



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

COMMAND SERVICE MODULE SYSTEM HANDBOOK

AS-501

JANUARY 16, 1967



PREPARED BY

FLIGHT CONTROL DIVISION



MANNED SPACECRAFT CENTER
HOUSTON, TEXAS

(NASA-TM-X-68878) COMMAND SERVICE MODULE
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COMMAND SERVICE MODULE SYSTEMS HANDBOOK

AS-501

PREFACE

This handbook has been prepared by the Flight Control Division, Manned Spacecraft Center, Houston, Texas, with technical support by North American Aviation. Information contained within this section represents the Command Service Module Systems for the AS-501 Mission as of January 16, 1967.

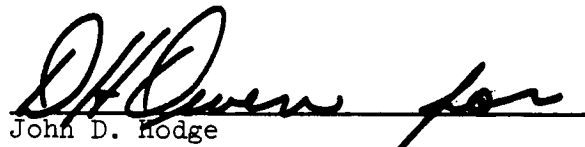
Information as shown reflects spacecraft systems with major emphasis on material for use by Flight Controllers in real time; however, caution should be exercised in using these systems drawings for any purpose other than flight control.

This handbook is not to be reproduced without written approval of the Chief, Flight Control Division, Manned Spacecraft Center, Houston, Texas.

Approved by:



Arnold D. Aldrich
Chief, CSM/Gemini Systems Branch



John D. Hodge
Chief, Flight Control Division



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SECTION 1
INTRODUCTION

CSM
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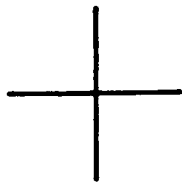
DRAWING SYMBOLS STANDARDS

1. ZONE

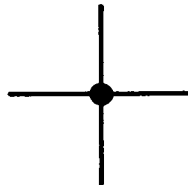


2. LEADS

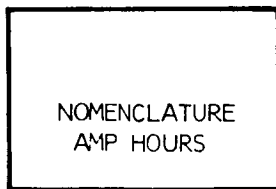
A. CROSSOVER



B. CONNECTED



3. BATTERY

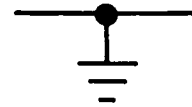


4. BUS

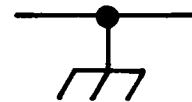


5. GROUNDS

A. SYSTEM

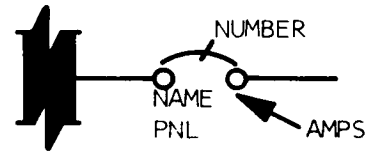


B. FRAME

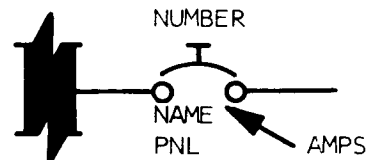


6. CIRCUIT BREAKERS

A. TOGGLE



B. PUSHBUTTON



7. FUSES

A. GENERAL



B. FUSISTOR



** SEE BUS DESIGNATION PAGE 1-12

DRAWING SYMBOLS STANDARDS

8. DIODES

A. GENERAL



B. ZENER



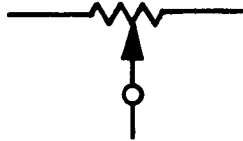
C. TUNNEL



D. CONTROL RECTIFIER



9. POTENTIOMETER



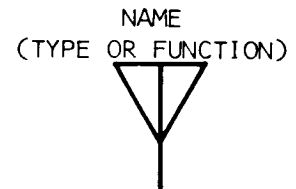
10. HEATER



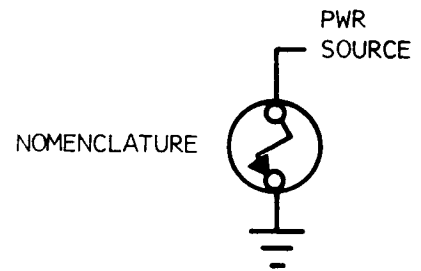
11. THERMOSTAT



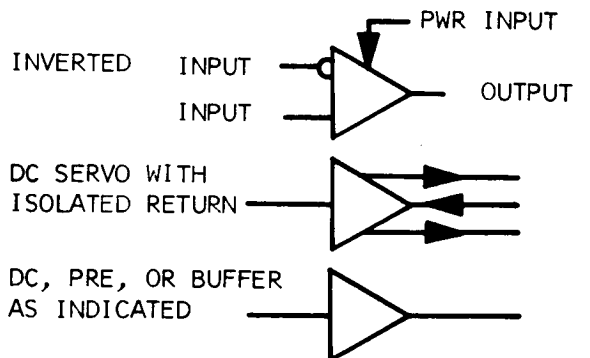
12. ANTENNA



13. EXPLOSIVE



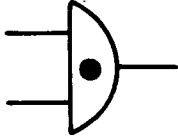
14. AMPLIFIER



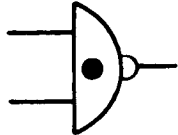
DRAWING SYMBOLS STANDARDS

15. GATES

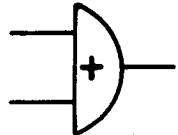
A. AND



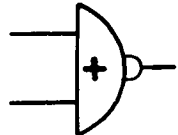
B. NAND



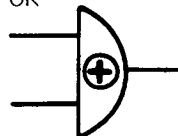
C. OR



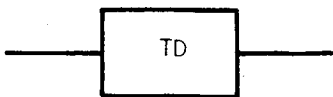
D. NOR



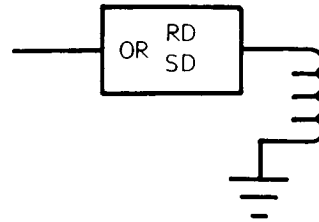
E. EXCLUSIVE OR



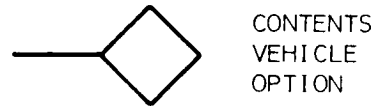
16. TIME DELAY



17. RELAY DRIVER OR SOLENOID DRIVER



18. COMMAND



19. SENSOR

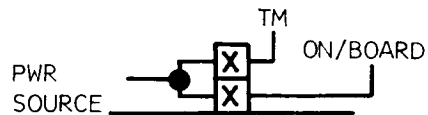
A. SINGLE SOURCE



LETTER INDICATES TYPE

- PA = PRESS PSIA W = WETNESS
- PD = PRESS PSID POS = POSITION
- T = TEMP
- 1 = QUANTITY, ETC.
- Δ = DELTA

B. DOUBLE SOURCE



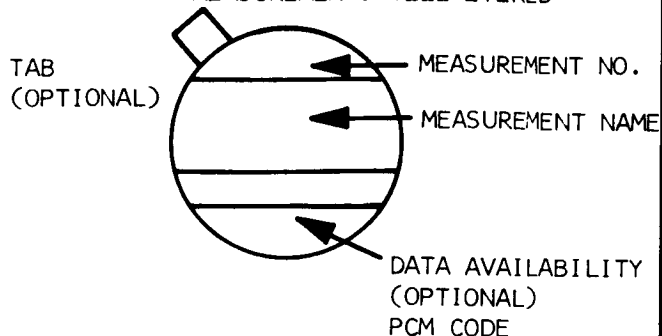
⊙ VG VELOCITY GENERATOR
FEEDBACK TRANSDUCER

⊙ POS POSITION FEEDBACK TRANSDUCER

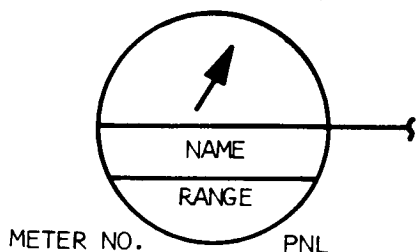
DRAWING SYMBOLS STANDARDS

20. TELEMETRY

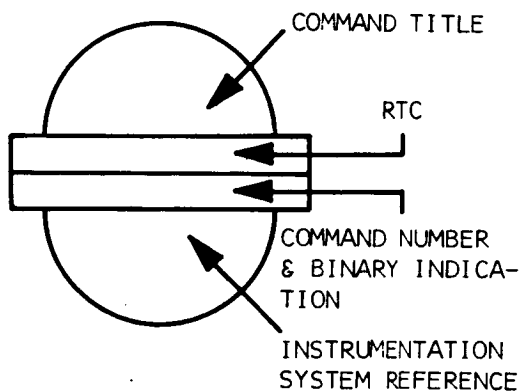
A. MEASUREMENTS TELEMETERED



B. ONBOARD METERS

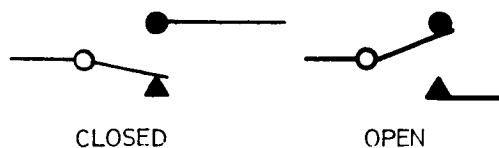


C. BI-LEVEL CMD

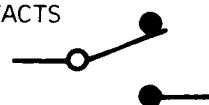


21. RELAYS

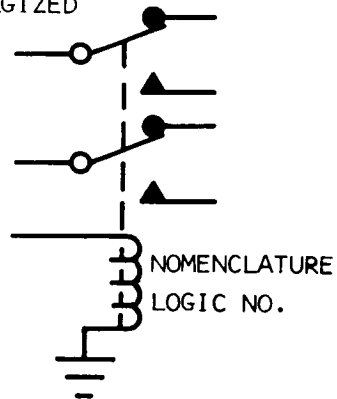
A. MOMENTARY CONTACTS



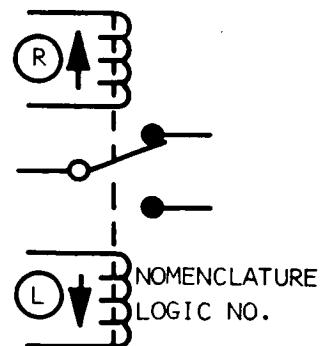
B. SOLID CONTACTS



C. NON-LATCHING RELAYS SHOWN IN DE-ENERGIZED POSITION



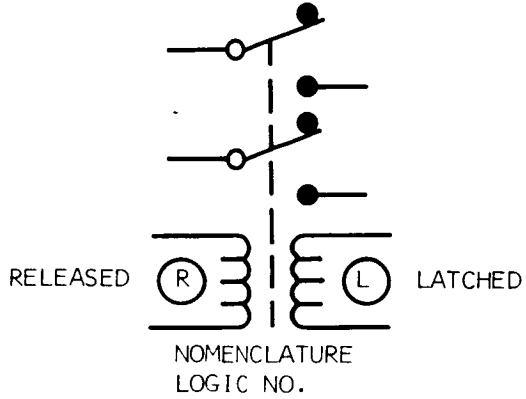
D. LATCHING



DRAWING SYMBOLS STANDARD

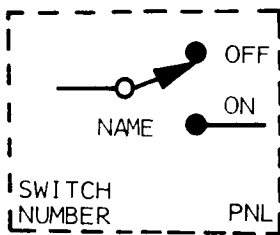
21. RELAYS (CONT'D)

E. LATCHING RELAYS SHOWN IN RELEASED POSITION

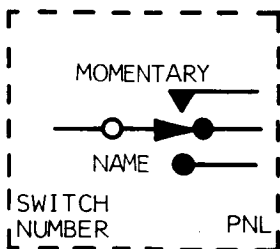


22. SWITCHES

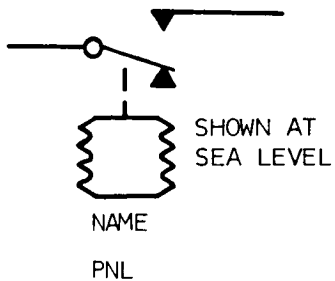
A. TWO POSITION



B. THREE POSITION



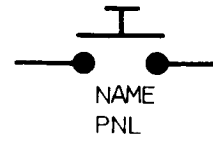
C. BARO



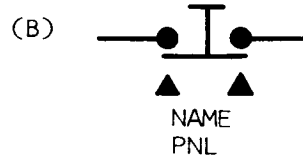
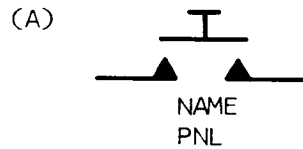
22. SWITCHES (CONT'D)

C. PUSH BUTTON

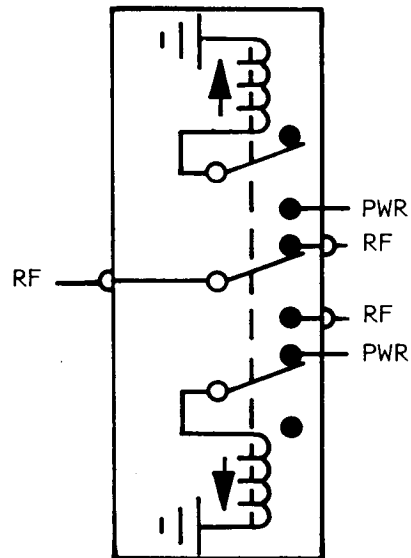
1. SOLID



2. MOMENTARY



D. COAX

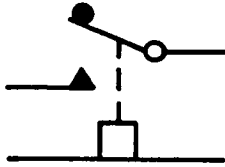


DRAWING SYMBOLS STANDARDS

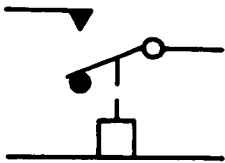
22. SWITCHES

E. PRESSURE

1. CLOSED DECREASE PRESSURE

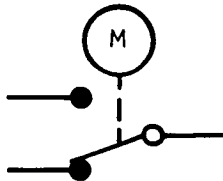


2. CLOSED INCREASED PRESSURE

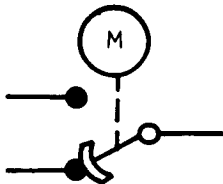


F. MOTOR

1. BREAK BEFORE MAKE

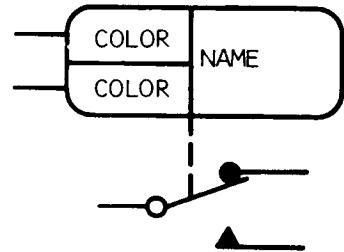
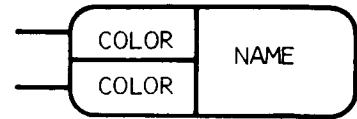


2. MAKE BEFORE BREAK



23. LIGHTS

A. TELELIGHTS




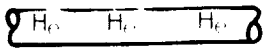
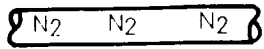
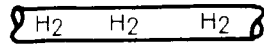
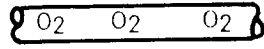
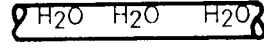
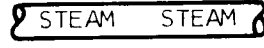
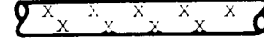
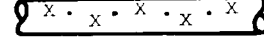




24. ANNUNCIATOR FLAG



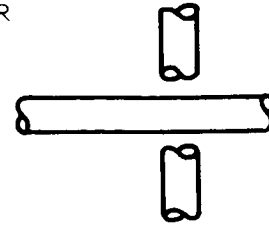
(GENERALLY, THIS IS ASSOCIATED WITH A SWITCH POSITION AND SHOULD BE LOCATED IN THE SAME BLOCK AS THE SWITCH.)

DRAWING SYMBOLS STANDARDS

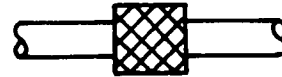
25. LINES

- A. GLYCOL 
- B. HELIUM 
- C. NITROGEN 
- D. HYDROGEN 
- E. OXYGEN 
- F. WATER 
- G. STEAM 
- H. FUEL 
- I. FUEL RETURN 
- J. OXIDIZER 
- K. OXIDIZER RETURN 
- L. HYD HIP 
- M. HYD LOP 

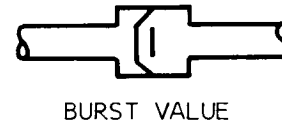
26. PIPE CROSSOVER



27. FILTER



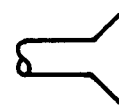
28. BURST DIAPHRAGM



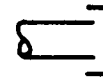
29. VENTURI



30. VENT



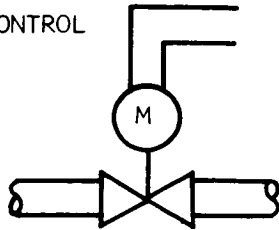
31. FILL AND DRAIN



DRAWING SYMBOLS STANDARDS

32.

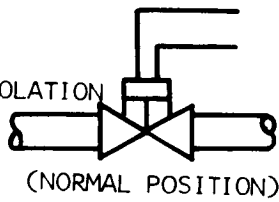
A. MOTOR CONTROL



B. MANUAL CONTROL



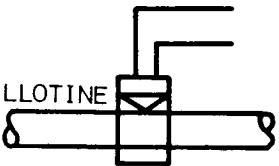
C. PYRO ISOLATION



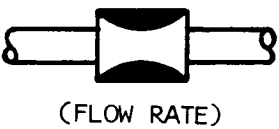
D. CHECK



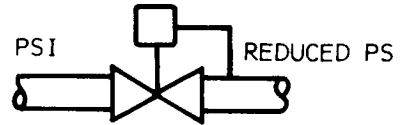
E. PYRO GUILLOTINE



F. ORIFICE



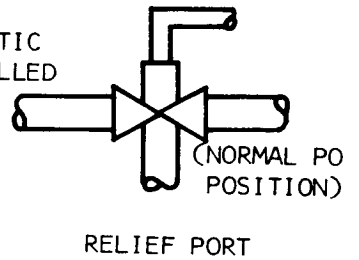
G. PRESSURE REGULATOR



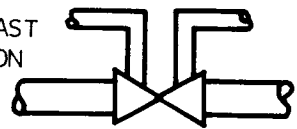
H. RELIEF VALVE



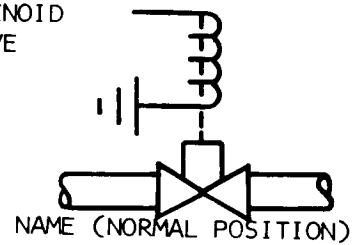
I. PNEUMATIC CONTROLLED VALVE WITH LINE BLEED



J. FAIL LAST POSITION PNEUMATIC VALVE



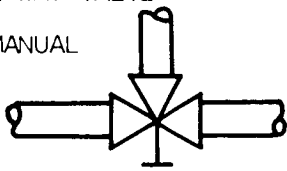
K. SOLENOID VALVE



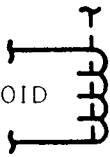
DRAWING SYMBOLS STANDARDS

L. THREE-WAY VALVE

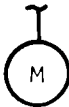
1. MANUAL



2. SOLENOID



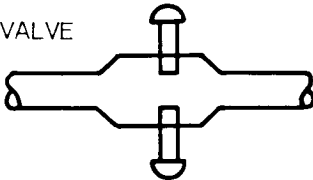
3. MOTOR CONTROLLED



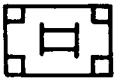
M. BALL VALVE



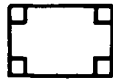
N. PU VALVE



33. DISCONNECTS



SELF-SEALING



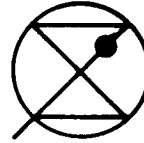
QUICK

34. DEADFACE CHARGE



- S1 CM DEADFACE CHARGE NO. 1
- S2 CM DEADFACE CHARGE NO. 2
- S3 CM DEADFACE CHARGE NO. 3
- S4 CM DEADFACE CHARGE NO. 4
- S5 SM DEADFACE CHARGE NO. 1
- S6 SM DEADFACE CHARGE NO. 2

35. 4 WIRE RESOLVER



X = SINE WINDING

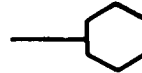
● = MINUS SINE

— = COSINE WINDING

36. NON-AMPLIFYING DEVICE, IDENTIFIED



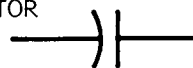
37. SYSTEM INTERCONNECT



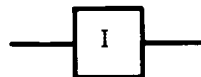
38. DRAWING NOTE REFERENCE



39. CAPACITOR

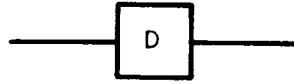


40. DIGITAL INVERTER

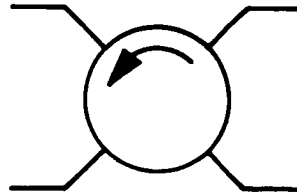


DRAWING SYMBOLS STANDARDS

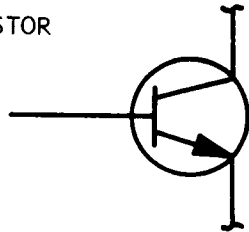
41. DEMODULATOR



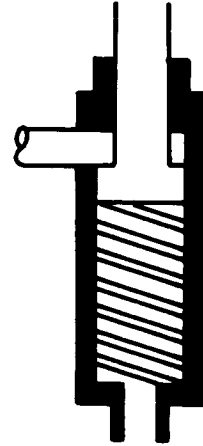
42. R.F. CIRCULATOR



43. TRANSISTOR



43. BALL VALVE ACTUATOR

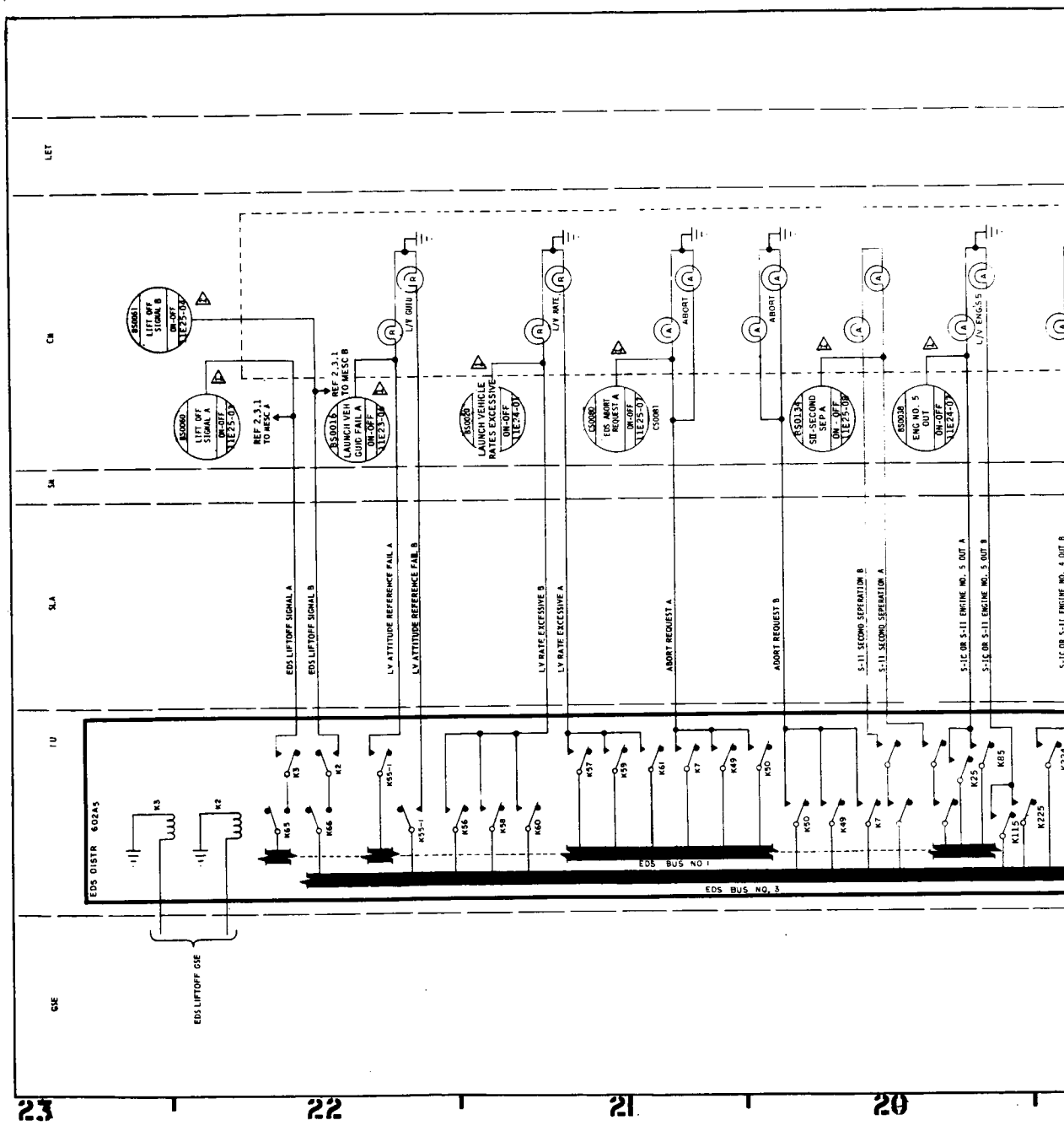


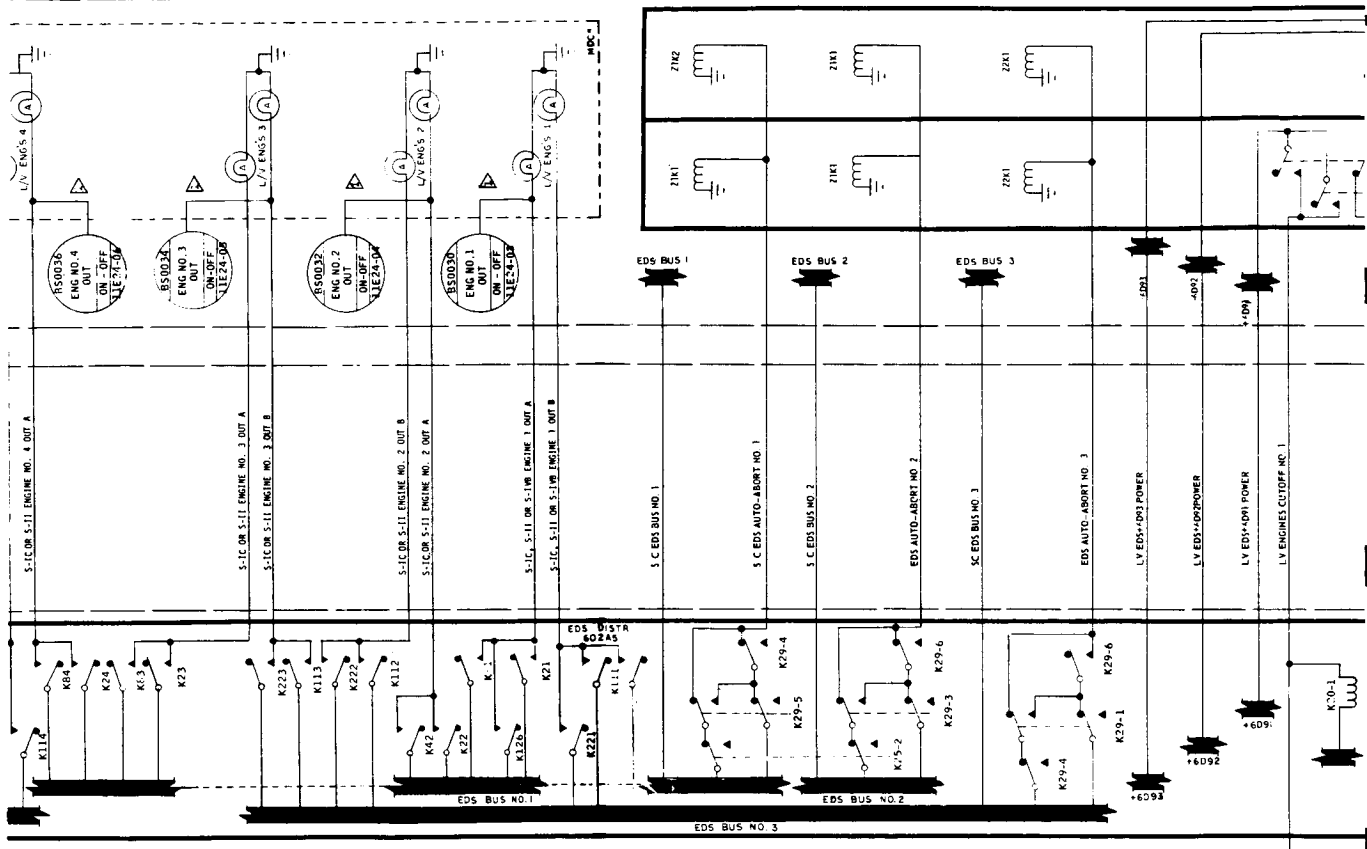
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CSM
AS-501

44. BUS DESIGNATIONS

DC MAIN BUS A	VMA
DC MAIN BUS B	VMB
BATTERY BUS A	VBA
BATTERY BUS B	VBB
FLIGHT AND POST LANDING BUS	VFP
BATTERY RELAY BUS	VBR
AC BUS NO. 1	VAC1
AC BUS NO. 2	VAC2
NON ESSENTIAL BUS 1	VNE1
NON ESSENTIAL BUS 2	VNE2
SERVICE MODULE BUS A	V SMA
SERVICE MODULE BUS B	V SMB
MESC PYRO BUS A	V MQA
MESC PYRO BUS B	V MQB
MESC LOGIC BUS A	V MLA
MESC LOGIC BUS B	V MLB
RCSC LOGIC BUS A	V RLA
RCSC LOGIC BUS B	V RLB
RCSC PYRO BUS A	V RQA
RCSC PYRO BUS B	V RQB
ELSC LOGIC BUS A	V ELA
ELSC LOGIC BUS B	V ELB
ELSC PYRO BUS A	V EQA
ELSC PYRO BUS B	V EQB
EMERGENCY DETECTION SYSTEM BUS NO. 1	V ED1
EMERGENCY DETECTION SYSTEM BUS NO. 2	V ED2
EMERGENCY DETECTION SYSTEM BUS NO. 3	V ED3
SECS SWITCH LOGIC BUS	V SL
AUX BATTERY BUS A	V AA
AUX BATTERY BUS B	V AB
SIGNAL CONDITIONING (5VDC)	V SC





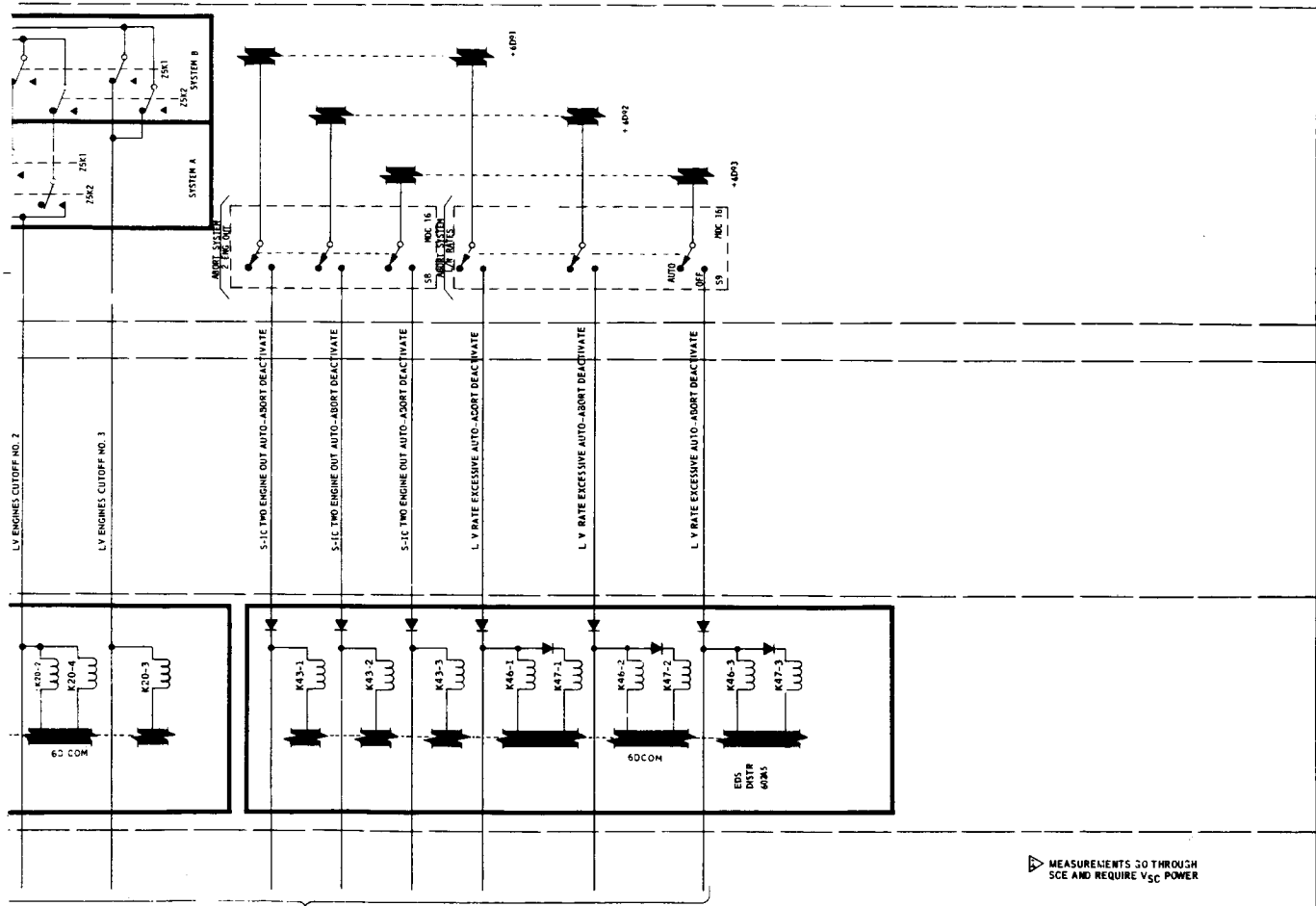
19

18

17

16

REVISIONS		
BY	APPROVED	DATE
8		



MEASUREMENTS GO THROUGH SCE AND REQUIRE V_{SC} POWER

THIS DWG FOR REF ONLY

5 APR 66	TITLE: SLV INTERFACE- ELECTRICAL SATURN LAUNCH VEHICLE AND SPACECRAFT	MISSION: AS-501
APPROVED	DESIGNED	DRAWN
CHECKED	TESTED	ASSEMBLED
DATE	DATE	DATE
14	13.1	13
FLIGHT CONTROLLER		

15

14

13

12

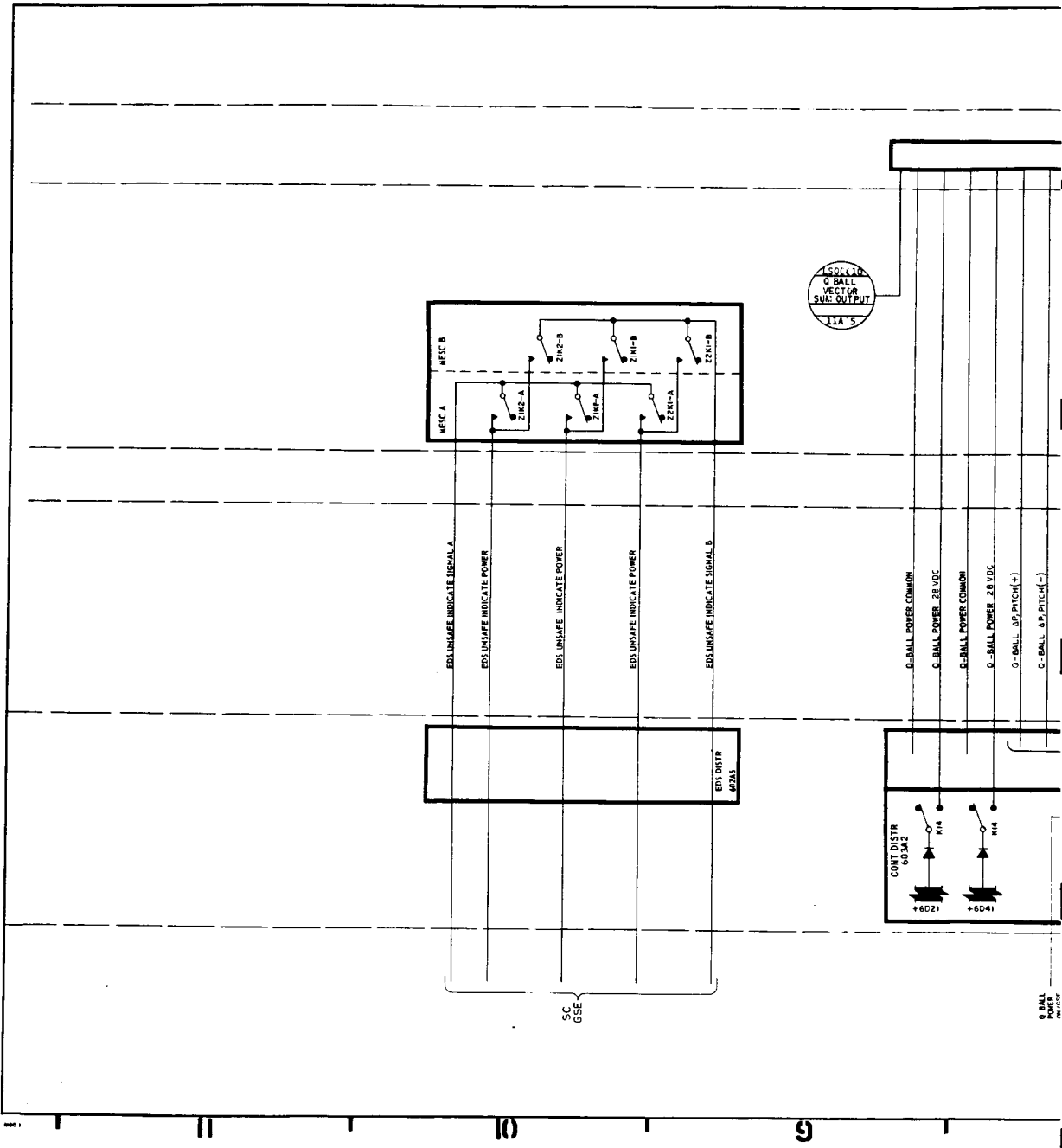
E

D

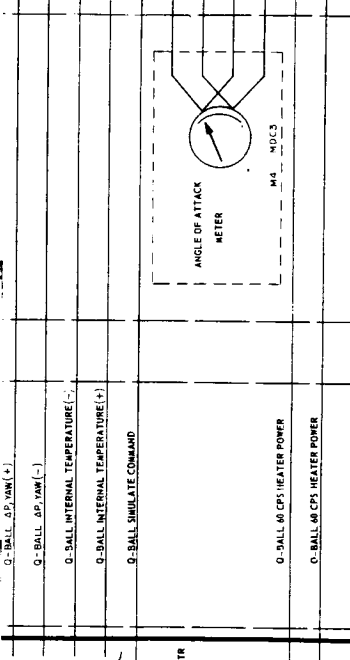
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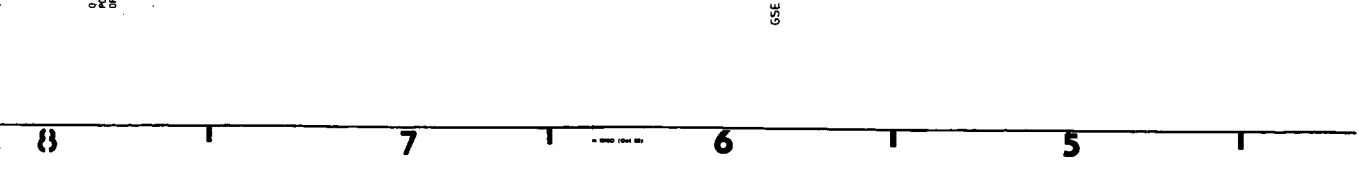
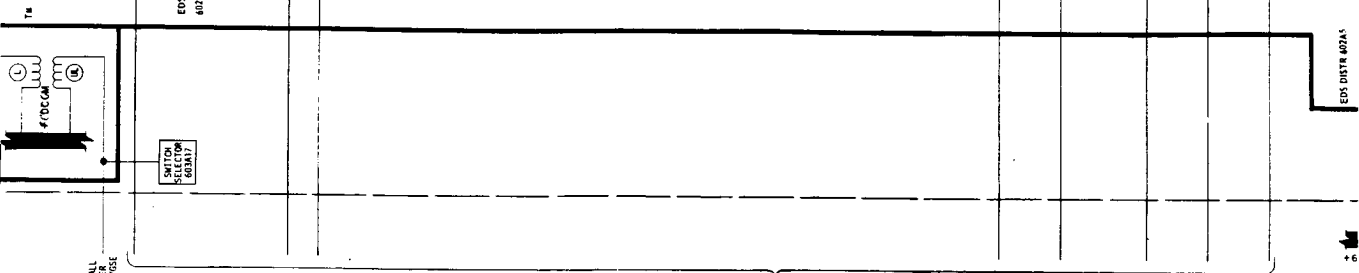
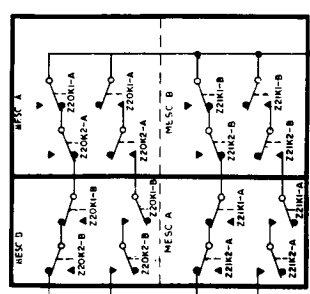
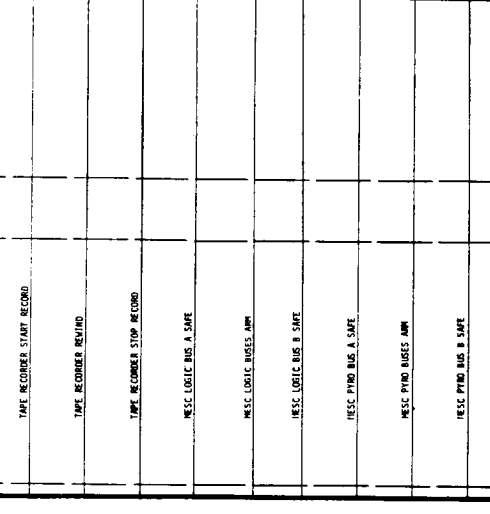
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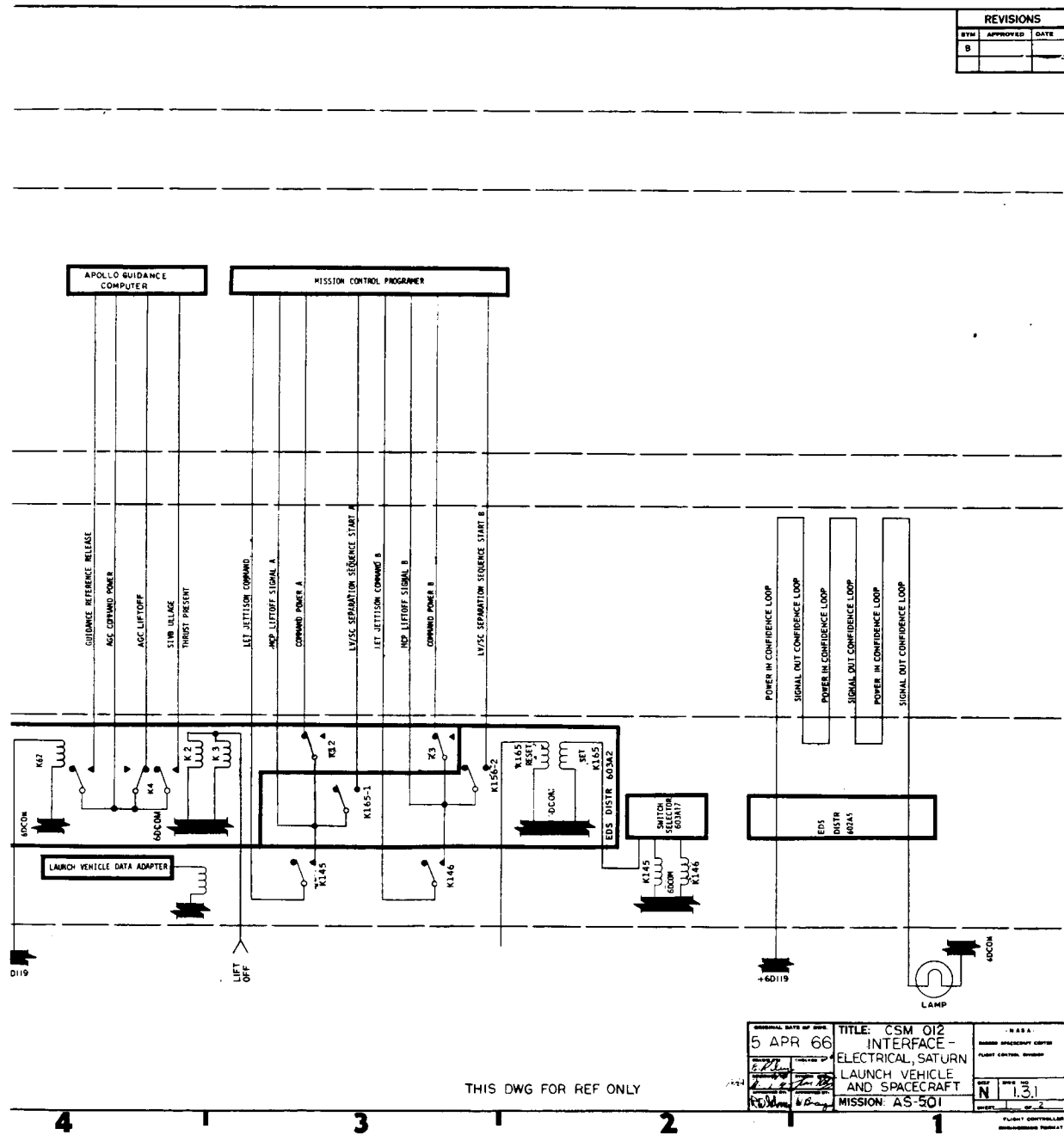
Q-BALL



