-related items are specified in the Guidance System Operations Plan.

The guidance operational concept is designed to comprise a set of manually-initiated programs and functions which may be arranged by the flight crew to implement a large class of flight plans. This concept of operation will permit both a late flight-plan definition and a capability for real-time flight-plan changes.

The GNC System is designed to perform the CM guidance and navigation functions required on lunar landing missions in a self-contained mode within specified accuracy and maneuver propellant constraints. The System is also designed to accept navigation data from earth-based facilities whenever required to improve accuracy, to reduce maneuver propellant requirements, or to gain some other operational advantage. It is essential on Earth Orbital Missions to demonstrate to the maximum possible extent both the self-contained and earth-cooperative modes of operation, since either mode may be required on lunar missions.

4.1 AGC Program Control

To efficiently coordinate the design of the AGC* Programs, as well as define the astronaut and ground control procedures with respect to the GNC system, it is necessary to define the operating inter-relationships between the GNC system, other S/C systems, the astronauts and the ground.

In primary GNCS control modes the AGC can automatically compute required mission parameters and automatically command both GNCS and CSM subsystems. Complete automation of this control throughout a mission is neither feasible nor desirable. For primary as well as secondary GNCS control modes the astronauts and/or the ground must be capable of initiation or termination of AGC Programs. These procedures must be thoroughly defined to permit the design of the AGC Program logic for astronaut/ground participation.

4.1.1 AGC Program Initiation

4.1.1.1 AGC Programs

Due to the random time sequencing of many of the AGC tasks the design of Programs capable of being utilized at varied times and in varied circumstances offers the best method of accomplishing these tasks. These Programs must incorporate sufficient logic to clearly define the particular time and/or application for which they are to be used. They must also standardize astronaut/AGC communication procedures, ground/AGC communication procedures and GNCS and SCS Mode determination.

A logical arrangement of these Programs has been supplemented by simpler routines not requiring identification as Programs. The Programs, their associated routines and the crew check list are outlined in detail in Section 4.4.

Programs in process in the AGC are identified by the Program light on the keyboard and display panels with one exception, P20. This Program may be in process at the same time as another Program whose number is displayed.

The AGC is programmed to initiate a Program only in response to the initiation of a specific mission task and will continue the programmed sequence of computations and displays for the specific task until Program completion or termination.

Programs are generally initiated by manual keyboard entry (astronaut) or by AGC UPLINK command (ground). In certain cases Program initiation is automatically performed by the preceding Program. The diagrams of Section 4.4 show Program selection as it should occur normally.

*AGC is an acronym for Apollo Guidance Computer. In the CSM, this computer is officially designated as the CMC (CM Guidance Computer).

4.1.1.2 Special AGC Routines

In addition to the AGC Programs there are many routines and subroutines not specifically identified with a Program. The majority of these are automatically performed in a particular computation or control sequence and involve no notification to the "outside world" that they are in process. While they may occasionally be referred to in this document their large number requires that detailed descriptions be restricted to special AGC program documents.

Several special routines are described in detail herein because of one or more of the following characteristics:

(a) The routine involves AGC communication with the astronaut.
(b) The routine is of importance in understanding the Programs.
(c) The routine involves significant sequences of AGC/Astronaut action but could be performed while certain programs are in process.

These routines include those automatically called by the AGC as well as those manually called. If the routine required AGC/astronaut communication, it will start with a particular display which acts as a key to the astronaut that the AGC has automatically entered the routine.

4.1.2 AGC Program Termination

Normally there are two ways by which an AGC Program in process is terminated:

1. At completion, the program in process will transfer control to (a) the Final Automatic Request Terminate Routine (ROO), (b) a subsequent Program.
2. Via a terminate response by the astronaut to an AGC generated flashing display on the DSKY (usually results in transferring control to ROO).

In addition to the above, the astronaut may terminate a particular AGC Program as follows:

1. Select a new Program to operate via the DSKY.
2. Select a routine via the DSKY which has been specifically designed to terminate a particular program or activity (e.g. state vector integration).
3. Select the FRESH START routine which essentially initializes the AGC.

4.2 AGC/Astronaut/Ground Communications

4.2.1 AGC/Ground Communications

The AGC/Ground Communications are via the AGC UPLINK and AGC DOWNLINK and are described in detail in Section 2 of the GSOP.

4.2.2 AGC/Astronaut Communications

The display and keyboard logic in the AGC processes information exchanged between the AGC and the computer operator. This information is exchanged via the display and keyboard (DSKY).

The modes of operation are basically:

(a) Display of internal data - This includes simple displays and periodically updated displays of data; and displays of requests for operator action required by the AGC.

(b) Loading of external data - the process of inserting data into the AGC via the DSKY.

(c) Program or Routine calling - Initiated by operator action via the DSKY.

The following paragraphs and Table 4-1 (page 4-18) provide a limited description of the DSKY, and the crew/DSKY operating procedures. They are included herein to facilitate understanding of the Program logic in Section 4.4 and do not comprise a complete instruction manual for the use of the DSKY. For detailed DSKY operating instructions refer to other MIT documents.

4.2.2.1 The DSKY (refer to Figure 4-1 page 4-19)

(a) UPLINK ACTY Light

1. is energized by the first character of a digital UPLINK message received by the AGC. If the light is not extinguished by the UPLINK transmission it should be extinguished by crew use of the RSET or KEY REL buttons when the UPLINK transmission is complete.

2. is energized during the rendezvous navigation program (P20) when the tracking attitude routine (R61) detects that a gimbal angle change of greater than 10^{o} is required to align the CSM to the desired attitude and that the astronaut has disabled automatic tracking of the LM by taking the rotational hand controller out of detent while SC control switch is switched to CMC and the thrust controller is not fully clockwise.

(b) NO ATT Light - is energized when the AGC is in operate mode and there is no inertial reference; i.e. the ISS is off, caged, or in the coarse align mode.

(c) STBY Light - is energized when the AGC is in standby mode and deenergized when the AGC is in operate mode.

(d) KEY REL Light

(1) Energized when:

(a) An internal display comes up while astronaut has the DSKY.

(b) An astronaut keystroke is made when an internal flashing display is currently on the DSKY. (Note three exceptions: PRO (proceed), RSET (reset) and ENTR (enter) if ENTR is a single button response.)

(c) The astronaut makes a keystroke on top of (his own) Monitor Verb display. This is the so-called "suspended monitor" case. (Monitor Verbs display data updated every one second.)

(2) De-energized when:

(a) Astronaut relinquishes DSKY by hitting KEY REL button.

(b) Astronaut terminates his current sequence normally, e.g.

i) with final ENTR of a load sequence.

ii) the ENTR of a response to a flashing display.

iii) the ENTR of an extended verb request.

(3) Some special DSKY cases that may not be universally appreciated are:

(a) The astronaut may select a non-Monitor Verb display on top of his own previously selected Monitor Verb. This will cause KEY REL light to flash (See 1 (c) above). Hitting the KEY REL button will bring back (unsuspend) the monitor and extinguish the light. However, if these sequences are selected on top of an internal display, the KEY REL light will not go out as the monitor is unsuspended. It requires one more KEY REL button operation to extinguish the light and bring back the internal display.

(b) Suppose the astronaut selects another verb-noun combination (e.g. a V16 monitor) on top of an internal flashing

display. That internal display can still be answered with an ENTR, PRO or VERB 34 ENTR (terminate), which wipes everything from the DSKY till the next internal display. Therefore, an astronaut selected monitor should, as a rule, never be terminated with VERB 34 ENTR, because that may not be the desired response to the flashing display. The KEY REL button should be used instead.

(e) TEMP Light - the AGC receives a signal from the IMU when the stable member temperature is in the range 126.3°F to 134.3°F. In the absence of this signal, the TEMP light on the DSKY is actuated.

(f) GIMBAL LOCK Light - energized when the middle gimbal angle exceeds ± 70° from its zero position. When the middle gimbal angle exceeds ± 85° from its zero position the AGC automatically commands the coarse align mode in the ISS to prevent gimbal oscillation. The NO ATT light will then be energized (see (b)).

(g) PROG Light - The program alarm actuates the PROG light on the DSKY. A program alarm is generated under a variety of situations. Under program control the AGS inhibits this alarm for 10 sec after system turn-on. For further information see section 4.3.3.

(h) TRACKER Light

1. Failure within the optics CDUs generates an error signal which is input to the computer. The TRACKER light is energized by this error signal. Any of the following conditions in either OCDU will cause the alarm to occur in approximately 5-7 seconds.

   a. CDU hunting (oscillating) at greater than 150 ± 50 CPS.
   b. Fine error exceeds 10 ± 2 degrees (internal). This error corresponds to about 0.7 degrees shaft or 0.35 degrees on the trunnion.
   c. 14V supply improper.
   d. Cos ($\theta - \psi$) is too small, (an internal check). (There is no coarse align error signal on CM OCDUs.)

2. In addition to the conditions described in (1.) the TRACKER light is energized during the rendezvous navigation program (P20) when the rendezvous data processing routine (R22)

reads VHF Range data via the VHF DATA link but the DATA GOOD DISCRETE is missing.

3. It is de-energized if the DATA GOOD DISCRETE is present after reading VHF Range data and by keying in V88E (shuts off the VHF Range data processing section of R22).

   It is also de-energized if the conditions described in (1.) and (2.) do not exist.

(i) OPR ERR Light - is energized when the DSKY operator performs an improper sequence of key depressions. The light is de-energized by pressing the RSET button.

(j) COMP ACTY Light - is energized when the AGC is occupied with an internal sequence. It is not an indicator of whether the operator may use the DSKY or whether the AGC is not capable of handling further computation.

(k) RESTART Light - in the event of Restart during operate a latch is set in the AGC which maintains the RESTART light on the DSKY until the latch is manually reset by present RSET. For further detail see section 4.3.3.

(l) Display Panel - consists of 24 electroluminescent sections arranged as in Fig. 4-1, page 4-19. Each section is capable of displaying any decimal character or remaining blank, except the 3 sign sections. These display a plus sign, a minus sign, or a blank. The numerical sections are grouped to form 3 data display registers, each of 5 numerical characters; and 3 control display registers, each of 2 numerical characters. The data display registers are referred to as R1, R2, R3. The control display registers are known as VERB, NOUN, and PROGRAM.

At maximum activity, the complete display panel may be updated in 1/4 second.

(m) Keyboard - contains the following buttons:

VERB - pushing the button indicates that the next two numerical characters keyed in are to be interpreted as the Verb Code.

NOUN - pushing the button indicates that the next two numerical characters keyed in are to be interpreted as the Noun Code.

+ and − -sign keys used for sign convention and to identify decimal data.

0 – 9 -numerical keys.

CLR - used during a data loading sequence to clear or blank the data display register (R1, R2, R3) being used. It allows the operator to reload the data word.

PRO - this pushbutton performs two functions:

1. When the AGC is in a standby mode, pressing this button will put the AGC in the operate mode, turn off the STBY light (see(c)), and automatically select Program 00 in the AGC.
2. When the AGC is in the operate mode but Program 06 is not selected, pressing the button will provide the proceed function. Proceed directs the AGC to continue to the next programmed event. In response to an AGC request it further indicates crew compliance with the request.

2a. When the AGC is in the operate mode and Program 06 is selected, pressing the button will put the AGC in the standby mode and turn on the STBY light (see (c)).

ENTR - is used in three ways:

1. To direct the AGC to execute the Verb/Noun code now appearing on the Verb Noun lights.
2. To direct the AGC to accept a data word just loaded.
3. In response to a "please perform" request (see section 4.2.2.7).

RSET - turns off alarm conditions on the DSKY providing the alarm condition has been corrected.

4.2.2.2 Verbs and Nouns

The basic language of communication between the astronaut and the DSKY consists of Verb and Noun Codes. The Verb Code indicates what action is to be taken. The Noun Code indicates to what this action is applied.