MISSION CONTROL PROGRAMMER



REVISIONS		
SYM	APPROVED	DATE
B		



THIS DWG FOR REF ONLY

ORIGINAL DATE OF ISSUE 5 APR 66	TITLE CSM 012 INTERFACE - ELECTRICAL, SATURN LAUNCH VEHICLE AND SPACECRAFT MISSION AS-501	NASA SPACECRAFT CENTER PLANT CONTROL DIVISION
DRAWN BY <i>[Signature]</i>	CHECKED BY <i>[Signature]</i>	DATE 1.3.1
REVISIONS B		SHEET NO. 1 OF 2

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SECTION 2
SEQUENTIAL

CSM
AS-501

2.1 PYROTECHNICS, GENERAL NOTES

2.1.1 Initiator, Standard Apollo

Fire Current: The initiator will ignite when subject to a current of 3.5 amperes on the bridge wires.

Operating Voltage: The operating voltage of the initiator is 35 volts open circuit.

Operating Time: The operating time is approximately 2 to 4 milliseconds at operating voltage.

2.2 POWER DISTRIBUTION

A. Switch Configuration

1. The EDS POWER Switch should be placed in the ON position to supply power to the EDS buses.
2. The MESC LOGIC and PYRO Switches should be placed to the ARM (ON) position; however, these functions are controlled by the MCP.

B. The following circuit breakers are slugged:

1. Pyro A Seq A RHEB-203 CB14
2. Pyro B Seq B RHEB-203 CB17

C. Battery Buses A and B and the Entry Battery C furnish power for the EDS displays and logic circuitry.

D. Battery Bus A and B furnish power to the Master Events Sequence Controller A and B respectively.

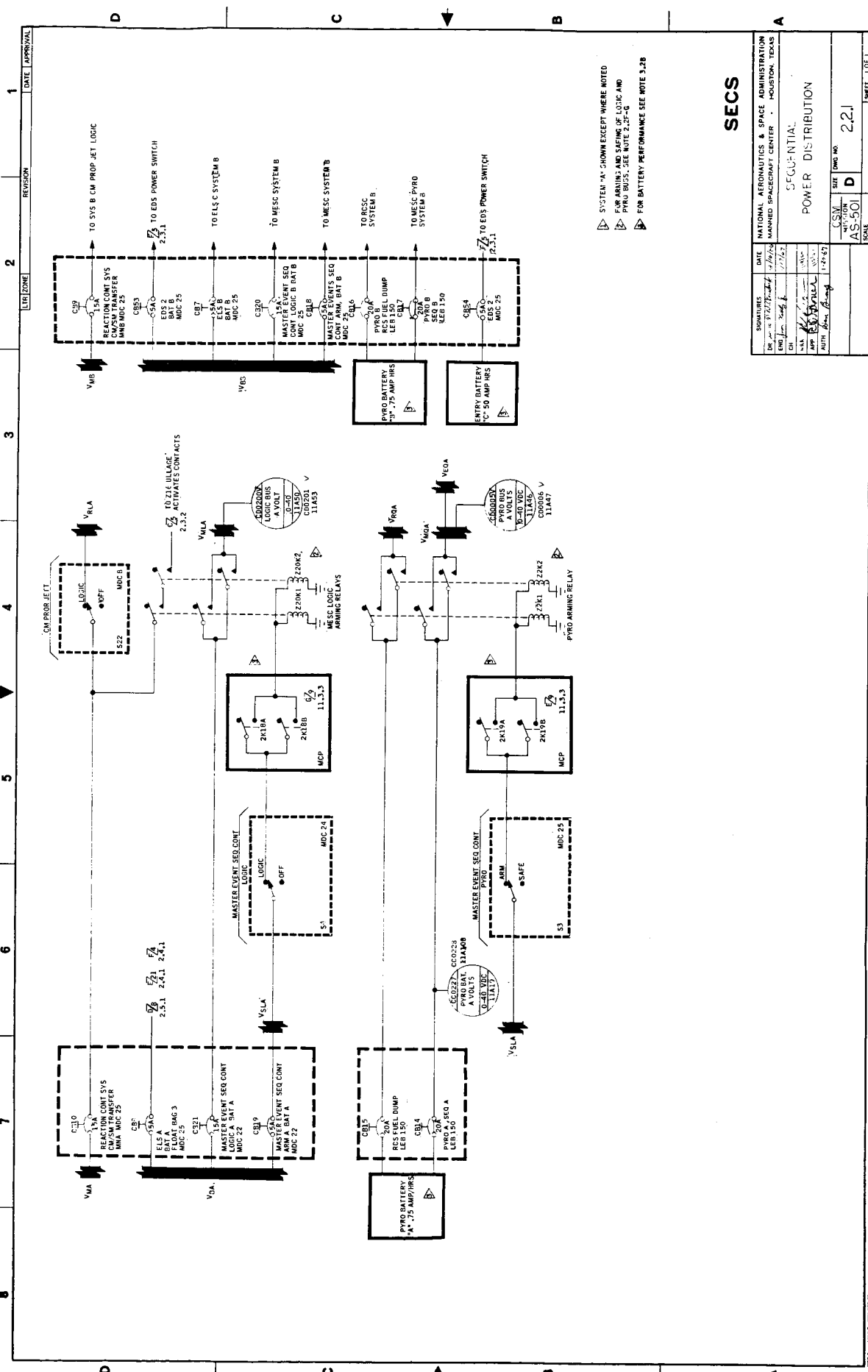
E. Pyro Batteries A and B furnish power for the detonation of pyrotechnic devices of System A and B respectively.

F. The Master Event Sequence Control Pyro and Logic buses can be armed in one of the following manners:

1. By GSE prior to launch:
 - a. Logic Armed at T - 60 seconds
 - b. Pyro Armed at T - 40 seconds
2. The MCP will arm the respective bus as a result of RTC 61 or by the G&N Computer commanding a SM/CM separation.

G. The Master Event Sequence Control Pyro and Logic buses can be disarmed in one of the following manners:

1. By GSE
2. The MCP will "SAFE" the respective bus as a result of a LV-SC + 6 second discrete signal.
3. The MCP will SAFE the logic bus at impact + 11 seconds and the Pyro at an impact + 12 seconds providing the CSM is in a Stable I configuration.



*

2.3 LAUNCH TO INSERTION NOTES

2.3.1 General

A. Switch Configuration

1. Since the EDS is to be launched in an opened-loop configuration, the following switches should be placed in the respective positions:

<u>SWITCH</u>	<u>POSITION</u>
<u>MDC 16</u>	
2 ENG OUT (AUTO/OFF) S8	AUTO
L/V RATES (AUTO/OFF) S9	AUTO
EDS (AUTO/OFF) S2	OFF

MDC 24

- | | |
|-----------------------|----|
| EDS POWER (ON/OFF) S1 | ON |
|-----------------------|----|
2. The LES MODE/TWR JETT SPS MODE (S15-MDC16) should be in the TWR JETT SPS MODE position. The functions of this switch are controlled by the MCP.
- B. The normally closed first-motion relays (K3 System A; K2 System B) remain energized by GSE until actual liftoff occurs. The liftoff enable relays (K65 - System A; K66 - System B) are latching types, which are latched closed by GSE prior to liftoff and latched open by the switch selector of the IU after the first 5 seconds of flight.
- C. The excessive Launch Vehicle Rate Parameter (BS0020) will be sent via telemetry when the launch vehicle rates are in excess of 20 ± 0.5 degrees/second in roll and 5 ± 0.5 degrees/second in pitch and yaw.
- D. The Guidance Fail Parameter (BS0016) will be sent via telemetry to indicate failure of the guidance unit of the IU.
- E. The Launch Vehicle Engine Out parameters will be sent via telemetry when a respective launch vehicle engine develops less than 90 percent of total thrust output.

- F. The Q-Ball provides an electrical signal input to the L/V AOA/SPS PC indicator on MDC 3, and an electrical signal input to ground control via telemetry LS0001. The indicator is graduated to 150 percent which corresponds to a differential pressure of 0 to 4 psid when selected for the L/V AOA function. The position of the red line (approximately 100 percent) on the indicator is based on vehicle structural limits and launch vehicle capabilities.
- G. At T+42 seconds when the launch vehicle has attained an altitude of approximately 10,000 feet, the automatic oxidizer dump relay (K1) times out.
- H. Max Q will occur at approximately 1 minute 18 seconds. If the launch vehicle rates become excessive through this region an automatic abort will not be triggered by the EDS.
- I. The S-IC inboard engines will stop thrusting at approximately 2 minutes, 23 seconds and 4 seconds later the outboard engines will cut off.
- J. Staging of the S-II will occur at approximately 2 minutes, 31 seconds.
- K. The launch escape tower will be jettisoned by the S-IVB/IU at approximately 3 minutes 4 seconds.

2.3.2 Launch Escape System Aborts

- A. The opening of the high and low altitude baroswitches defines the abort mode. The high altitude baroswitch controls automatic LET jettison, apex cover jettison, and drogue motor fire. This baroswitch is designed to close at 25,000 \pm 1000 feet and open at 36,000 \pm 2000 feet; however; because of a venting lag it will not open until approximately 40,500 feet. The low altitude baroswitch is designed to close at 10,750 \pm 750 feet and open at 15,900 \pm 1900 feet.
- B. The MESC will attempt to shut down the booster on all launch aborts; however; the Instrumentation Unit of the launch vehicle

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AS-501

)
will delay BECO for the first 42 seconds from liftoff.

- C. The launch escape motor fires for approximately 8 seconds.
- D. The canards will be deployed on all LES aborts following a time delay of 11 seconds after the initiation of the abort.
- E. When the Command Module descends to an altitude of approximately 24,000 feet, the SCS/RCS activate relays will be reset and the tower jettison motor and leg bolts relay will be activated.

2.3.2.1 T 0.0 to 42.0 Seconds (10,000 Feet)

- A. The capability exist for a low altitude LES abort from umbilical drop away through time T-42 seconds. Upon receipt of the abort command, the Launch Escape Motor, the Pitch Control Motor, and the CSM tension tie pyrotechnics are initiated simultaneously separating the Command Module from the Service Module.
- B. The pitch control motor will burn in this abort mode only for a duration of approximately 0.6 seconds.

2.3.2.2 T Greater than 42.0 Sec.

- A. The Command Module Reaction Control System/Stabilization Control System will be automatically sequenced to start functioning at 1.0 seconds following the abort initiation.
- B. Entry into more dense atmosphere will be accomplished with the LES attached to the Command Module with the Canards extended.
- C. After approximately 42 seconds of flight the 42 second TD relays, AUTO OX DUMP DISABLE (K1), times out.

2.3.2.3 SPS Aborts

- A. The capabilities of an SPS abort will exist after jettison of the LET.

*

TABLE 2-1 TOWER ABORTS

Time Hr:Min:Sec	Δ Time (Sec)	Initiated By	Event	Output To
	0.00	RTC	Abort	MCP
		MCP	Separation/Abort Command On	MESC
		MCP	DSE Recorder ON	TC
		MCP	Inhibit 42 Second Timer in MCP	MCP
		MCP	Inhibit G&N Control Relays	G&N
		MCP	Heat Shield Instrumentation ON	EPS
		MCP	Inhibit Removal of Entry Batteries from Main Buses	EPS
		MESC	CM RCS Pressurization	RCS
		MESC	RCS Transfer (SM to CM)	RCS
		MESC	Initiate RCS Oxidizer Dump	RCS
		MESC	CSM Deadfacing	CSM
	0.10	MESC	CSM Separation Squibs Fired	CSM
		MESC	N ₂ Purge Valve Cutoff	CSM
		MESC	CSM Umbilical Destruct	CSM
	1.00	MESC	SCS/RCS Enable ON	SCS/RCS
	2.80	MESC	CSM Separation Pyros Cutout	MESC
	11.00	MESC	Canard Deploy	LES
	14.00	MESC	ELS Activate	ELS
		MESC	24K Baroswitch Armed	ELS
	0.00	ELS	24K Baro Signal	MESC
		MESC	LES Jettison Motor Ignited	LES
		MESC	Fire Tower Explosive Bolts	LES
		MESC	Fire Tower Separation Linear Charges	LES
		MESC	SCS/RCS Enable OFF	SCS/RCS
	0.40	MESC	Apex Cover Jettisoned	CM
	2.00	ELS	Drogue Chutes Deployed	CM
	10.50	ELS	Drogue Chutes Disreefed (4 cutters)	CM
	14.00	ELS	12K Baroswitch Armed	ELS

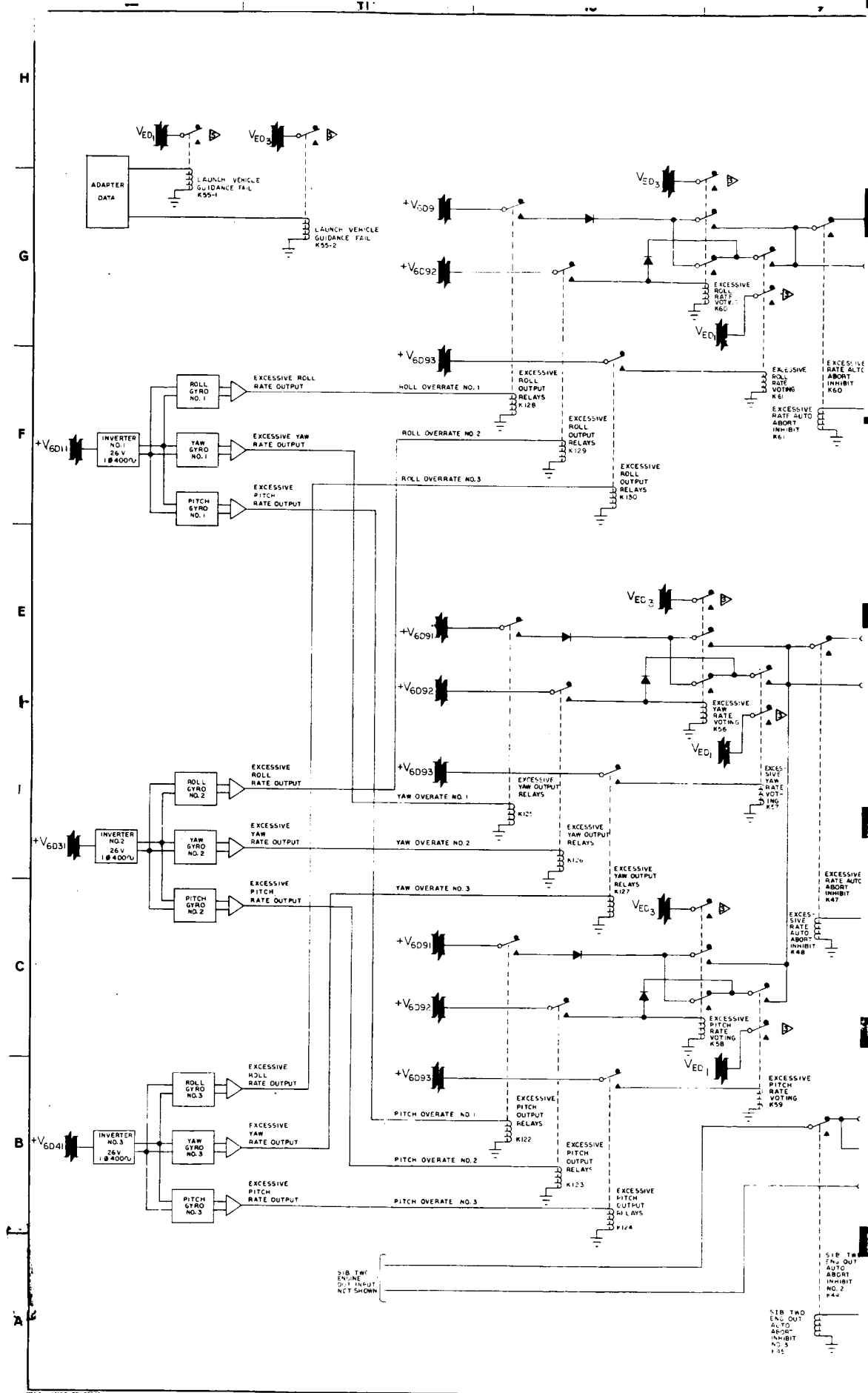
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TABLE 2-1 TOWER ABORTS (Cont'd)

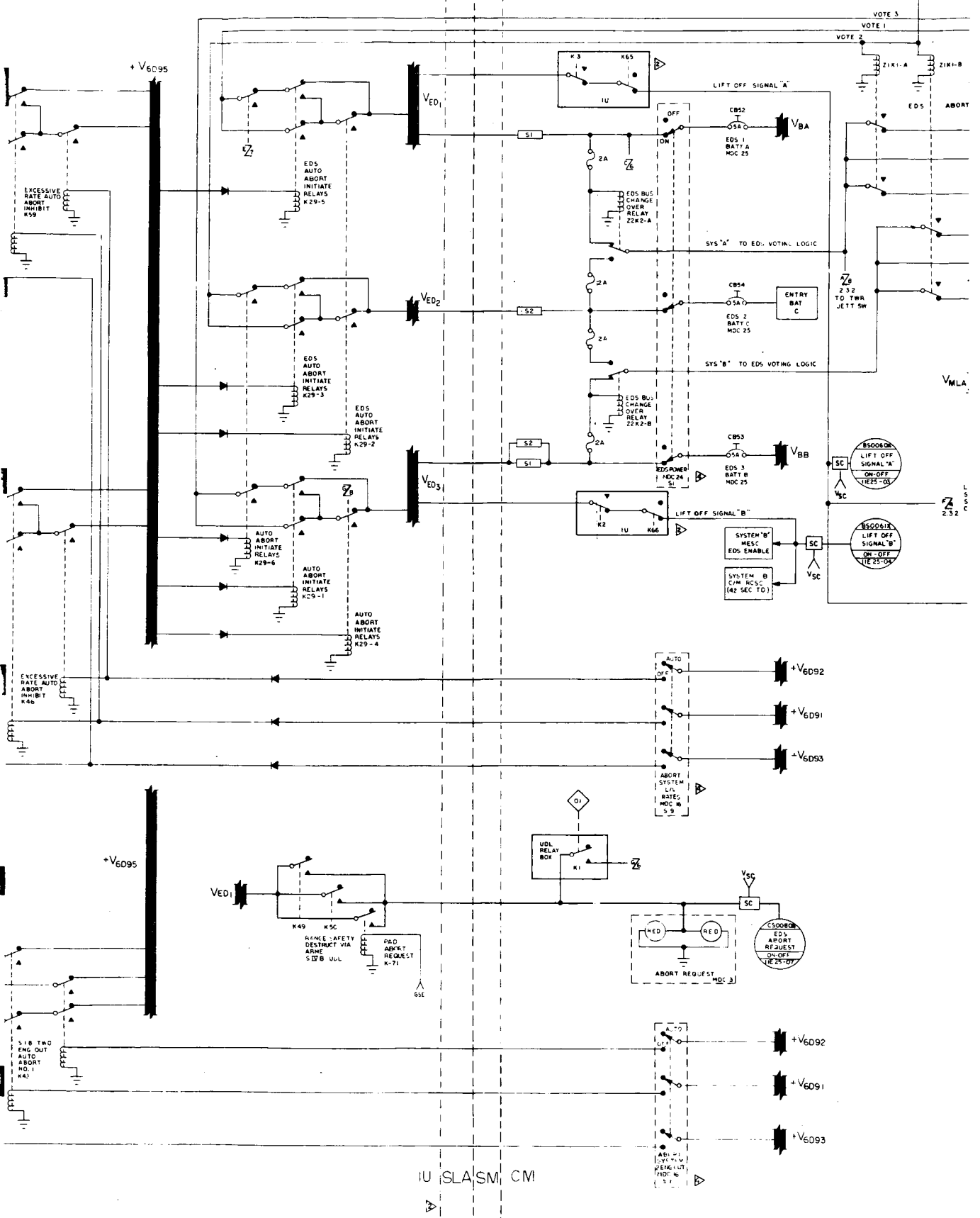
Time Hr:Min:Sec	Δ Time (Sec)	Initiated By	Event	Output To
	0.00	ELS	* 12K Baro Signal	MCP



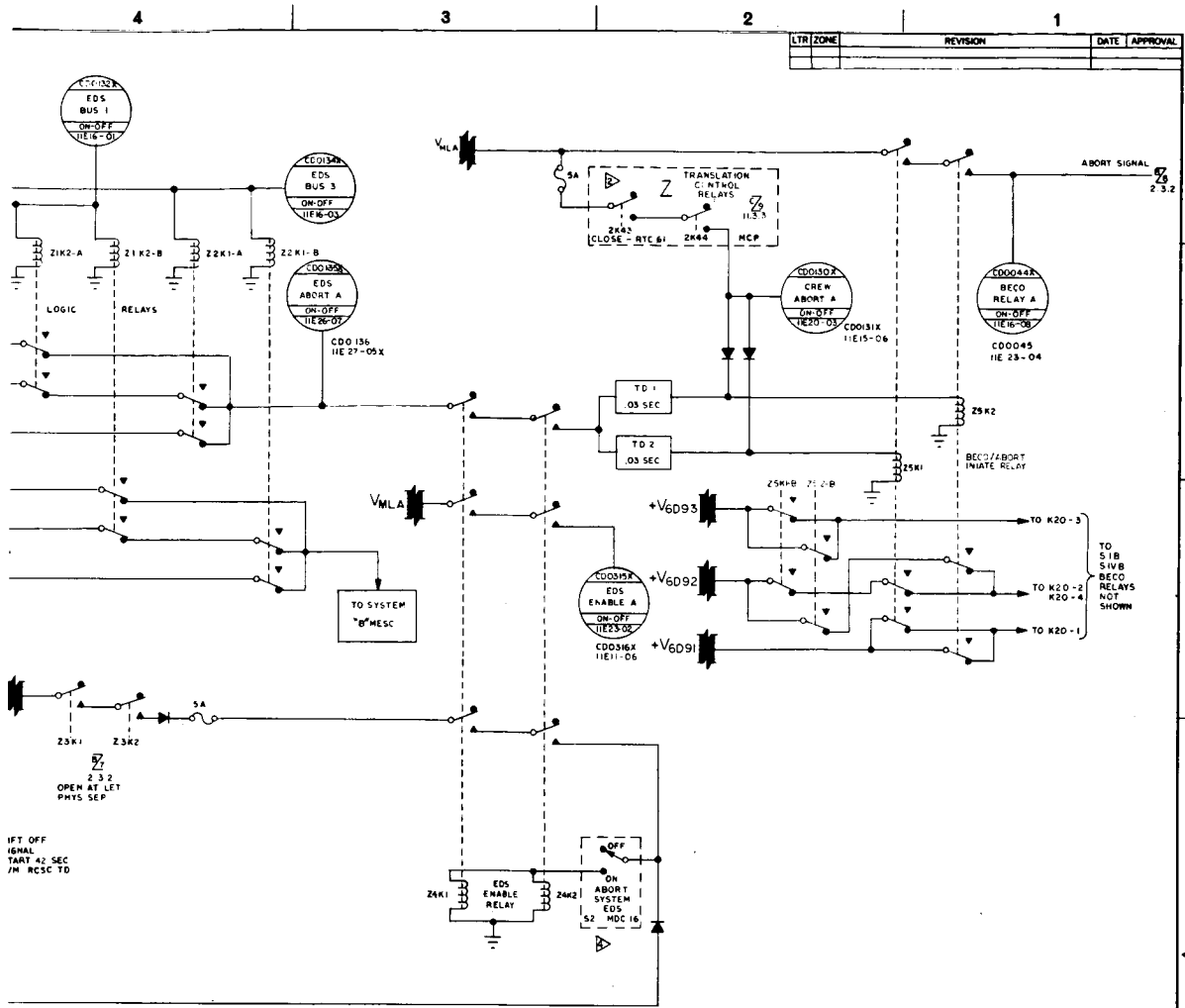


IU SLA/SM CM

EDS BUS 2 ON-OFF I/E 16-02



I U S L A / S M C M



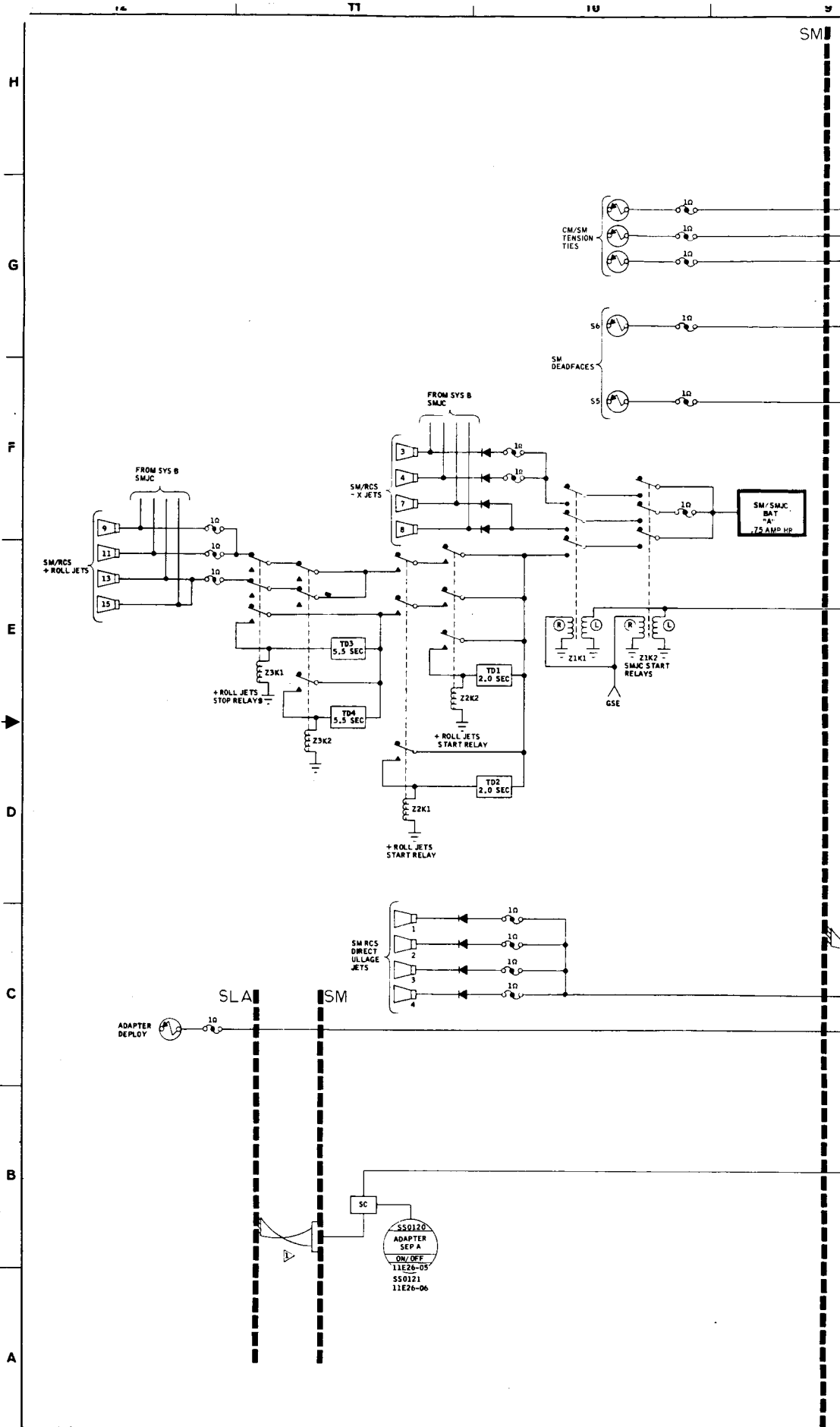
IFT OFF
SIGNAL
TART 42 SEC
/M RCSC TO

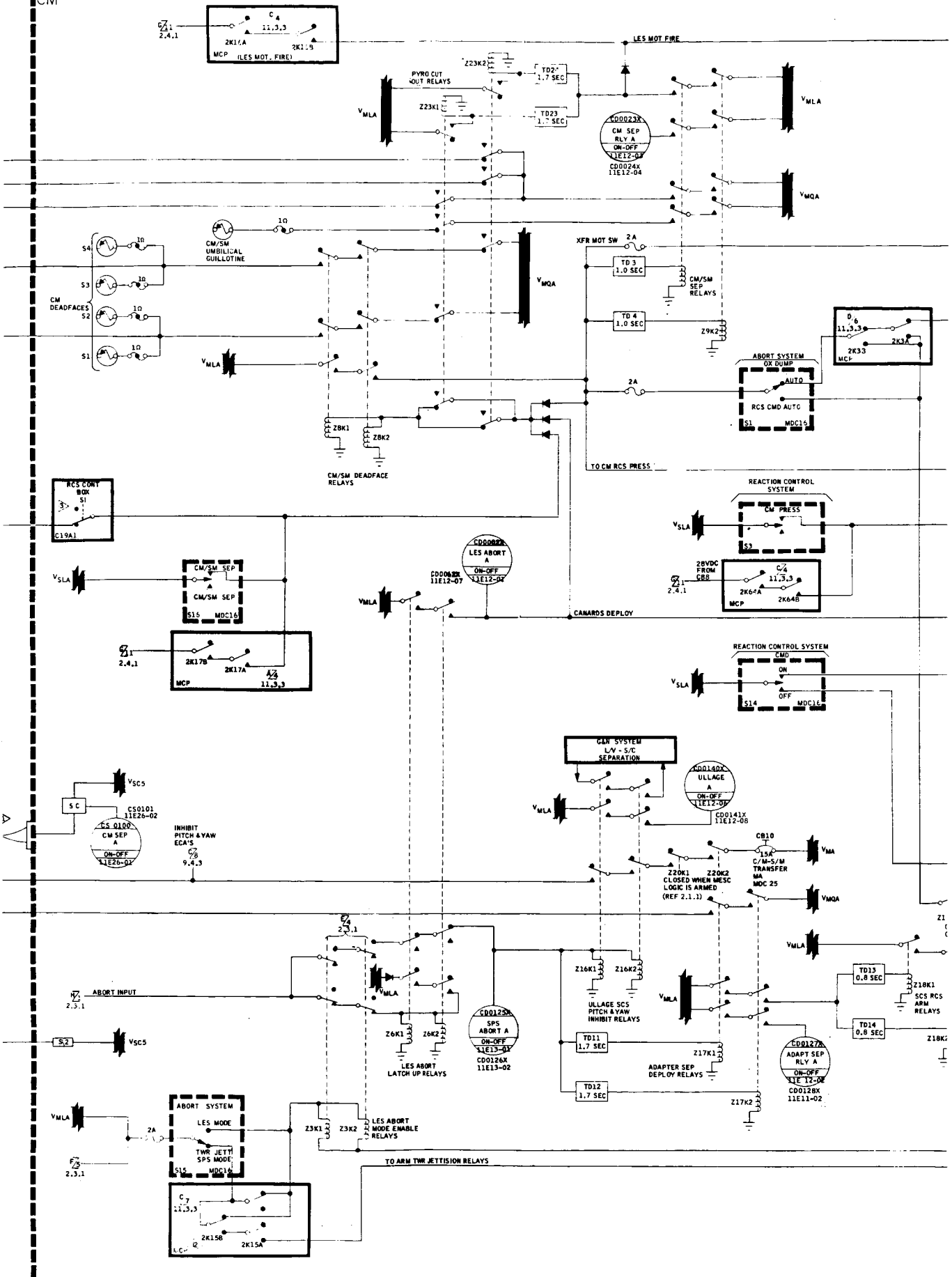
SYSTEM *A* SHOWN
EXCEPT WHERE NOTED.

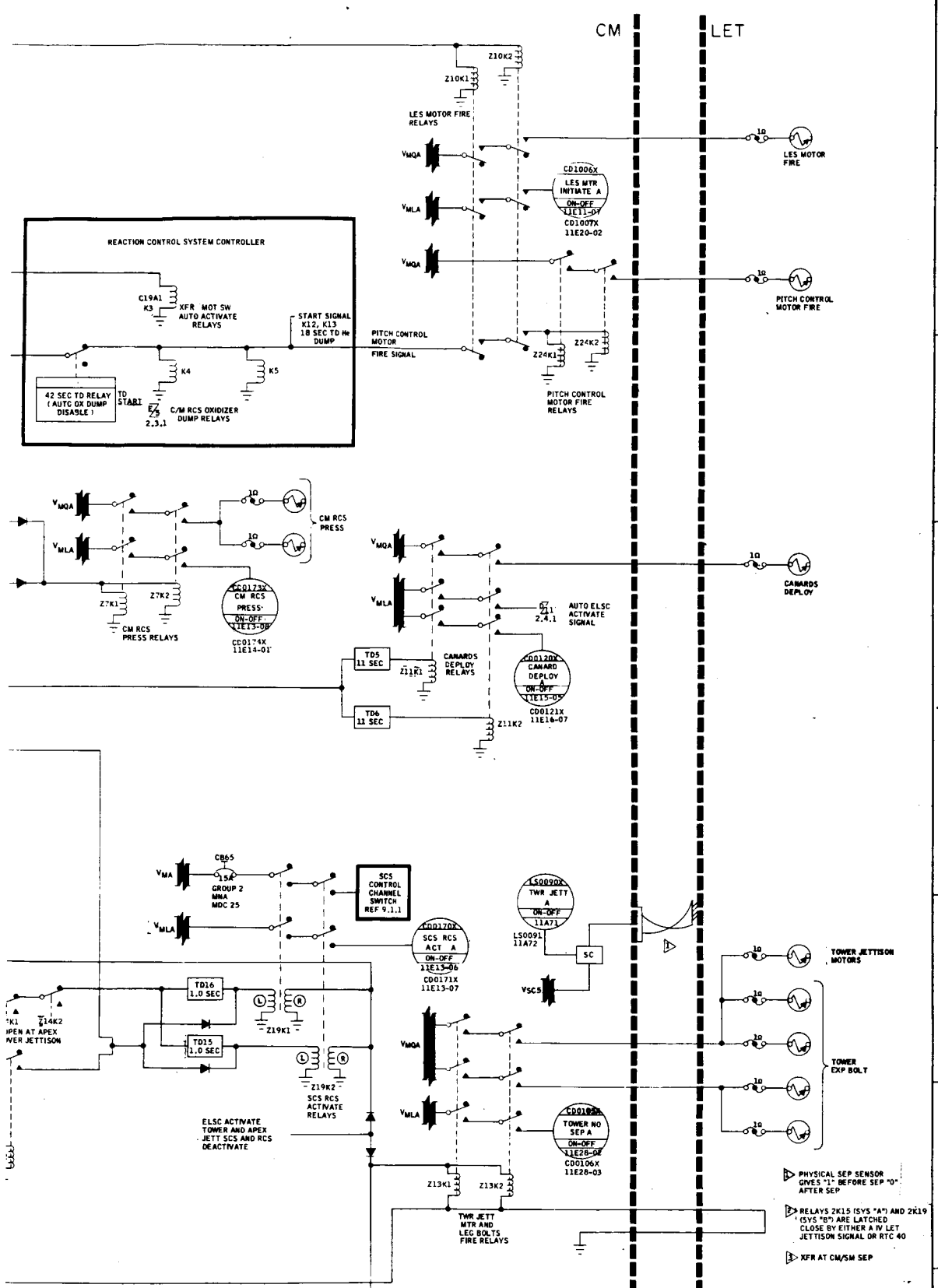
- △ I.U. SHOWN FOR REFERENCE ONLY
- △ SEE NOTE 2.3.1-B
- △ FOR CONTINUATION OF EXCESSIVE RATE OUTPUTS TO PCM SEE 2.3.1
- △ SEE NOTE 2.3.1-A 1.3.1
- △ FOR CONTINUATION OF LV GUD FAIL OUTPUTS TO PCM SEE 2.3.1 1.3.1

SECS

SIGNATURES		DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION MANNED SPACECRAFT CENTER - HOUSTON, TEXAS	
DR	<i>[Signature]</i>	1/16/67	SEQUENTIAL ABORT INITIATE	
ENG	<i>[Signature]</i>	1/17/67		
CH				
NAA	<i>[Signature]</i>	1/18/67		
APP	<i>[Signature]</i>	1/18/67		
AUTH	<i>[Signature]</i>	1-2-67		
		CSM MISSION AS-501	SIZE J	ORIG NO. 2.3.1
		SCALE	SHEET 1 OF 1	







PHYSICAL SEP SENSOR GIVES "1" BEFORE SEP "0" AFTER SEP
 RELAYS 2K15 (SYS "A") AND 2K19 (SYS "B") ARE LATCHED CLOSE BY EITHER A TV LET JETTISON SIGNAL OR RTC 40
 XFR AT CM/SM SEP

SECS

SIGNATURES		DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION MANNED SPACECRAFT CENTER HOUSTON, TEXAS		
DR	<i>[Signature]</i>	11/11/67	SEQUENTIAL LES AND SPS ABORT SYSTEMS		
ENG	<i>[Signature]</i>	11/11/67			
CH	<i>[Signature]</i>	11/11/67			
NAA	<i>[Signature]</i>	11/11/67			
APP	<i>[Signature]</i>	11/11/67			
AUTH	<i>[Signature]</i>	11/11/67	CSM	SIZE	DWG NO.
			MISSION	J	2.3.2
			AS-501		
			SCALE		SHEET 1 OF 1

2.4 NORMAL PREENTRY AND DESCENT

2.4.1 General

A. Switch Configuration

1. The ELS LOGIC Switch (S16, MDC 8) should be in the DOWN or OFF position.
2. The ELS Switch (S15, MDC 16) should be in the AUTO position.