Verb Noun codes may be originated either by manual operation or by the AGC Program in process.

The standard procedure for a manual keyboard operation consists of a sequence of 7 key depressions:

VERB V_1 V_2 NOUN N_1 N_2 ENTR

The VERB key depression blanks the Verb lights on the display panel and clears the Verb Code register within the computer. The next two numerical characters punched in are interpreted as the Verb Code. Each of these characters is displayed in the Verb lights on the display panel as it is punched in. The NOUN key operates similarly for the Noun lights and Noun Code register.

The depression of the ENTR key causes the performance of the Verb-Noun combination appearing in the lights at the time of depression. Thus it is not necessary to follow any order in punching in the Verb or Noun Code. They may be done in reverse order, or an old Verb or old Noun may be used without repunching it.

No action is ever taken in performing the Verb-Noun combination until ENTR is pressed. If an error is noticed in either the Verb Code or the Noun Code before the ENTR is pressed, correction is simple. Merely press the VERB or NOUN key and repunch the originally intended code, without necessarily changing the other. Only when the astronaut has verified that the desired Verb and Noun Codes are in the lights, should he press the ENTR key to execute the Verb-Noun combination.

A Noun Code can refer to a group of computer erasable registers, a group of counter registers, or may serve merely as a label. A label Noun referes to no particular computer registers, but conveys information by its Noun Code number only. The group of registers to which a Noun Code refers may be a group of 1, 2 or 3 members. These are generally referred to a 1, 2, or 3 component Nouns. The component is understood as a component member of the register group to which the Noun refers. The machine addresses for the registers to which a Noun refers are stored within the computer in Noun tables.

A single Noun Code refers to a group of 1, 2, or 3 component members. It is the Verb Code that determines which component member of the Noun group is operated on. Thus, for instance, there are 5 different Load Verbs. Verb 21 is required for loading the first component of whatever Noun is used therewith; Verb 22 loads the second component of the Noun; Verb 23, the third component; Verb 24, the first and second components of the Noun; and Verb 25 loads all three components of the Noun. A similar component format is used in the Display and Monitor Verbs.

When the decimal Display Verb is employed, all the component members of the Noun being used are scaled as appropriate, converted to decimal, and displayed in the data display registers.

Decimal data is identified by a + or - sign preceding the 5 numerical characters. If decimal is used for loading data of any component members of a multi-component Load Verb, it must be used for all components of the Verb. Thus no mixture of decimal and octal data is permitted for different components of the same Load Verb. (If this is violated, the OPR ERR light is turned on.)

There is a class of verbs called Monitor Verbs which display data every one second. Once a Monitor Verb is executed, the data on the display panel continues to be updated until the Monitor is turned off.

The Monitor may be turned off by keying in: PRO, VERB 34 ENTR (terminate) by internal program initiation of the Keyboard and Display System Program, (if the DSKY is not busy) or by a Fresh Start of the AGC.

Monitor action is suspended (but not ended) by the depression of any key, except RSET. This turns on the KEY REL light immediately. Monitor action continues after the Keyboard and Display System is released. Thus it is possible to suspend a monitor while the astronaut loads some data (or requests another display) and to return to the original monitor when his intervention is concluded.

After any use of the DSKY, the numerical characters (verb, noun, and data words) remain visible until the next use of the DSKY. If a particular use of the DSKY involves fewer than 3 data words, the data display registers (R1, R2, R3) not used remain unchanged, unless blanked by deliberate program action.

The DSKY procedures above were described for manual operation; however, the principles described remain the same for DSKY operation by the AGC Programs and routines.

As outlined in the Mission Programs (section 4.4) the majority of DSKY operations are of the following categories:

a) Display - to display data to the operator. Display Verbs present data computed by the mission program.

b) Load - to request a data load as described in detail below.

c) Please Perform - to request an action from the astronaut. (see section 4.2.2.7)

d) Please Mark - to request the astronaut to push the "MARK" button for an optics sighting. (see section 4.2.2.8)

AGC initiated Verb/Noun combinations are either statically displayed or flashed. If static they identify data displayed only for astronaut information requiring no response from him. If the Verb/Noun is flashing, appropriate astronaut response is required as dictated by the Verb/Noun combination. In this case the AGC Program or Routine is interrupted until the astronaut responds appropriately, then the Verb/Noun flash is terminated and the Program or Routine is resumed.

An appropriate astronaut response to a flashing Verb/Noun should be a data load and ENTR, VERB 32 ENTR (recycle), PRO, or VERB 34 ENTR (terminate). The internal program response to any one of these astronaut responses varies according to the Verb/Noun flashing and the Program in process as described below and in Section 4.4.

4.2.2.3 Acceptance of Keys

The numerical keys, the CLR key, and the sign keys are rejected if struck after completion (final ENTR) of a data display or data load Verb. At such time, only the VERB, NOUN, ENTR, RSET, or KEY REL are accepted. Thus the data keys are accepted only after the control keys have instructed the program to accept them.

Similarly the plus (+) and minus (-) keys are accepted just before the first numerical character of R1, R2, R3 is punched in, and at no other time.

The 8 or 9 key is accepted only while defining a verb or noun, or when loading a data word into R1, R2, or R3 which was preceded by a plus or minus sign. (If this is violated, the OPR ERR light is turned on.)

If more than two numerical characters are punched in while loading the Verb, Noun, or Program code, or more than five numerical characters while loading a data word, the excess characters are not accepted.

4.2.2.4 Release of Keyboard and Display System

The Keyboard and Display System Program can be used by internal computer programs. However, any operator keyboard action (except RSET) makes the Keyboard and Display System Program busy to internal routines. The operator has control of the Keyboard and Display System until he wishes to release it. Thus he is assured that data he wishes to observe will not be replaced by internally initiated data displays. In general, it is recommended that the operator release the Keyboard and Display System for internal use when he has temporarily finished with it. This is done by pressing the KEY REL button.

If an internal program attempts to use the Keyboard and Display System, but finds that the astronaut has used it and not yet released it, the KEY REL light is turned on. When the astronaut finds it convenient, he should strike the

KEY REL button to allow the internal program to use the keyboard and display panel.