B. A CM/SM separation signal will be generated by the Guidance and Navigation System sending a separation command to the MCP or by ground control sending RTC 61. The Master Event Sequence Controller receives the separation command 1.0 seconds after initiation of the separation signal.

C. After initiation of CM/SM separation, a -X Translation will be started immediately. This -X Translation will continue until depletion of the SM/RCS propellants or until the SM batteries fail. At the same time the RCS control is transformed from the SM to the CM. After a time delay of 2 seconds, a 5.5 seconds positive roll is initiated.

D. The pyro power to the tension tie plates and the guillotine is cut off 1.8 seconds after the initiation of separation.

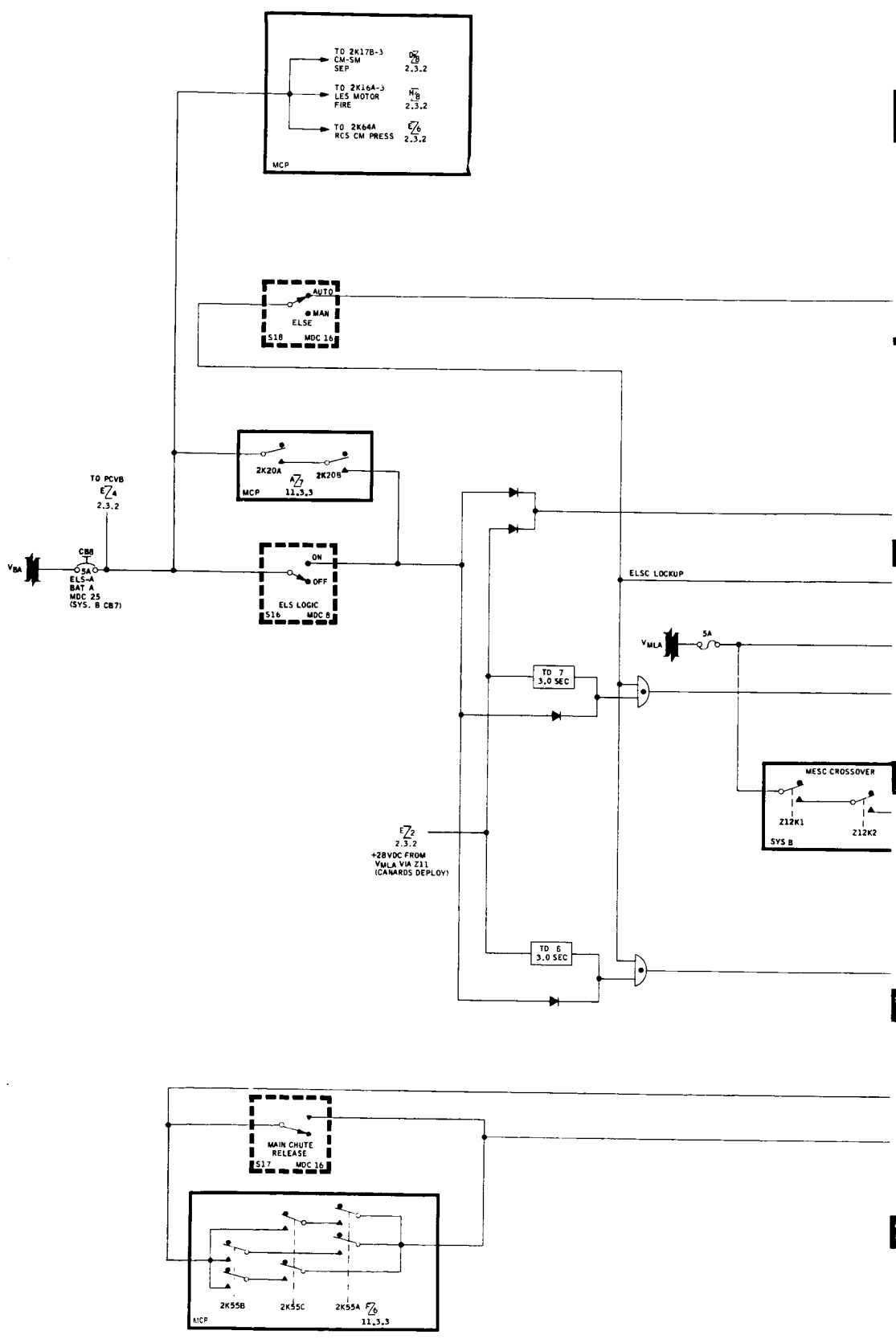
2.4.2 Earth Landing System

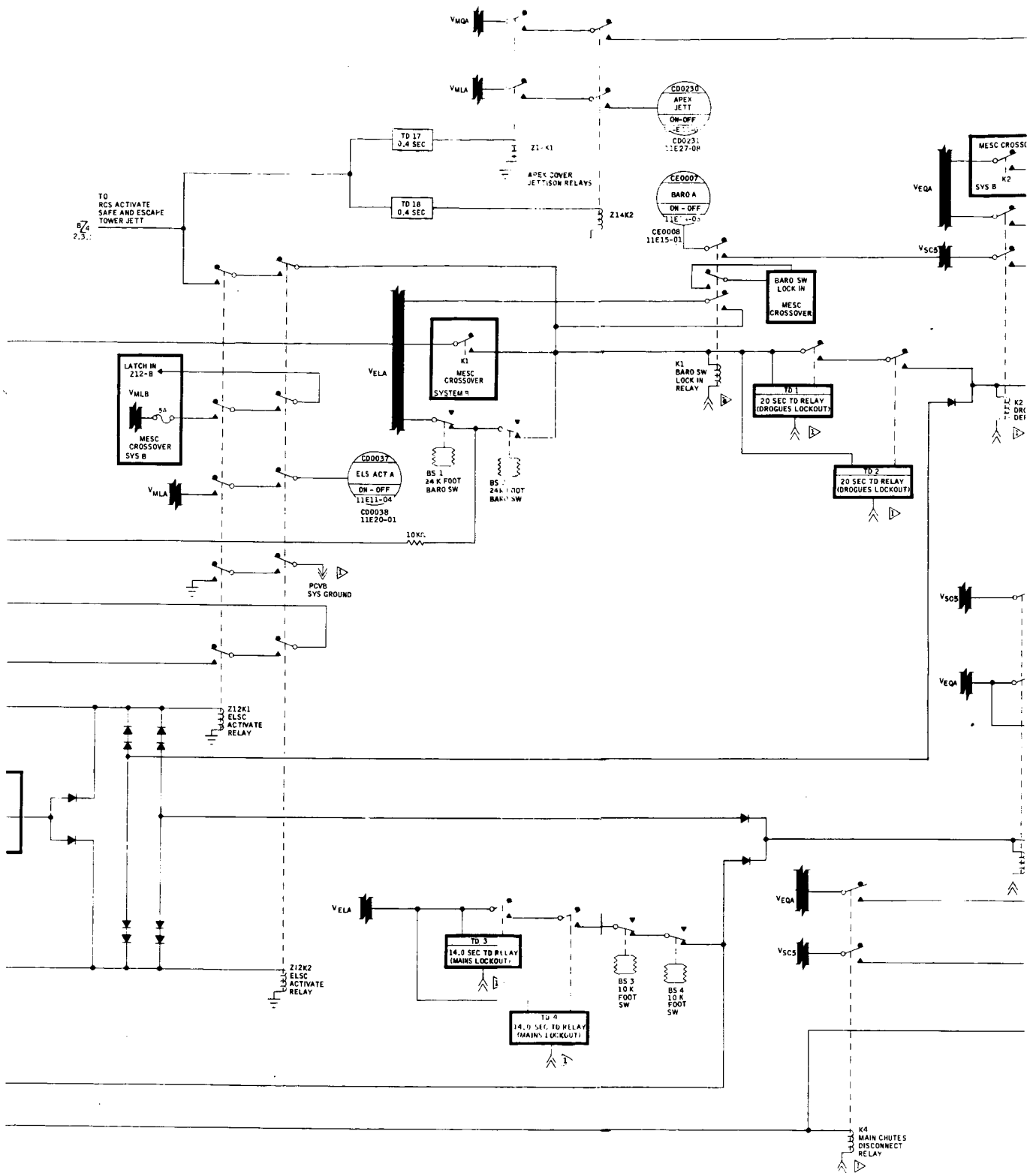
- A. With the sensing of 0.05 g's the MCP (2K20) will send an ELSC activate signal to the two and gates of the Earth Landing Sequence Controller; however, the and gate circuit is not completed until the closing of the 24,000 foot baroswitches.
- B. Closing of the 24,000 foot baroswitches in the ELSC applies voltage to the disarming coils of the SCS RCS activate relay since the ELS Switch (MDC 16) will be in the AUTO position. This signal also energizes redundant 0.4 second time delays (apex cover jettison 2-second time delays (drogues lockout) and 14 second time delays (mains lockout)).

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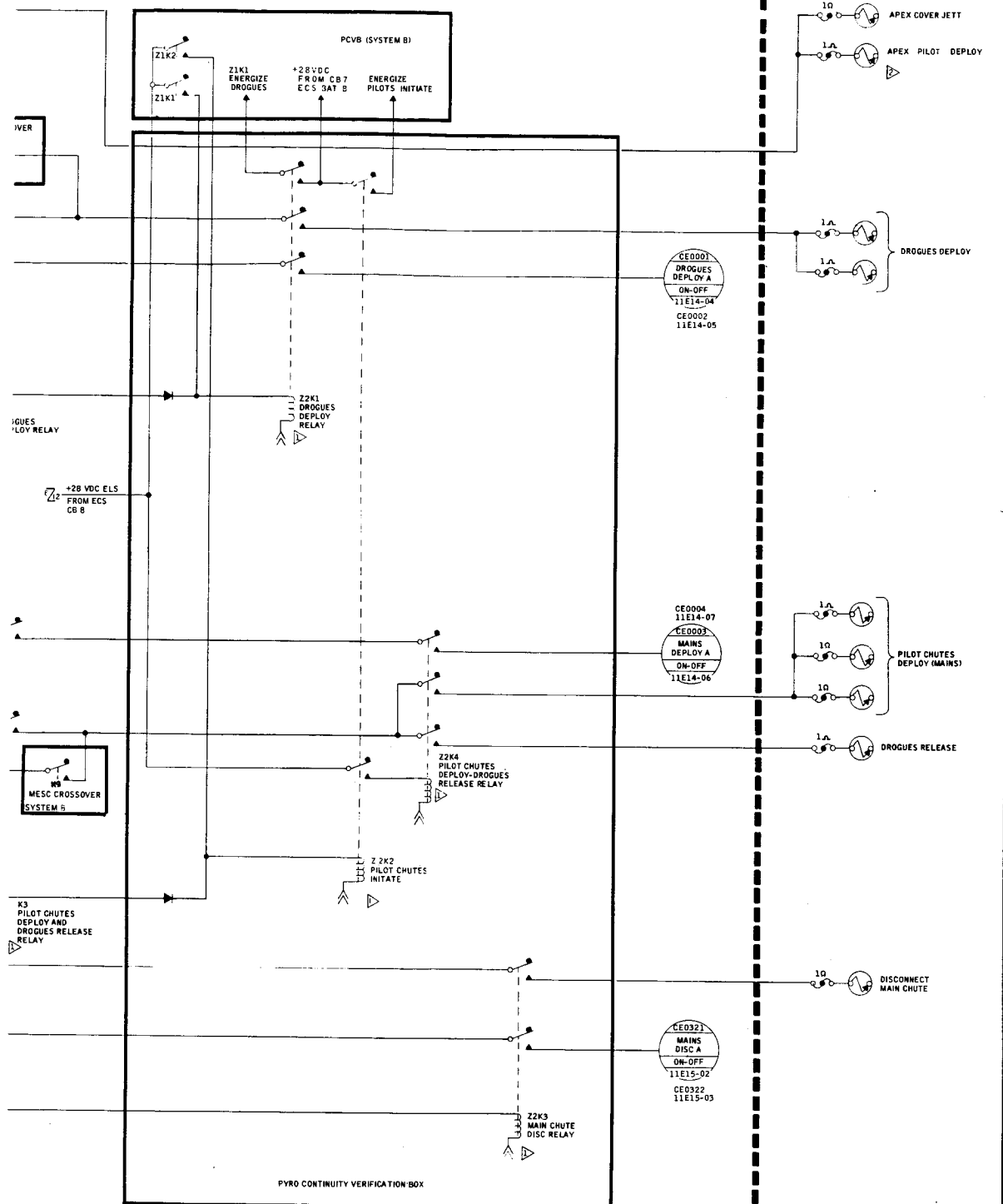
- second time delays (apex cover jettison 2 second time delays (drogues lockout) and 14 second time delays (mains lockout).
- C. The apex drogue parachute will be deployed approximately 10 milliseconds before the apex cover is jettisoned.
 - D. The two drogues are deployed in a reefed condition 1.6 seconds after apex cover jettison. Within 9 seconds after deployment, the two drogues are disreefed.
 - E. When the 10,000 foot baroswitches in the ELSC's close, the drogue parachutes are released and the three pilot parachutes are deployed, which in turn deploys the three main landing parachutes in a reefed condition. The main chutes are disreefed approximately 10 seconds following deployment of the pilot chute.
 - F. The VHF recovery antennas and flashing beacon are deployed 8 seconds after main chute deployment.
 - G. Touchdown velocity on all three parachutes is approximately 28 feet/second. If one chute fails to open the remaining two parachutes will allow the CM to impact at approximately 33 feet/second.

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CM FORWARD COMPARTMENT



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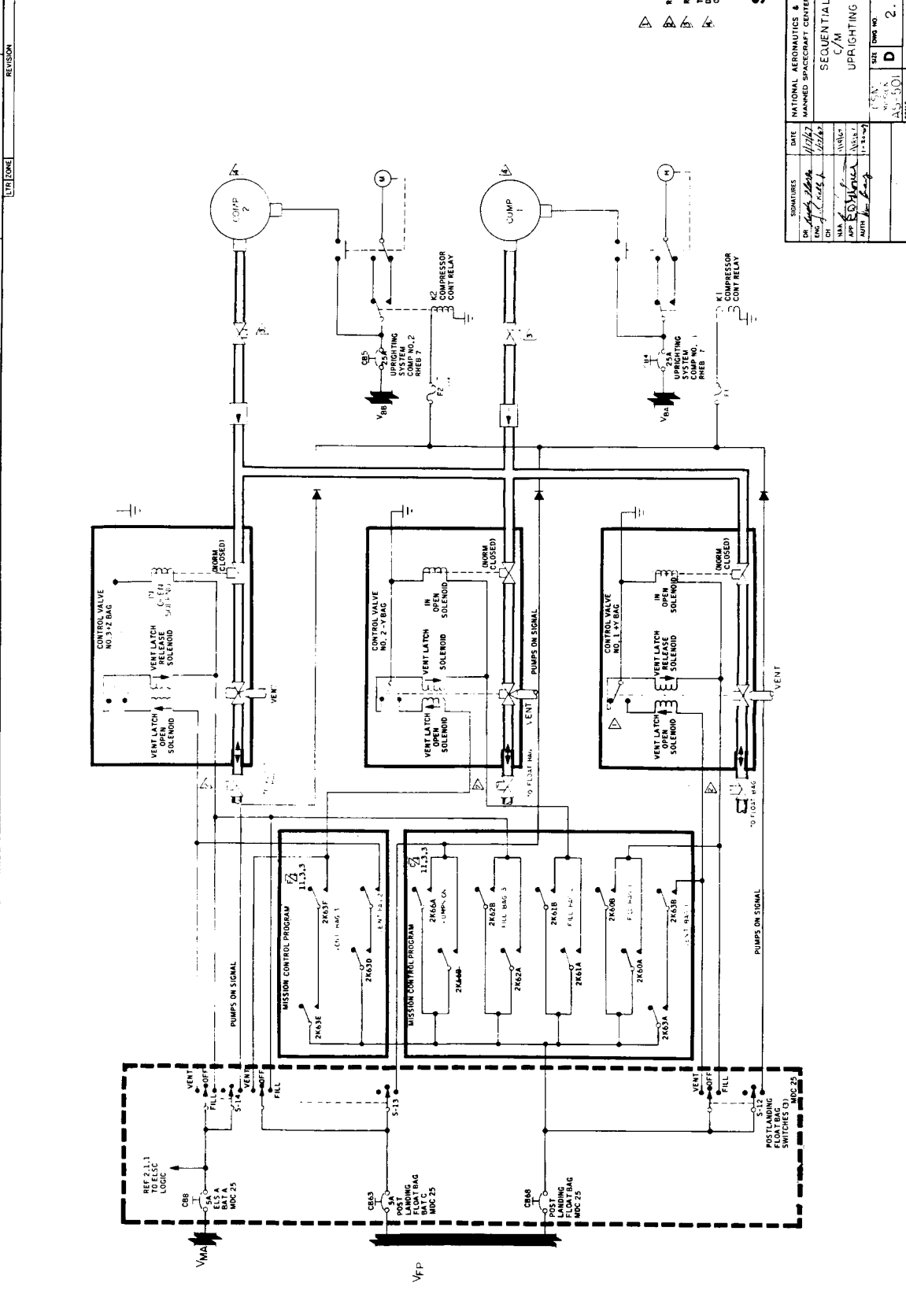
SECS

SIGNATURES		DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION MANNED SPACECRAFT CENTER - HOUSTON, TEXAS	
DR	<i>[Signature]</i>	11/15/68	EARTH LANDING SYSTEM	
EC	<i>[Signature]</i>	11/15/68		
CH	<i>[Signature]</i>	11/15/68		
MA	<i>[Signature]</i>	11/15/68		
APP	<i>[Signature]</i>	11/15/68		
AUT	<i>[Signature]</i>	11/15/68	CSM MISSION AS-501	
			SYN J	DWG NO. 24.1
			SCALE	SHEET 1 OF 1

*

2.5 LANDING

- A. An impact signal is generated within the MCP in one of the following manners:
 1. The 12K foot baroswitches activate a 14 minute time delay which in turn generates an impact signal.
 2. The 12K foot baroswitches activate a 20 second time delay which in turn supplies 28 Vdc to the impact switches. The output of this impact switch provides the same function as the 14 minute time delay.
- B. This impact signal supplies the necessary logic to disconnect the main chute and set up the Stable I, Stable II control logic.
- C. If the CM becomes inverted (Stable II), after landing, the MCP will turn on both pumps (by energizing 2K66) and start a sequence to fill the three float bag at five minute intervals, however, because of the internal wiring within the uprighting system all three float bags will fill upon receiving any of the commands from the MCP to fill. In the event that the CM uprights (Stable I), prior to the completion of the fill cycle, the pumps will be shut off. The float bags will vent when the MCP is reset.
- D. The HF RECOVERY ANT will be deployed only in a Stable I configuration.
- E. Each of the three float bags are 43 inches in diameter and has a capacity of approximately 24 cubic feet of air when inflated.
- F. A 4.25 ± 0 psi relief valve is located in the inlet of each bag. Backup relief valves set at 13.5 psi are located in the outlet of each compressor.
- G. For safing of Logic and Pyro buses see 2.2-6.



MECHANICAL SWITCH
RELIEVES AT 4.25 ± .25PSI
RELIEVES AT 13.5 PSI
THE COMPRESSOR IS DESIGNED FOR CONTINUOUS OPERATION OF 15 MINUTES.

SECS

SIGNATURES	DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION	
<i>James M. ...</i>	1/21/72	MANNED SPACECRAFT CENTER HOUSTON, TEXAS	
DESIGNED BY	INTEGRATED	SEQUENTIAL	AS-501
<i>J. ...</i>	<i>...</i>	C/M	2.5.1
APPROVED BY	DATE	UPRIGHTING SYSTEM	AS-501
<i>...</i>	1-2-72	SIZE	D
AUTHORITY		REV. NO.	
		REV. NO.	
		REV. NO.	
		REV. NO.	

SHEET 1 OF 1

SECTION 3
ELECTRICAL

CSM
AS-501

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3.1 FUEL CELL NOTES

- A. The fuel cells will be activated prior to launch and will remain on throughout the mission until jettisoned at CM/SM separation.
- B. Any two of the three fuel cells can provide sufficient power to complete the mission. All three fuel cells will be on during normal operation. In case two fuel cells should malfunction, the remaining fuel cell will provide enough power, with all nonessential loads removed from the buses, to assure a safe return during an early mission termination from any point.
- C. The minimum regulator inlet pressures for proper fuel cell operation are as follows:
1. Oxygen Regulator
 - 0 power (with purge) - 75 psia
 - 1420 watts (with purge) - 95 psia
 - 0 power (without purge) - 63 psia
 - 1420 watts (without purge) - 85 psia
 2. Hydrogen Regulator
 - 0 power (with purge) - 90 psia
 - 1420 watts (with purge) - 98 psia
 - 0 power (without purge) - 60 psia
 - 1420 watts (without purge) - 65 psia
- D. In case of a leak in the fuel cell's nitrogen system, the regulated pressure could drop as low as 23 psia and still maintain a high performance level. A 1 volt drop in performance can be expected at 23 psia. The performance drops sharply as the regulated N₂ pressure drops below 23 psia.
- E. There are no scheduled inflight purges for the AS-501 mission, however, the ground stations have the command capability to perform purges should fuel cell performance degrade during the mission. Each purge command will purge both O₂ and H₂ simultaneously for the particular cell. The nominal purge duration is 2 minutes.

- *
- F. Purge Rates: In addition to normal flow
 1. Oxygen - 0.6 lb/hr/fuel cell
 2. Hydrogen - 0.75 lb/hr/fuel cell
 - G. H₂ Regulator - Regulates the H₂ pressure to 8.5 psi above sensed N₂ pressure. The regulated H₂ pressure is 60.0 ± 2.0 psia. The regulator vents overboard at 0.2 to 0.4 psi back pressure.
 - H. O₂ Regulator - Regulates the O₂ pressure to 11.0 psi above sensed N₂ pressure. The regulated O₂ pressure is 62.5 ± 2.0 psia. The regulator vents at 0.2 to 0.4 psi back pressure.
 - I. N₂ Regulator - Regulates the N₂ pressure to 51.5 ± 2.0 psia. The regulator vents into the SM at 2 to 3 psi above the regulator setting.
 - J. Coolant Bypass Valve - When the temperature sensor detects low condensor exhaust temperature, the valve passes more glycol returning from the radiators through the coolant regenerator, thus raising glycol temperature and effecting a mean temperature increase in the system. When the sensor detects 155°F or less, the valve gives full flow through the collant regenerator. When the sensor detects 170°F or above, the valve diverts full flow bypassing the coolant regenerator.
 - K. H₂ Bypass Valve - When the temperature sensor detects low fuel cell exhaust temperature, the valve passes more H₂ and water through the H₂ regenerator, increasing the temperature of H₂ and water going to the fuel cell. When the sensor detects 425°F or below, the valve gives full flow through the regenerator. When the sensor detects 495°F or above, the valve diverts full flow bypassing the regenerator.
 - L. Fuel Cell Temperatures:
 - Low - The critical temperature of KOH is 300°F. The KOH becomes a liquid above 300°F and the F/C electrochemical reaction can begin. The in-line heater should keep the

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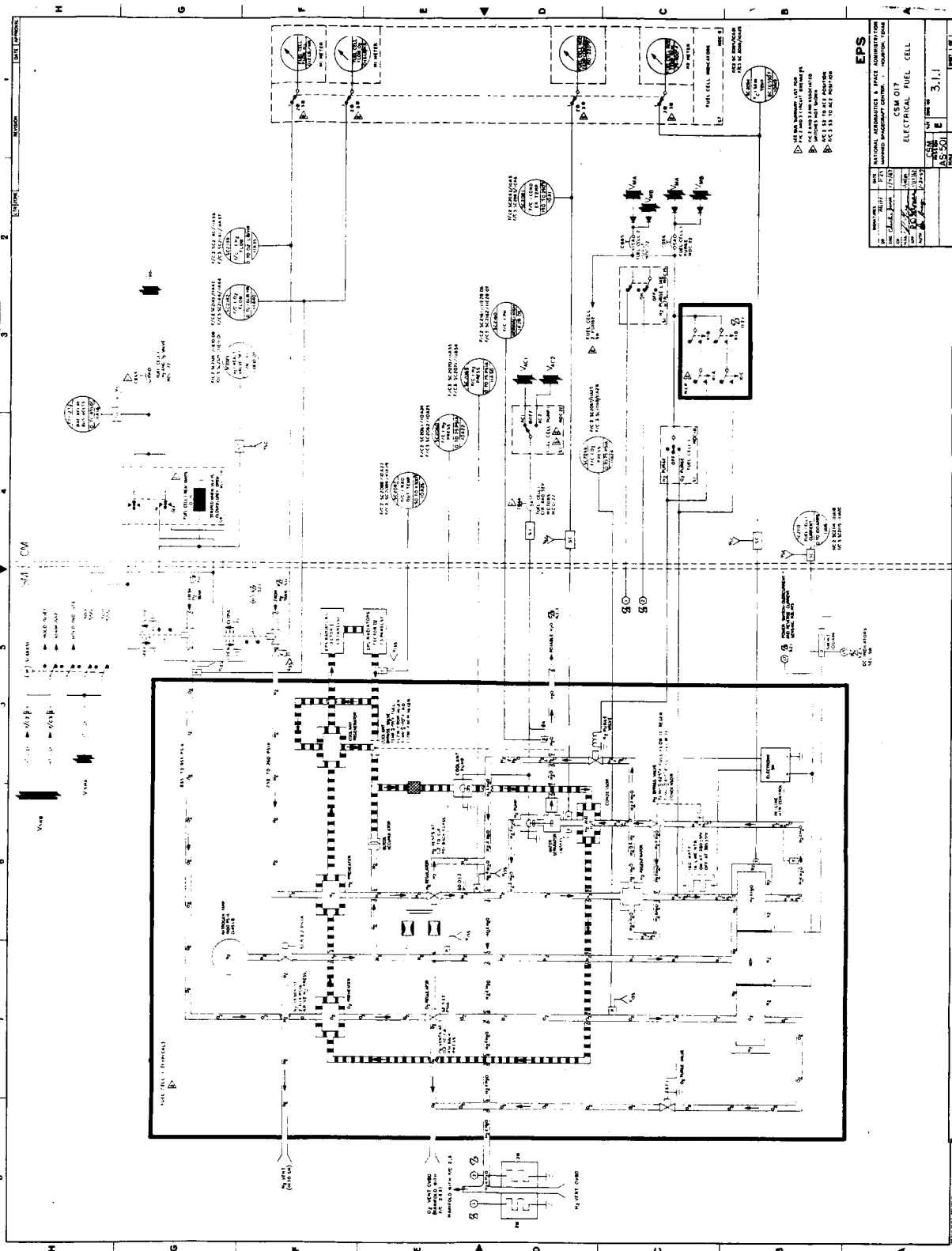
module temperature at or above $385 \pm 5^\circ\text{F}$ while the fuel cell is in a standby condition (open circuited) or at a low power level. Temperatures below 360°F are abnormal for skin temperature. The fuel cell performance will degrade below 360°F and the cell will be lost between 360° and 300°F . High - Temperatures above 500°F are abnormal for skin temperature. The teflon seals will break down between 500 and 550°F and cause a loss of the cell. The cell should be open circuited and allowed to cool to prevent its loss. Purging hydrogen gas is another method of cooling.

M. Flow Rates

1. Oxygen Consumption - 2.04×10^{-2} lb/amp-hr(100 percent efficient cells)
2. Hydrogen Consumption - 2.57×10^{-3} lb/amp-hr(100 percent efficient cells)
3. Water Production - 2.297×10^{-2} lb/amp-hr(100 percent efficient cells)
4. Glycol Flow - 35 to 80 lb/hr (viscosity and temperature dependent)

N. Purge Line Heater - The H_2 purge line heaters will be turned ON prior to launch and left on for the mission duration.

O. High pH - A high pH is normally caused by KOH entering into the $\text{H}_2/\text{H}_2\text{O}$ loop. A pH of 9 or greater is abnormal. Any KOH entering the $\text{H}_2/\text{H}_2\text{O}$ loop will normally cause a failure of the hydrogen pump.



EPS

NATIONAL AERONAUTICS & SPACE ADMINISTRATION
 NATIONAL SPACE CENTER - MISSION SYSTEMS
 ELECTRICAL FUEL CELL

REV	DATE	BY	CHKD
1	11/15/68	J. J. ...	J. J. ...
2	12/15/68	J. J. ...	J. J. ...
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104	6/15/77	J. J. ...	J. J. ...
105	7/15/77	J. J. ...	J. J. ...
106	8/15/77	J. J. ...	J. J. ...
107	9/15/77	J. J. ...	J. J. ...
108	10/15/77	J. J. ...	J. J. ...
109	11/15/77	J. J. ...	J. J. ...
110	12/15/77	J. J. ...	J. J. ...
111	1/15/78	J. J. ...	J. J. ...
112	2/15/78	J. J. ...	J. J. ...
113	3/15/78	J. J. ...	J. J. ...
114	4/15/78	J. J. ...	J. J. ...
115	5/15/78	J. J. ...	J. J. ...
116	6/15/78	J. J. ...	J. J. ...
117	7/15/78	J. J. ...	J. J. ...
118	8/15/78	J. J. ...	J. J. ...
119	9/15/78	J. J. ...	J. J. ...
120	10/15/78	J. J. ...	J. J. ...
121	11/15/78	J. J. ...	J. J. ...
122	12/15/78	J. J. ...	J. J. ...
123	1/15/79	J. J. ...	J. J. ...
124	2/15/79	J. J. ...	J. J. ...
125	3/15/79	J. J. ...	J. J. ...
126	4/15/79	J. J. ...	J. J. ...
127	5/15/79	J. J. ...	J. J. ...
128	6/15/79	J. J. ...	J. J. ...
129	7/15/79	J. J. ...	J. J. ...
130	8/15/79	J. J. ...	J. J. ...
131	9/15/79	J. J. ...	J. J. ...
132	10/15/79	J. J. ...	J. J. ...
133	11/15/79	J. J. ...	J. J. ...
134	12/15/79	J. J. ...	J. J. ...
135	1/15/80	J. J. ...	J. J. ...
136	2/15/80	J. J. ...	J. J. ...
137	3/15/80	J. J. ...	J. J. ...
138	4/15/80	J. J. ...	J. J. ...
139	5/15/80	J. J. ...	J. J. ...
140	6/15/80	J. J. ...	J. J. ...
141	7/15/80	J. J. ...	J. J. ...
142	8/15/80	J. J. ...	J. J. ...
143	9/15/80	J. J. ...	J. J. ...
144	10/15/80	J. J. ...	J. J. ...
145	11/15/80	J. J. ...	J. J. ...
146	12/15/80	J. J. ...	J. J. ...
147	1/15/81	J. J. ...	J. J. ...
148	2/15/81	J. J. ...	J. J. ...
149	3/15/81	J. J. ...	J. J. ...
150	4/15/81	J. J. ...	J. J. ...
151	5/15/81	J. J. ...	J. J. ...
152	6/15/81	J. J. ...	J. J. ...
153	7/15/81	J. J. ...	J. J. ...
154	8/15/81	J. J. ...	J. J. ...
155	9/15/81	J. J. ...	J. J. ...
156	10/15/81	J. J. ...	J. J. ...
157	11/15/81	J. J. ...	J. J. ...
158	12/15/81	J. J. ...	J. J. ...
159	1/15/82	J. J. ...	J. J. ...
160	2/15/82	J. J. ...	J. J. ...
161	3/15/82	J. J. ...	J. J. ...
162	4/15/82	J. J. ...	J. J. ...
163	5/15/82	J. J. ...	J. J. ...
164	6/15/82	J. J. ...	J. J. ...
165	7/15/82	J. J. ...	J. J. ...
166	8/15/82	J. J. ...	J. J. ...
167	9/15/82	J. J. ...	J. J. ...
168	10/15/82	J. J. ...	J. J. ...
169	11/15/82	J. J. ...	J. J. ...
170	12/15/82	J. J. ...	J. J. ...
171	1/15/83	J. J. ...	J. J. ...
172	2/15/83	J. J. ...	J. J. ...
173	3/15/83	J. J. ...	J. J. ...
174	4/15/83	J. J. ...	J. J. ...
175	5/15/83	J. J. ...	J. J. ...
176	6/15/83	J. J. ...	J. J. ...
177	7/15/83	J. J. ...	J. J. ...
178	8/15/83	J. J. ...	J. J. ...
179	9/15/83	J. J. ...	J. J. ...
180	10/15/83	J. J. ...	J. J. ...
181	11/15/83	J. J. ...	J. J. ...
182	12/15/83	J. J. ...	J. J. ...
183	1/15/84	J. J. ...	J. J. ...
184	2/15/84	J. J. ...	J. J. ...
185	3/15/84	J. J. ...	J. J. ...
186	4/15/84	J. J. ...	J. J. ...
187	5/15/84	J. J. ...	J. J. ...
188	6/15/84	J. J. ...	J. J. ...
189	7/15/84	J. J. ...	J. J. ...
190	8/15/84	J. J. ...	J. J. ...
191	9/15/84	J. J. ...	J. J. ...
192	10/15/84	J. J. ...	J. J. ...
193	11/15/84	J. J. ...	J. J. ...
194	12/15/84	J. J. ...	J. J. ...
195	1/15/85	J. J. ...	J. J. ...
196	2/15/85	J. J. ...	J. J. ...
197	3/15/85	J. J. ...	J. J. ...
198	4/15/85	J. J. ...	J. J. ...
199	5/15/85	J. J. ...	J. J. ...
200	6/15/85	J. J. ...	J. J. ...

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3.2 DC SYSTEM NOTES

A. The total spacecraft power source consists of three fuel cells, three entry batteries, three auxiliary batteries, two pyrotechnic batteries, and two SM jettison controller batteries.

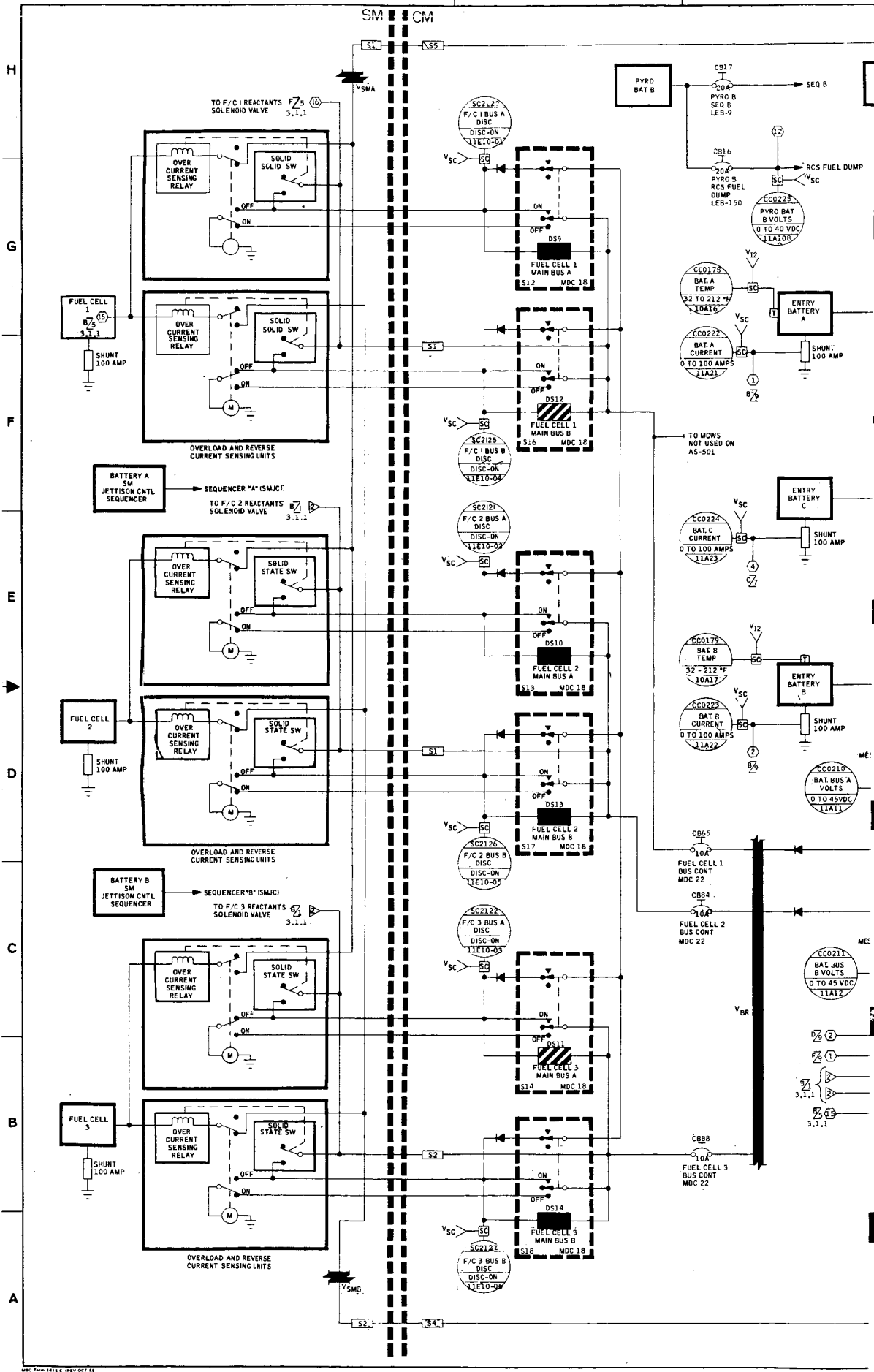
1. Fuel Cells (3) - The fuel cells supply the bulk of spacecraft power from liftoff through CM/SM separation. One fuel cell will be connected to each main bus and the third fuel cell will be connected to both main buses. A malfunctioning cell can be disconnected only through automatic circuitry (overload >75 amps or reverse current >4 amps for specific times).
2. Entry Batteries (3) - The entry batteries supply backup power during SPS burns, primary power after CM/SM separation, and help the auxiliary supply the flight and postlanding bus after impact. The MCP performs the battery bus switching operations. At impact the entry batteries are switched onto the flight and postlanding bus. At impact plus 11 seconds the entry batteries are removed from the main buses.
3. Auxiliary Batteries (3) - The auxiliary batteries supply power to the MCP inflight and to the flight and postlanding bus after impact.
4. Pyrotechnic Batteries (2) - The pyro batteries supply power to initiate ordinance devices in the spacecraft.
5. Jettison Controller Batteries (2) - The jettison controller batteries supply power to two jettison sequencers to sustain the SM RCS retrofire, as well as firing the SM positive roll RCS engines 2 seconds after CM/SM separation.

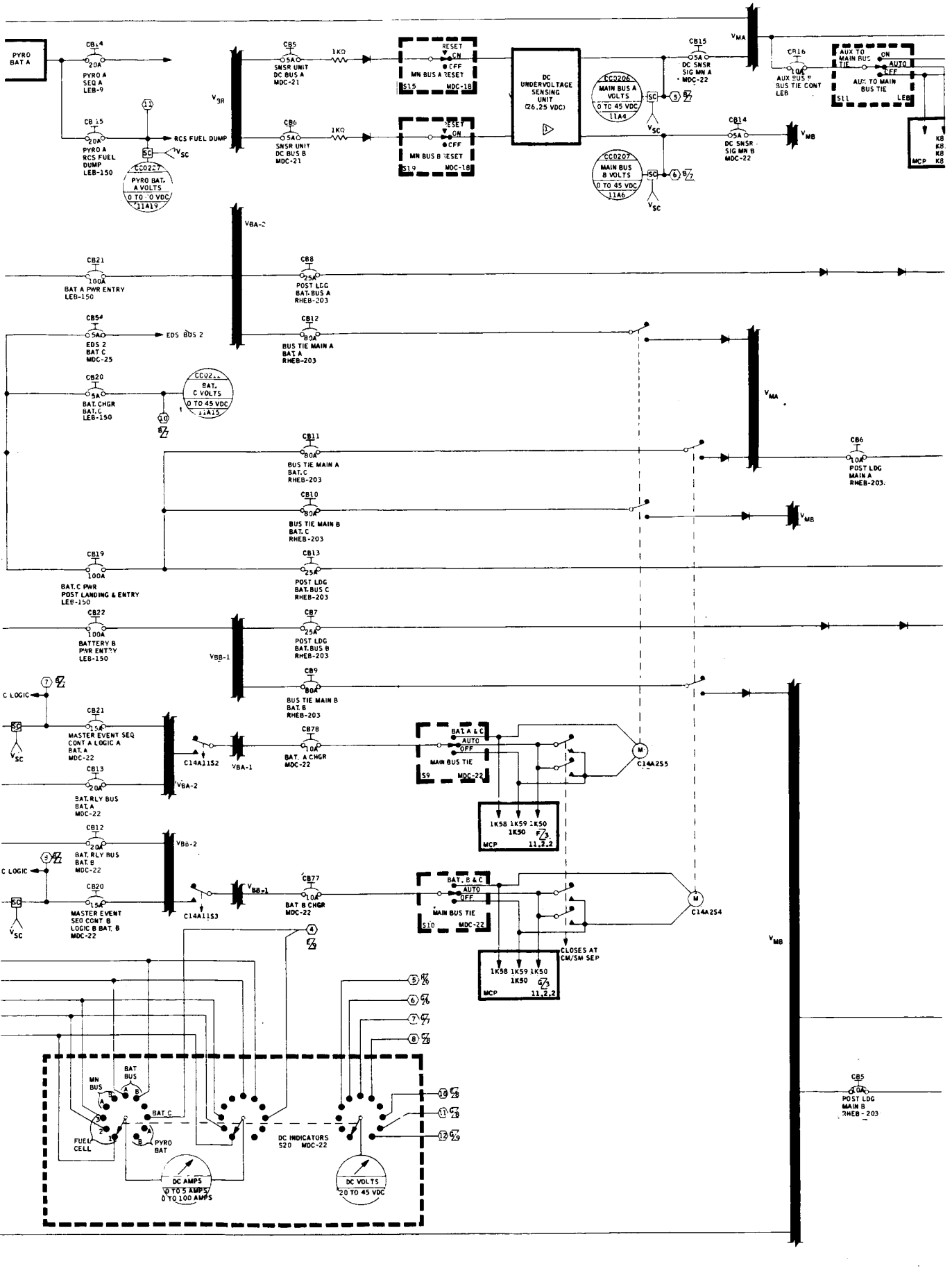
B. Battery Performance

1. Entry and Auxiliary Batteries - These batteries will be charged at liftoff with 50 amp-hr. The battery open circuit voltage is 37.2 volts (inflight).

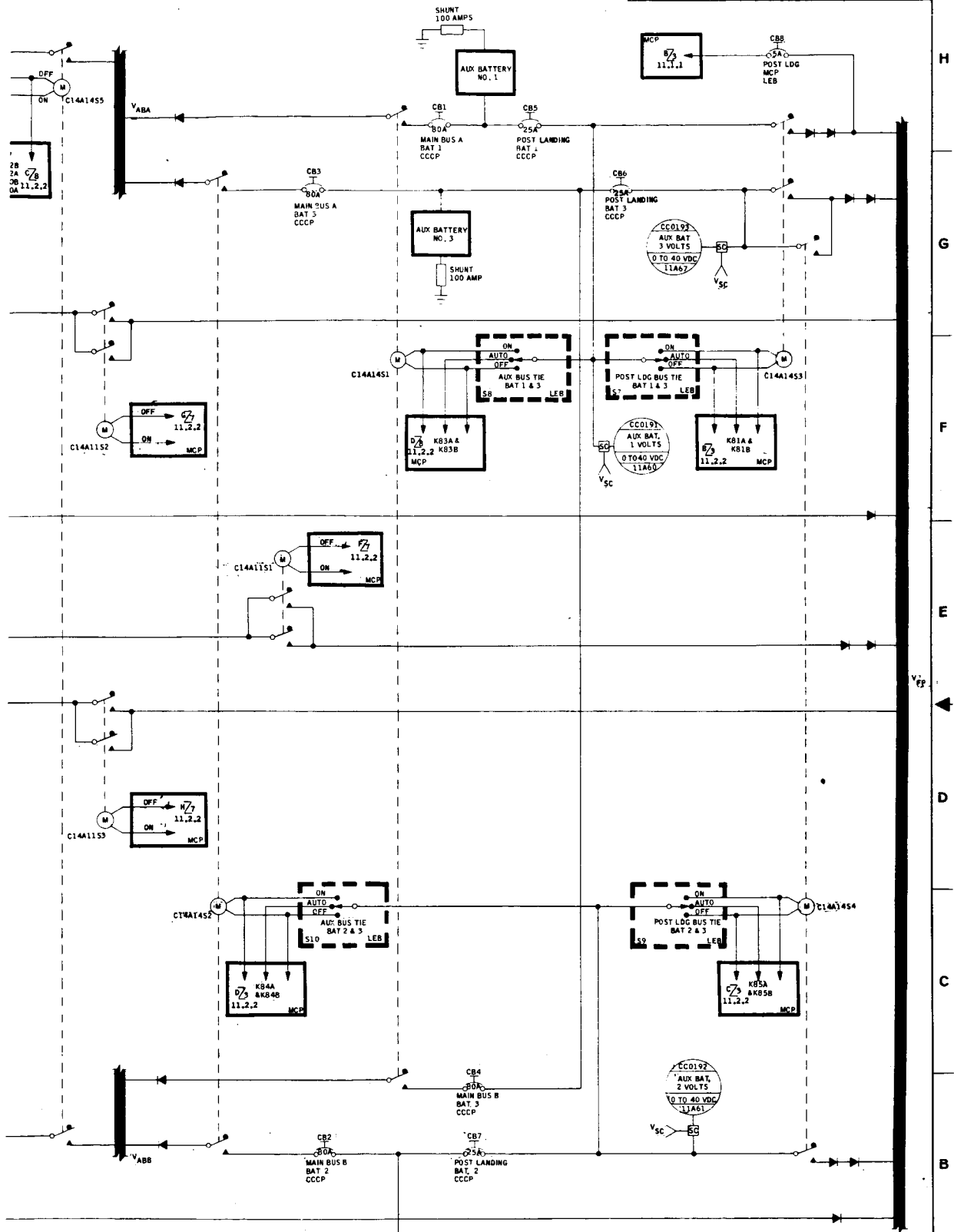
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2. Pyrotechnic and Jettison Controller Batteries - These batteries are rated at 0.75 amp-hr. and 23 Vdc. The battery open circuit voltage is 37.2 volts (inflight). The pyrotechnic batteries are considered lost at 35 Vdc (open circuit).
- C. Battery Relief Valves - Each cell of each entry battery contains a relief valve set to relieve at 45 ± 5 psid (amb. ref.). These valves vent into the battery case which in turn vents to the waste water and urine disposal line. The pyrotechnic batteries have relief valves in each cell set to relieve at 35 psid (amb. ref.) into the battery case. The case has a valve set to relieve at 30 ± 5 psid (amb. ref.) into the surrounding environment and reseal at 20 psid (amb. ref.).
- D. Overload and Reverse Current Sensing Units - The fuel cells are connected to the main dc buses through the FUEL CELL 1 (2 or 3) MAIN BUS A (or B) switches. The sensing circuit provides an automatic disconnect for an overload of 75 amps for 15 minutes or 112 amps for 30 to 300 seconds and for a reverse current of 4 to 11 amps for 10 seconds or 11 to 20 amps for 1 to 10 seconds.





A



▷ HAS NO FUNCTION ON AS-501

ELEC

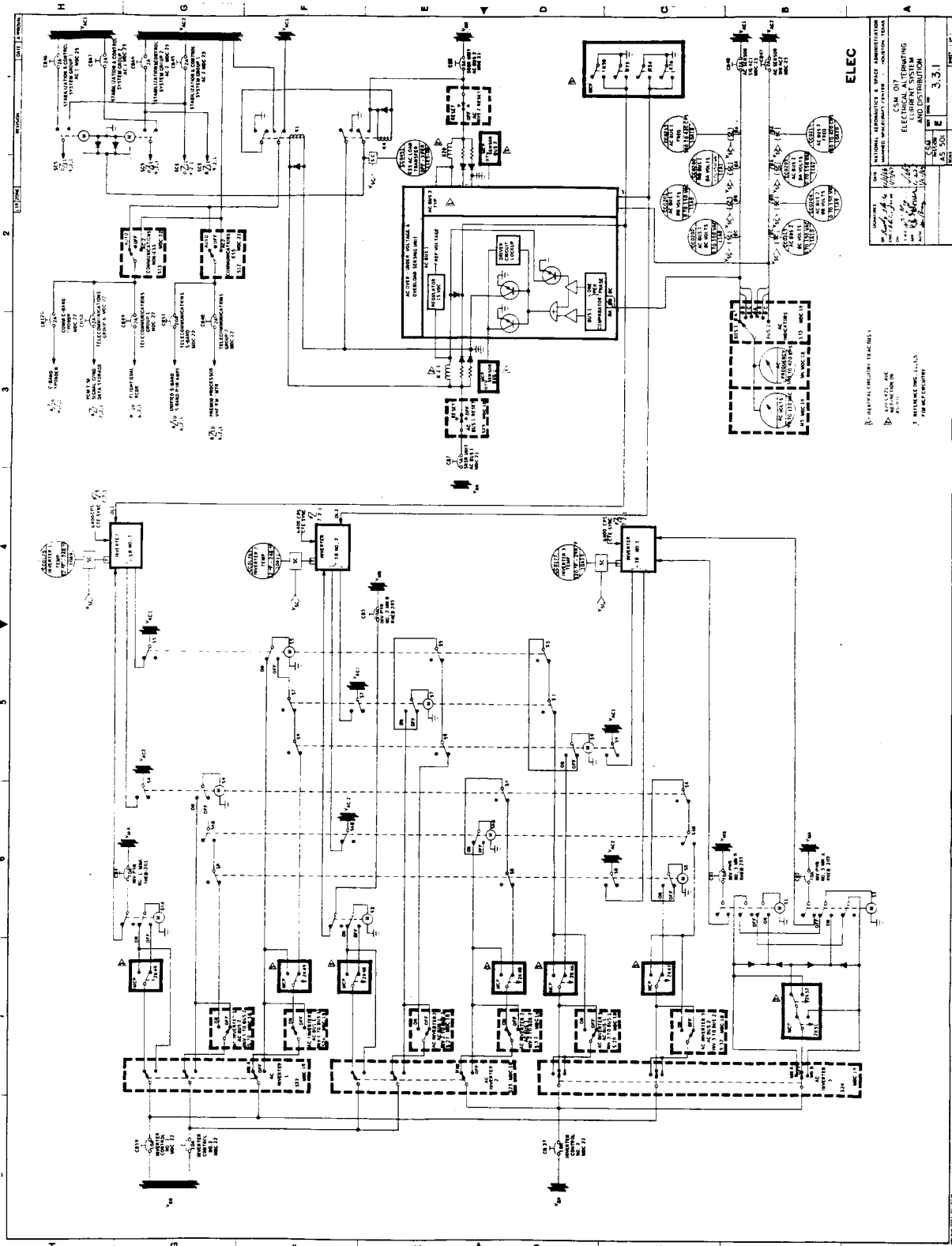
SIGNATURES		DATE		NATIONAL AERONAUTICS & SPACE ADMINISTRATION	
DR. W. S. ...		11/7/67		MANNED SPACECRAFT CENTER - HOUSTON, TEXAS	
ENG. Charles ...		11/7/67			
CH					
APP. R. W. ...		11/21/67		ELECTRICAL-DIRECT CURRENT SYSTEM AND DISTRIBUTION	
AUTH. ...		11/21/67			
SCALE		SIZE	DWG NO.	3.2.1	
		J		SHEET 1 OF 1	

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3.3 AC SYSTEM NOTES

- A. The spacecraft ac power is generated by three solid state inverter units. Each unit produces 115/200 Vac, 3 ϕ , 400 cycle power and is rated at 1250 volt amps with a life span of 1200 hours.
- B. Operational Configuration - At liftoff and during normal flight, Inverter No. 1 will supply AC Bus 1 and Inverter No. 2 will supply AC Bus 2. Inverter No. 3 will be OFF unless some problem develops.
- C. AC Over-Undervoltage Sensing Unit - Six of these units, one for each phase, will sense an undervoltage (below 95 ± 3 Vac) or an overvoltage (above 130 ± 2 Vac) and will automatically disconnect the inverter from the ac bus after 9 seconds. The MCP will then replace the inverter (Inverter No. 1 or Inverter No. 2) with the spare inverter (Inverter No. 3). If the affected bus is AC Bus 1 then the essential ac loads will transfer to AC Bus 2. The transfer time is 0.5 seconds. For an undervoltage condition the MCP will attempt a reset before disconnecting the inverter.
- D. AC Overload Sensing Unit - This circuit monitors the rectified dc signal representing current output. The trip circuit will be activated when total 3 ϕ inverter output exceeds 250 percent of rated current (approximately 27.7 amps) or when current output on any one phase exceeds 300 percent of rated current (approximately 11 amps). Any overload condition (15 ± 5 seconds for 3 ϕ or 5 ± 1 seconds for 1 ϕ) will cause the inverter to be removed from the bus. In this case the inverter would not be replaced and the affected bus would be lost. The MCP will not attempt a reset for an overload condition. For an overload condition on AC Bus 1 the essential ac loads will be switched to AC Bus 2.



ELEC

PROJECT	NO. 1000	REV.	1
DATE	10/15/50	BY	J. J. [Signature]
DESIGNED BY	J. J. [Signature]	CHECKED BY	J. J. [Signature]
APPROVED BY	J. J. [Signature]	DATE	10/15/50
ELECTRICAL ALTERNATING AND DISTRIBUTION			
3.3.1			

1. ELECTRICAL CONTROL SYSTEMS
 2. ELECTRICAL ALTERNATING AND DISTRIBUTION
 3. ELECTRICAL ALTERNATING AND DISTRIBUTION

*

3.4 CIRCUIT BREAKER SUMMARY

MAIN BUS A

	<u>CB NOMENCLATURE</u>	<u>PANEL LOCATION</u>	<u>CB NO.</u>	<u>RATING</u>
EPS	POST LDG MAIN A	RHEB-203	CB6	10 AMP
	INVERTER PWR NO. 1 MN A	RHEB-203	CB4	70 AMP
	INVERTER PWR NO. 3 MN A	RHEB-203	CB2	70 AMP
	FUEL CELL 1 PURGE	MDC-22	CB66	5 AMP
	FUEL CELL 2 PURGE	MDC-22	CB85	5 AMP
	FUEL CELL 3 PURGE	MDC-22	CB89	5 AMP
	DC SNSR SIG MN A	MDC-22	CB15	5 AMP
	BATTERY CHARGER MN A	MDC-22	CB80	5 AMP
CRYO	COUCH ATTEN MN A FLOODLIGHTS	MDC-25	CB38	15 AMP
	CRYOGENIC SYSTEM TANK HEATERS O ₂ 1 MN A	MDC-22	CB5	15 AMP
	CRYOGENIC SYSTEM TANK HEATERS H ₂ 1 MN A	MDC-22	CB7	5 AMP
ECS	ECS H ₂ O ACCUM MN A	MDC-22	CB94	5 AMP
	ECS STEAM DUCT HEATERS MN A	RHEB-206	CB23	5 AMP
	ECS TRANSDUCER WASTE & POT H ₂ O MN A	MDC-22	CB92	5 AMP
	ECS POT H ₂ O HTR MN A	MDC-22	CB3	5 AMP
	ECS TRANSDUCER PRESS. GROUPS 2 MN A	MDC-22	CB43	5 AMP
	ECS TRANSDUCER PRESS. GROUPS 1 MN A	MDC-22	CB9	5 AMP
	BIOMED COMM MN A	MDC-25	CB59	5 AMP
	EC TRANSDUCER TEMP MN A	MDC-22	CB11	5 AMP

INSTRUMENTATION

CENTRAL TIMING SYS MN A	MDC-22	CB53	5 AMP
ESS INST MN A	LEB	CB14	10 AMP
BIOMED COMM MN A	MDC-25	CB59	5 AMP

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	<u>CB NOMENCLAUTE</u>	<u>PANEL LOCATION</u>	<u>CB NO.</u>	<u>RATING</u>
SEQUENTIAL	EVENT TIMER MN A	MDC-25	CB57	5 AMP
G&N	G&N OPTICS MN A	MDC-22	CB55	10 AMP
	G&N IMU MN A	MDC-22	CB59	25 AMP
	G&N IMU HTR MN A	MDC-22	CB61	7.5 AMP
	G&N COMPUTER MN A	MDC-22	CB57	10 AMP
SCS	SCS DIRECT CONT MN A	MDC-25	CB42	30 AMP
	SCS A&C ROLL MN A	MDC-25	CB36	20 AMP
	SCS B&D ROLL MN A	MDC-25	CB34	20 AMP
	SCS PITCH 1 MN A	MDC-25	CB40	20 AMP
	SCS YAW 1 MN A	MDC-25	CB32	20 AMP
	SCS GROUP 1 MN A	MDC-25	CB44	15 AMP
	SCS GROUP 2 MN A	MDC-25	CB65	15 AMP
SPS	SPS GAGING MN A	MDC-25	CB22	5 AMP
	SPS HE. VALVE MN A	MDC-25	CB28	7.5 AMP
RCS	RCS GAGING MN A	MDC-25	CB18	5 AMP
	RCS PROP ISOL MN A	MDC-25	CB16	15 AMP
	RCS C/M-5/M TRANSFER MN A	MDC-25	CB10	15 AMP
	RCS HEATERS B MN A	MDC-21	CB2	5 AMP
	RCS HEATERS D MN A	MDC-21	CB4	5 AMP

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MAIN BUS B

	<u>CB NOMENCLATURE</u>	<u>PANEL LOCATION</u>	<u>CB NO.</u>	<u>RATING</u>
EPS	POSTLDG MAIN R	RHEB-203	CB5	10 AMP
	INVERTER PWR NO. 2 MN B	RHEB-203	CB3	70 AMP
	INVERTER PWR NO. 3 MN B	RHEB-203	CB1	70 AMP
	FUEL CELL 1 PURGE	MDC-22	CB66	5 AMP
	FUEL CELL 2 PURGE	MDC-22	CB85	5 AMP
	FUEL CELL 3 PURGE	MDC-22	CB89	5 AMP
	DC SNSR SIG MN B	MDC-22	CB14	5 AMP
	BATTERY CHARGER MN B	MDC-22	CB79	5 AMP
	COUCH ATTEN MN B FLOODLIGHTS	MDC-25	CB37	15 AMP
CRYO	CRYOGENIC SYSTEM TANK HEATERS O ₂ MN B	MDC-22	CB6	5 AMP
	CRYOGENIC SYSTEM TANK HEATERS H ₂ MN B	MDC-22	CB4	15 AMP
ECS	ECS H ₂ O ACCUM MN B	MDC-22	CB95	5 AMP
	ECS STEAM DUCT HEATERS MN B	RHEB-206	CB24	5 AMP
	ECS TRANSDUCER WASTE & POT H ₂ O MN B	MDC-22	CB91	5 AMP
	ECS POT H ₂ O HTR MN B	MDC-22	CB2	5 AMP
	ECS TRANSDUCER PRESS. GROUPS 1 MN B	MDC-22	CB8	5 AMP
	ECS TRANSDUCER PRESS.GROUPS 2 MN B	MDC-22	CB34	5 AMP
	ECS TRANSDUCER TEMP MN B	MDC-22	CB10	5 AMP
	BIOMED COMM MN B	MDC-25	CB60	5 AMP
INST & COMM	COMM FT QUAL RCDR	MDC-22	CB96	5 AMP
	CENTRAL TIMING SYS MN B	MDC-22	CB52	5 AMP



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	<u>CB NOMENCLATURE</u>	<u>PANEL LOCATION</u>	<u>CB NO.</u>	<u>RATING</u>
ECS	ESS INST MN B	LEB	CB15	10 AMP
	NON ESS BUS MN B	LEB	CB13	35 AMP
	TELECOMMUNICATIONS GROUP 3	MDC-22	CB47	2 AMP
	COMM C-BAND	MDC-22	CB97	7.5 AMP
SEQUENTIAL				
	EVENT TIMER MN B	MDC-25	CB58	5 AMP
G&N	G&N OPTICS MN B	MDC-22	CB54	10 AMP
	G&N IMU MN B	MDC-22	CB58	25 AMP
	G&N IMU HTR MN B	MDC-22	CB60	7.5 AMP
	G&N COMPUTER	MDC-22	CB56	10 AMP
SCS	SCS DIRECT CONT MN B	MDC-25	CB41	30 AMP
	SCS A&C ROLL MN B	MDC-25	CB35	20 AMP
	SCS B&D ROLL MN B	MDC-25	CB33	20 AMP
	SCS PITCH 2 MN B	MDC-25	CB39	20 AMP
	SCS YAW 2 MN B	MDC-25	CB31	20 AMP
	SCS GROUP 1 MN B	MDC-25	CB43	15 AMP
	SCS GROUP 2 MN B	MDC-25	CB64	15 AMP
SPS	SPS GAGING MN B	MDC-25	CB21	5 AMP
	SPS HE. VALVE MN B	MDC-25	CB27	7.5 AMP
RCS	RCS GAGING MN B	MDC-25	CB17	5 AMP
	RCS PROP ISOL MN B	MDC-25	CB15	15 AMP
	RCS C/M-S/M TRANSFER MN B	MDC-25	CB9	15 AMP
	RCS HEATERS A MN B	MDC-21	CB1	5 AMP
	RCS HEATERS C MN B	MDC-21	CB3	5 AMP

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BATTERY BUS A

	<u>CB NOMENCLATURE</u>	<u>PANEL LOCATION</u>	<u>CB NO.</u>	<u>RATING</u>
EPS	BAT A PWR ENTRY	LEB-150	CB21	100 AMP
	AMIN A BAT BUS A	RHEB-203	CB12	80 AMP
	POSTLDG BAT BUS A	RHEB-203	CB8	25 AMP
	BAT RLY BUS BAT A	MDC-22	CB13	20 AMP
	BATTERY CHARGER BAT A CHGE	MDC-22	CB78	10 AMP

SEQUENTIAL

	EDS 1 BAT A	MDC-25	CB52	5 AMP
	MESC LOGIC A BAT A	MDC-22	CB21	15 AMP
	ELS A BAT A FLOAT BAG 3	MDC-25	CB8	5 AMP
	UPRIGHTING SYSTEM COMPR NO.1	RHEB-205	CB4	25 AMP
	MESC ARM A BAT A	MDC-22	CB19	5 AMP
SPS	SPS GIMBAL MOTOR CONTROL PITCH 1 BAT A	MDC-25	CB26	15 AMP
	SPS GIMBAL MOTOR CONTROL YAW 1 BAT A	MDC-25	CB24	15 AMP

BATTERY BUS B

EPS	BAT B PWR ENTRY	LEB-150	CB22	100 AMP
	MAIN B BAT BUS B	RHEB-203	CB9	80 AMP
	POSTLDG BAT BUS B	RHEB-203	CB7	25 AMP
	BAT RLY BUS BAT B	MDC-22	CB12	20 AMP
	BATTERY CHARGER BAT B CHGE	MDC-22	CB77	10 AMP

SEQUENTIAL

	EDS 3 BAT B	MDC-25	CB53	5 AMP
	MESC LOGIC B BAT B	MDC-22	CB20	15 AMP
	MESC ARM B BAT B	MDC-22	CB18	5 AMP
	ELS B BAT B	MDC-22	CB7	5 AMP
	UPRIGHTING SYSTEM COMP NO.2	RHEB-205	CB5	25 AMP

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	<u>CB NOMENCLATURE</u>	<u>PANEL LOCATION</u>	<u>CB NO.</u>	<u>RATING</u>
SPS	SPS GIMBAL MOTOR CONTROL PITCH 2 BAT B	MDC-25	CB25	15 AMP
	SPS GIMBAL MOTOR CONTROL YAW 2 BAT B	MDC-25	CB23	15 AMP
<u>BATTERY C</u>				
EPS	BAT CHGR BAT C	LEB-150	CB20	5 AMP
	BAT C PWR POSTLANDING ENTRY	LEB-150	CB19	100 AMP
	EDS 2 BAT C	MDC-25	CB54	5 AMP
<u>CB19 (BAT C PWR POSTLANDING ENTRY)</u>				
EPS	MAIN A BAT C	RHEB-203	CB11	80 AMP
	MAIN B BAT C	RHEB-203	CB10	80 AMP
	POST LDG BAT C	RHEB-203	CB13	25 AMP
<u>FLIGHT AND POSTLANDING BUS</u>				
ECS	POSTLANDING VENT FAN PL BUS FLOAT BAG 2	MDC-25	CB63	5 AMP
	POSTLANDING FLOAT BAG 1 PL BUS	MDC-25	CB68	5 AMP
<u>INSTR & COMM</u>				
	TELECOMMUNICATIONS GROUP 4	MDC-22	CB46	7.5 AMP
	TELECOMMUNICATIONS GROUP 5	MDC-22	CB45	7.5 AMP
<u>PYRO BUS A</u>				
<u>SEQUENTIAL</u>				
	PYRO A SEQ A	LEB-150	CB14	20 AMP
RCS	PYRO A RCS FUEL DUMP	LEB-150	CB15	20 AMP
<u>PYRO BUS B</u>				
<u>SEQUENTIAL</u>				
	PYRO B SEQ B	LEB-150	CB17	20 AMP
RCS	PYRO B RCS FUEL DUMP	LEB-150	CB16	20 AMP

BATTERY RELAY BUS

	<u>CB NOMENCLATURE</u>	<u>PANEL LOCATION</u>	<u>CB NO.</u>	<u>RATING</u>
EPS	FUEL CELL 1 H ₂ & O ₂ VALVE	MDC-22	CB63	10 AMP
	FUEL CELL 2 H ₂ & O ₂ VALVE	MDC-22	CB82	10 AMP
	FUEL CELL 3 H ₂ & O ₂ VALVE	MDC-22	CB86	10 AMP
	SNSR UNIT DC BUS A	MDC-21	CB5	5 AMP
	SNSR UNIT DC BUS B	MDC-21	CB6	5 AMP
	INVERTER CONTROL 1	MDC-22	CB39	10 AMP
	INVERTER CONTROL 2	MDC-22	CB38	10 AMP
	INVERTER CONTROL 3	MDC-22	CB37	10 AMP
	SNSR UNIT AC BUS 1	MDC-21	CB7	5 AMP
	SNSR UNIT AC BUS 2	MDC-21	CB8	5 AMP
	FUEL CELL 1 BUS CONT	MDC-22	CB65	10 AMP
	FUEL CELL 2 BUS CONT	MDC-22	CB84	10 AMP
	FUEL CELL 3 BUS CONT	MDC-22	CB88	10 AMP
<u>AC BUS NO. 1</u>				
EPS	AC SNSR SIG AC 1	MDC-25	CB48	2 AMP
	FUEL CELL 1 CIR & SEP MOTORS	MDC-22	CB64	3 AMP
	FUEL CELL 2 CIR & SEP MOTORS	MDC-22	CB83	3 AMP
	FUEL CELL 3 CIR & SEP MOTORS	MDC-22	CB87	3 AMP
ECS	GAS ANAL AC 1	MDC-22	CB116	2 AMP
	ECS CABIN AIR FAN 1 AC 1φA	MDC-22	CB76	2 AMP
	ECS CABIN AIR FAN 1 AC 1φB	MDC-22	CB75	2 AMP
	ECS CABIN AIR FAN 1 AC 1φC	MDC-22	CB74	2 AMP
	ECS SUIT COMPRESSORS AC 1φA	MDC-22	CB33	2 AMP

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	<u>CB NOMENCLATURE</u>	<u>PANEL LOCATION</u>	<u>CB NO.</u>	<u>RATING</u>
ECS	ECS SUIT COMPRESSORS AC 1 φB	MDC-22	CB32	2 AMP
	ECS SUIT COMPRESSORS AC 1 φC	MDC-22	CB31	2 AMP
	ECS RAD VALVE AC 1 1A	MDC-22	CB70	2 AMP
	ECS RAD VALVE AC 1 2B	MDC-22	CB69	2 AMP
	ECS GLYCOL PUMPS AC 1 φA	MDC-22	CB27	2 AMP
	ECS GLYCOL PUMPS AC 1 φB	MDC-22	CB26	2 AMP
	ECS GLYCOL PUMPS AC 1 φC	MDC-22	CB25	2 AMP
CRYO	CRYOGENIC TANK FAN MOTORS 1 AC 1 φA	MDC-22	CB100	2 AMP
	CRYOGENIC TANK FAN MOTORS 1 AC 1 φB	MDC-22	CB99	2 AMP
	CRYOGENIC TANK FAN MOTORS 1 AC 1 φC	MDC-22	CB98	2 AMP
	CRYOGENIC SYSTEM QTY AMPL 1 AC 1 φC	MDC-22	CB44	2 AMP
INSTRUMENTATION & COMM				
	TELECOMMUNICATIONS S-BAND	MDC-22	CB51	2 AMP
	TELECOMMUNICATIONS GROUP 6	MDC-22	CB50	2 AMP
	TELECOMMUNICATIONS GROUP 1	MDC-22	CB49	2 AMP
	TELECOMMUNICATIONS GROUP 2	MDC-22	CB48	2 AMP
	COMM C-BAND XPNDR	MDC-22	CB120	2 AMP
G&N	G&N VIEWER AC 1	MDC-22	CB93	2 AMP
SCS	SCS GROUP 1 AC 1	MDC-25	CB46	2 AMP
	SCS GROUP 2 AC 1	MDC-25	CB67	2 AMP
SPS	SPS GAGING AC 1	MDC-25	CB20	2 AMP

*

	<u>CB NOMENCLATURE</u>	<u>PANEL LOCATION</u>	<u>CB.NO.</u>	<u>RATING</u>
	<u>AC BUS NO. 2</u>			
EPS	FUEL CELL 1 CIR & SEP MOTORS	MDC-22	CB64	3 AMP
	FUEL CELL 2 CIR & SEP MOTORS	MDC-22	CB83	3 AMP
	FUEL CELL 3 CIR & SEP MOTORS	MDC-22	CB87	3 AMP
	AC SNSR SIG AC 2	MDC-25	CB47	2 AMP
ECS	ECS CABIN AIR FAN 2 AC 2 ϕ A	MDC-22	CB73	2 AMP
	ECS CABIN AIR FAN 2 AC 2 ϕ B	MDC-22	CB72	2 AMP
	ECS CABIN AIR FAN 2 AC 2 ϕ C	MDC-22	CB71	2 AMP
	ECS SUIT COMPRESSORS AC 2 ϕ A	MDC-22	CB30	2 AMP
	ECS SUIT COMPRESSORS AC 2 ϕ B	MDC-22	CB29	2 AMP
	ECS SUIT COMPRESSORS AC 2 ϕ C	MDC-22	CB28	2 AMP
	ECS RAD VALVE AC 2 1B	MDC-22	CB68	2 AMP
	ECS RAD VALVE AC 2 2A	MDC-22	CB67	2 AMP
	ECS GLYCOL PUMPS AC 2 ϕ A	MDC-22	CB24	2 AMP
	ECS GLYCOL PUMPS AC 2 ϕ B	MDC-22	CB23	2 AMP
	ECS GLYCOL PUMPS AC 2 ϕ C	MDC-22	CB22	2 AMP
CRYO	CRYOGENIC TANK FAN MOTORS 2 AC 2 ϕ A	MDC-22	CB103	2 AMP
	CRYOGENIC TANK FAN MOTORS 2 AC 2 ϕ B	MDC-22	CB102	2 AMP
	CRYOGENIC TANK FAN MOTORS 2 AC 2 ϕ C	MDC-22	CB101	2 AMP
	CRYOGENIC SYSTEM QTY AMPL 2 AC 2 ϕ C	MDC-22	CB90	2 AMP



*

	<u>CB NOMENCLATURE</u>	<u>PANEL LOCATION</u>	<u>CB NO.</u>	<u>RATING</u>
INST & COMM	TELECOMMUNICATIONS S-BAND	MDC-22	CB51	2 AMP
	TELECOMMUNICATIONS GROUP 6	MDC-22	CB50	2 AMP
	TELECOMMUNICATIONS GROUP 1	MDC-22	CB49	2 AMP
	TELECOMMUNICATIONS GROUP 2	MDC-22	CB48	2 AMP
	COMM C-BAND XPNDR	MDC-22	CB120	2 AMP
G&N	G&N VIEWER AC 2	MDC-22	CB62	2 AMP
SCS	SCS GROUP 1 AC 2	MDC-25	CB45	2 AMP
	SCS GROUP 2 AC 2	MDC-25	CB66	2 AMP
SPS	SCS GAGING AC 2	MDC-25	CB19	2 AMP



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3.5 AC EQUIPMENT SUMMARY

<u>COMPONENT</u>	<u>PHASES USED (NORMAL OPERATION)</u>	<u>BUS USED</u>
F/C 1 COOLANT PUMP	3 ϕ	AC1/AC2
F/C 1 H ₂ PUMP	3 ϕ	AC1/AC2
F/C 1 pH SENSOR	ϕ A	AC1/AC2
F/C 2 COOLANT PUMP	3 ϕ	AC1/AC2
F/C 2 H ₂ PUMP	3 ϕ	AC1/AC2
F/C 2 pH SENSOR	ϕ A	AC1/AC2
F/C 3 COOLANT PUMP	3 ϕ	AC1/AC2
F/C 3 H ₂ PUMP	3 ϕ	AC1/AC2
F/C 3 pH SENSOR	ϕ A	AC1/AC2
SUIT COMPRESSOR NO.1	3 ϕ	AC1/AC2
SUIT COMPRESSOR NO.2	3 ϕ	AC1/AC2
CABIN AIR FAN NO.1	3 ϕ	AC1
CABIN AIR FAN NO.2	3 ϕ	AC2
WASTE MGT BLOWER	3 ϕ	AC1
CABIN TEMP CNTL BOX	ϕ C	AC2
GLYCOL PUMP NO.1	3 ϕ	AC1/AC2
GLYCOL PUMP NO.2	3 ϕ	AC1/AC2
GLYCOL EVAP BACK PRESS. CNTL	ϕ C	AC1
GLYCOL TEMP CNTL	ϕ A	AC1
GLYCOL EVAL H ₂ O FLOW CNTL	ϕ A	AC2
AC SENSING UNIT	3 ϕ	AC1/AC2
AC VOLTMETER SELECT SW	3 ϕ	AC1/AC2
ECS RAD 1A ISOL VLV	ϕ A	AC1
ECS RAD 1B ISOL VLV	ϕ A	AC2
ECS RAD 2A ISOL VLV	ϕ C	AC2
ECS RAD 2B ISOL VLV	ϕ B	AC1
CRYO O ₂ TANK NO.1 FANS	3 ϕ	AC1
CRYO O ₂ TANK NO.2 FANS	3 ϕ	AC2

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<u>COMPONENT</u>	<u>PHASES USED (NORMAL OPERATION)</u>	<u>BUS USED</u>
CRYO H TANK NO. 1 FANS	3 ϕ	AC1
CRYO H TANK NO. 2 FANS	3 ϕ	AC2
CRYO O TANK NO. 1 FANS QTY UNIT	ϕ C	AC1
CRYO O TANK NO. 2 FUEL QTY UNIT	ϕ C	AC2
CRYO H TANK NO. 1 FUEL QTY UNIT	ϕ C	AC1
CRYO O TANK NO. 1 FUEL QTY UNIT	ϕ C	AC2
TELECOM PCM & DATA STORAGE EQUIP	3 ϕ	AC1/AC2
TELECOM SIG COND EQUIP & S-BAND PWR AMPL	3 ϕ	AC1/AC2
PREMOD PROCESSOR & UNIFIED S-BAND (GR. 2)	3 ϕ	AC1/AC2
FLIGHT QUAL RCDR & C-BAND XPONDER & VHF/FM XMITTER (GR. 1)	3 ϕ	AC1/AC2
G&N VIEWER LIGHTING	ϕ B	AC1/AC2
SCS GROUP 1	3 ϕ	AC1/AC2
SCS GROUP 2	3 ϕ	AC1/AC2
SCS GAGING UNIT	ϕ C	AC1/AC2
GAS ANALYZER	ϕ A	AC1

*

SECTION 4

CSM
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ENVIRONMENTAL

4.1 CM PRESSURIZATION

4.1.1 Cabin Pressure Control

A. Cabin Pressure Relief Valve

1. Configuration

- a. Two independent pressure relief valve sections with manual overrides.
- b. Either section will outflow to limit cabin-to-ambient ΔP (positive pressure relief).
- c. Either section will inflow to limit ambient to cabin ΔP (negative pressure relief).

2. Positions (LHEB 307)

- a. CLOSED - Will not open automatically.
- b. NORMAL - Automatic with full flow.
- c. BOOST and ENTRY - Automatic with full flow.
- d. DUMP - Manually open with full flow (one relief valve does not have dump position).

3. Positive Pressure Relief

- a. $6.0 \begin{matrix} +0.2 \\ -0.4 \end{matrix}$ psi cabin-to-ambient ΔP .

4. Negative Pressure Relief

- a. 25 inch H₂O ambient-to-cabin ΔP maximum.