4.2.2.5 Display - Verb/Noun Flashing

This is an internally initiated action. The appropriate astronaut response to a flashing display Verb/Noun combination is:

(a) Correct the data (see Section 4.2.2.6 below). Perform the appropriate Load Verb sequence. Upon the final ENTR, the program proceeds normally.

(b) VERB 32 ENTR (recycle). This causes the program to return to a previous location.

(c) PRO. This indicates acceptance of the displayed data, and a desire for the internal sequence to continue normally.

(d) VERB 34 ENTR (terminate). The astronaut wishes to terminate the operation.

NOTE: Uncommon responses are defined in the program logic of Section 4.4.

4.2.2.6 Load - Verb/Noun Flashing

Whenever any data is to be loaded the Verb/Noun flashes. The flash occurs whether the data load is initiated by the AGC or by the astronaut. The appropriate data display register (R1, R2, or R3) is blanked in anticipation of the data load. Data is loaded in 5-character words and is displayed character-by-character in one of the 5-position data display registers as it is keyed in.

Numerical data is considered decimal if the 5-character data word is preceded by a plus or minus sign; if no sign is supplied it is considered octal. The plus and minus keys are accepted only when they precede the first numerical character of the data word; they are ignored at any other time. Decimal data must be loaded in full 5-numerical-character words (no zeros may be suppressed); octal data may be loaded with high order zeros suppressed. If decimal is used for any component of a multi-component Load Verb, it must be used for all components of that Verb. No mixing of octal and decimal data is permitted for different components of the same Load Verb. (If this principle is violated, the OPR ERR light is turned on.)

The ENTR key must be pressed after each data word. This tells the program that the numerical word punched in is complete. The flash is turned off after the last ENTR of a loading sequence.

As data is loaded, it is temporarily stored in buffers. It is not placed into its final destination, as specified by the Noun Code, until the final ENTR of the load sequence.

If an attempt is made to key in more than 5 numerical characters in sequence, the sixth and subsequent characters are simply rejected. If the 8 or 9 key is punched during octal load (as identified by lack of a sign entry), it is rejected and the OPR ERR light is turned on.

In multi-component load situations, the appropriate single component Load Verbs are flashed one at a time. The computer always instructs the astronaut through a loading sequence. For example: the astronaut (or the internal program) initiates the sequence by selecting VERB 25, "load 3 components of:" (any 3-component noun will do). The Verb Code is changed to 21, "load first component of:" and the flash is turned on. VERB 21 continues to be flashed as the astronaut punches in the first word of data. When the ENTR is pressed, the Verb Code is changed to 22. Flashing continues while the astronaut punches the second data word. When ENTR is pressed, the Verb Code is changed to 23, "load third component," and again the flash continues while the third data word is punched in. When ENTR is pressed, the flash is turned off, and all three data words are placed in the locations specified by the Noun. Throughout the changing of the Verb Codes, the Noun Code is left unchanged.

The CLR button is used during data loading to remove errors in R1, R2, or R3. It allows the astronaut to begin loading the data word again. It does not clear the Program, Noun, or Verb lights. (The Noun lights are blanked by the NOUN key; the Verb lights, by the VERB key.) In the following discussions, the term Clearing Function will be used to mean blanking the data display register.

For single component Load Verbs, the CLR button depression performs the Clearing Function on whichever register is being loaded, provided that CLR is punched before data ENTR. Once ENTR is depressed, CLR does nothing. The only way to correct an error after the data ENTR for a single component Load Verb is to begin the Load Verb again.

For the 2- or 3-component Load Verbs, there is a retrograde sequencing feature of CLR. The first depression of the CLR button performs the Clearing Function on whichever register is being loaded. (CLR may be pressed after any character, before its ENTR.) Consecutive depressions of CLR perform the Clearing Function on the data display register preceding the current one, and also change the VERB light to indicate the register being acted upon until R1 is cleared. Any attempt to back up beyond R1 is simply ignored.

The retorgrade sequencing of CLR operates only on data pertinent to the Load Verb which initiated the loading sequence. For example, if the initiating Load Verb was a load second component only, no backing-up action is possible.

4.2.2.7 Please Perform - Verb/Noun Flashing

This is always an internally initiated action, as astronaut response is always required to the "please perform" request; the Verb-Noun is always flashed, and the Program is interrupted. The "please perform" verb (50) is usually used with the "Checklist" noun (25) with an appropriate "checklist code" number in R1. The appropriate response is:

(a) PRO to indicate an affirmative response to the request.
(b) ENTR to indicate a negative response to the request.

4.2.2.8 Please Mark

The "please mark" verbs (51, 52, 53, 54, or 59) are flashed when the AGC is prepared to accept optical sighting data upon the pushing of the "MARK" button. The logic associated with the "please mark" function is completely described in Section 4.4.

4.2.2.9 Machine Address to be Specified

There is a class of Noun available to allow any machine address to be used. These are called "Machine Address to be Specified" Nouns. When the ENTR which causes the Verb-Noun combination to be executed senses a noun of this type, R3 is blanked and the flash is immediately turned on. The Verb Code is left unchanged. The astronaut should load the 5-octal-character complete machine address of interest. It is displayed in R3 as it is punched in. If an error is made in loading the address, the CLR may be used to remove it. Pressing ENTR causes the verb to be executed.

4.2.2.10 Program Selection

VERB 37 ENTR is used to select a Program. This causes the Noun display register to be blanked and the Verb Code to be flashed. The 2-character Program Code would then be loaded. For verification purposes, it is displayed as it is loaded in the Noun display register. The ENTR causes 1) the flash to be turned off, 2) a request for the new Program to be entered, and 3) the new Program Code to be displayed in the Program display register.

4.2.2.11 Alarm Philosophy

The OPR ERR light is turned on when the astronaut performs some improper sequence of key depressions.

4.2.2.12 Illegal Verbs, Nouns and Combinations

The simplest alarm situation is an attempt to use an undefined (or spare) Verb Code or Noun Code. The OPR ERR light is turned on when the ENTR that attempts to execute the Verb/Noun combination is pressed. No further action is taken.