B. Cabin Pressure Regulator

1. Configuration

- a. Two flow-limited, absolute pressure, demand regulators operating in parallel and inflowing to cabin.
- b. Regulators maintain cabin at 5 ± 0.2 psia and shutoff during depressurized cabin (pressure below 3.5 psia).

2. (LHEB 314) Cabin Repress

- a. Manual control bypasses regulators to repressurize cabin after emergency.

3. Flows

- a. Pressure regulators: 1.4 lb/hr O₂ maximum (flow limited) through both regulators at 3.5 to 5.2 psia cabin (0.7 lb/hr O₂ flow through each regulator).

*

- b. Repressurization Valve: 0.1 lb/minute.
- C. Emergency O₂ Inflow Control Valve
 - 1. Valve Position (Emergency Cabin Press.) (LHEB 314)
 - a. "1" - Flow to regulator 1 only.
 - b. "2" - Flow to regulator 2 only.
 - c. NORMAL - Flow to regulator 1 and 2.
 - d. OFF - Shuts OFF flow to both regulators.
 - 2. Flow Capacity
 - a. Limiter in Oxygen Pressure Regulator limits emergency O₂ flow to 0.67 lb/minute O₂ with 4.2 to 4.6 psia cabin. (Either valve can flow 0.67 lb/minute.)
- D. Oxygen Pressure Regulator
 - 1. Valve Positions (Main Regulator) LHEB 314
 - a. "1" - Flow to regulator 1 only.
 - b. "2" - Flow to regulator 2 only.
 - c. NORMAL - Flow to regulator 1 and 2.
 - d. OFF - Shuts OFF SM and CM supply to both regulators
 - 2. Flow Capacity
 - a. Limiter at outlet of O₂ Pressure Regulator limits flow to 0.67 lb/minute O₂. (either regulator can supply 0.67 lb/minute.)
 - 3. Regulated Pressure
 - a. 90 to 110 psig.
 - 4. Relief Valve
 - a. With failed open regulators, limits downstream pressure to 130 ± 10 psig.
- E. Water and Glycol Tank Pressure Regulator Valves (LHEB 314)
 - 1. Valve Position
 - a. "1" - Flow to regulator 1 only.
 - b. "2" - Flow to regulator 2 only.
 - c. NORMAL - Flow to regulator 1 and 2.
 - d. REGULATOR OFF - Shuts OFF flow to both regulators.
 - 2. Regulated Pressure
 - a. 20 ± 2 psig.

*

F. Water and Glycol Tank Pressure Relief Valves (LHEB 314)

1. Valve Position

- a. "1" - Relieves from 1 only.
- b. "2" - Relieves from 2 only.
- c. NORMAL - Relieves from 1 and 2.
- d. RELIEF OFF - Will not relieve.

2. Relief Pressure

- a. 25 ± 2 psig.

*
4.1.2 Water Supply

A. Potable Water Tank

1. Configuration

- a. Cylindrical tank with pressurized bladder for water expulsion at zero "g".
- b. Transducer for water quantity consists of potentiometer driven by a string attached to bladder.

2. Storage Capacity

$36 \begin{smallmatrix} +3 \\ -0 \end{smallmatrix}$ lb H₂O

3. Expulsion Gas Pressure

18 to 27 psig

4. Water Delivery Rate

5 lb/minute minimum at 18 psig expulsion pressure.

B. Waste Water Tank

1. Configuration

Same as potable water tank.

2. Storage Capacity

$56 \begin{smallmatrix} +3 \\ -0 \end{smallmatrix}$ lb H₂O

3. Expulsion Gas Pressure

18 to 27 psig

4. Water Delivery Rate

11 lb/minute minimum at 18 psig expulsion rate.

C. Waste Tank Inlet Valve (LHEB 315)

1. Valve Position

CLOSE - Prevents flow of fuel cell or SM water to Waste Water Tank.

AUTO - Allows fuel cell or SM water to flow into Waste Water Tank.

2. Crack and Reseat

Crack, full flow and reseat with 4.5 to 6.5 psi ΔP range.

3. Flow Capacity

12 lb/hr H₂O minimum.

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D. Water Pressure Relief Valve (LHEB 315)

1. Valve Position

- a. "1" - Allows overboard venting or dumping of H₂O through relief valve 1 only.
- b. "2" - Allows overboard venting or dumping of H₂O through relief valve 2 only.
- c. BOTH - Allows overboard venting or dumping of H₂O through relief valves 1 and 2.
- d. OFF - Prevents overboard venting or dumping of H₂O.

2. Flow Capacity

0.3 gpm H₂O minimum at 48 psi ΔP.

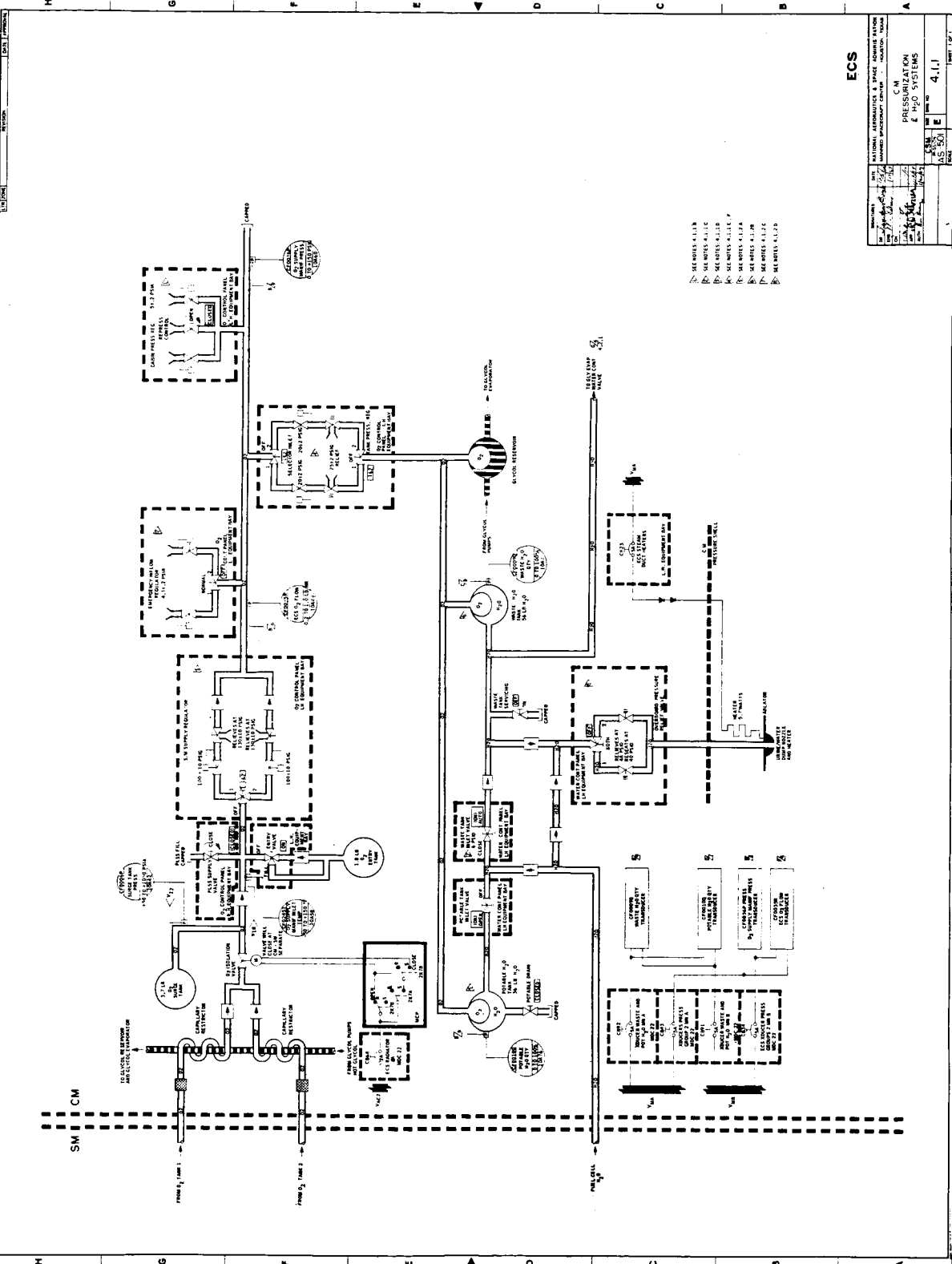
3. Reseat

40 psi ΔP minimum

ECS

DATE	REV	BY	CHKD	APP'D
1/10/68	1	J. J. ...	J. J. ...	J. J. ...
NATIONAL AERONAUTICS & SPACE ADMINISTRATION RESEARCH AND DEVELOPMENT CENTER				
C.M. PRESENTATION & H2O SYSTEMS				
SM	E	4, L1		
AS	500			

- SEE NOTE 4.1.1.B
- SEE NOTE 4.1.1.C
- SEE NOTE 4.1.1.D
- SEE NOTE 4.1.1.E
- SEE NOTE 4.1.1.F
- SEE NOTE 4.1.1.G
- SEE NOTE 4.1.1.H
- SEE NOTE 4.1.1.I
- SEE NOTE 4.1.1.J



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4.2 COOLANT NOTES

4.2.1 General

The ECS radiator is not connected into the water-glycol coolant loop for Mission AS-501. GSE will supply the cooling during ground operation, and evaporative cooling will be employed during flight. Both glycol pumps will be turned on prior to hatch closeout for redundancy. Pump 1 will be turned on by closing Circuit Breakers 25 through 27 on MDC 22. Pump 2 will be turned on by closing Circuit Breakers 22 through 24 and setting ECS GLYCOL PUMP Switch on MDC 21 to PUMP 2 - ac 2.

The following events will be accomplished by the MCP at the specified times indicated.

- A. Start ECS Operation (T-75 seconds)
 - 1. Steam Pressure Control to AUTO by closure of 2K56 in MCP.
 - 2. Glycol Shutoff Valve closed by closure of 2K8 in MCP.
 - 3. If there is a hold after T-75 seconds, the Glycol Shutoff valve will be opened by a COUNTDOWN RESET command through GSE.
- B. LET JETT (Approx 185 seconds)
 - 1. Glycol Wetness Control START by closure of 2K6 C and D in MCP.
- C. CM/SM SEP
 - 1. O₂ Isolation Valve CLOSED by 2K7 in MCP.
 - 2. Glycol Shutoff Valve CLOSED by 2K8 in MCP.

4.2.2 Coolant Circuit Notes

- A. Glycol Evaporator
 - 1. Heat Transfer Rate
7620 Btu/hr maximum
 - 2. Water Evaporation Rate
7.5 lb/hr maximum
- B. Glycol Reservoir
Capacity - 9.76 lb water-glycol.

*

C. Glycol Pump

Flow capacity - 200 lb/hr water-glycol at 100°F inlet and 29.5 psi minimum pressure rise. Inlet pump pressure 7.5 ± 1.5 psig.

D. Accumulator

Quantity - 1.36 lb water-glycol maximum.

E. Cabin Heat Exchanger

Cooling Heat Transfer AUTO 1250 Btu/hr.

NOTE

Total water-glycol quantity in system approximately 20 pounds.

4.2.3 Glycol Evaporator Temp Control Subsystem

The glycol evaporator is designed to maintain the temperature output of the evaporator between 40 to 50.5°F.

Activation of the steam pressure control section takes place when the input to the evaporator from the glycol pumps rises to the 48°F to 50.5°F range. The evaporator outlet temperature sensor supplies the controlling signal to the steam pressure control section for positioning the steam pressure control valve. Upon command from the control unit, the valve is opened a specific amount required to regulate steam duct pressure.



*

Initial movement of the valve out of the CLOSED position, positions a switch within the valve assembly that activates the water control section. After LET JETT, this unit automatically controls the amount of water admitted to the evaporator by the solenoid-operated water inlet control valve. The water control unit activates the valve in response to signals received from the evaporator wick temperature sensor and the reference glycol inlet temperature sensor. ON-OFF cycling of the water inlet control valve and steam pressure control valve continues as long as evaporative cooling is required.

Steam pressure indications should read between 0.125 and 0.135 for low heat loads, and between 0.097 and 0.106 for high heat loads.

4.2.4 Cabin Temperature Control Valve

The cabin temperature control valve is a motor driven modulating type, consisting of two mechanically-linked, three-way valves, and a manual override. The motor produces rotary mechanical motion for positioning the three-way valves, which function as inflow and outflow valves for the cabin heat exchanger.

CONDITION	FULL FLOW	ZERO FLOW
MAX COOLING	A&C	B&D
MAX HEATING	B&D	A&C
NEITHER COOLING OR HEATING	B&C	A&D

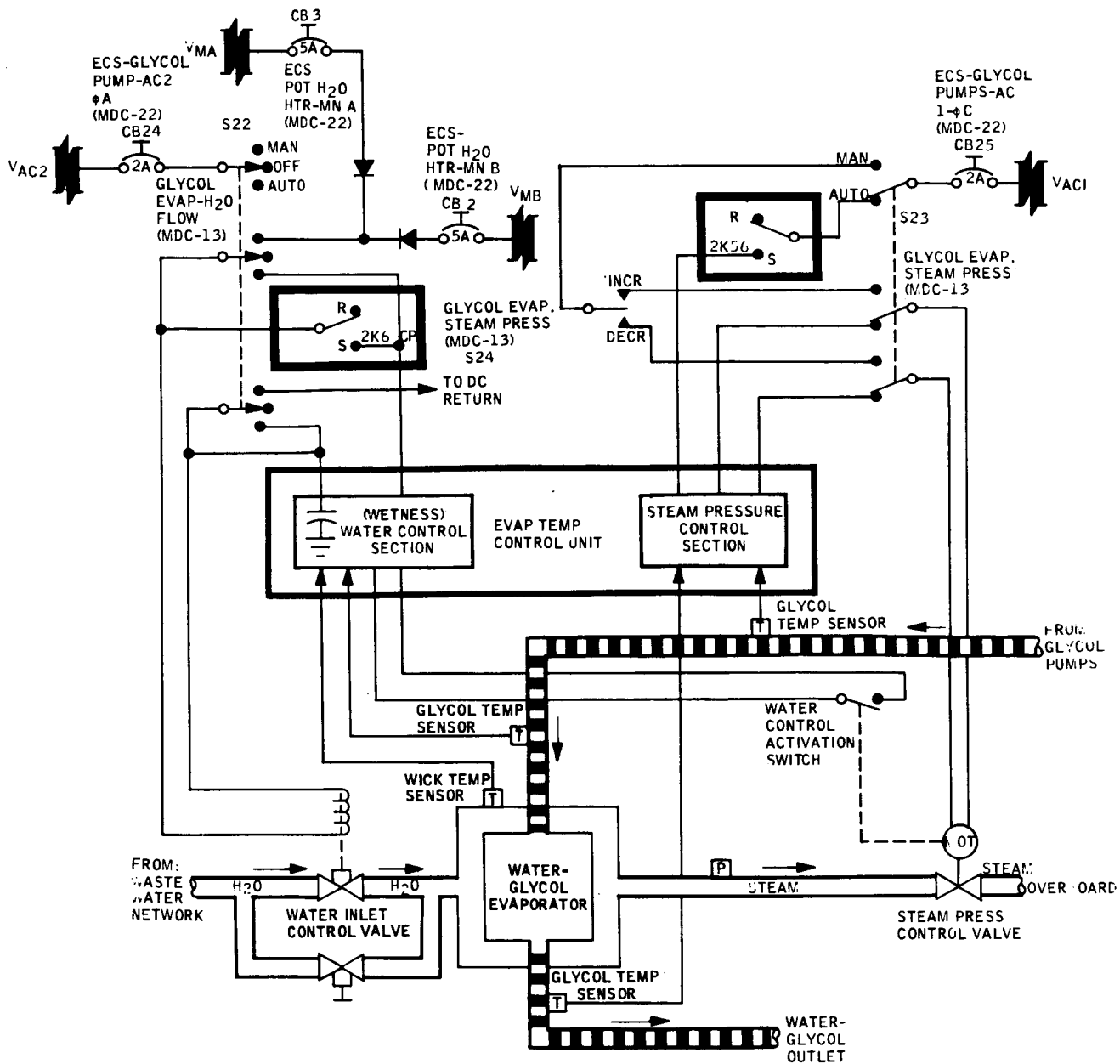
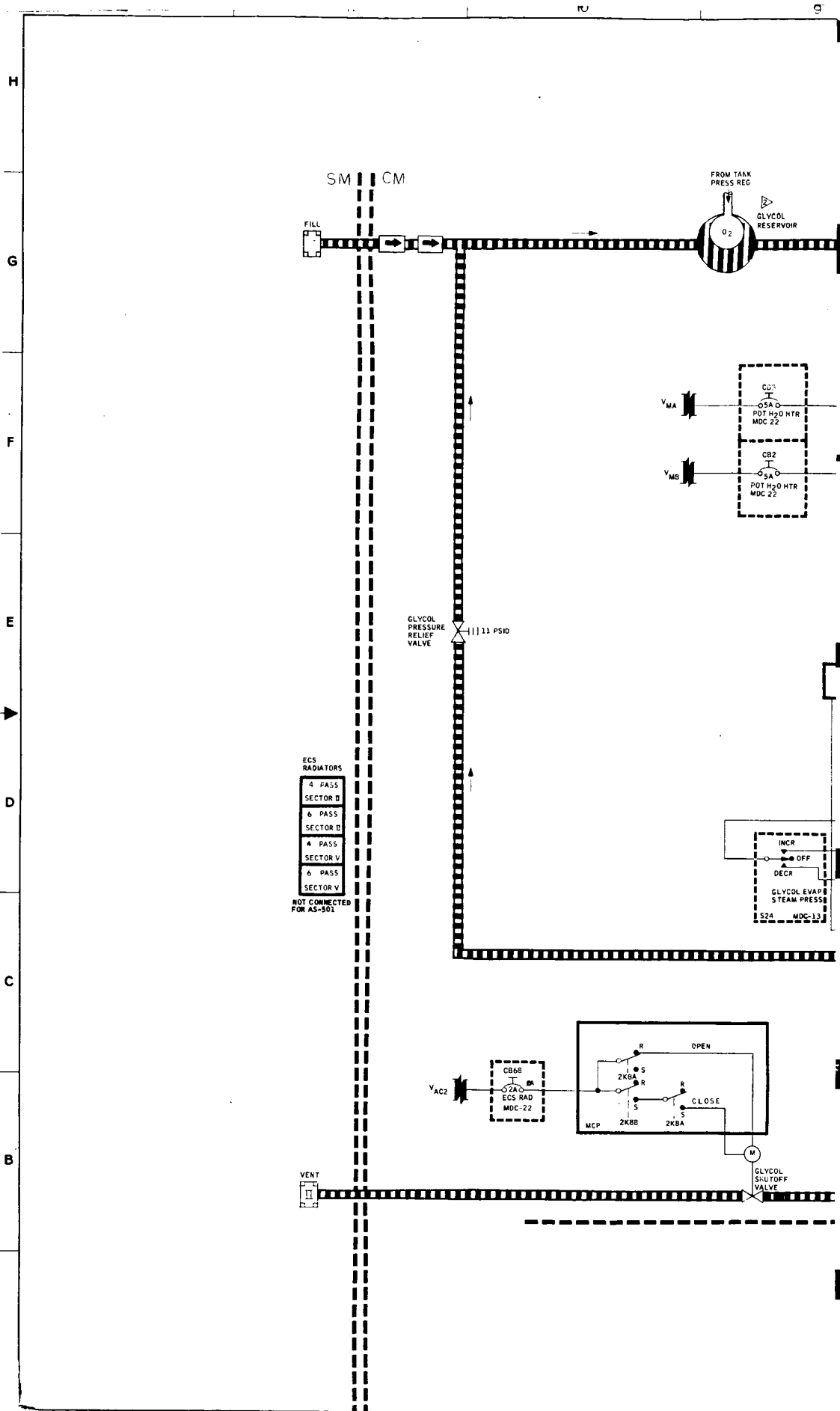
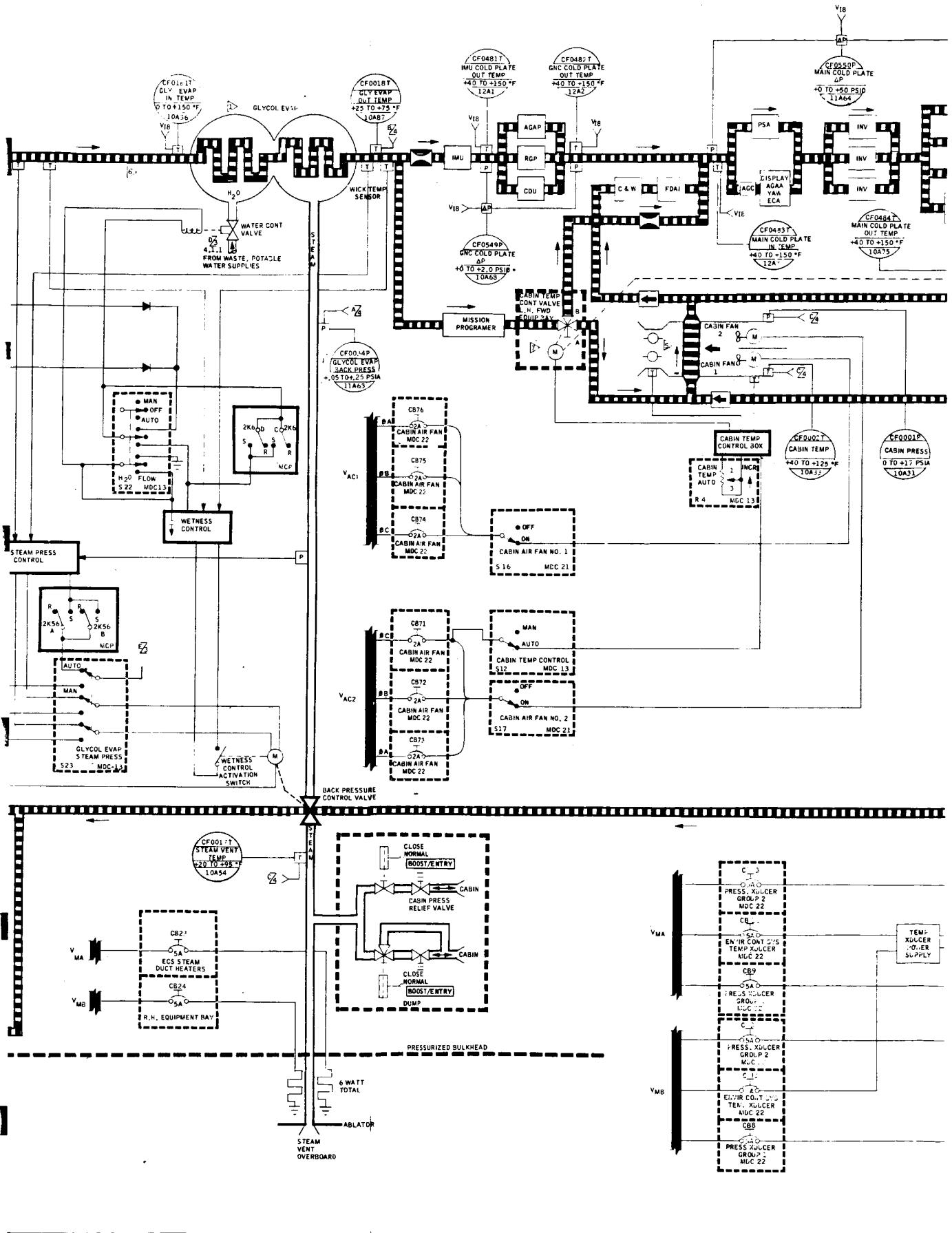
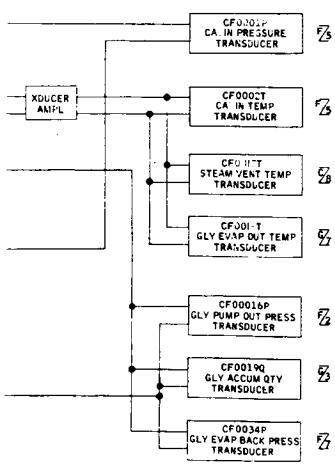
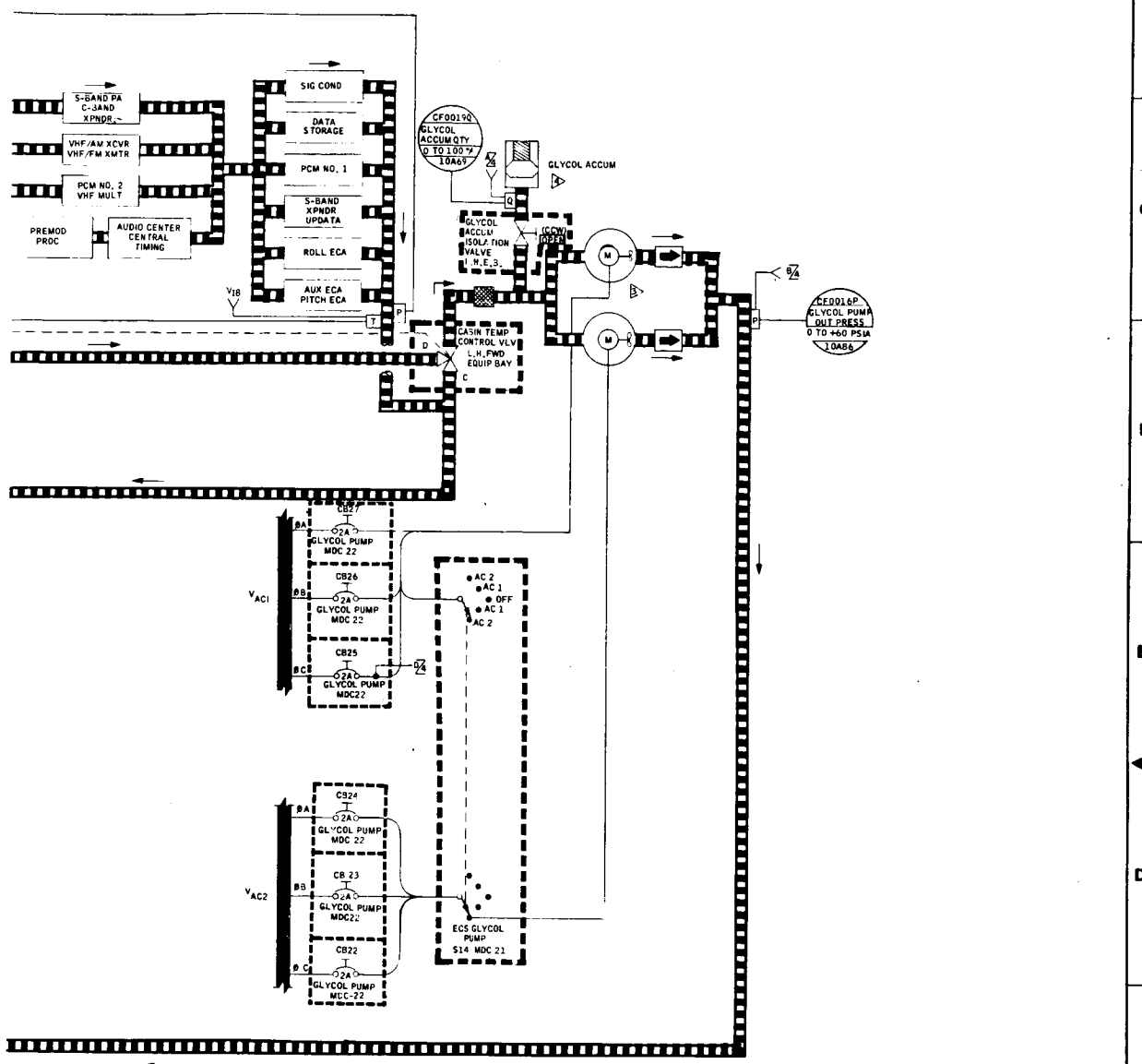


FIGURE 4.1 WATER-GLYCOL TEMPERATURE CONTROL DIAGRAM







- ▶ SEE NOTES: 4.2.2A
- ▶ SEE NOTES: 4.2.2B
- ▶ SEE NOTES: 4.2.2C
- ▶ SEE NOTES: 4.2.2D
- ▶ SEE NOTES: 4.2.2E
- ▶ SEE NOTES: 4.2.3
- ▶ SEE NOTES: 4.2.4

ECS

SIGNATURES		DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION	
DR		11/10/67	MANNED SPACECRAFT CENTER - HOUSTON, TEXAS	
ENG		11/16/67		
CH				
NAA			GLYCOL COOLING	
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AUTH				
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		AS-501	SCALE	SHEET 1 OF 1

CRYOGENICS

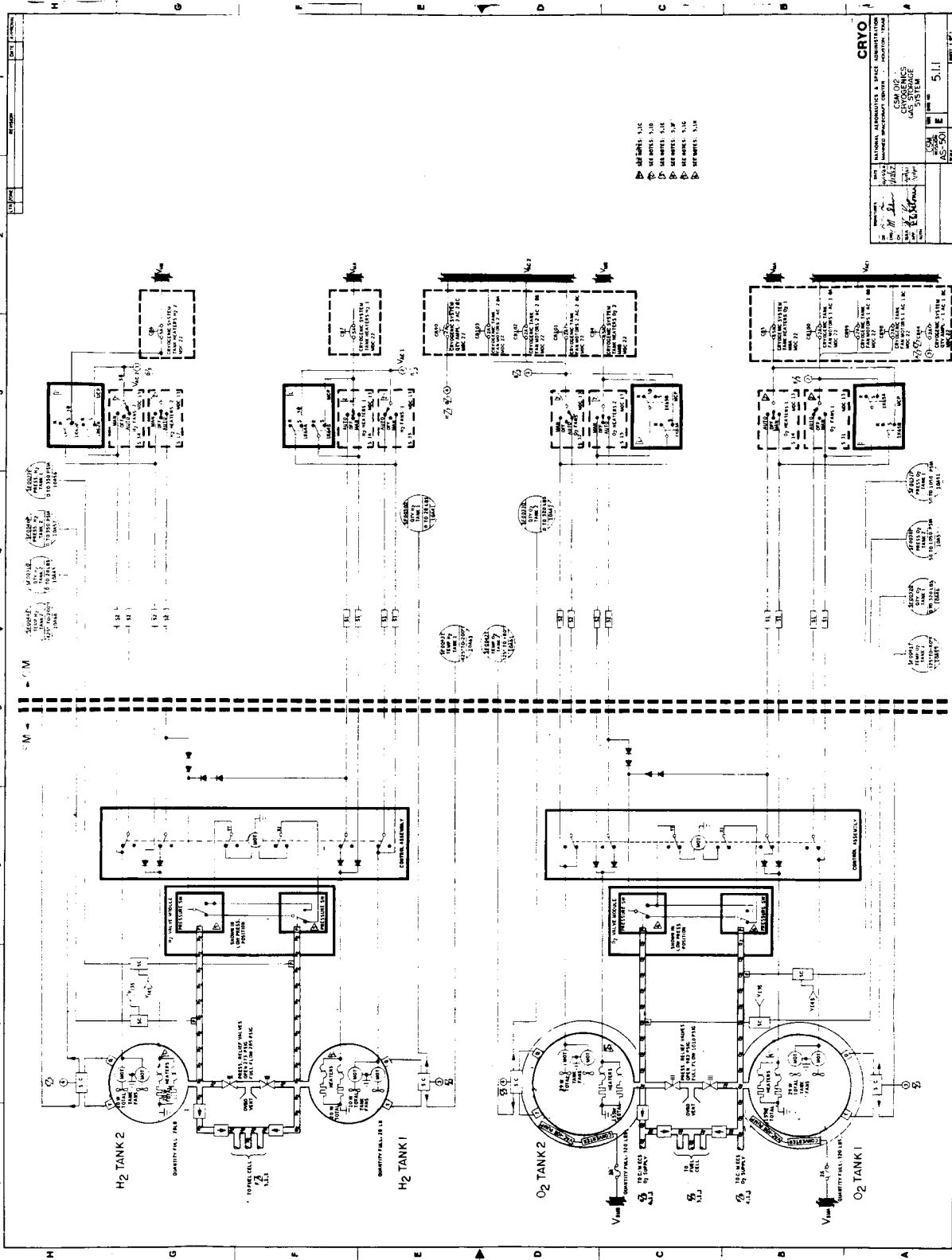
5.1 NOTES, CRYOGENICS, GENERAL

- A. Hydrogen tanks will be loaded to 45 percent of maximum.
(approx 13.0 lbs)
- B. Oxygen tanks will be loaded to 33 percent of maximum.
(approx 105 lbs)
- C. Real-Time commands can be sent to turn on the heaters and fans in the O₂ and H₂ tanks. The commands bypass the heater and fan switches (MAN-OFF-AUTO) and apply power directly to the heaters and fans until a reset command is sent. The following is a list-
ing of the Real-Time Commands for cryogenics:

RTC 64	H ₂ No.2	Heater-Fans
RTC 65	O ₂ No.2	Heater-Fans
RTC 66	H ₂ No.1	Heater-Fans
RTC 67	O ₂ No.1	Heater-Fans
RTC 70	Reset RTC 64-67	
- D. For AS-501 the O₂ and H₂ heater switches on MDC 13 will be turned OFF, and commanded ON as required. The O₂ and H₂ Fan switches on MDC 13 will be turned to AUTO.
- E. Cryogenic heaters thermo-switches in the Hydrogen Tanks, open to shut off heaters when the sensed temperature is 90°F or above. The thermo-switches close to turn heaters on when the sensed temperature is 70°F or below. Sensed temperature is that of the inner wall of the Hydrogen Tank.
- F. Cryogenic heaters thermo-switches in the Oxygen Tanks, open to shut off heaters when the sensed temperature is 90°F or above. The thermo-switches close to turn on heaters when the sensed temperature is 70°F or below. Sensed temperature is that of the inner wall of the Oxygen Tank.
- G. The Hydrogen Tanks pressure switches close when the sensed pressure is 230 psia or below and open when the sensed pressure is 260 psia or above. Both pressure switches must be closed to operate Hydrogen Tanks fans.

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- H. The Oxygen Tanks pressure switches close when the sensed pressure is 865 psia or below and open when the sensed pressure is 935 psia or above. Both pressure switches must be closed to operate Oxygen Tanks fans.
- I. H₂ Flow Rate for Fuel Cells. $H_2 \text{ lb/hr} = 2.57 \times 10^{-3} \times I \text{ (ampere)}$
- J. O₂ Flow Rate for Fuel cells. $O_2 \text{ lb/hr} = 20.56 \times 10^{-3} \times I \text{ (ampere)}$



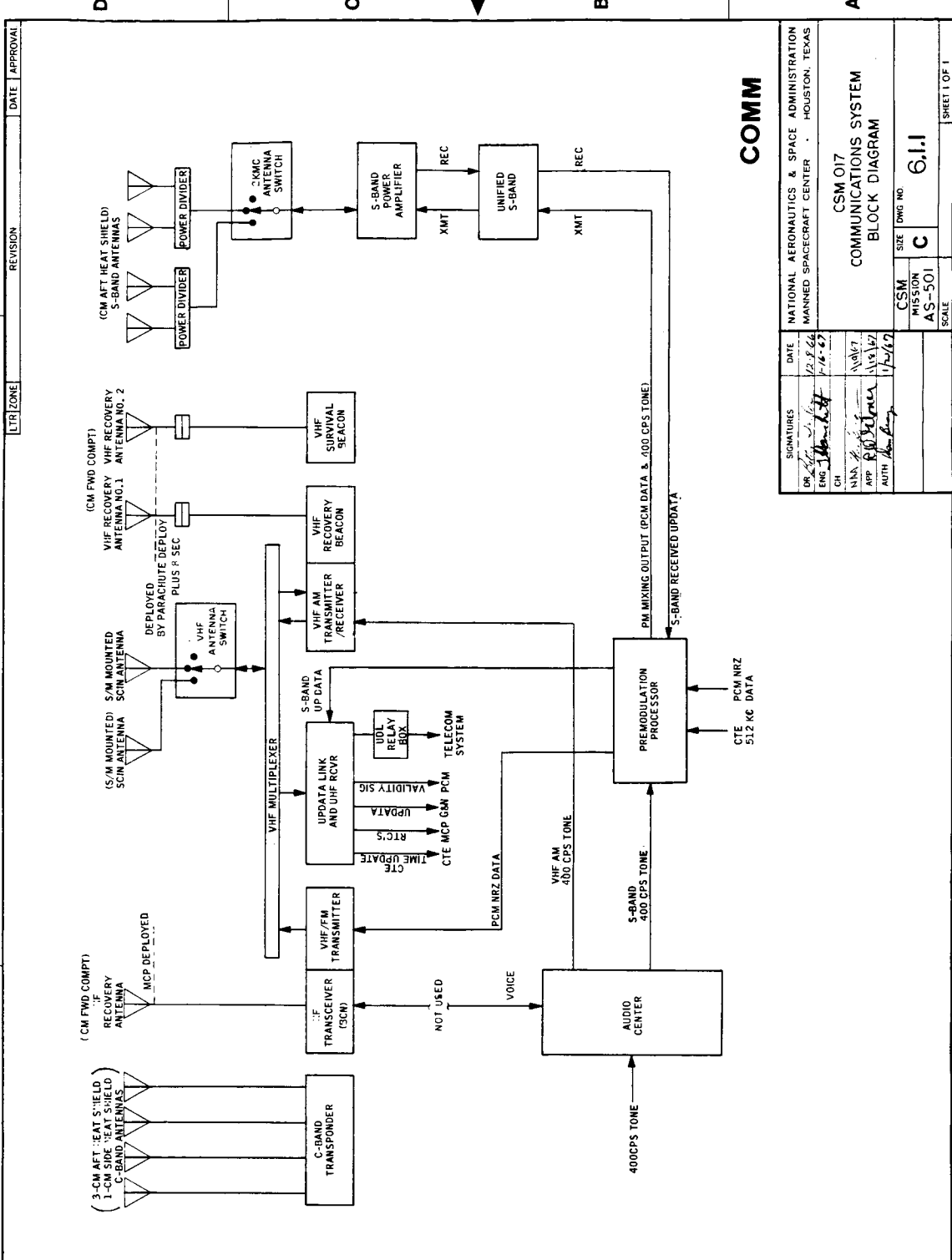
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SECTION 6
COMMUNICATIONS

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6.1 NOTES, COMMUNICATIONS SYSTEM BLOCK DIAGRAM

- A. Unified S-Band System Equipment
 - 1. PRN Ranging
 - 2. Downlink Voice (400 HZ Tone)
 - 3. PCM HBR and LBR Data (Real-Time Only)
 - 4. UDL Updata
- B. VHF AM Transceiver Equipment
 - 1. Downlink Voice (400 HZ Tone)
- C. VHF FM Transmitter Equipment
 - 1. PCM HBR Data (Real-Time Only)
 - 2. PCM LBR Data (Real-Time Only)
- D. C-Band Transponder Equipment
 - 1. Tracking
- E. Updata Link Equipment
 - 1. UHF FM Updata
 - 2. S-Band Updata
- F. HF Transceiver Equipment
 - 1. Recovery Beacon (CW)
- G. VHF Recovery Beacon Equipment
 - 1. Recovery Beacon
- H. VHF Survival Beacon Equipment
 - 1. Recovery Beacon
- I. See Table 6-6 for Updata Link Controlled Functions and Table 6-17 for MCP Automated Control Functions which operate Communication Equipment.
- J. See Drawings 11.2.1 thru 11.2.5 for all real-time commands to the MCP.