It is possible to choose a Verb that is defined and a Noun that is defined, but have the combination of Verb and Noun be illegal (for example, the "decimal display" Verb used with a Noun which is restricted to be "octal only"). The OPR ERR light is turned on at the ENTR that attempts to execute the Verb/Noun combination. No further action is taken.

Violation of the following principles causes the OPR ERR light to be turned on. No further action is taken.

(a) An undefined (or spare) verb must not be used.
(b) An undefined (or spare) noun must not be used.
(c) In octal Display and Monitor Verbs and all Load verbs, the components number of the verb must not exceed the number of components in the noun. (Note, all "machine address to be specified" noun are considered 3 component.)
(d) The octal display and Monitor Verbs must not be used with a "decimal only" noun.
(e) The decimal Display and Monitor Verbs must not be used with an "octal only" noun.
(f) The double precision decimal Display and Monitor Verbs (07, 17) must not be used with mixed nouns (codes 40-99).
(g) No Load Verb may be used with a noun restricted to be "no load". All nouns having split MIN/SEC scale or 2 integers for any component are "no load" for the entire noun.
(h) An input code other than those which are defined is received from the keyboard.
(i) The contents of the register used to determine which display panel character is to be lighted has exceeded its limit.

4.2.2.13 Illegal Data and Recycle

Many legal Verb/Noun combinations require the loading of additional data (either numerical or machine address). It is possible that the data supplied may itself be improper for the Noun selected. Examples are: (1) the numerical data exceeds the maximum value allowed by the scale factor associated with the Noun, and (2) decimal data is loaded into an "octal only" noun.

In general the offense is detected at the final ENTR of the loading sequence. The alarm is turned on and a recycle is performed back to the beginning of the loading sequence. The flash is left on, and the data display register associated with the first data word in the sequence is blanked again. It is necessary for the astronaut only to supply the data again; he need not attempt to re-execute the Verb/Noun combination. (Note, if decimal data is supplied for the address of a "machine address to be specified" noun, the alarm and recycle are performed at the ENTR immediately following the address keyed in.)

Violation of the following principles causes the OPR ERR light to be turned on, and a recycle to be performed.

(a) The address keyed in for a "machine address to be specified" noun must be octal.

(b) In multicomponent load verbs, no mixing of octal and decimal data is permitted. All the data words loaded for a given noun must either be all octal or all decimal.

(c) Octal data must not be loaded into a "decimal only" noun.

(d) Decimal data must not be loaded into an "octal only" noun.

(e) Decimal data loaded must not numerically exceed the maximum permitted by the scale factor associated with the appropriate component of the noun.

(f) Negative decimal data must not be loaded using the Y optics scale.

(g) All 3 words must be loaded for the Hours, Minutes, Seconds scale.

(h) When loading with the Hours, Minutes, Seconds scale, the minutes must not exceed 59; the seconds must not exceed 59.99; and the total number must not exceed 745 hours, 39 minutes, 14.55 seconds.

(i) Two numerical characters must be supplied for the Program Code under V37.

4.2.2.14 Operator Error and Key Rejection

There are four situations which cause the OPR ERR light to be turned on and the offending key depression to be simply rejected. These are:

(a) An attempt to ENTR a decimal data word having fewer than 5 numerical characters. The ENTR is simply rejected. The flash is left on and the Verb Code is not advanced. Thus it is possible to supply the remaining characters and to press the ENTR again for the same data word. Or the CLR key may be used if the operator wishes to begin loading the offending data word again.

(b) An 8 or 9 is punched while loading a word which was not preceded by a plus or minus sign. The 8 or 9 is simply rejected. The remaining characters may then be supplied or the offending word removed and its loading begun again.

(c) Certain program controlled cases (see Section 4.4).

(d) An attempt to call one extended verb on top of another without allowing proper termination of the first.

ASTRONAUT RESPONSE	DISPLAY OF INFORMATION		REQUEST FOR ASTRO ACTION		REQUEST FOR DATA LOAD	REQUEST FOR OPTICS MARK
	Type of information identified by V__N__ followed by up to three available registers of information, R1, R2, R3.		Request identified V50, V97, or V99	Request identified by V53	Request identified by V____ and type of data by N____. Loaded data appears in registers R1, R2, R3, At completion, key in "ENTER".	Request identified by V51. At completion of "MARK"s identify target (final entry is "ENTER")
	CMC Awaiting ASTRO Response V_N_Flashing	CMC Not Awaiting ASTRO V_N_Static	CMC Always Awaiting ASTRO Response	CMC always awaiting ASTRO response	V_N_ Flashing	CMC Always Awaiting ASTRO Response V51 Flashing
Key in "ENTR"	No CMC Action	No CMC Action	CMC assumes ASTRO did not comply, terminates flashing Verb-Noun, and continues	CMC assumes ASTRO complied	CMC takes loaded data, terminated flashing Verb-Noun and continues	See appropriate routine in Section 4.4
Key in "PRO"	CMC assumes displayed data is correct, terminates flashing Verb-Noun, and continues	No CMC Action	CMC assumes ASTRO complied, terminates flashing Verb-Noun, and continues	In R23 CMC assumes ASTRO has taken sufficient marks. In R56 reponse is not accepted	CMC assumes no data available, terminates flashing Verb-Noun, and continues if possible	No CMC Action
Key in "Terminate" (V34E)	Varies with program in progress	No CMC Action	Varies with program in process		Varies with program in process	Varies with program in process
Key in "Recycle" (V32E)	CMC returns to earlier point in sequence	No CMC Action	Incorrect Response		Incorrect response	No CMC action
Press MARK button	If there is no request for a mark at the time of key depression, the PROG Light is turned on.					CMC reads 2 optics angles, 3 CDU angles, and time, terminates flashing Verb-Noun if a suitable number of marks have been made and continues

ASTRONAUT RESPONSE TO DSKY DISPLAYS
AND CMC RESULTANT ACTION
Table 4-1

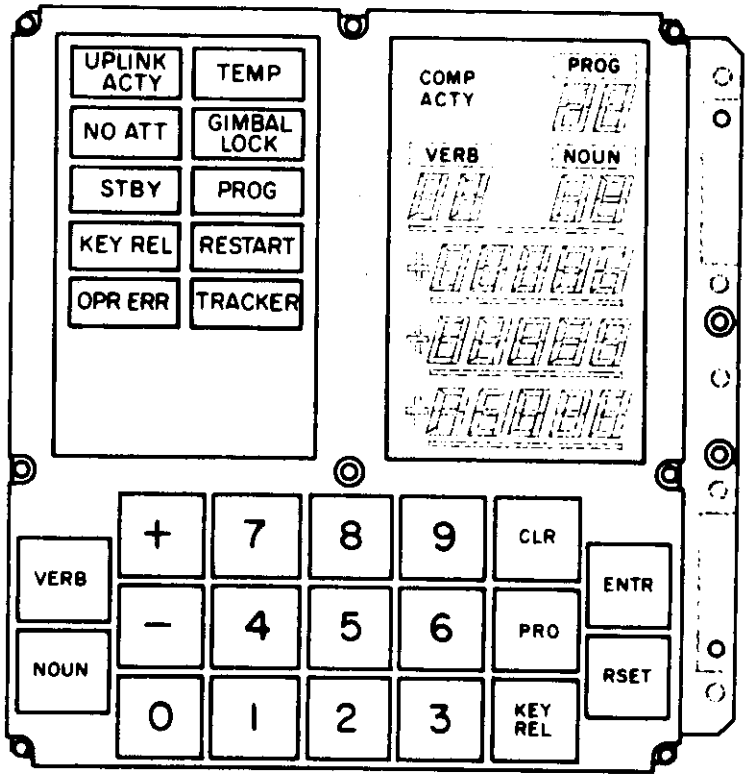

Fig. 4-1 Display and Control Panel

4.3 GNCS Failure Monitor

The GNCS performance and operational readiness are self-monitored and caution and warning information are displayed to the crew. Two warning (red) lamps are actuated by the GNCS on the Caution/Warning Panel: AGC Warning indicates computer failure; ISS warning indicates failure of the inertial subsystem. Also a GNCS Caution (amber) light is actuated to indicate non-critical problems in the system. Further detail regarding the caution items is displayed by means of the DSKY event lamps and the DSKY data registers (in the event of a program alarm).

4.3.1 AGC Warning

An AGC warning alarm is generated in the event of AGC power failure, scaler failure of either of two types, restart or counter failure during AGC operate, or in response to an alarm test program. A scaler fail or prime power fail result in an immediate alarm indication whereas the other inputs are buffered by a filter so as to prevent transient disturbances from causing a warning alarm. In this subsection the various inputs and conditions associated with AGC warning are defined.

(a) SCAFAL - Occurs if scaler stage 17 (1.28-sec. period) fails to produce pulses. This provides a check on the timing for all logic alarms.

(b) COUNTER FAIL - Occurs if counter increments happen too frequently or else fail to happen following an increment request. "Too frequently" means continuous counter requests and/or incrementing for from 0.625 to 1.875 ms.

(c) SCADBL - Occurs if the 100 pps scaler stage operates at a pulse rate or 200 pps or more.

(d) PARITY FAIL - Occurs if any accessed word in fixed or erasable memory whose address is octal 10 or greater contains an even number of "ones".

(e) RUPT LOCK - Occurs if interrupt is either too long or too infrequent. The criterion for "too long" is phase dependent, varying in duration from 140 ms. to 300 ms. Likewise the criterion for "too infrequent" varies in absence from 140 ms to 300 ms.

(f) TC TRAP - Occurs if too many consecutive TC or TCF instructions are run or TCF instructions are too infrequent. The criterion for "too many" varies in duration from 5 ms to 15 ms. The criterion for "too infrequent" varies in absence from 5 ms to 15 ms.

(g) NIGHT WATCHMAN - Occurs if the computer should fail to access address 67 within a period whose duration varies from 0.64 sec. to 1.92 sec.

(h) V FAIL - Occurs if the AGC voltages (28, 14, 4) are out of limits. This signal produces STRT1 if it stays on for a period of between 157 and 470μ sec. If the computer is in the STANDBY mode, an input to the AGC WARNING FILTER is generated simultaneously with STRT1. The following criteria apply for V FAIL:

4 V Supply > 4.4 V	14 V Supply > 16 V
4 V Supply < 3.65V	14 V Supply < 12.5V
	28 V Supply < ~22.6V

(i) STANDBY - This is a signal which turns on RESTART and turns off the switchable +4 and +14 voltage, thus putting the AGC into a low power mode where only the scaler, timing signal, and a few auxiliary signals are operative. STANDBY is initiated by first setting the ENABLE STANDBY outbit (CH13 B11), and then pressing the PRO button on the DSKY for a time which varies from 0.64 sec. to 1.92 sec. at the end of which time the STANDBY light is turned on. (All AGC alarms are inhibited during the Standby mode with the exception of AGC WARNING, which can be caused by VOLTAGE FAIL or SCALER FAIL; and TEMPERATURE CAUTION, which can be caused by TEMP ALARM.) Normal operation is resumed by pressing the PRO Button on the DSKY again, time of depression same as above.

(j) RESTART - RESTART occurs at next time 12 following occurrence of any one or more of the following parameters: Rupt lock, T.C. Trap, Night Watchman parity fail, and Standby as described above.

RESTART occurs immediately and forces time counter to 12 upon occurrence of OSCILLATOR FAIL. (See paragraph (l) below.)

RESTART causes the computer to transfer control to address 4000 as soon as it disappears. It sets a flip-flop which lights the RESTART CAUTION lamp in the DSKY.

The flip-flop is reset either by the ALARM RESET hard-wired signal or by the CAUTION RESET outbit CH11 B10. ALARM TEST operates the lamp but not the flip-flop.