COMM

SIGNATURES		DATE		NATIONAL AERONAUTICS & SPACE ADMINISTRATION	
DR	<i>[Signature]</i>	12-8-61	12-8-61	MANNED SPACECRAFT CENTER HOUSTON, TEXAS	
ENR	<i>[Signature]</i>	1-16-62	1-16-62		
CH					
INSA	<i>[Signature]</i>	1-19-67	1-19-67	CSM 017	
APP	<i>[Signature]</i>	1-19-67	1-19-67	COMMUNICATIONS SYSTEM	
AUTH	<i>[Signature]</i>	1-19-67	1-19-67	BLOCK DIAGRAM	
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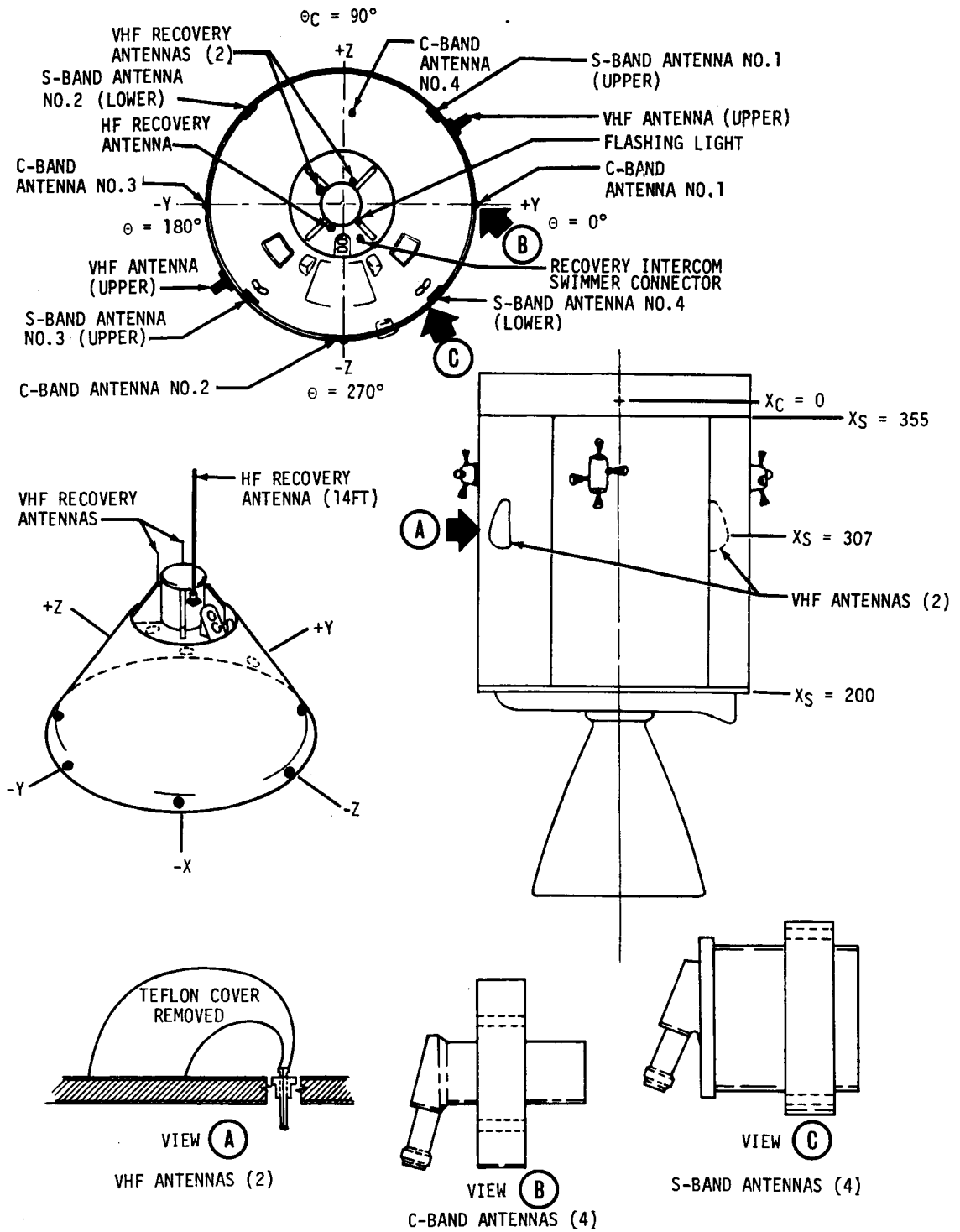


FIGURE 6.1 ANTENNA LOCATIONS

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6.2 COMMUNICATIONS SYSTEM EQUIPMENT

6.2.1 C-Band Transponder and Antenna Equipment

The C-Band Transponder is used in conjunction with ground instrumentation radars to provide range, rate, bearing and elevation tracking data during launch, boost, orbital and entry phases of the mission.

The Transponder receives either single or double pulse interrogations from the ground radar. When the two-pulse mode is chosen, the code interrogation pulse spacing must be shown in Table 6-1 for the transponder to reply. The transponder replies in a single pulse for each pulse or double pulse received with a fixed internal time delay. The time delay is to allow sufficient time for the antenna switch to select the proper antenna and to allow the ground operator to observe the skin track reply pulse for comparison with the transponded pulse.

The transponder will respond to interlaced interrogations from more than one radar with the limitations specified in Table 6-1. Nominal interrogation rate is 160 pps.

The transponder operates in conjunction with four circularly polarized resonant cavity Helix antennas, flush mounted and spaced 90 degrees apart about the spacecraft. The transponder decoder determines which antenna is receiving the strongest signal and switches the transmitter reply pulse to this antenna.

6.2.2 VHF FM Transmitter

The VHF FM Transmitter's sole function is to transmit NRZ PCM data to MSFN during launch, boost, earth orbit, and entry phases of the mission.

6.2.3 VHF AM Transceiver

The VHF AM Transceiver provides voice communications with MSFN during launch, boost, orbit, and entry phases of the mission. The transmitter portion of the transceiver can be used as a recovery beacon.

During Mission AS-501, a 400 HZ Tone from the audio center will be transmitted via the VHF AM Transceiver to the MSFN for voice simulation tests.

TABLE 6-1 C-BAND TRANSPONDER DATA

ITEM	C-BAND TRANSPONDER DATA
POWER	400 HZ, 3 ϕ , 115/200 Vac 75 Watts maximum at 500 PRF +28 Vdc Control Power
RECEIVER FREQUENCY	Tuneable: 5640 to 5740 MHZ Assigned: 5690 MHZ Stability: \pm 2 MHZ
RECEIVER SENSITIVITY	0 to -70 DBM with 95 percent reply minimum measured at RCVR input
RECEIVER BANDWIDTH	12 MHZ minimum at 30 DB points 60 MHZ maximum at 60 DB points
DECODER CODE SPACING	Accept: Double Pulse spaced within 6 ± 0.3 microseconds Reject: Double Pulse spaced outside 6 ± 0.8 microseconds Measured: Leading edge to leading edge
COMPARATOR AND ANTENNA SELECTION SWITCH	-70 to -55 DBM range requires at least 4 DB differential for Antenna Selection. -55 to -25 DBM range requires at least 6 DB Differential. -25 to 0 range not defined.
TRANSMITTER FREQUENCY	Tuneable: 5715 to 5815 MHZ Assigned: 5765 MHZ Stability: \pm 4 MHZ Drift: Less than 1 MHZ per minute
TRANSMITTER REPLY PULSE	Pulse Width: 0.75 ± 0.2 microseconds Rise Time: Less than 0.1 microseconds between 10 and 90 percent amplitude points Fall Time: Less than 0.25 microseconds
TRANSMITTER REPLY POWER	Peak Power greater than 2.5 kW averaged over pulse width at 70 percent amplitude.

* TABLE 6-1 C-BAND TRANSPONDER DATA (Concluded)

ITEM	C-BAND TRANSPONDER DATA (Concluded)
INTERROGATION RATE	1 to 1300 Interrogations per second Countdown less than 5 percent
NOISE FIRING	Less than 5 pulses per minute
TRANSMITTER RECOVERY TIME	Less than 70 microseconds after last reply
TRANSMITTER LOCKOUT	Yes - See TRANSMITTER RECOVERY TIME
FREQUENCY SEPARATION	Greater than 40 MHz
REPLY DELAY	A. Differential: 0.05 microseconds between receiver-transmitter combinations. B. Artificial: 3.0 plus or minus 0.2 microseconds C. Variations: 0.1 microseconds including antenna paths.
WARMUP TIME	2 minutes to reach frequency stability spec. 32 seconds to become operational

ITEM	TABLE 6-2 C-BAND ANTENNA DATA
C-BAND	Helix, Four, Spaced at 90 degrees about the spacecraft. (See Figure 6-1)
ANTENNA PATTERN	Omnidirectional in S/C YZ Plane. (RCP Polarization)
ANTENNA NULL	36.4 DB with Respect to Isotropic
ANTENNA GAIN	0 DB on Axis (Referenced to Isotropic Source)

TABLE 6-3 VHF - FM TRANSMITTER DATA

ITEM	VHF - FM TRANSMITTER DATA
POWER	+28 Vdc Control Power 1.5 Watts dc 400 HZ, 3 ϕ , 115/200 Vac 50 Watts ac
FREQUENCY	237.8 MHz Stability \pm 0.7134 MHz
RF POWER	10 Watts (40 DBM) Minimum
MODULATION DEVIATION	250 \pm 20 kc for 3V P-P Input from PCM TM
WARMUP TIME	2 minutes to meet specifications. 45 seconds for minimum operation stability.
ANTENNAS	(See Table 6-15)

*
TABLE 6-4 VHF-AM TRANSCEIVER DATA

ITEM	VHF AM TRANSCEIVER DATA
POWER	+28 Vdc 1.5 Watts Receive only 15.5 Watts Standby T/R 61.5 Watts Transmit
TRANSMIT FREQUENCY	296.8 MHz Stability \pm 0.8904 MHz
RECEIVER NO. 1 FREQUENCY	296.8 MHz (Simplex)
RECEIVER NO. 2 FREQUENCY	259.7 MHz (Duplex)
RECEIVER BAND PASS	70 kc at 6 DB Points
RECEIVER SENSITIVITY	0.5 Micro Volt at signal-to-noise ratio of 10 DB or better.
RECEIVER DISTORTION	Less than 10 percent
RECEIVER WARMUP	Less than 0.1 seconds
TRANSMIT POWER	5 Watts Minimum
TRANSMITTER WARMUP	Less than 120 seconds to meet specifications

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6.2.4 Uplink Equipment

The UDL provides the means for MSFN to update the CTE Time Accumulator, update the G&N Computer, and select certain vehicle functions during a mission. The equipment basically contains a UHF FM Receiver and a Command Decoder Unit.

The UDL has two operational modes, UHF and S-Band. These modes allow selection of either UHF FM received commands or S-Band received commands. The UHF FM command link is used for near-earth operation and is the primary mode. The S-Band link can be used in near-earth or deep space.

6.2.5 Uplink Real-Time Commands

Real-Time Commands effecting the communications systems are shown in Table 6-6.

6.2.6 The Unified S-Band Equipment (USBE)

The USBE provides near-earth backup for the C-Band Transponder (tracking), VHF AM Transceiver (voice), VHF FM Transmitter (PCM Data) and UHF Uplink Receiver (Uplink Commands) on Block I spacecrafts. The following S-Band information modes will be used during Mission AS-501. S-Band uplink information (PM only)

- A. Voice (Not Used)
- B. Uplink Link Commands
- C. Ranging

S-Band downlink information:

- A. PM Mode
 - 1. Voice (400 cps Tone)
 - 2. PCM Data (Real-Time only)
 - 3. Ranging
 - 4. Emergency Key (Not Used)
 - 5. Emergency Voice (Not Used)
- B. FM Mode (Not Used)
 - 1. Voice

- 2. PCM Data
- 3. TV
- 4. Recorded PCM Data



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TABLE 6-5 UPDATA LINK DATA

CSM
AS-501

ITEM	UPDATA LINK DATA
POWER	+28 Vdc 9.6 Watts (UHF Mode) 6.6 Watts (S-Band Mode)
RCVR FREQUENCY	450 MHz Stability \pm 2.25 MHz
FM CARRIER DEVIATION	\pm 50 MHz (See Modulation Signal)
MODULATION SIGNAL	2 KHz phase shift keyed 180 degrees at 1000 sub- bits per second composite with A 1 KHz Sync Tone. (See subbit characteristics.)
RECEIVER SENSITIVITY	-112 DBM for not more than 1 message rejection in 1000 messages sent.
<u>MESSAGE STRUCTURE</u>	
SUB-BIT CODE	5 sub-bits per information bit (See sub-bit characteristics.)
INFORMATION BITS	30 bits total a. Bits 1, 2, and 3 Vehicle Address b. Bits 4, 5, and 6 System Address c. Bits 7 thru 30 Message.
REAL-TIME COMMAND MESSAGE	Bits 7 to 12, Bit 7 is MSB. Actuation time is normally 10 milliseconds after receipt of message.
G&N COMPUTER MESSAGE	Bits 7 thru 22, Bit 7 is MSB.
CTE TIME ACCUMULATOR UPDATA	Bits 7 thru 30 a. 7 thru 12 for seconds Bit 7 is LSB b. 13 thru 18 for minutes Bit 13 is LSB c. 19 thru 24 for hours Bit 19 is LSB d. 25 thru 30 for days Bit 25 is LSB

ITEM	UPDATA LINK DATA
UDL TEST MESSAGE A&B	Bits 4 thru 30 a. 4, 5, and 6 Test Message ID b. 7 thru 30 Data Word
SIGNAL ACCEPTANCE CRITERIA	a. Correct Vehicle Address b. Valid System Address c. Correct Message Length d. Correct Sub-bit Coding e. Correct PSK Timing. (See sub-bit characteristics)
VALIDITY SIGNAL	a. 8-bit word to PCM TM present for 50 milliseconds on PCM Word 51D (Items c, d & e) b. Standby word Bit No. 1 2 3 4 5 6 7 8 Binary 1 0 1 0 0 1 0 0 c. System Validity Word Binary 0 1 0 1 1 0 1 1 d. Test Message "A" Word Binary 1 0 1 1 1 0 0 0 e. Test Message "B" Word Binary 0 1 0 0 0 1 0 0 f. UDL OFF Binary 0 0 0 0 0 0 0 0
NON-VALIDITY CRITERIA	No change from standby word to test message or system validity word following transmission of a command.
<u>SUB-BIT CHARACTERISTICS</u>	
SUB-BIT ONE	One cycle of a one KHz reference signal and two cycles of a two KHz information signal which are both in-phase and positive going at the beginning of the sub-bit period.
SUB-BIT ZERO	One cycle of a one KHz reference signal and two cycles of a two KHz information signal which are 180 degrees out of phase and where one KHz signal is positive going and two KHz is negative going at the beginning of the sub-bit period.
SUB-BIT PERIOD	1 millisecond.

TABLE 6-6 UDL REAL-TIME COMMANDS FOR COMMUNICATION SYSTEM

NO.	COMMAND	UDL RELAY BOX	MCP	FUNCTION
00	ABORT LIGHT OFF (SYSTEM A)	K1 (reset)	NA	Turns ABORT LIGHT A OFF. Binary "0" on PCM. (CS0080X/11E25-07)
01	ABORT LIGHT ON (SYSTEM A)	K1 (Set)	NA	Turns ABORT LIGHT A ON. Binary "1" on PCM. (CS0080X/11E25-07)
06	ABORT LIGHT OFF (SYSTEM B)	K2 (reset)	NA	Turns ABORT LIGHT B OFF. (no PCM)
07	ABORT LIGHT ON (SYSTEM B)	K2 (set)	NA	Turns ABORT LIGHT B ON. (no PCM)
51	-Z ANTENNA ON (VHF SCIMITAR)	NA	1K33R 1K34S	Switches VHF AM, VHF FM, and UHF UDL to -Z ANTENNA on S/M.
52	+Z ANTENNA ON (VHF SCIMITAR)	NA	1K33S 1K34R	Switches VHF AM, VHF FM, and UDL to +Z ANTENNA on S/M.
53	G&N ANTENNA SWITCHING	NA	NA	Not implemented
61	CM/SM SEPARATION	NA	1K38S 1K42S 1K43R	Turns OFF the following equipment: a. VHF AM TRANSCEIVER b. VHF FM TRANSMITTER NOTE: RTC 61 also initiates CM/SM separation and is not used as a direct command function to turn off the above equipment for this reason.
62	UDL S-BAND RCVR SELECT	NA	1K37S	Routes S-Band received updata from S-Band RCVR via PMP 70 kc discriminator to UDL Decoder. MDC 20, 8, UDL Switch may be in UHF or S-Band position.

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TABLE 6-6 UDL REAL-TIME COMMANDS FOR COMMUNICATION SYSTEM (Cont'd)

NO.	COMMAND	UDL RELAY BOX	MCP	FUNCTION
63	UDL UHF RCVR SELECT	NA	LK37R	Routes UHF received updata from UHF RCVR in UDL to UDL Decoder. MDC 20, S8, UDL Switch must be in UHF position for command operation.
74	C-BAND OFF	K3 (reset)	NA	Effect is as follows depending upon MDC 20, S13, C-Band Switch position: (a) 1 Pulse: No effect (b) OFF : Turns C-BAND OFF (c) 2 Pulse: No effect
75	C-BAND ON (2-PULSE)	K3 (set)	NA	Effect is as follows depending upon MDC 20, S13, C-BAND Switch position: (a) 1 Pulse: No effect (b) OFF : C-Band ON in 2-Pulse Mode (c) 2 Pulse: C-Band ON in 2-Pulse Mode
76	PCM LBR VHF FM XMTR OFF	K4 (reset)	NA	Effect is as follows depending upon MDC 20, S12, and S20 (VHF FM XMTR POWER Switch and PCM MODE Switch) positions: (a) VHF FM ON: No effect (b) VHF FM OFF: Turns VHF FM XMTR OFF (c) PCM HIGH : No effect (d) PCM LOW : PCM operation to LBR.
77	PCM HBR VHF FM XMTR ON	K4 (set)	NA	Effect is as follows depending upon MDC 20, S12 and S20 (VHF FM POWER Switch and PCM MODE Switch) positions: (a) VHF FM ON: No effect (b) VHF FM OFF: Turns VHF FM XMTR ON (c) PCM HIGH: No effect (d) PCM LOW: PCM operation to HBR.

NOTE: See Paragraph 6.5 for switch positions at liftoff.

ITEM	UNIFIED S-BAND DATA
POWER	115/200 Vac 3 ϕ , 400 HZ 13.5 Watts kc
RECEIVER	Double Superheterodyne Phase Lock Loop
RECEIVER FREQUENCY	2106.40625 MHz
TRACKING THRESHOLD	-132 DBM to maintain phase lock with no Modulation
TRACKING RANGE	Center Frequency \pm 60 KHz minimum
TRANSMITTER FREQUENCY	2287.5 MHz, stability \pm 0.005 percent
TURN-AROUND RATIO	240/221
TRANSMITTER POWER	250 to 400 milliwatts
ANTENNA SWITCHING	a. Level: -122 DBM or below switches ANT -104 to -122 Undefined, may switch. -104 DBM or above holds switching b. Delay: 4.5 to 10 seconds before switching back to original antenna, switch will continue to switch from one ANT to the other until signal level is increased.



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6.2.7 S-Band Power Amplifier

The S-Band power amplifier is used to amplify the USBE RF signal for increase range and data capabilities. The unit contains a diplexer for uplink/downlink signal isolation.

During Mission AS-501 the S-Band Power Amplifier will be operated in the HIGH POWER Mode.

6.2.8 HF Transceiver/Beacon

The HF transceiver equipment is used to provide beyond line-of-sight direction finding and voice communications during postlanding phase of the mission. The HF transceiver has three modes of operation: (A) Single-Sideband transmit-receive, lower sideband only, (B) Amplitude modulation transmit-receive, with full carrier and lower sideband, (C) Beacon on CW with full carrier no modulation. The SSB Mode is used for increased voice range capability.

During Mission AS-501 the HF transceiver will be operated in the BEACON Mode.

6.2.9 VHF Recovery Beacon

The VHF recovery beacon is used to provide line-of-sight direction finding operation during the recovery phase of the mission. The beacon transmits an interrupted AM modulated CW carrier.

6.2.10 VHF Survival Transceiver/Beacon

The survival transceiver is part of the crew survival equipment used as a backup to the VHF/AM transceiver and VHF recovery beacon. The unit will operate from its own internal battery and provide beacon, voice transmission, and voice reception. In the voice mode, it will provide simplex two-way voice between vehicle, astronaut, and the recovery force after main parachute deployment for 48 hours.

The survival beacon which is part of the unit consists of a beacon and battery pack. The unit will operate for 24 hours.

The survival beacon will be connected to VHF Recovery Antenna No. 2.

During Mission AS-501, the VHF Survival Transceiver/Beacon will be operated in the BEACON Mode.

*

TABLE 6-8 S-BAND POWER AMPL DATA

CSM
AS-501

ITEM	S-BAND POWER AMPL DATA
POWER	115/200 Vac, 3 ϕ , 400 Hz 27.4 Watts Low pwr, 80 Watts high pwr +28 Vdc control 3 Watts dc
RF OUTPUT POWER	a. High Power: 14.4 Watts minimum b. Low Power: 3.3 + 0.6, -0.4 Watts with 250 MW drive
INSERTION LOSS	a. Bypass Receive: -1 DB maximum b. Bypass Transmit: -1.8 DB maximum
WARMUP TIME	90 seconds (Time Delay Relay Delays TWT operation during warmup). Power amplifier will remain in the Bypass Mode during warmup.



TABLE 6-9 HF TRANSCEIVER EQUIPMENT DATA

ITEM	HF TRANSCEIVER EQUIPMENT DATA
POWER	+28 Vdc Receive AM and SSB 0.6 Watts Transmit AM or BCN 29 Watts Transmit SSB 40 Watts Keying Relay 3.5 Watts
TRANSMIT FREQUENCY	10.006 MGz Stability ± 50 Hz
RECEIVER SENSITIVITY	a. SSB: 1.0 microvolts b. AM: 3.0 microvolts with both sidebands
RECEIVER MUTING	Applied when transmitting
TRANSMIT RF POWER	a. SSB: 10 Watts average 20 Watts PEP b. AM: 5 Watts average c. Beacon: 5 Watts average
ACTIVATION TIME	With the equipment energized the transmitter will achieve full transmit operation within 100 milliseconds of PPT key closure.

TABLE 6-10 VHF RECOVERY BEACON DATA

ITEM	VHF RECOVERY BEACON DATA
POWER	+28 Vdc, 8 Watts
FREQUENCY	243.0 MHz stability \pm 0.01265 MHz
RF POWER	3 Watts minimum peak
MODULATION	AM, 20 to 40 percent, 1000 \pm 50 Hz squarewave
INTERRUPTION RATE OF 1KHz MODULATION	a. ON: 1.8 to 2.2 seconds b. OFF: 2.7 to 3.3 seconds



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TABLE 6-11 VHF SURVIVAL TRANSCEIVER/BEACON DATA

CSM
AS-501

ITEM	VHF SURVIVAL TRANSCEIVER/BEACON DATA
POWER	Internal Battery Pack
OPERATION LIFE	24 Hours in CW Mode 48 Hours in voice mode
RF POWER OUTPUT	2 Watts average
FREQUENCY	243 MHZ
BEACON MODE DUTY CYCLE	a. Modulation: 1 KHz sine Wave b. On Time: 2 sec (Carrier + 1KHz) c. Off Time: 3 sec (Carrier + 1KHz)
MICROPHONE/SPEAKER	Integral to unit
MODE SWITCH	BCN/Voice/OFF
PTT BUTTON	Integral



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6.2.11 Flashing Light Beacon

The Flashing light is used as a visual beacon during recovery phases of the mission.

6.2.12 VHF Recovery Antennas

There are two VHF Recovery Antennas, No. 1 and No. 2, stowed in the forward compartment of the C/M. They are deployed by the main parachute riser lines which actuate redundant pyrotechnic line cutters (delayed 8 seconds) releasing the spring-loaded antennas to the upright position.

6.2.13 HF Recovery Antenna

The HF recovery antenna is coiled in a small container stored in the forward equipment compartment. After the C/M has reached Stable I and impact plus 11 seconds, the antenna control circuits will be actuated by the mission control programmer. The antenna is pyrotechnically released and unfurls into a tubular pole.

6.2.14 Scimitar Antennas

The Scimitar Antennas, so called because of their shape are located on the service module. This type of antenna has a broad bandwidth to cover VHF and UHF frequencies.

6.2.15 S-Band OMNI Antennas

Four S-Band OMNI Antennas are mounted in the AFT heat shield of the command module at 90 degree intervals about the X-Axis. The antennas operate in pairs 180 degrees apart. Each antenna of a pair is fed from a common power divider. Only one pair is selectable at a time.

6.2.16 Audio Center Equipment

The Audio Center Equipment consists of three audio modules, one each for the command pilot, senior pilot, and pilot positions. Each audio module is used to process and control audio signals between the VHF AM, HF, and S-Band equipment and the crew headsets. The intercomm bus between each module is used for intra crew communications and

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hardline voice prior to liftoff. A swimmer umbilical disconnect is tied to the intercom bus for voice communications during recovery operation after landing.

Since Mission AS-501 is unmanned, a 400 Hz tone derived from the 400 Hz ac power, will be used to assimilate downlink voice communications. The senior pilot's audio module will process this tone to the VHF AM and S-Band equipment.



* TABLE 6-12 FLASHING LIGHT BEACON DATA

CSM
AS-501

ITEM	FLASHING LIGHT DATA
FLASH RATE	30 \pm flashes per minute
INTENSITY	2 million lumens
FLASH DURATION	3 milliseconds
SERVICE LIFE	24 hours minimum



ITEM	VHF RECOVERY ANTENNA
LOCATION	See antenna location drawing (Figure 6.1)
TYPE	Stub, quarter wave length, omnidirectional
FREQUENCY	243 MHz tuned
GAIN	+6 DB with respect to isotropic
MAXIMUM NULL	-18 DB with respect to isotropic
BEAMWIDTH (MAIN LOBE)	+ 70 degrees elevation, 360 degree azimuth
POLARIZATION	Vertical

*

TABLE 6-14 HF RECOVERY ANTENNA DATA

CSM
AS-501

ITEM	HF RECOVERY ANTENNA DATA
LOCATION	See antenna location drawing (Figure 6.1)
TYPE	Monopole
PATTERN	Omnidirectional in a plane perpendicular to C/M X-Axis
FREQUENCY RANGE	9.95 to 10.05 MHz
GAIN	0 DB minimum with respect to isotropic



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TABLE 6-15 VHF SCIMITAR ANTENNAS

CSM
AS-501

ITEM	VHF SCIMITAR ANTENNAS
BANDWIDTH	225 to 450 MHz
RADIATION PATTERN	Hemispherical
GAIN LOCATION	-3 DB with respect to isotropic (See DWG 6.1)



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TABLE 6-16 S-BAND ANTENNAS

CSM
AS-501

ITEM	S-BAND ANTENNA DATA
BANDWIDTH	2100 to 2300 MHz
POLARIZATION	Right-Hand circular
RADIATION PATTERN AND GAIN*	Nulls: Less than 20 DB with respect to isotropic level external to a solid angle of ± 15 degrees about the S/C \pm X-Axis. Gain: Greater than -3 DB with respect to isotropic level for a minimum of 10 steradians of spherical coverage. (4π steradians in a sphere)
LOCATION	(See DWG 6.1)

*ALL FOUR ANTENNAS RADIATING SIMULTANEOUSLY.

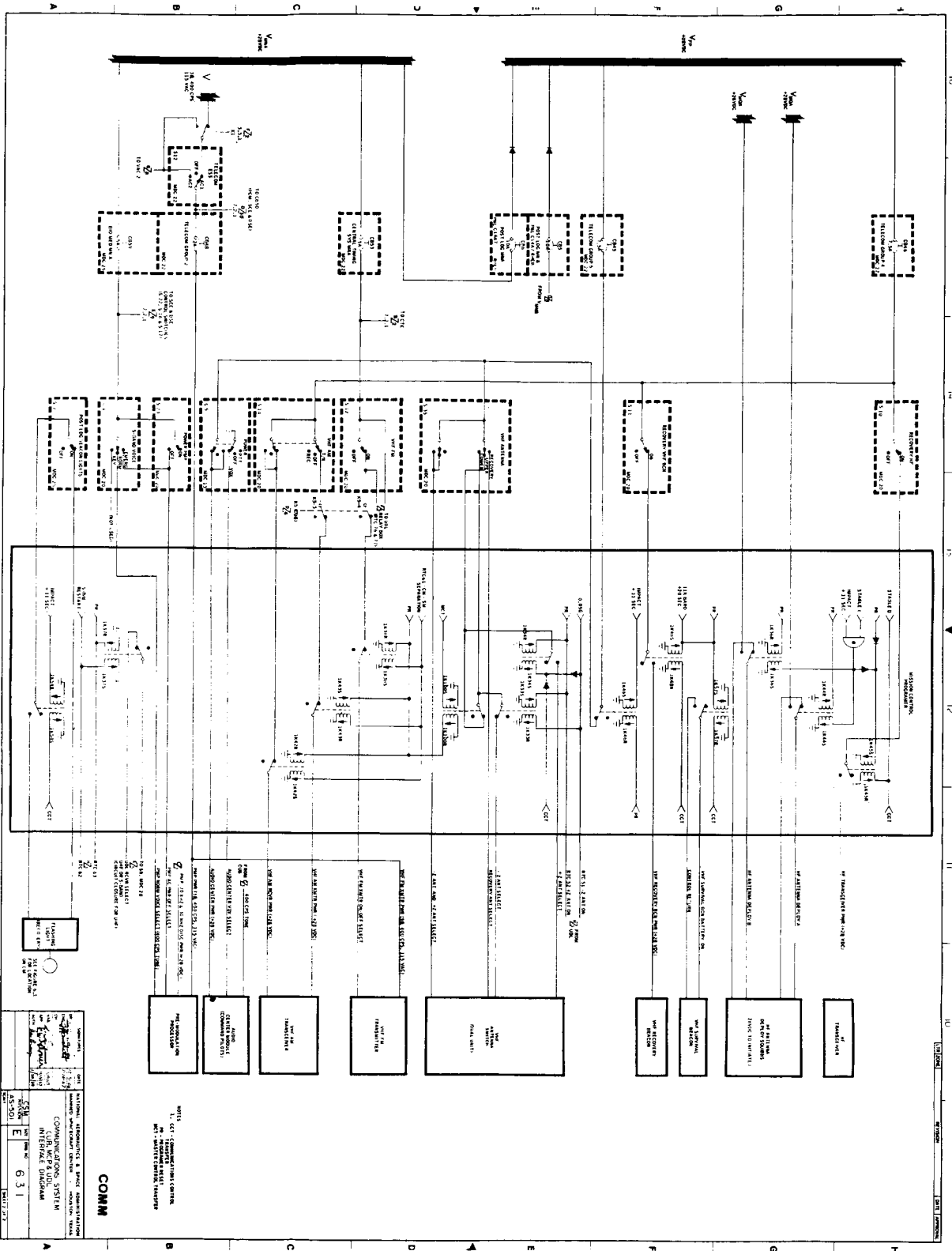
TABLE 6-17 MISSION CONTROL PROGRAMER

MCP RELAY	FUNCTION	1K33R	1K33C	1K34R	1K34S	1K36R	1K36S	1K37S	1K37R	1K38R	1K38S	1K42S	1K42R	1K43S	1K43R	1K44S	1K44R	1K45S	1K45R	1K46S	1K46R	1K48S	1K48R	1K54S	1K54R	1K100S	1K100R	1K57S	1K57R
	① REQUIRES TWO CONDITIONS																												
	RTC 51 -Z ANTENNA ON (VHF)	X																											
	RTC 52 +Z ANTENNA ON (VHF)		X																										
	RTC 61/CM-SM SEPARATION																												
	RTC 62 UDL S-BAND RCVR SELECT																												
	RTC 63 UDL UHF RCVR SELECT																												
	PR (PROGRAMER RESET)																												
	MCT (MASTER CONTROL TRANSFER)																												
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	0.05 G SIGNAL																												
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	STABLE II																												
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6.3 NOTES, COMMUNICATION SYSTEM MCP, CUB, AND UDL INTERFACE DIAGRAM

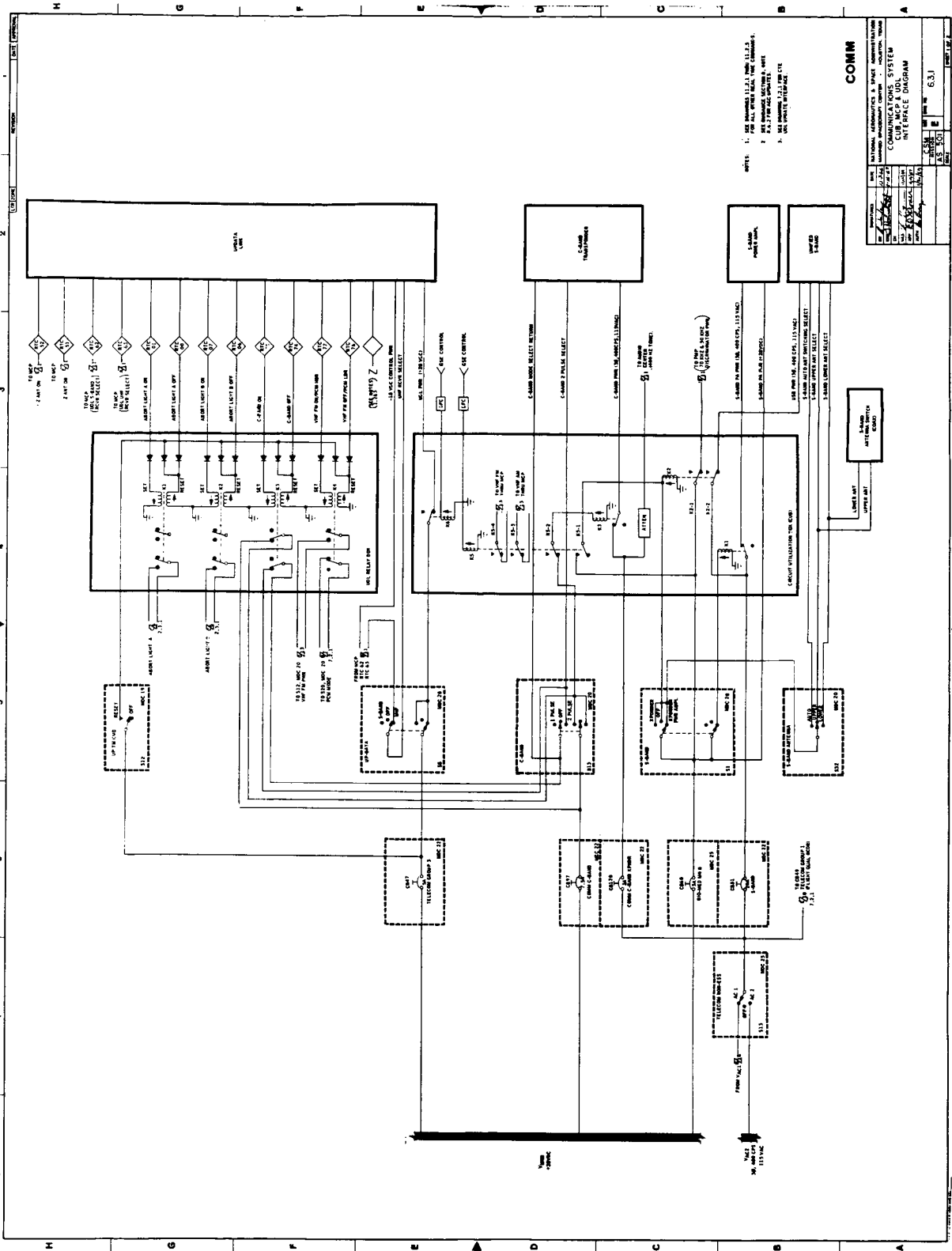
- A. This drawing is provided to show automated and remote control functions which operate the COMM system equipment.
- B. See communication system detailed diagram, Drawing 6.4.1, for complete system schematic.
- C. See Table 6-6 for communication system control functions by the Udata Link (UDL),
- D. See Table 6-17 for communication system control functions by the MCP.
- E. The Communication System Circuit Utilization Box (CUB) provides control of ac and dc power to the following:
 1. VHF FM Transmitter (ac)
 2. VHF AM Transceiver (dc)
 3. C-Band Transponder (ac)
 4. Unified S-Band (ac)
 5. S-Band Power Amplifier (ac)
 6. Udata Link (dc)
 7. Premodulation Processor (dc only)

Hardline commands to the CUB by Ground Support Equipment (GSE) can remove power from the above equipment after closeout and before liftoff if required.



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INTERPHONE	



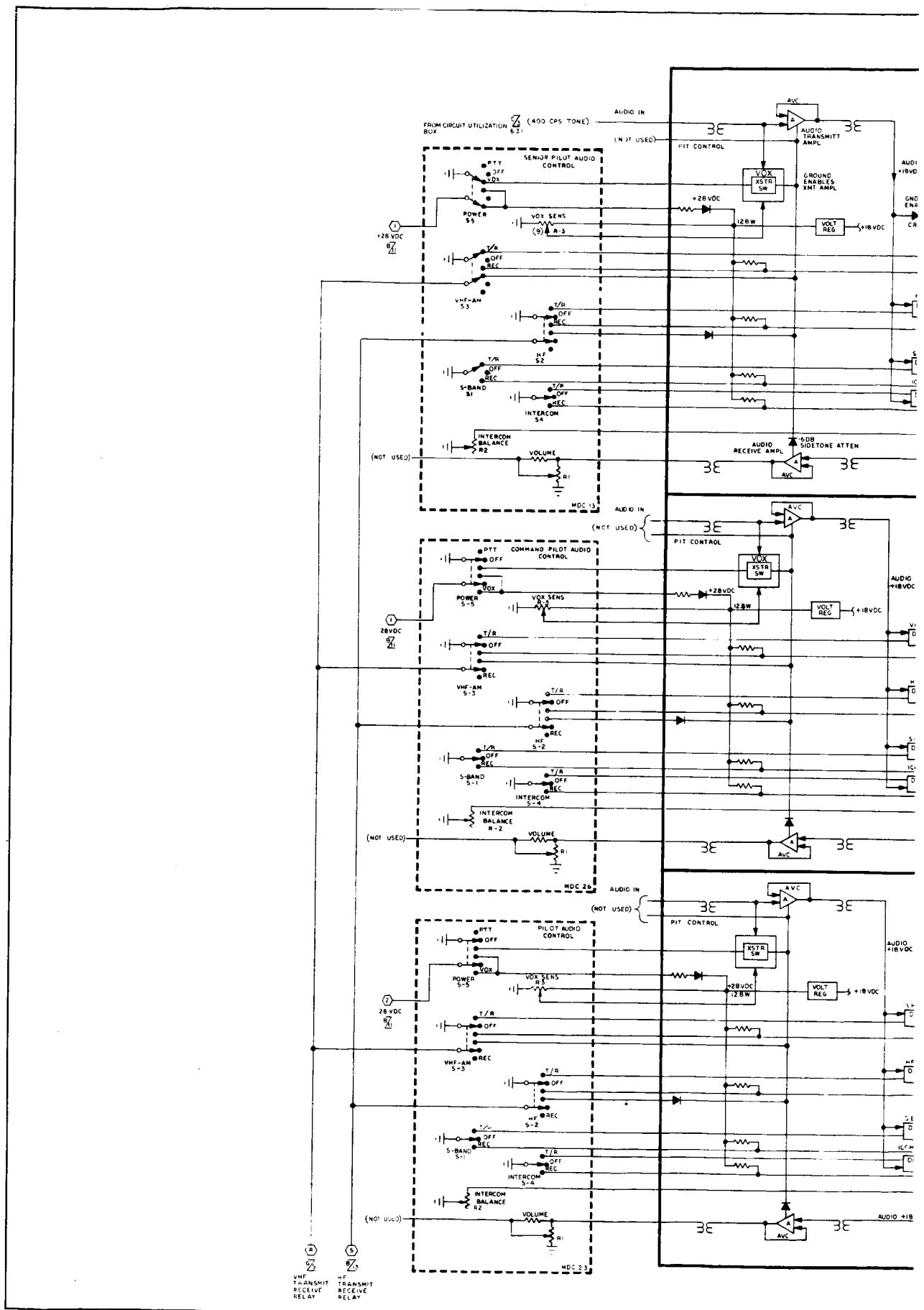
- NOTES:
1. SEE DRAWINGS 11.1, 11.2, 11.3, 11.4, 11.5, 11.6, 11.7, 11.8, 11.9, 11.10, 11.11, 11.12, 11.13, 11.14, 11.15, 11.16, 11.17, 11.18, 11.19, 11.20, 11.21, 11.22, 11.23, 11.24, 11.25, 11.26, 11.27, 11.28, 11.29, 11.30, 11.31, 11.32, 11.33, 11.34, 11.35, 11.36, 11.37, 11.38, 11.39, 11.40, 11.41, 11.42, 11.43, 11.44, 11.45, 11.46, 11.47, 11.48, 11.49, 11.50, 11.51, 11.52, 11.53, 11.54, 11.55, 11.56, 11.57, 11.58, 11.59, 11.60, 11.61, 11.62, 11.63, 11.64, 11.65, 11.66, 11.67, 11.68, 11.69, 11.70, 11.71, 11.72, 11.73, 11.74, 11.75, 11.76, 11.77, 11.78, 11.79, 11.80, 11.81, 11.82, 11.83, 11.84, 11.85, 11.86, 11.87, 11.88, 11.89, 11.90, 11.91, 11.92, 11.93, 11.94, 11.95, 11.96, 11.97, 11.98, 11.99, 12.00.
 2. SEE DRAWING 11.1 FOR THE C-BOARD SELECT RETURN.
 3. SEE DRAWING 11.2 FOR THE C-BOARD PULSE SELECT.
 4. SEE DRAWING 11.3 FOR THE C-BOARD PULSE ADDRESS/ADDRESS.
 5. SEE DRAWING 11.4 FOR THE C-BOARD PULSE ADDRESS/ADDRESS.