(k) WARNING FILTER - This circuit is used to operate the AGC WARNING output following repeated or prolonged occurrences of any of certain parameters. All occurrences of these signals are stretched so that no more than one input to the filter is generated in each 160-millisecond period. Approximately six consecutive stretched pulses cause AGC WARNING to turn on for about 5 seconds. Non-consecutive stretched pulses may also cause AGC WARNING after an interval dependent on the frequency of the pulses. The output will not occur if input pulses occur at a frequency of less than 0.9 pps; and the output will reamin on if pulses occur at a frequency of 0.6 pps or more. The threshold of the filter resumes its normal level with a time constant of many seconds after the filter has received inputs. An immediate reset of the AGC WARNING due to a WARNING FILTER output is therefore not possible.

(l) OSCILLATOR FAIL - Occurs if the oscillator stops. Has nominal 250-millisecond delay to keep signal present after the oscillator starts. Also occurs when AGC is in STANDBY because of loss of power to front end of circuit. This results in a 250-millisecond delay in starting when AGC comes out of STANDBY into OPERATE and causes an immediate restart without waiting for time pulse 12.

4.3.2 ISS Warning

The ISS Warning signal is the logical "OR" of the following parameters, any one of which will cause an ISS Warning under the following conditions:

(a) IMU Fail

(1) IG Servo Error - greater than 2.9 mr for 2 sec

(2) MG Servo Error - greater than 2.9 mr for 2 sec

(3) OG Servo Error - greater than 2.9 mr for 2 sec

(4) 3200 cps supply - decrease to 50% of normal voltage level

(5) 800 cps wheel supply - decrease to 50% of normal voltage level

These parameters are generated in the Inertial Subsystem. However, the "FAIL" signal itself is under AGC program control. It is ignored by the 5-second interval following Coarse Align. During this mode the servo errors normally exceed the above criteria.

(b) PIPA FAIL

Pipa fail occurs if no pulse arrive from a PIPA during a 312.5-sec period, or else if both plus and minus pulses occur, or if a "long

time" elapses without at least one plus pulse and at least one minus pulse arriving. By "long time" is meant a period between 1.28 sec. and 3.84 sec.

This FAIL signal is generated totally within the AGC and thus is completely under AGC program control. Its generation is enabled by the AGC only during AGC controlled translation or thrusting maneuvers.

(c) ISS CDU FAIL (Monitored for each of 3 CDU's)

(1) CDU fine error - in excess of 1.0 V rms

(2) CDU coarse error - in excess of 2.5 V rms

(3) READ COUNTER limit cycle - in excess of 160 cps

(4) Cos (θ - ϕ) - below 2.0 V

(5) +14 VDC Supply - decrease to 50%

These parameters are generated in the Inertial Subsystem. It is ignored by the AGC program for 10.24 seconds when the G&N System is in the CDU Zero Mode. During this Mode the CDU errors normally exceed the above criteria.

4.3.3 GNCS Caution

The GNCS Caution lamp is actuated by the following undesirable and non-critical events:

(a) CMC Restart during operation. In the event of Restart during operate a latch is set in the CMC which maintains the GNCS Caution alarm and the RESTART lamp on the DSKY until the latch is reset by program or until the latch is manually reset by ALARM RESET. For furhter detail see section 4.3.4.

(b) Temperature out of Limits. The CMC receives a signal from the IMU when the stable member temperature is in the range 126.3^{o}F to 134.3^{o}F. In the absence of this signal, the Caution alarm and the TEMP lamp on the DSKY are actuated.

(c) Gimbal Lock. When the CMC determines that the middle gimbal angle (MGA) of the IMU is greater than 70^{o}, the Caution alarm and the Gimbal Lock lamp on the DSKY are actuated. When MGA exceeds 85^{o} the ISS is downmoded to Coarse Align and the No Attitude lamp on the DSKY is actuated.

(d) Program Alarm. Under a variety of situations a program alarm is generated. Under program control the CMC inhibits this alarm for 10 sec. after system turn-on. The program alarm actuates the Caution alarm and the Program light on the DSKY. For further information see section 4.3.4.

4.3.4 Restart and Program Alarms

When the Restart or Program Alarm lamps are illuminated on the DSKY, either V05N09 will automatically appear on the DSKY with the alarm code displayed in R1, R2, R3, or this information can be displayed by astronaut call up from the DSKY. This allows the astronaut to identify and normally correct the alarm condition. The listing of program alarms is included in Section 4.9.

4.4 AGC Logic/Ground/Crew Interface Diagrams

These diagrams outline the detailed logic of the inter-relationship between the AGC/Crew/Ground. For ease of correction and reproduction the diagrams have been incorporated on IBM cards and are presented as a computer printout.

The diagrams contain the following:

1) Program Control - Indication of sequence interruptions and the following display notation:

   a) PRIO (Priority) - denotes a priority display
   b) HOLD - denotes that the flashing verb-noun and data will continue to be displayed until the astronaut takes DSKY action.
   c) TEMP HOLD (Temporary HOLD) - denotes that the duration of the display on the DSKY (non-flashing) is controlled by the AGC.
   d) POSS HOLD (Possible HOLD) - denotes that the display is a possible path taken by the AGC.
   e) MON (Monitor) - denotes that the displayed data is automatically updated and displayed by the AGC.
   f) SNAP - denotes that the displayed data is not automatically updated (monitored) by the AGC.

2) AGC
3) Ground
4) Crew

   } The sequence logic and interface relationships of the AGC logic, ground operations and crew activities.

5) A line count is provided on the far right hand side of the page.

6) The AGC Program (or Routine) number and the PROGRAM assembly specification are printed on the lower right hand corner of each page e.g. P40/COLOSSUS. In addition, the commonality of Programs and Routines contained in LUMINARY, COLOSSUS, and SUNDANCE is also designated e.g. P34/LUMINARY, P34/COLOSSUS, P34/SUNDANCE. This commonality is defined to be identical man-machine interface operation and identical intent. However, it should be clearly understood that commonality so defined does not imply identical logic flow either in the diagrams or the computer program.

The reproduction of IBM print-outs in Sections 4.4.1 through 4.9 inclusive are deliberately not paginated. Reference to the material on these pages is accomplished by using Program and line numbers of Section 4.4, and Page Title (lower right corner) and line number for Sections 4.5 through 4.9.

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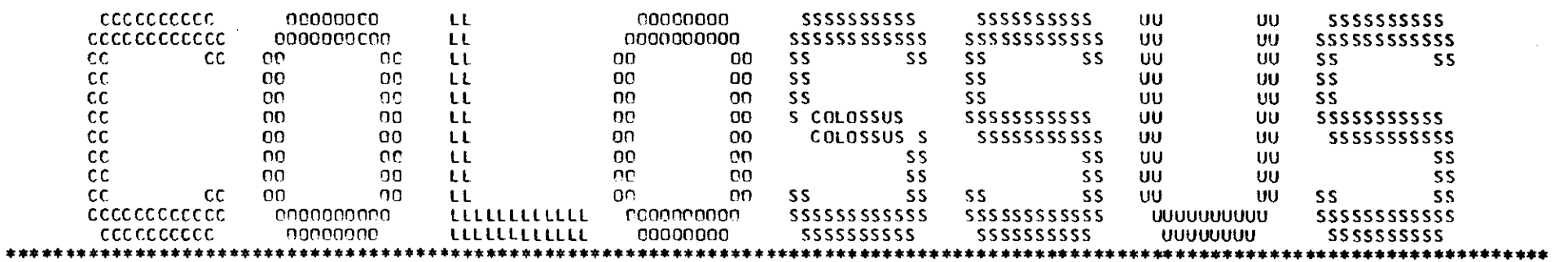

4.4.1 THIS LIST REPRESENTS THE PROGRAMS AND ROUTINES DIAGRAMMED IN SECTION 4.4.2 FOR PROGRAM COLOSSUS.

PHASE	PROGRAM NUMBER	PROGRAM TITLE
PRE-LAUNCH AND SERVICE	00	CMC IDLING
	01	PRELAUNCH OR SERVICE-INITIALIZATION
	02	PRELAUNCH OR SERVICE-GYRO COMPASSING
	03	PRELAUNCH OR SERVICE-OPTICAL VERIFICATION OF GYRO COMPASSING
	04	-----*
	05	-----*
	06	CMC POWER DOWN
	07	SYSTEM TEST**
	08	-----*
	09	-----*
BOOST	10	-----*

	11	EARTH ORBIT INSERTION MONITOR
	12	-----*
	13	-----*
	14	-----*
	15	-----*
	16	-----*
	17	TPI SEARCH
	18	-----*
	19	-----*
COAST	20	RENDEZVOUS NAVIGATION
	21	GROUND TRACK CETERMINATION
	22	CRBITAL NAVIGATION
	23	CISLUNAR MIDCCURSE NAVIGATION
	24	-----*
	25	-----*
	26	-----*
	27	CMC UPDATE
	28	-----*
	29	-----*
PRE-THRUSTING	30	EXTERNAL DELTA V
	31	LAMBERT AIM POINT GUIDANCE
	32	-----*
	33	-----*
	34	TRANSFER PHASE INITIATION (TPI)
	35	TRANSFER PHASE (MIDCOURSE)
	36	-----*
	37	RETURN TC EARTH

	64	ENTRY - POST 0.05G
	65	ENTRY - UPCONTROL
	66	ENTRY - BALLISTIC
	67	ENTRY - FINAL PHASE
	68	-----*
	69	-----*
PRE-THRUSTING OTHER VEHICLE	70	-----*
	71	-----*
	72	-----*
	73	-----*
	74	LM TRANSFER PHASE INITIATION (TPI) TARGETING
	75	LM TRANSFER PHASE (MIDCOURSE) TARGETING
	76	TARGET DELTA V
	77	LM TPI SEARCH
	78	LM STABLE ORBIT RENDEZVOUS(SOR) TARGETING
	79	LM STABLE ORBIT MIDCOURSE(SOM) TARGETING

ROUTINE	ROUTINE TITLE
0	FINAL AUTOMATIC REQUEST TERMINATE
1	-----*
2	IMU STATUS CHECK
3	DIGITAL AUTOPILOT DATA LOAD
4	-----*
5	S-BAND ANTENNA
6	-----*

7 -----*

8 -----*

9 -----*

10 -----*

11 -----*

12 -----*

13 -----*

14 -----*

15 -----*

16 -----*

17 -----*

18 -----*

19 -----*

20 -----*

21 RENDEZVOUS TRACKING SIGHTING MARK

22 RENDEZVOUS TRACKING DATA PROCESSING

23 BACKUP RENDEZVOUS TRACKING SIGHTING MARK

24 -----*

25 -----*

26 -----*

27 -----*

28 -----*

29 -----*

30 ORBIT PARAMETER DISPLAY

31 RENDEZVOUS PARAMETER DISPLAY ROUTINE NO. 1

32 -----*

33 CMC/LGC CLOCK SYNCHRONIZATION

34 RENDEZVOUS PARAMETER DISPLAY ROUTINE NO. 2

35 LUNAR LANDMARK SELECTION

36 RENDEZVOUS OUT OF PLANE DISPLAY ROUTINE

37 -----*

38 -----*

39 -----*

40 SPS THRUST FAIL

41 STATE VECTOR INTEGRATION (MID TO AVE)

42 -----*

43 -----*

44 -----*

45 -----*

46 -----*

47 -----*

48 -----*

49 -----*

50 COARSE ALIGN

51 -----*

52 AUTOMATIC OPTICS POSITIONING

53 SIGHTING MARK

54 SIGHTING DATA DISPLAY

55 GYRO TORQUING

56 ALTERNATE LOS SIGHTING MARK

57 OPTICS CALIBRATION

58 -----*

59 -----*

60 ATTITUDE MANEUVER

* THIS PROGRAM OR ROUTINE DOES NOT EXIST FOR ASSEMBLY COLOSSUS

** THIS PROGRAM IS DOCUMENTED IN SECTION 1 OF R577

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