COMMUNICATIONS CONTROL SYSTEM		DATE	11/11/63	REV	1
		BY	J. J. HARRIS	CHECKED	J. J. HARRIS
COMMUNICATIONS CONTROL SYSTEM		PROJECT	COMMUNICATIONS CONTROL SYSTEM		
INTERFACE DIAGRAM		SCALE	AS SHOWN		
DRAWING NO.		6.31			
REV.		1			
DATE		11/11/63			
BY		J. J. HARRIS			
CHECKED		J. J. HARRIS			
APPROVED		J. J. HARRIS			

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6.4 NOTES, COMMUNICATION SYSTEM DETAILED BLOCK DIAGRAM

- A. MAIN DISPLAY Switches are shown in the final closeout position according to Mission AS-501 flight plan.
- B. See communication system MCP, CUB, and UDL Diagram, Drawing 6.3.1, for simplified diagram of automated and remote control functions effecting the COMM system.
- C. See Drawing 6.3.1 and Table 6-17 for further detail of control wires which interface with the MCP.
- D. See Drawing 6.3.1 and Table 6-6 for detail of real-time commands which effect the COMM system.
- E. The command pilot's audio module of the audio center equipment will be used to process a 400 Hz tone to the VHF AM and S-Band equipment for downlink voice simulation test.



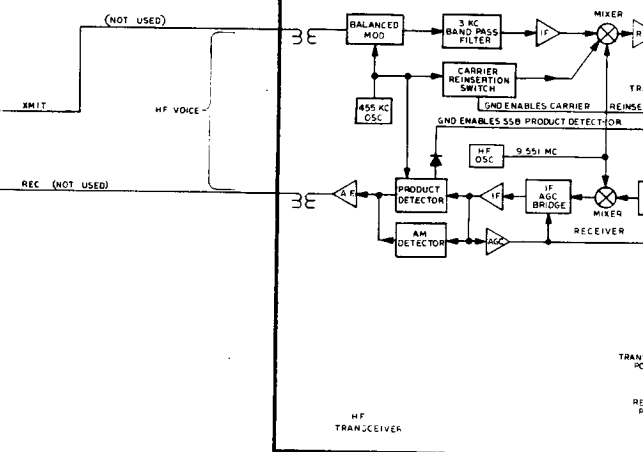
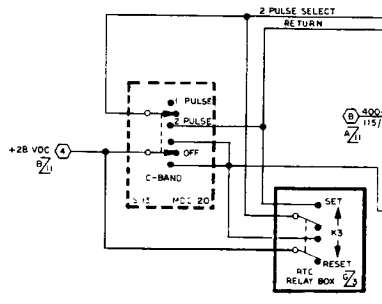
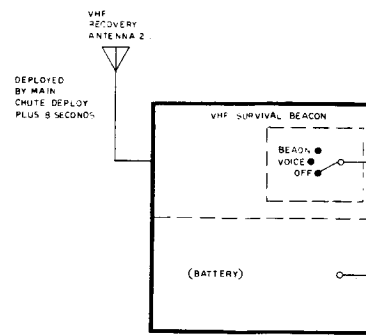
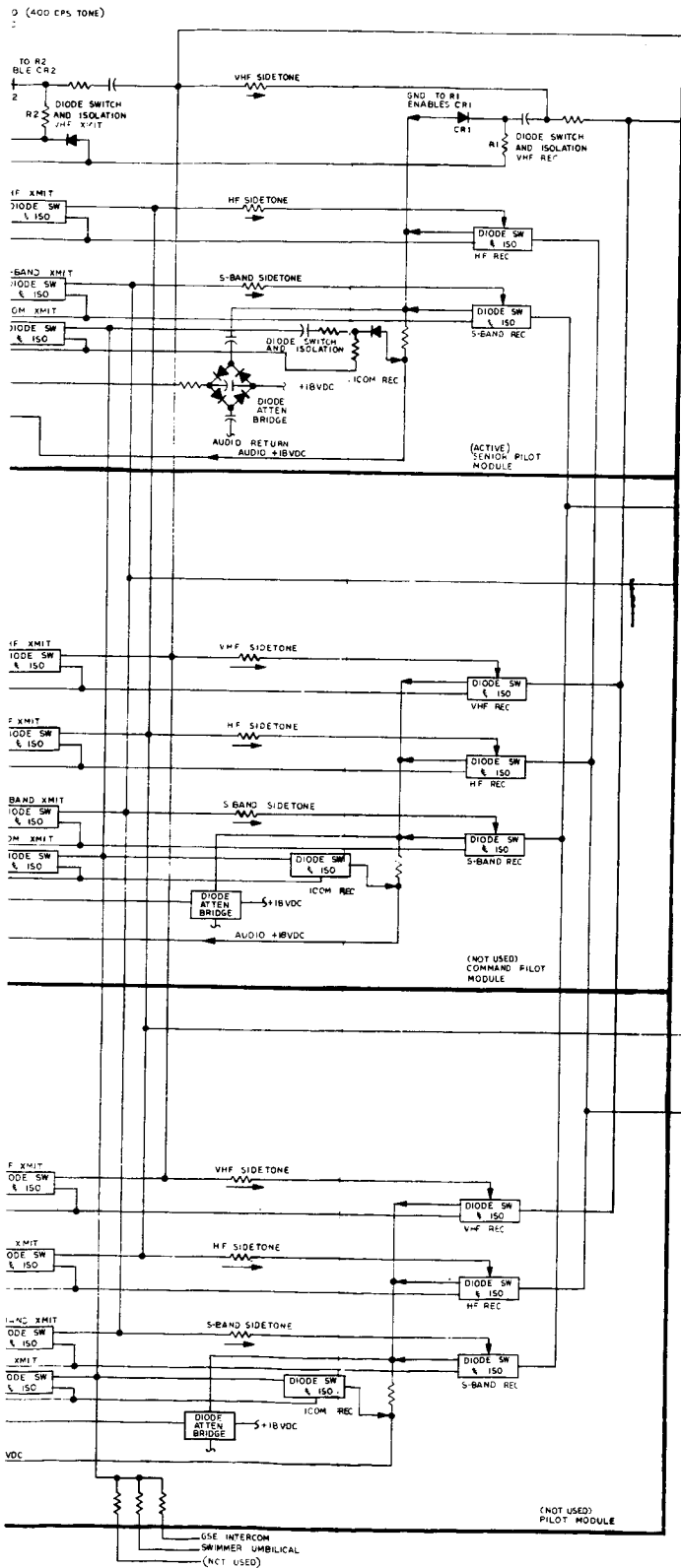
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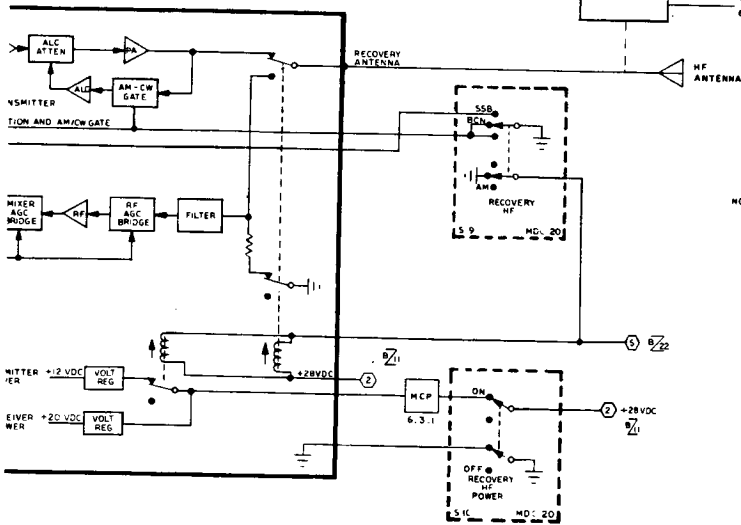
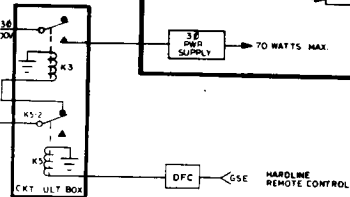
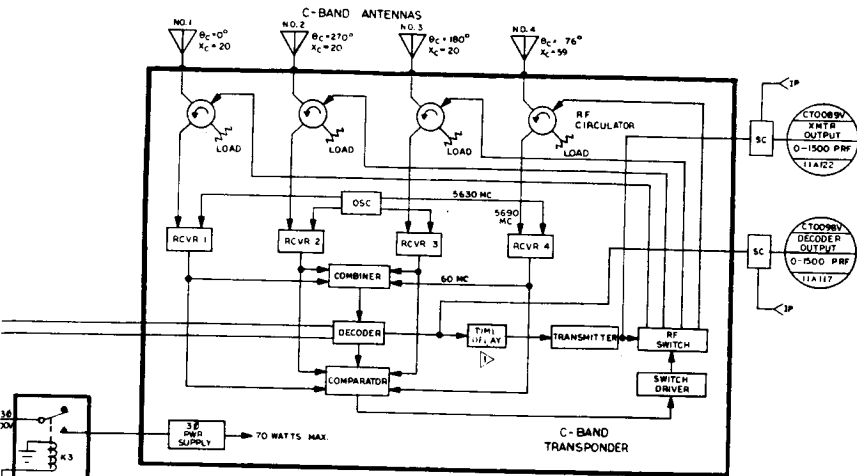
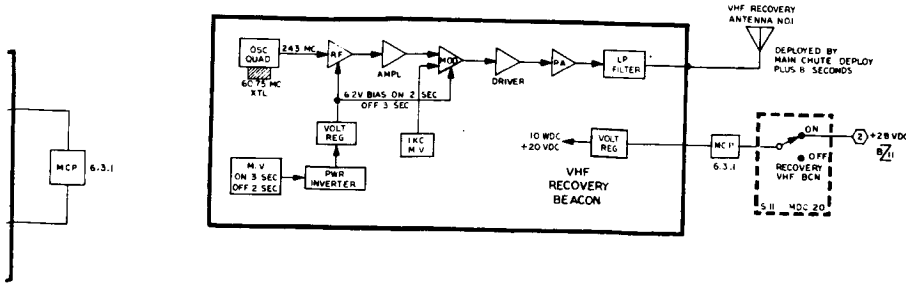
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AUDIO CENTER EQUIP

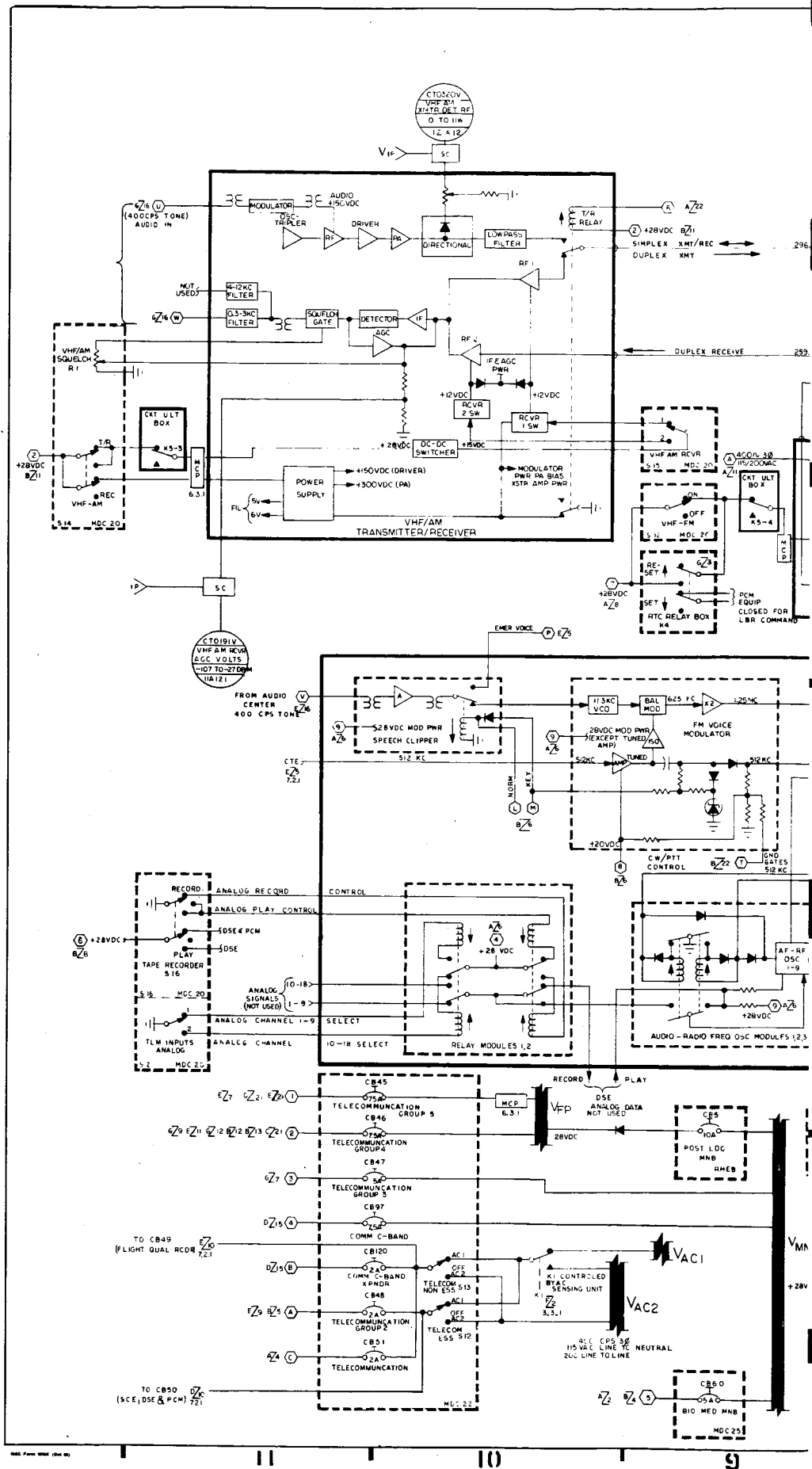


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COMM

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MISSION: AS-501		

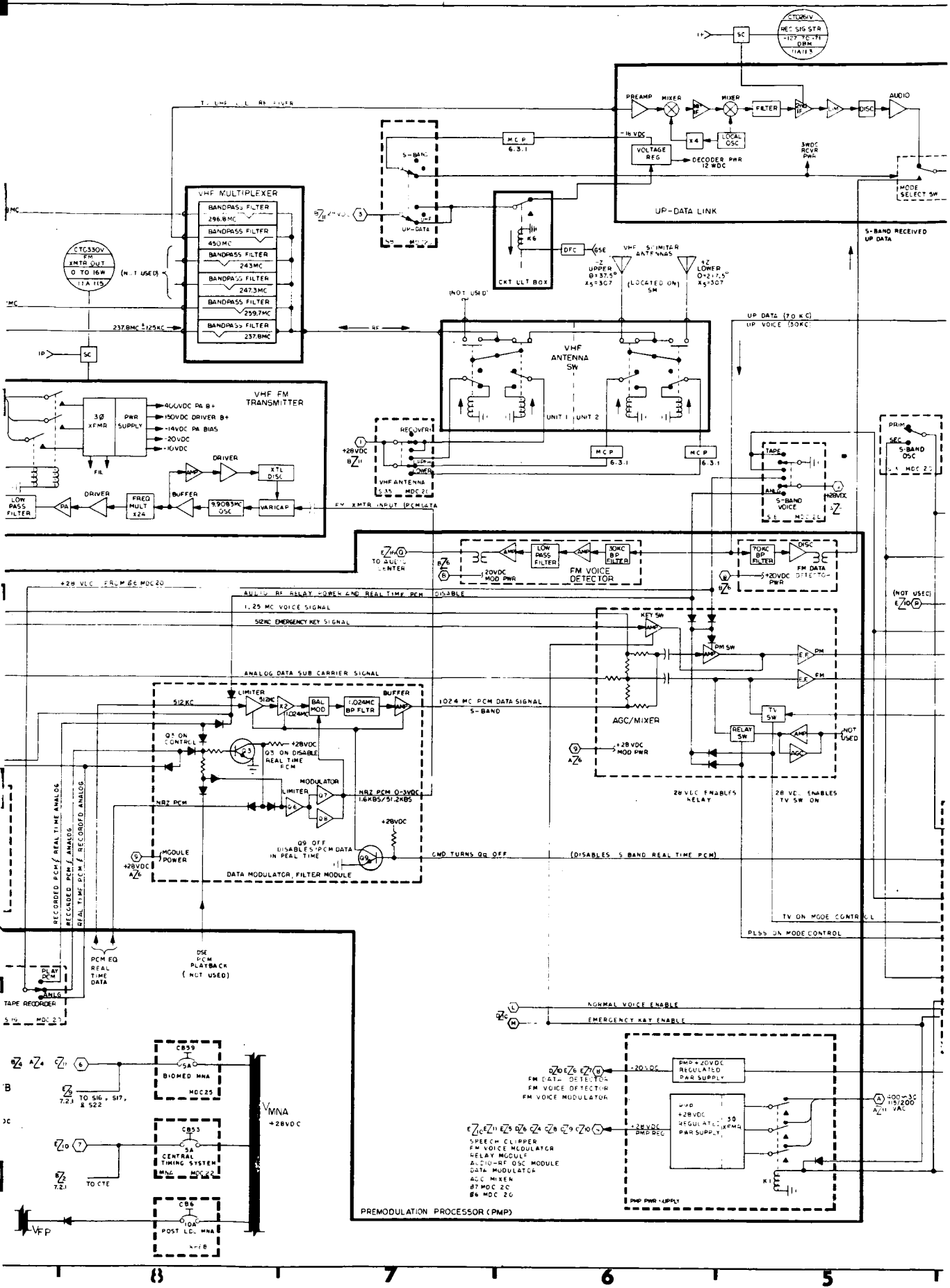


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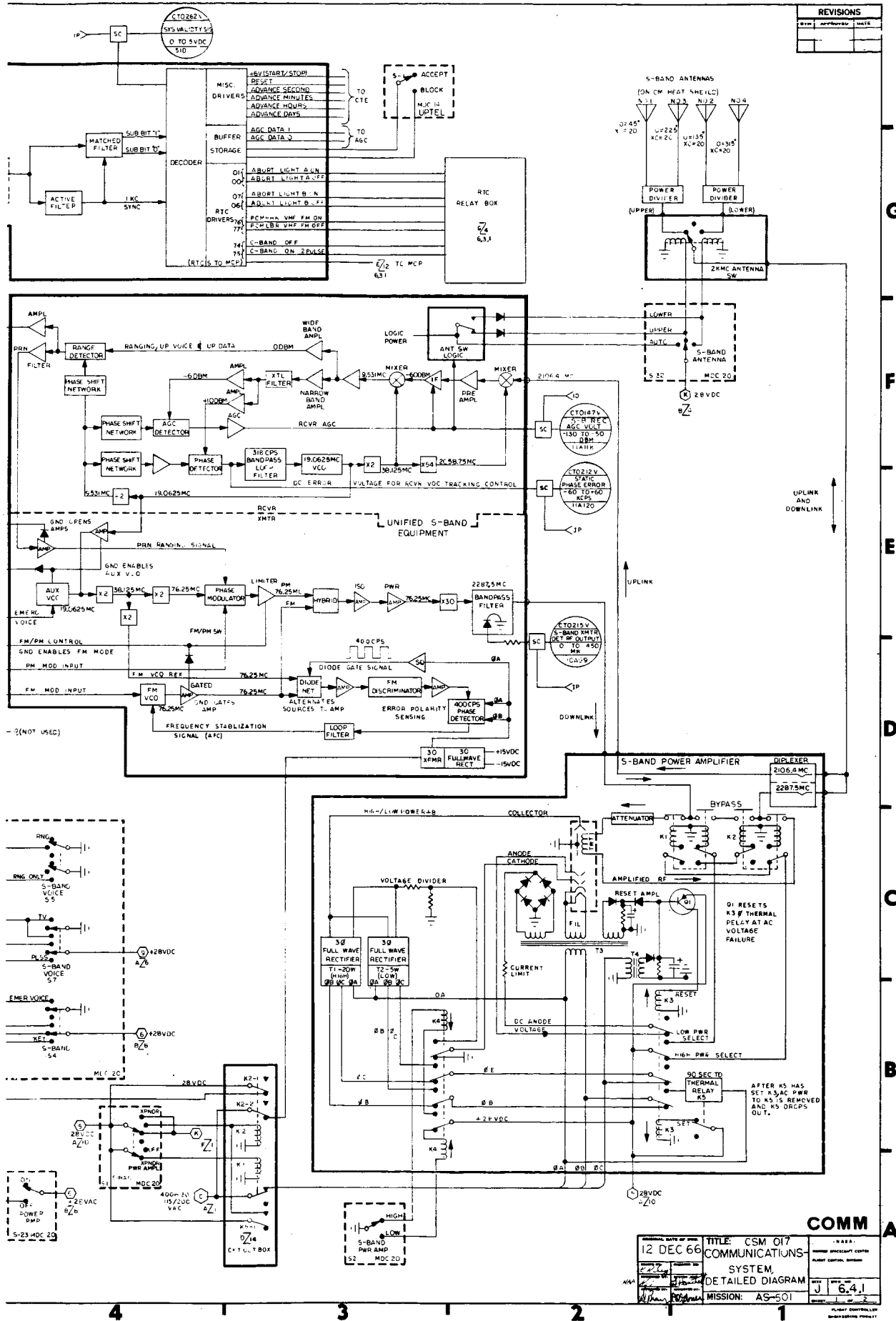
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6.5 COMMUNICATION SYSTEM CIRCUIT MARGINS

6.5.1 Communication Links

Communication links with the MSFN are basically sensitive to two mission parameters: vehicle-to-MSFN slant range and antenna gain in the direction of the vehicle-to-MSFN line of sight. S-Band communications are additionally sensitive to combinations of uplink and downlink modulation modes.

6.5.2 Ranges of Communication Links

Figure 6.4 shows the ranges of the communication links where the circuit margins are positive. Negative circuit margins result in excessive bit error rates, voice distortion, command rejects, and ranging errors.

6.5.3 Calculated Ranges

Ranges shown in Figure 6.4 were calculated using the following ground rules and data obtained from CSM circuit margin interface control documents.

A. S-Band system

1. MSFN 30 foot dish (43 DB Gain Uplink)
2. CSM antenna gain of -3 DB (OMNI)
3. MSFN power of 10 kw
4. CSM power of 10 watts (P.A. HIGH)
5. Worse case margin:
 - a. Voice -7.99 DB (Downlink)
 - b. PRN ranging 4.38 DB
 - c. HBR PCM -13.42 DB
 - d. Uplink 17.87 DB
6. Reference range of 15,000 n.mi.

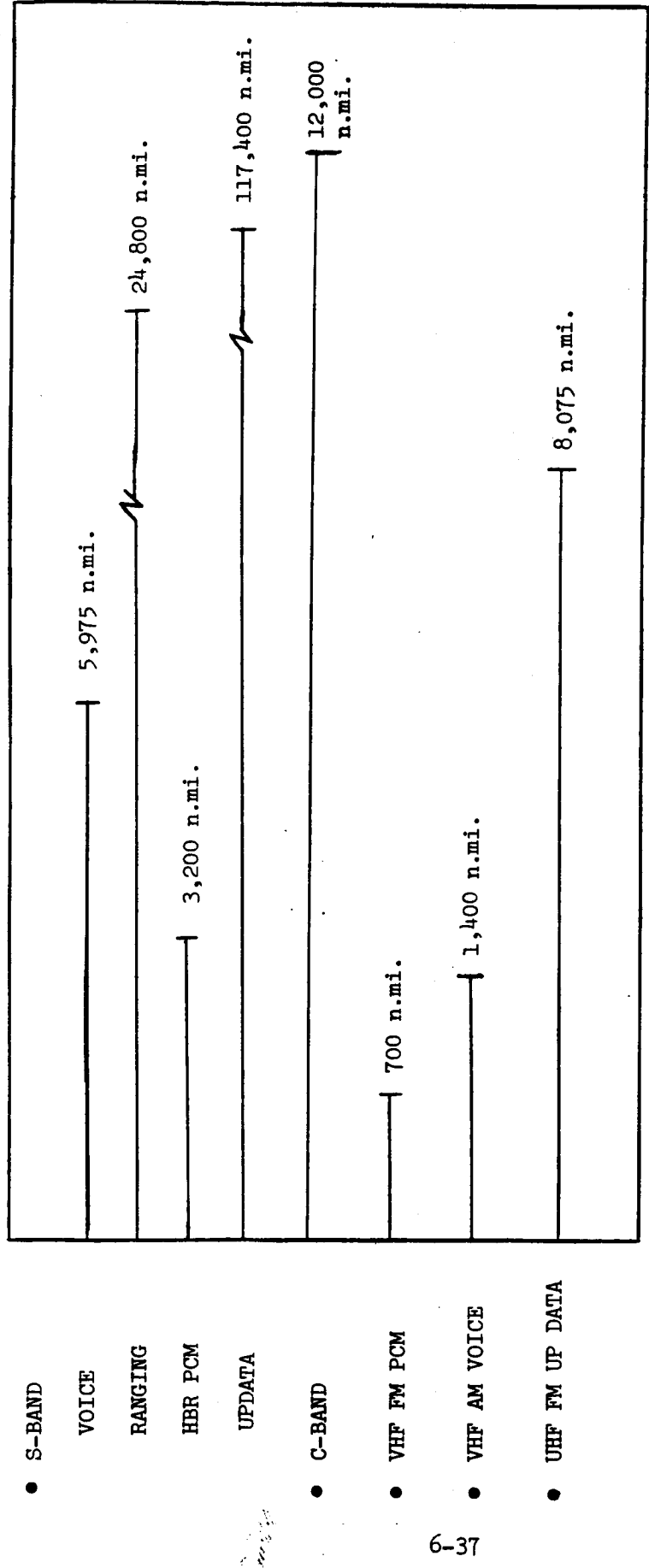
B. C-Band system

1. MSFN AN/FPQ6 or AN/TPQ - 18 RADARS
2. CSM antenna gain 0 DB
3. CSM power of 2.5 kw peak

- 4. Worst case margin of 9.56 DB (Downlink)
 - 5. Reference range of 4000 n.mi.
- C. VHF FM PCM system
- 1. MSFN antenna gain of 18 DB
 - 2. CSM antenna gain of -3 DB
 - 3. CSM power of 10 watts
 - 4. Worst case margin of -9.12 DB
 - 5. Reference range of 2,000 n.mi.
- D. VHF AM voice and UHF FM updata systems
- 1. MSFN antenna gain of 18 DB
 - 2. CSM antenna gain of -3 DB
 - 3. Worst case margin -3.09 DB (VHF AM) and 12.12 DB (UHF FM)
 - 4. Reference range 2,000 n.mi.

NOTE: Data shown in Figure 6.4 represents minimum design requirements and worse case conditions with the exception of optimum antenna look angles. Actual circuit margin parameters are expected to exceed design requirements.

COMMUNICATION MODE



MSFN-TO-CSM SLANT RANGE
FIGURE 6.2 COMMUNICATION MODE RANGE CAPABILITIES

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6.6 COMMUNICATION SYSTEM FINAL CLOSEOUT SWITCH AND CIRCUIT BREAKER CONFIGURATION. (REFERENCE: AS-501 FLIGHT PLAN, SEPTEMBER 12, 1966)

6.6.1 MDC - 13, Audio Control Panel

Power (PTT/OFF/VOX) (S5)	VOX
S-Band (T/R / OFF/REC) (S1)	T/R
HF (T/R / OFF/REC) (S2)	OFF
VHF/AM (T/R /OFF/REC) (S3)	T/R
Intercom (T/R /OFF/REC) (S4)	OFF
VOX Sens (Thumbwheel) (R3)	MAX (9)
Intercom Balance (Thumbwheel) (R2)	NOT USED
Volume (Thumbwheel) (R1)	NOT USED

6.6.2 MDC 23 and 26 Audio Control Panel

All audio center control switches will be OFF.

6.6.3 MDC-25 Circuit Breaker Panel

ANTENNA Deploy (HF)	
A. (A/OFF) (S8)	OFF
B. (B/OFF) (S16)	OFF
BEACON LIGHTS/OFF (S9)	BEACON LIGHTS (UP)
BIOMED COMM	
A. MNA (CB59)	CLOSED
B. MNB (CB60)	CLOSED

6.6.4 MDC-19 Control Panel

UP TM CMD (RESET/OFF) (S12)	OFF
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6.6.5 MDC-20 Communications Control Panel

S-Band

Xponder (Xponder/Off/Xponder Pwr Amp) (S1)	XPONDER PWR AMP
Pwr Amp (High/Low) (S2)	HIGH
OSC (Prim/Sec) (S3)	PRIM

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Voice	
Rng (Rng/Off/Rng Only) (S5)	RNG
Tape/Analog (Tape/Off/Analog) (S6)	OFF
TV/PLSS (TV/Off/PLSS) (S7)	OFF
Emerg (Voice/Off/Key) (S4)	OFF
Updata (S-Band/Off/UHF) (S8)	UHF
S-Band Antenna (Auto/Upper/Lower) (S32)	UPPER
<u>VHF/AM</u>	
Squelch (Thumbwheel) (R1)	TBD
T/R/Off/Rec (S14)	T/R
Rcvr (1/2) (S15)	1
C-Band (1 Pulse/Off/2 Pulse) (S13)	OFF
VHF/FM (On/Off) (S12)	ON
Recovery	
VHF BCN (ON/OFF) (S11)	ON
HF	
ON/OFF (S10)	ON
SSB/BCN/AM (S9)	BCN
Tape Recorder	
PLAY (PCM/NORM/ANALOG) (S19)	NORM
SPEED (HIGH/NORM/LOW) (S18)	NORM
RECORD/OFF/PLAY (S16)	RECORD
FWD/STOP/REV (S17)	FWD
Power	
SCE (ON/OFF) (S22)	ON
PMP (ON/OFF) (S23)	ON
TM Inputs	
PCM (HIGH/LOW) (S20)	HIGH
ANALOG (1/2) (S21)	NOT USED

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BIOMED (1/2/3) (S24)	NOT USED
VHF Antenna (Recovery/Upper/Lower) (S35)	UPPER
6.6.6 <u>MDC-14 G&N Computer Control Panel</u>	
UPTL (ACCEPT/BLOCK) (S1)	ACCEPT
6.6.7 <u>VHF Survival Beacon (Switch ON Beacon)</u>	
VHF Survival Beacon (BCN/VOICE/OFF)	BCN
6.6.8 <u>MDC-22 Circuit Breaker Panel</u>	
Central Timing System	
MN A (CB53)	CLOSED
MN B (CB52)	CLOSED
COMM C-BAND XPNDR (CB120)	CLOSED
Communications	
ESS A (AC 1/OFF/AC 2) (S13)	AC 1 (AUTO)
NONESS B (AC 1/OFF/AC 2) (S13)	
Telecommunications	
GROUP 1 (CB49)	CLOSED
GROUP 2 (CB48)	CLOSED
GROUP 3 (CB47)	CLOSED
GROUP 4 (CB46)	CLOSED
GROUP 5 (CB45)	CLOSED
GROUP 6 (CB50)	CLOSED
S-BAND (CB51)	CLOSED
Comm	
FLT QUAL RCDR (CB96)	CLOSED
C-BAND (CB97)	CLOSED
6.6.9 <u>RHEB Circuit Breaker Panel</u>	
POSTLDG	
MAIN A (CB6)	CLOSED
MAIN B (CB5)	CLOSED

*

SECTION 7
INSTRUMENTATION

CSM
AS-501

7.1 GENERAL SYSTEM NOTES

All Apollo spacecraft instrumentation measurements are divided into two classifications: Operational and Flight Qualification.

7.1.1 Operational Measurements

Operational measurements are those measurements which remain fixed for a block of vehicles fulfilling a similar type of mission. They are divided into three categories as follows:

A. Preflight Checkout of the Spacecraft

These preflight checkout measurements are used to insure proper system operation and flight readiness of the spacecraft.

B. Inflight Management of the Spacecraft

These are onboard display measurements used by the astronaut during real time for inflight spacecraft management. The measurements give status of consumable items, provide spacecraft performance information and indicate proper sequencing of operations.

C. Mission Evaluation and Subsystem Performance

These telemetered measurements are used by ground personnel to monitor spacecraft performance for real-time flight control. The measurements are recorded on the ground and used in post-flight mission evaluation. These measurements along with telemetered flight qualification measurements are listed in Section 7.3.

7.1.2 Flight Qualification Measurements

Flight qualification measurements are those measurements relating to qualification and verification of spacecraft and subsystem engineering design. Some flight qualification measurements are displayed onboard the spacecraft and/or telemetered for ground observation. Flight qualification measurements available for analysis during real time are listed with the operational measurements in Section 7.3.

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7.2 INSTRUMENTATION CONTROL SYSTEM NOTES

The CSM Instrumentation System has five major components:

- A. The Pulse Code Modulation Telemetry Equipment (PCM)
- B. The Central Timing Equipment (CTE)
- C. The Signal Conditioning Equipment (SCE)
- D. The Flight Qualification Recorder (FQR)
- E. The Data Storage Equipment (DSE).

Other components include transducers for sensing CSM system parameters, high and low level commutators for flight qualification measurements and instrumentation power distribution circuits.

Table 7-1 presents the power requirements of the five major components.

TABLE 7-1 INSTRUMENTATION SYSTEM EQUIPMENT POWER REQUIREMENTS

EQUIPMENT	MODE/(STATUS)	DC WATTS	AC WATTS
PCM TM	High or Low Bit Rate	----	10.5
CTE	(ON)	21.0	----
DSE	Record and Playback	0.5	32.5
FQR	Record	34.0	15.0
SCE	(ON)	----	45.0

*

7.2.1 Pulse Code Modulation Telemetry (PCM TM) Equipment

The Pulse Code Modulation (PCM) telemetry equipment, receives data inputs from various sampling points throughout the spacecraft and converts them into a single Non-Return to Zero (NRZ) digital output to the DSE for recording and to the PMP for transmission to the ground.

Two modes of operation are possible: the High Bit Rate (HBR) mode of 51.2 kilobits per second (kbps) and the Low Bit Rate (LBR) mode of 1.6 kbps. The desired mode is selected by placing the TM INPUTS PCM switch on MDC 20 to HIGH or LOW, or, when this switch is in the LOW position, HBR mode can be commanded by transmitting RTC 05 via the UDL. The DSE recording and playback operations will be effected by changes in PCM bit rate. In HBR mode, all telemetry inputs to the PCM equipment are processed and appear in the output signal. In LBR mode, some of the parameters will not appear in the PCM output signal. See Section 7.3 for LBR parameters.

The PCM timing is normally derived from the CTE 512 KHz clock input signal and the CTE 1 PPS signal is used for subframe synchronization. If the CTE 512 KHz clock is lost for more than 10 microseconds, PCM timing is switched to an internal clock and the 1 PPS subframe sync is disabled. If the CTE clock recovers after a switchover, timing is automatically switched to the CTE clock and a new subframe is started with the next 1 PPS sync input.

7.2.2 Central Timing Equipment

The CTE provides basic clock signals to time correlate all CSM time sensitive functions.

The CTE supplies a 512 KHz signal to the PCM telemetry equipment, to the PMP, and to ground checkout equipment. Three 6.4 KHz signals are supplied to the three ac power inverters for synchronization of the 400 Hz frequency of the ac power. A 4 KHz signal is supplied to the Delta V section of the SCS for change in velocity calculations.

Synchronization of the subframe of the PCM is accomplished by a 1 pps signal from the CTE.

*

A 1 pulse per 10 minutes signal is supplied to the ECS for use in the water separator accumulator. The CTE time accumulator supplies a 32 bit time word (CT0142F) to the PCM which indicates the day of the month, the hour, the minute, and the second. The time accumulator may be set to any predetermined time up to 31 days, 23 hours, 59 minutes, and 59 seconds via the UDL. Any interruption of power to the CTE will cause the time accumulator to reset to 01 day, 00 hour, 00 minutes and 00 seconds.

In the primary or normal mode of operation, the Apollo guidance computer (AGC) provides a 1024 KHz signal to the CTE. This automatically synchronizes (phase locks) the CTE with the AGC and provides a stability of $\pm 2 \times 10^{-6}$ parts in 14 days. In the event of sync signal failure, the CTE automatically switches to its own crystal oscillator with a stability of $\pm 2.2 \times 10^{-6}$ parts in 5 days.

7.2.3 Signal Conditioning Equipment (SCE)

The signal conditioning equipment is designed to process inputs from spacecraft sensors and produce analog outputs ranging from 0 to +5.0 volts dc. The signal conditioning equipment can consist of up to 45 modules of the following kind: frequency demodulators, bi-phase demodulators, dc differential amplifiers, dc differential bridge amplifiers, active attenuators, active inverter attenuators, ac to dc converters and dc low gain amplifiers.

7.2.3.1 Frequency Demodulator Module (FD)

The frequency demodulator module contains one circuit capable of transforming an input signal frequency change from 380 to 420 Hz to an output signal from 0 to 5 Vdc. Input signals are used to trigger a one shot multivibrator feeding an active filter. The filter along with a dc differential amplifier and output driver transforms the multivibrator frequency to a 0 to 5 Vdc signal. The dc differential amplifier and output driver circuits are adjustable for zero output volts and gain.

- A. Requires SCE +20 and -20 Vdc power.
- B. Input Signal - 105 to 150 VRMS, 400 Hz ac voltage.

*

- C. Input Impedance - > 500 K ohms
- D. Output Impedance - < 500 ohms.
- E. Output signal - 0 to 5Vdc, varies linearly with input from 380 to 420 Hz. Output is zener diode clamped for voltages less than -0.8 Vdc or greater than +6.2 Vdc.
- F. Overall response is flat for input frequency changes up to 15 Hz/sec.

7.2.3.2 Bi-Phase Demodulator Module (PD)

The biphas demodulator module contains one circuit capable of measuring 0 and 180 degrees phase relation between input and reference ac voltages. The module can be adjusted to handle input signal levels between 0.5 and 50 VRMS and 400 to 1600 Hz.

Zero and gain adjustments are provided to adjust 0 Vdc (180 degrees out of phase) and +5 Vdc (0 degrees in phase) outputs for a specific input voltage level. The input signal is gated by a reference signal so that a half wave signal is fed to an integrator circuit. With 0 volts input or with a ± 90 degrees phase relation the output signal will be +2.5 Vdc.

- A. Requires SCE +20 and -20 Vdc power
- B. Input signals are dc isolated
- C. Input Impedance - > 500 K ohms
- D. Output Impedance - < 500 ohms
- E. Output signal varies linearly, 2.5 to 0 or +5 Vdc, with input voltage. Output voltage is zener diode clamped for voltages less than -0.8 Vdc or greater than +6.2 Vdc.

7.2.3.3 DC Differential Amplifier Modules (DA)

The dc differential amplifier module consists of two circuits, each capable of amplifying a differential 20 to 250 MVdc input signal to 5 Vdc output or a single ended 0.25 to 7.0 Vdc input signal to 5 Vdc output. After making connections for proper range, potentiometer adjustments are made for gain, balance and zero.

*

- A. Requires SCE +20 and -20 Vdc power
- B. Input Ranges:
 - 1. Differential - 20 to 200 MVdc,
and
200 to 250 MVdc
 - 2. Single ended - 250 to 320 MVdc,
320 to 410 MVdc,
0.41 to 4.46 Vdc
and
4.46 to 7.0 Vdc
- C. Output voltage, 0 to 5 Vdc, varies linearly with input voltage. Output is zener diode clamped for voltages less than -0.8 Vdc or greater than +6.2 Vdc.
- D. Frequency Response - flat to 200 Hz.
- E. Input Impedance - > 500 K ohms
- F. Output Impedance - < 500 ohms

7.2.3.4 DC Differential Bridge Amplifier Module (DBA)

The dc differential bridge amplifier module consists of two circuits, each capable of providing a 0 to 5 Vdc output for a change in resistance of an external sensor. Bridge and amplifier can be adjusted to provide linear output voltage with sensor resistance changes over the following ranges: 455 to 650 ohms, 328 to 355 ohms, 270 to 525 ohms, 2800 to 5700 ohms, or 315 to 369 ohms. For the above ranges, 0 Vdc output corresponds with minimum resistance. The output is zener diode clamped for voltages less than -0.8 Vdc or greater than +6.2 Vdc. A short circuited input will cause -0.8 Vdc to appear at the output. An open circuited input will cause +6.2 Vdc to appear at the output. The bridge circuit requires SCE +10 Vdc power and the amplifier circuits requires SCE +20 and -20 power.

7.2.3.5 Active Attenuator Module (AA)

The dc active attenuator module contains seven separate circuits, each capable of attenuating a 7.0 to 50 Vdc input signal to 5 Vdc output. After connecting for the proper attenuation range, a potentiometer is

*

adjusted for the desired gain.

- A. Requires SCE +20 and -20 Vdc power.
- B. Input Ranges - 7.0 to 18.7 Vdc
18.7 to 50.0 Vdc
- C. Output voltage varies from 0 to +5.0 Vdc linearly with the input voltage. Output is zener diode clamped for voltages less than -0.8 Vdc or greater than +6.2 Vdc
- D. Frequency Response - flat to 200 Hz
- E. Input Impedance - 20 K ohms.
- F. Output Impedance - < 500 ohms.

7.2.3.6 Active Inverter Attenuator Module (AIA)

The active inverter attenuator module contains seven circuits, each capable of attenuating and inverting a -7.0 to -50 Vdc input signal to a 5 Vdc output. After connecting for the proper attenuation range, a potentiometer is adjusted for the desired gain.

- A. Requires SCE +20 and -20 Vdc power.
- B. Input Ranges - 7.0 to -18.7 Vdc,
- 18.7 to -50.0 Vdc
- C. Output voltage, 0 to 5 Vdc, varies linearly with input voltage. Output is zener diode clamped for voltages less than -0.8 Vdc or greater than +6.2 Vdc
- D. Input Impedance - 20 K ohms
- E. Output Impedance - < 500 ohms.

7.2.3.7 AC to DC Converter Module (AC)

The ac to dc converter Module contains two circuits, each capable of converting a 1 to 150 VRMS ac voltage to a 5 Vdc output. After an input ac voltage range is selected, the gain is adjusted for the maximum desired ac voltage input. The ac signal is rectified to produce a dc output proportional to the amplitude of the input signal.

- A. Requires SCE +20 and -20 Vdc power

*

- B. Input Ranges - 1.0 to 10.0 VRMS and
10.0 to 150 VRMS for
400 to 3200 Hz signals.
- C. Input Impedance - > 500 K ohms
- D. Output Impedance - < 500 ohms
- E. Output is zener diode clipped for voltages less than -0.8 Vdc
or greater than +6.2 Vdc.

7.2.3.8 Low Gain DC Amplifier Module (LGA)

The low gain dc amplifier module contains two circuits, each capable of providing +2.5 Vdc output for zero signal input, 0 Vdc output for -2.5 to -35 Vdc signal input and 5 Vdc output for +2.5 to +35 Vdc signal input. The gain of the conditioner is adjusted for the maximum desired input signal for the ± 2.5 to ± 35 Vdc range.

- A. Requires SCE +20 and -20 Vdc
- B. Input Impedance - > 20 K ohms
- C. Output Impedance - < 500 ohms
- D. Output is zener diode clipped for voltages less than -0.8 Vdc
or greater than +6.2 Vdc

7.2.4 Flight Qualification Recorder (FQR)

The FQR is a 14-track magnetic tape recorder used to record certain flight qualification measurements during critical phases of the mission. This data will be used for postflight analysis only; the FQR has no inflight playback or transmission capability. It will be activated to record the ascent and entry phases of the mission.

The FQR has four external commands:

- A. REWIND
- B. CALIBRATE
- C. RECORD
- D. STOP

The REWIND command moves the tape transport in the reverse direction at 120 ips and locks out RECORD. The CALIBRATE command removes the data

*

input signal and applies a calibration signal to each VCO. The RECORD command energizes the electronics and moves the tape transport in the forward direction at 15 ips. Thirty one minutes of RECORD time is available. The entire tape width is erased prior to recording in the RECORD mode. The STOP command de-energizes the RECORD electronics and de-activates the transport. End of tape sensing with automatic tape transport and electronics shutoff is provided in both directions.

7.2.5 Data Storage Equipment (DSE)

7.2.5.1 DSE Record Capability

The DSE provides the capability to record and reproduce one track of PCM data clock, four tracks of PCM data and nine tracks of analog data in parallel. The DSE uses Main Bus A power for the control circuits and ac Bus 1 or ac Bus 2 ac power for the electronics and tape drive motors.

The DSE is a bi-directional machine with a tape transport mechanism capable of forward or reverse operation at any of three speeds: 3.75 ips (low speed), 15 ips (normal speed), and 120 ips (high speed). The low speed of 3.75 ips is used only to record low bit rate PCM TM data. The normal speed of 15 ips is used to record and playback high bit rate PCM TM data. The high speed of 120 ips is used for fast dump of the low bit rate PCM TM data which was recorded at 3.75 ips. The high speed is also used for fast forward or reverse rewinding. Maximum operating times, to record or playback the entire 2250 feet of tape, are as follows: 2 hours at the low speed of 3.75 ips, 30 minutes at the normal speed of 15 ips, and 3.75 minutes at the high speed of 120 ips.

7.2.5.2 DSE Control Switches

DSE control switches located on MDC 20 along with relays 1K39 and 1K40 in the MCP provide the following DSE control signals.

- A. RECORD - Energizes the record, erase (the ERASE/OFF switch on the DSE must be in ERASE) and tape motion electronics

*

provided:

1. A HIGH signal and a NORMAL SPEED signal are both present, or
a LOW signal and a LOW SPEED signal are both present.
If conditions 1 or 2 are not met, tape movement will be inhibited and all electronics de-energized.
- B. PLAYBACK - Energizes the tape motion electronics. The PCM playback electronics will be energized provided there is no LOW SPEED signal present. The analog playback electronics will be energized provided there is no LOW SPEED or HIGH SPEED signal present. Inhibits erase circuits.
- C. FORWARD - Tape will move in the forward direction provided:
 1. End of tape has not been reached, or
 2. A record inhibit signal is not present.
- D. REVERSE - Tape will move in the reverse direction provided:
 1. Start of tape has not been reached, or
 2. A record inhibit signal is not present.
- E. HIGH SPEED - Tape will move at 120 ips when tape movement is commanded. Inhibits analog playback electronics.
- F. NORM SPEED - Tape will move at 15 ips when tape movement is commanded. Inhibits tape movement if RECORD signal is present and HIGH signal not present.
- G. LOW SPEED - Tape will move at 3.75 ips when tape movement is commanded. Inhibits tape movement if RECORD signal is present and LOW signal is not present. Inhibits playback electronics.
- H. HIGH - Inhibits tape movement if RECORD signal is present and NORM SPEED signal is not present.
- I. LOW - Inhibits tape movement if RECORD signal is present and LOW SPEED signal is not present.

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7.2.5.3 Internal DSE Controls

The DSE provides the following internal controls.

- A. An ERASE/OFF switch on the DSE allows recording without erasure.
- B. The DSE is completely turned off if no RECORD, PLAYBACK, FORWARD, or REVERSE control signal is present.
- C. End of tape sensing and automatic tape transport shutoff without loss of tape end is provided in both directions.
- D. Tape motion indication (CT0012) will not be valid unless a RECORD or PLAYBACK control signal is present.
- E. There will be no tape movement unless a FORWARD or REVERSE control signal is present.
- F. LBR recorded PCM data must be played back at 120 ips, HBR recorded PCM data must be played back at 15 ips and analog recorded data must be played back at 15 ips or the output data will be inhibited or garbled.

7.2.5.4 DSE - PMP Interface

The DSE - PMP interface is controlled by relays in the PMP and switches on MDC 20 (shown on Dwg. 6.4.1). When the TAPE RECORDER - RECORD/PLAY switch is placed to the RECORD position, relays in the PMP are energized connecting nine channels of analog signals to the DSE analog record circuits. During AS-501 flight, four of these channels will be used to record the output from the flight qualification HL and LL commutators. Placing the TAPE RECORDER - RECORD/PLAY switch to OFF (center) or to PLAY resets these relays disconnecting the analog signals from the DSE.

In order to transmit DSE playback data to the ground via S-Band or VHF-FM, the S-BAND - VOICE - TAPE switch must be in the TAPE position. This places the S-Band (if powered) in the FM mode of operation and arms the TAPE RECORDER - PLAY switch enabling one of the following operational modes.

*

- A. PCM - Energizes circuitry in PMP to transmit PCM playback data and analog real-time data.
- B. NORMAL (center) - Energizes circuitry in the PMP to transmit PCM and analog playback data.
- C. ANALOG - Energizes circuitry in the PMP to transmit analog playback data along with real-time PCM data.

There will not be any playback of data during the AS-501 flight. Analog data can only be transmitted via S-Band whereas PCM data can be transmitted via VHF-FM or S-Band.

7.2.5.5 DSE Time Code Signal

The DSE receives a time code modulated 25 KHz signal from the FQR which is used as a timing reference for the analog parameters. This time reference will not be available when the FQR is stopped.

7.2.5.6 DSE PCM Data

The DSE PCM data is obtained from the PCM equipment as a single NRZ serial pulse train at a high bit rate of 51.2 kbps or a low bit rate of 1.6 kbps. In the DSE, a serial-to-parallel converter converts this signal into four parallel digital channels, each of which has a resulting pulse repetition rate (PRR) of only 12.8 kbps or 0.4 kbps (one fourth of the original PRR). The PCM TM equipment furnishes a 51.2 KHz or 1.6 KHz square wave data clock signal to the DSE, which is also divided by four.

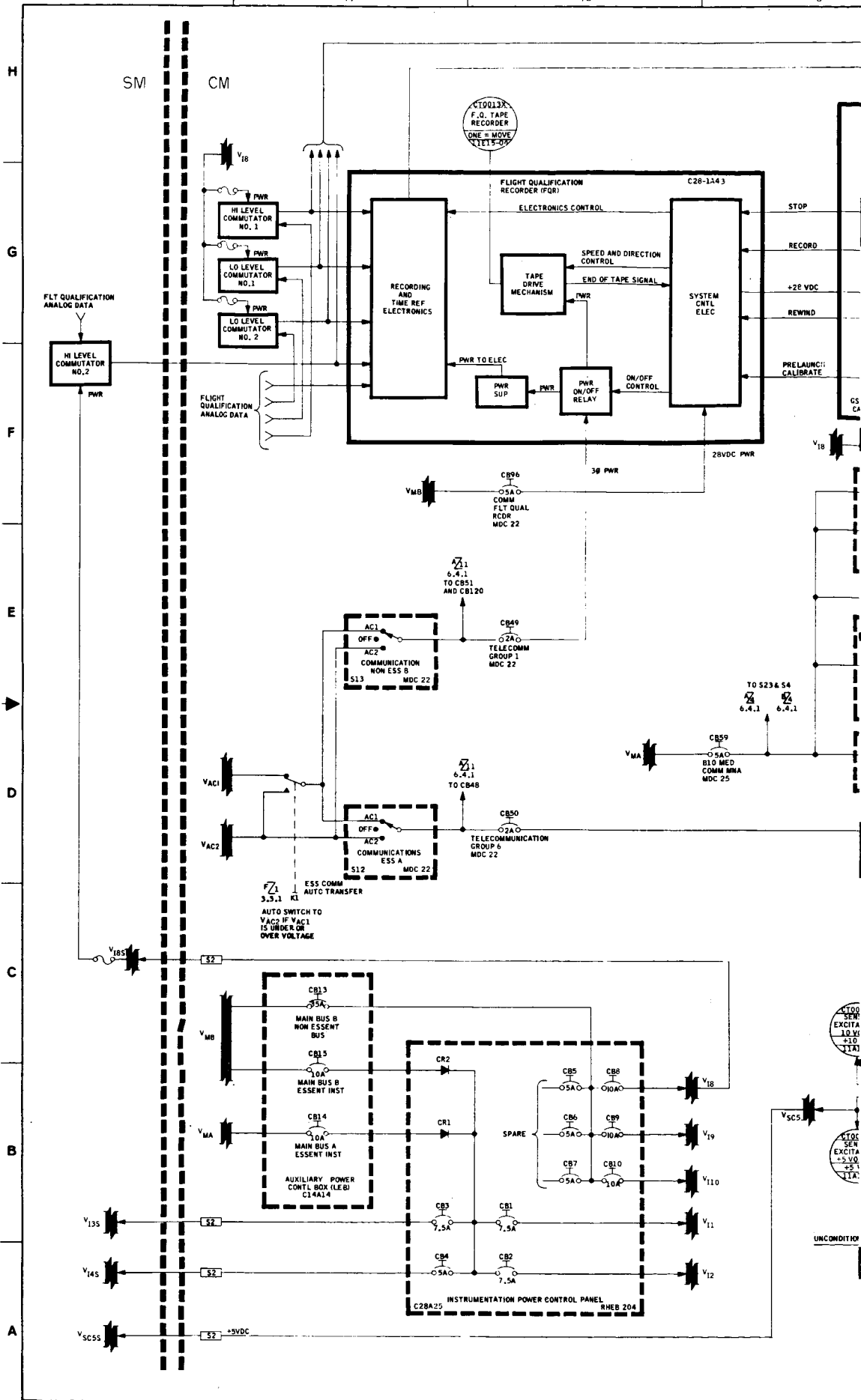
During playback, the four parallel channels of recorded digital data and the data clock signal are routed to a parallel-to-serial converter where the four digital signals are converted back to a single NRZ serial pulse train output to the PMP. The bit rate of this output will always be 51.2 kbps, even if the recorded data was originally 1.6 kbps. The 51.2 kbps high bit rate PCM signal is recorded at 15 inches per second (ips) and played back at the same speed. The low bit rate signal of 1.6 kbps is recorded at 3.75 ips, and played back at 120 ips, an increase of 32 times. This increases the 1.6 kbps to 51.2 kbps.

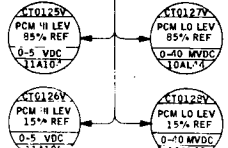
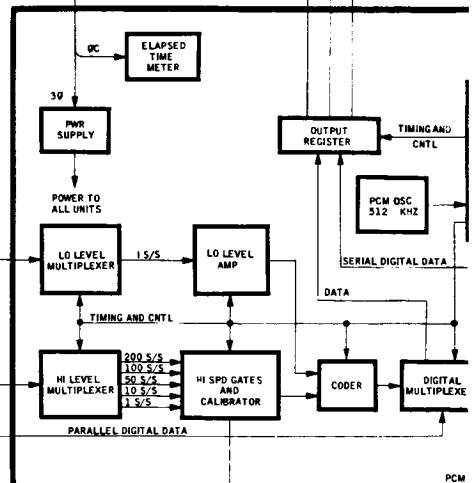
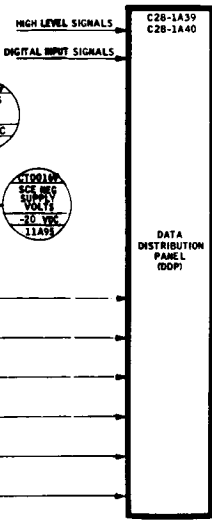
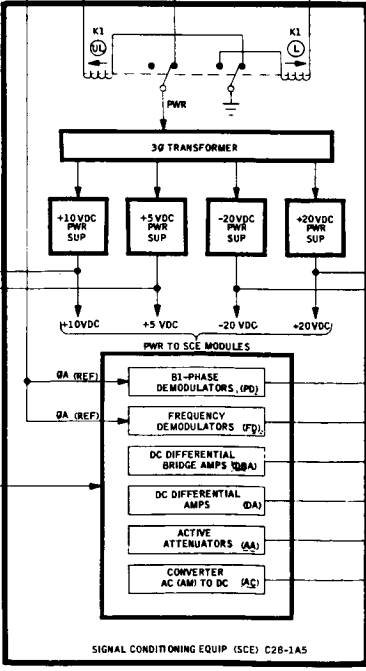
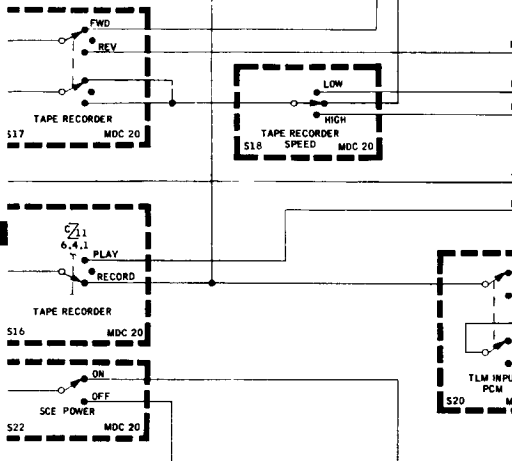
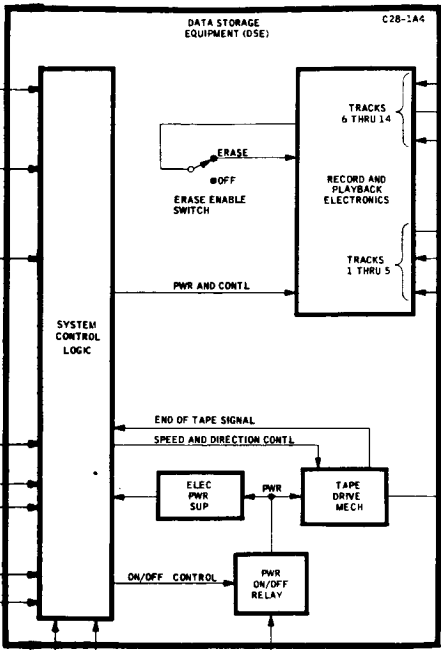
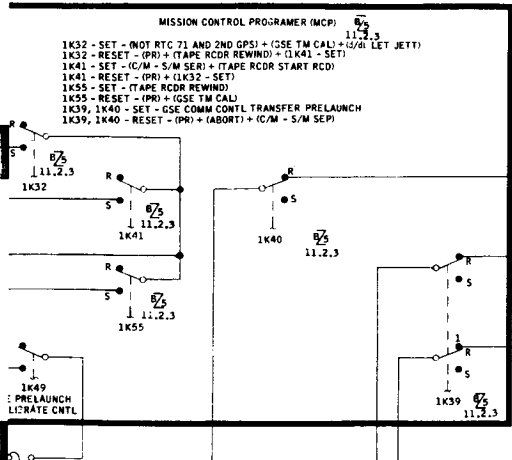
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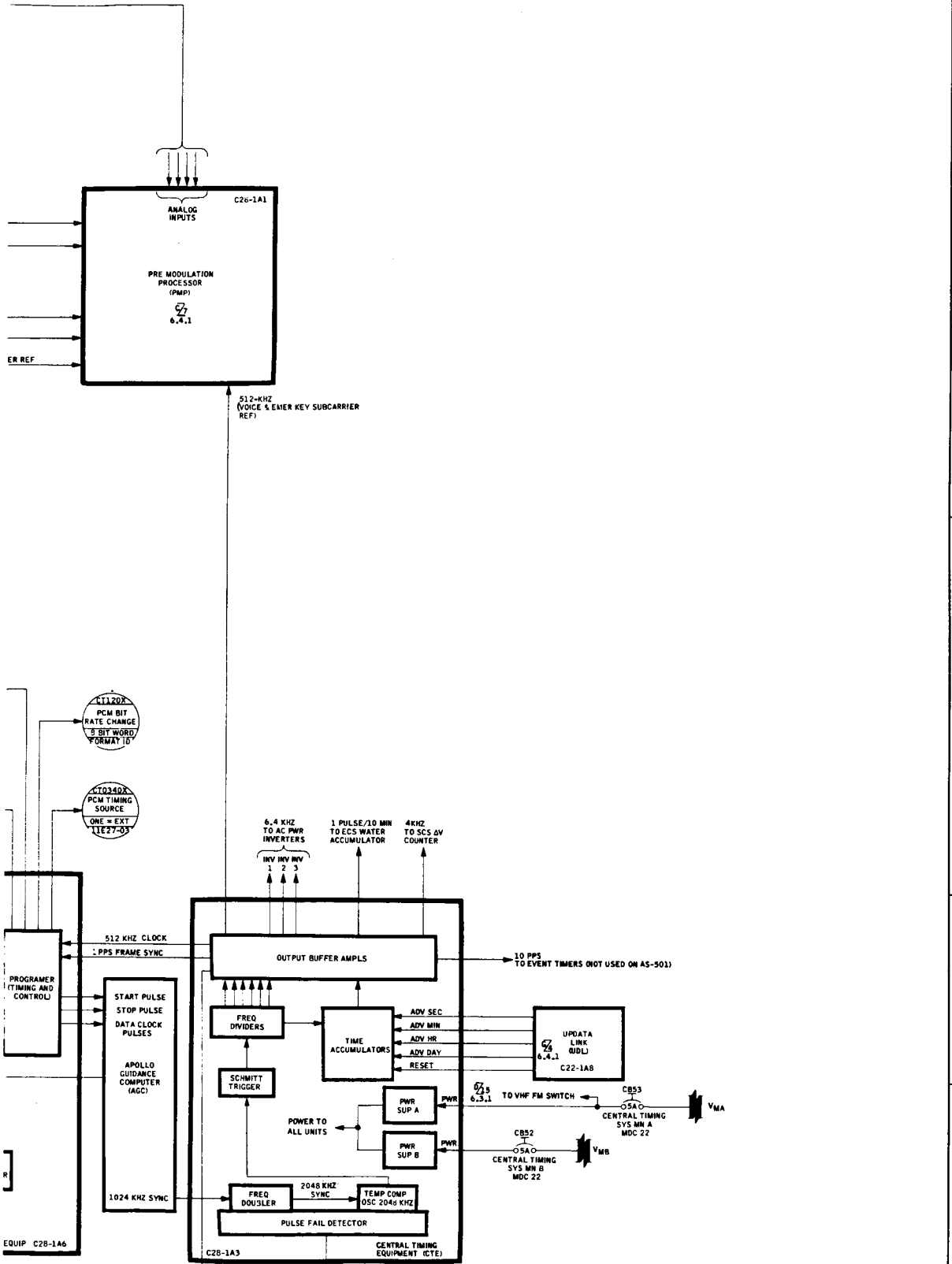
7.2.5.7 DSE Characteristics

- A. PCM Input Signal Levels - Binary "1" = 6.0 (± 0.6) Vdc
Binary "0" = 0.0 (+0.5, -0.0) Vdc
- B. PCM Output Signal Levels - Binary "1" = 6.0 (± 0.5) Vdc
Binary "0" = 0.0 (+0.5, -0.0) Vdc
- C. Audio circuitry and patching capability is available for recording and playback of two wire audio signals; however, this capability will not be used.
- D. Analog channel inputs and outputs are single wire unbalanced signals (0 to 5 volts peak to peak).
- E. The tape transport and electronics will reach operational stability in less than 3 seconds after application of power.
- F. Tape speed will be controlled within ± 0.5 percent of selected speed. The tape drive motors are 400 cps synchronous motors.
- G. Rewind time from end to end of tape in either direction at 120 ips is 3.75 minutes.
- H. Tape motion monitor is bi-directional.
Tape in motion output - 7 (+3, -2) Vdc
Tape stopped output - 0 (+0.5, -0.0) Vdc
- I. One inch wide Mylar tape 2250 feet long is used.
- J. DSE Operational Mode Characteristics

PARAMETER	DIGITAL CHANNELS		ANALOG CHANNELS	
	HI BIT	LOW BIT	HI BIT	LOW BIT
Input Data Rate	51.2 kbps	1.6 kbps	50-10,000 cps	12.5-2500 cps
Record Speed	15 ips	3.75 ips	15 ips	3.75 ips
Playback Speed	15 ips	120 ips	15 ips	15 ips
Output Data Rate	51.2 kbps	51.2 kbps	50-10,000 cps	50,10,000 cps
Total Record Time	30 Minutes	2 Hours	30 Minutes	2 Hours
Total Playback Time	30 Minutes	3.75 Minutes	30 Minutes	30 Minutes







INSTR

SIGNATURES		DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION MANNED SPACECRAFT CENTER - HOUSTON, TEXAS	
DR	<i>[Signature]</i>	11/14/67	INSTRUMENTATION CONTROL CSM SIZE CHG NO AS-501 E 7.2.1 SCALE SHEET 1 OF 1	
ENG	<i>[Signature]</i>	11/14/67		
CH	<i>[Signature]</i>	11/14/67		
APP	<i>[Signature]</i>	11/20/67		
AUTH	<i>[Signature]</i>	11-20-67		

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7.3 PCM SIGNAL FLOW NOTES

Each analog and digital input to the PCM equipment is assigned to a channel and given a channel code number. A fixed program is provided for HBR and for LBR sampling. In HBR, all inputs will be sampled at least once during a subframe at sampling rates from 1 s/s to 200 s/s. In LBR, only selected inputs will be sampled during a subframe at a sample rate of 1 s/s (except channel code 51DS, AGC parameters, which will be sampled at 10 s/s). The sampling sequence for HBR and for LBR are shown in the HBR format and LBR format respectively.

In the HBR mode the PCM equipment is capable of handling the following input signals:

- A. Low Level Analog (0-40 MVdc) - 50 channels at 1 s/s
- B. High Level Analog (0-5 Vdc) - 270 channels (4 at 200 s/s, 16 at 100 s/s, 25 at 50 s/s, 125 at 10 s/s, and 100 at 1 s/s).
- C. Parallel Digital - 1 - 16 bit channel at 200 s/s
1 - 16 bit channel at 50 s/s
1 - 32 bit channel at 10 s/s
1 - 24 bit channel at 10 s/s
28 - 8 bit channels at 10 s/s
- D. Serial Digital - 1 - 40 bit channel at 50 s/s

In the LBR mode the PCM equipment is capable of handling the following input signals:

- A. Low Level Analog (0-40 MVdc) - 10 channels at 1 s/s
- B. High Level Analog (0-5 Vdc) - 100 channels at 1 s/s (these channels are not necessarily the same as the HBR 1 s/s channels).
- C. Parallel Digital - 1-32 bit channel at 1 s/s
28 - 8 bit channels at 1 s/s
- D. Serial Digital - 1 - 40 bit channel at 10 s/s

In the HBR mode, the PCM output data is shifted out serially bit by bit (one bit period equals approximately 19.5 μ sec - 51.2 kbps); eight bits make a word (one word period equals approximately 156 μ sec - 6400 words/sec);

*
128 words make a prime frame (one prime frame period equals 20 milliseconds - 50 prime frames/sec); and 50 prime frames make a subframe (one subframe period equals 1 second - 1 subframe/sec). In the LBR mode, the PCM output data is shifted out serially bit by bit (one bit period equals 625 milliseconds - 1.6 kbps); 8 bits make a word (one word period equals 5 milliseconds - 200 words/sec); 200 words make up a prime frame and a subframe (one prime frame or subframe period equals 1 second).

7.3.1 Programmer

The programmer maintains primary control of all functioning units of the PCM equipment. It uses CTE or internal clock pulses to generate gating and control signals for sampling and processing data.

7.3.2 Analog Data

Each analog data input is connected to an analog gate. The analog gates are grouped in matrix combinations, basically arranged such that five channel inputs (columns) are provided per row with multiple rows used to form the desired matrices. The five analog gates in each row utilize a common Sequencer Gate (SG). Drawing 7.3.1 shows the matrix combinations used for low level and high level analog signals. A row command and a column command must both be present for an analog gate to transfer the data signal via the sequencer gate and high-speed gate or low-level amplifier to the coder. The coder uses a successive approximation technique to code the analog 0 to 5 Vdc signal into an 8 bit binary coded decimal word. This 8 bit word is fed to the digital multiplexer where it is transferred to the output shift register when the coder gate is interrogated.

7.3.3 Parallel Digital Data

Each parallel digital (or event) signal is connected to a gate in the digital multiplexer. When the digital multiplexer gate is interrogated, the output shift register will be loaded with a "1" if the input signal is greater than 3.5 Vdc or if the input is open circuited. The output shift register will remain a zero provided the input signal is less than 0.5 Vdc

*

and the input impedance is less than 5 K ohms.

7.3.4 PCM Telemetry Parameters

Tables 7-2 through 7-11 list the PCM telemetry parameters that will be available for real-time analysis. Analog parameters recorded on the flight qualification recorder and the data storage equipment are not listed. Also, onboard display and GSE parameters are not listed. Information on parameters not listed is available in the Apollo Baseline Master Measurements list and/or the Apollo Instrumentation Equipment List for Spacecrafts 17 and 20.

7.3.4.1 Column Definitions for Tables 7-2 Through 7-11

A. Column 1 - Parameter No.

The Parameter Number consists of seven characters:

Two letters follow by four numbers and one letter.

1. Module Code

The first letter designates the measurement location by module.

- a. A - ADAPTER
- b. B - BOOSTER
- c. C - COMMAND MODULE
- d. L - LAUNCH ESCAPE TOWER
- e. S - SERVICE MODULE

2. Functional Subsystem Code

The second letter denotes the subsystem wherein the measurement originates.

- a. A - STRUCTURES
- b. C - ELECTRICAL POWER
- c. D - MASTER EVENTS SEQUENCE CONTROLLER
- d. E - EARTH LANDING SEQUENCE CONTROLLER
- e. F - ENVIRONMENTAL CONTROL
- f. G - GUIDANCE & NAVIGATION
- g. H - STABILIZATION & CONTROL

- h. J - CREW EQUIPMENT
- i. K - FLIGHT TECHNOLOGY
- j. L - SCIENTIFIC EQUIPMENT
- k. P - SERVICE PROPULSION
- l. R - REACTION CONTROL
- m. S - L/V EMERGENCY DETECTION
- n. T - COMMUNICATIONS & INSTRUMENTATION

3. Discrete Number

Characters three through six are discrete numbers listed sequentially within each subsystem.

B. Column 2 - Nomenclature

The nomenclature is a brief, definitive title given to each measurement. Standard abbreviations are used, where applicable.

C. Column 3 - TM

The telemetry column contains two characters. The first character indicates the type of signal measured as follows:

- H - High level analog
- L - Low level analog
- E - Event (one bit)
- D - Digital word (more than one bit)
- S - Serial digital word (more than one bit)

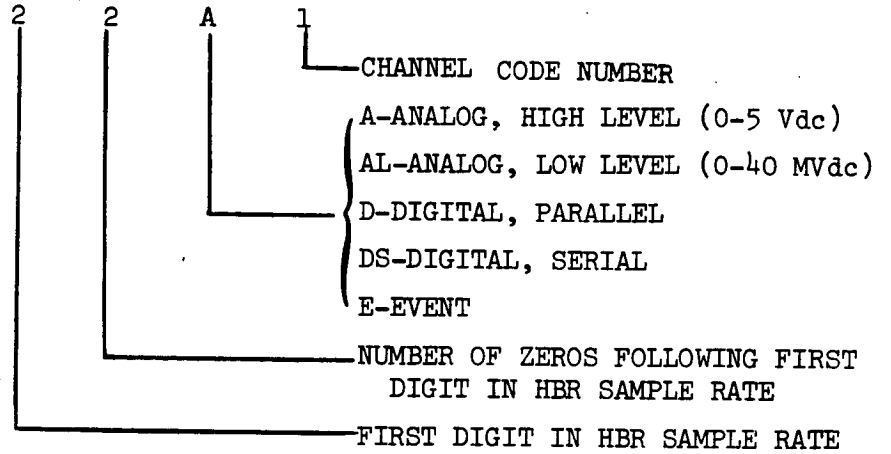
The second character indicates the telemetry format as follows:

- 1 - HBR format only
- 2 - HBR and LBR formats

D. Column 4 - Channel Code

The channel code contains information giving the high bit rate (HBR) sample rate, the type of parameter measurement (analog, digital, etc.), and the channel code number associated with that type of measurement.

EXAMPLE:



E. Column 5 - INST BUS

The Instrumentation Bus column will indicate the power source for that parameter. Some measurements are generated and/or signal conditioned within a particular system, using that systems' power and will be indicated by G&N, S&C, ELECT, and C&I.

The instrumentation system distributes +28 Vdc power directly to certain sensors and signal conditioners. These instrumentation power buses are shown on Dwg. 7.2.1 and designated V_{I1} , V_{I2} , V_{I3S} , V_{I4S} , V_{I8} , V_{I8S} , V_{I9} , V_{I10} , V_{SC5} , and V_{SC5S} . V_{I8S} and V_{SC5S} are created from V_{I8} and V_{SC5} respectively and feed sensors located in the service module.

F. Column 6 - SCE Cond

The SCE Conditioner column uses the following code to indicate the type of SCE module that is used to condition the signal. See Section 7.2.3 notes for module description.

AA - dc Active Attenuator module

AIA - dc Active Inverter Attenuator module

DA - dc Differential Amplifier module

DBA - dc Differential Bridge Amplifier module

*

LGA - dc Low Gain Amplifier module
AC - ac to dc Converter module
PD - Bi-phase Demodulator module
FD - Frequency Demodulator module

7.3.5 PCM Telemetry Formats

The HBR format, shown on drawing 7.3.1, gives the bit stream word and prime frame location for each channel. The 128 word blocks make up a prime frame. A 200 s/s channel will appear in 4 word blocks, a 100 s/s channel will appear in 2 word blocks and a 50 s/s channel will appear in 1 word block in each prime frame. The 10 s/s channels will appear in every fifth prime frame. The 1 s/s channels will appear in only one prime frame. Prime frame locations are given in the word blocks by the following code:

- A. A - All prime frames
- B. B - Prime frames 1, 6, 11, 16....46
- C. C - Prime frames 2, 7, 12, 17....47
- D. D - Prime frames 3, 8, 13, 18....48
- E. E - Prime frames 4, 9, 14, 19....49
- F. F - Prime frames 5, 10, 15, 20....50
- G. 1, 2, 3,....50 - Prime frames 1, 2, 3....50.

The LBR format gives the word location (1 thru 200) of each channel appearing in the LBR bit stream.

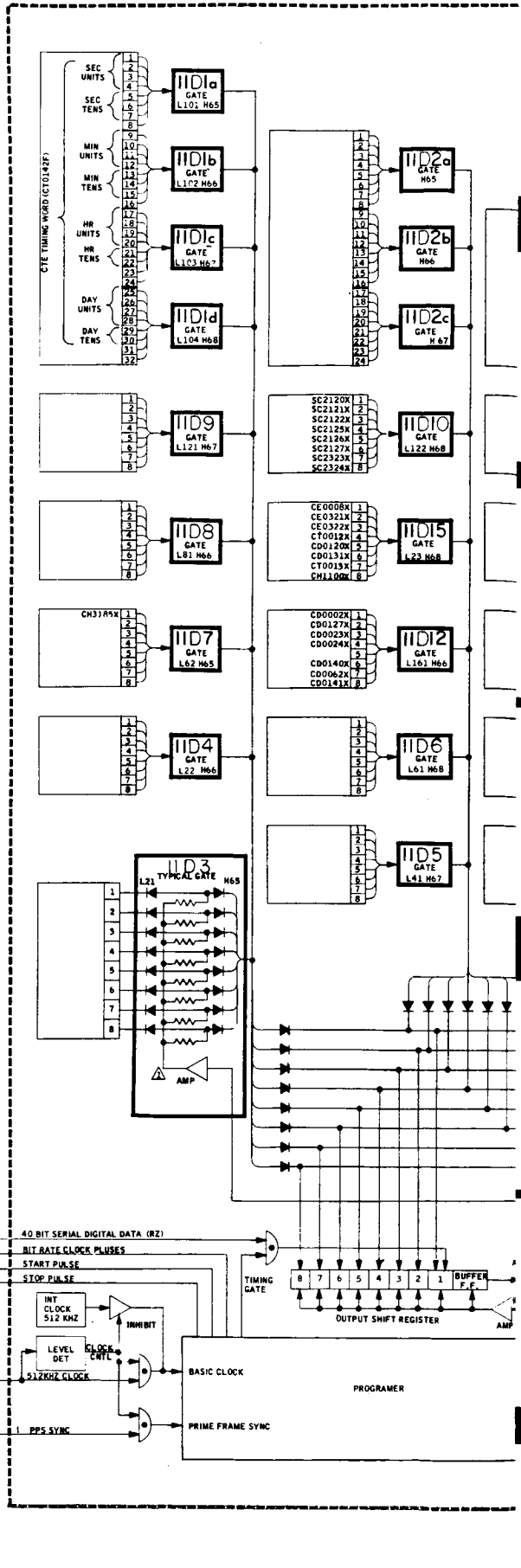
HBR FOPMAT

START

SYNCH	1	2	3	4	5	6	7	8
220a	A	220a	A	51A2	A	12A2	A	12A3
11A	3	11A	4	51A4	A	12A5	A	12A6
11A	5	10A	1	51A6	A	12A7	A	12A8
5105	A	5105	A	5105	A	5105	A	22A1
220a	A	220a	A	51A9	A	12A10	A	12A11
11A	8	12A12	A	51A11	A	12A13	A	22A3
11A	10	11A	11	51A13	A	12A15	A	22A4
11D	14	11D	15	11D	16	11A	13	22A1
220a	A	220a	A	51A16	A	12A2	A	51A17
11A	15	12A4	A	51A18	A	12A5	A	22A3
11A	17	10A	2	51A20	A	12A2	A	22A4
510a	A	510a	A	10A	1	11A	19	22A1
220a	A	220a	A	51A23	A	12A10	A	51A24
11A	21	12A12	A	51A25	A	12A13	A	22A3
11A	23	11A	24	11D	17	11A	25	22A4
10A	1	11A	1	10A	1	11A	2	11D
11	25	13	26	13	27	14	28	14
21	45	28	46	28	47	29	48	29
31	65	38	66	38	67	39	68	39
41	85	51	86	51	87	52	88	52
51	105	63	106	63	107	64	108	64
61	125	76	126	76	127	77	128	77
71	145	88	146	88	147	89	148	89
81	165	101	166	101	167	102	168	102
91	185	113	186	113	187	114	188	114
10	1	10	1	10	1	10	1	10
20	21	20	21	20	21	20	21	20
30	41	30	41	30	41	30	41	30
40	61	40	61	40	61	40	61	40
50	81	50	81	50	81	50	81	50
60	101	60	101	60	101	60	101	60
70	121	70	121	70	121	70	121	70
80	141	80	141	80	141	80	141	80
90	161	90	161	90	161	90	161	90
100	181	100	181	100	181	100	181	100

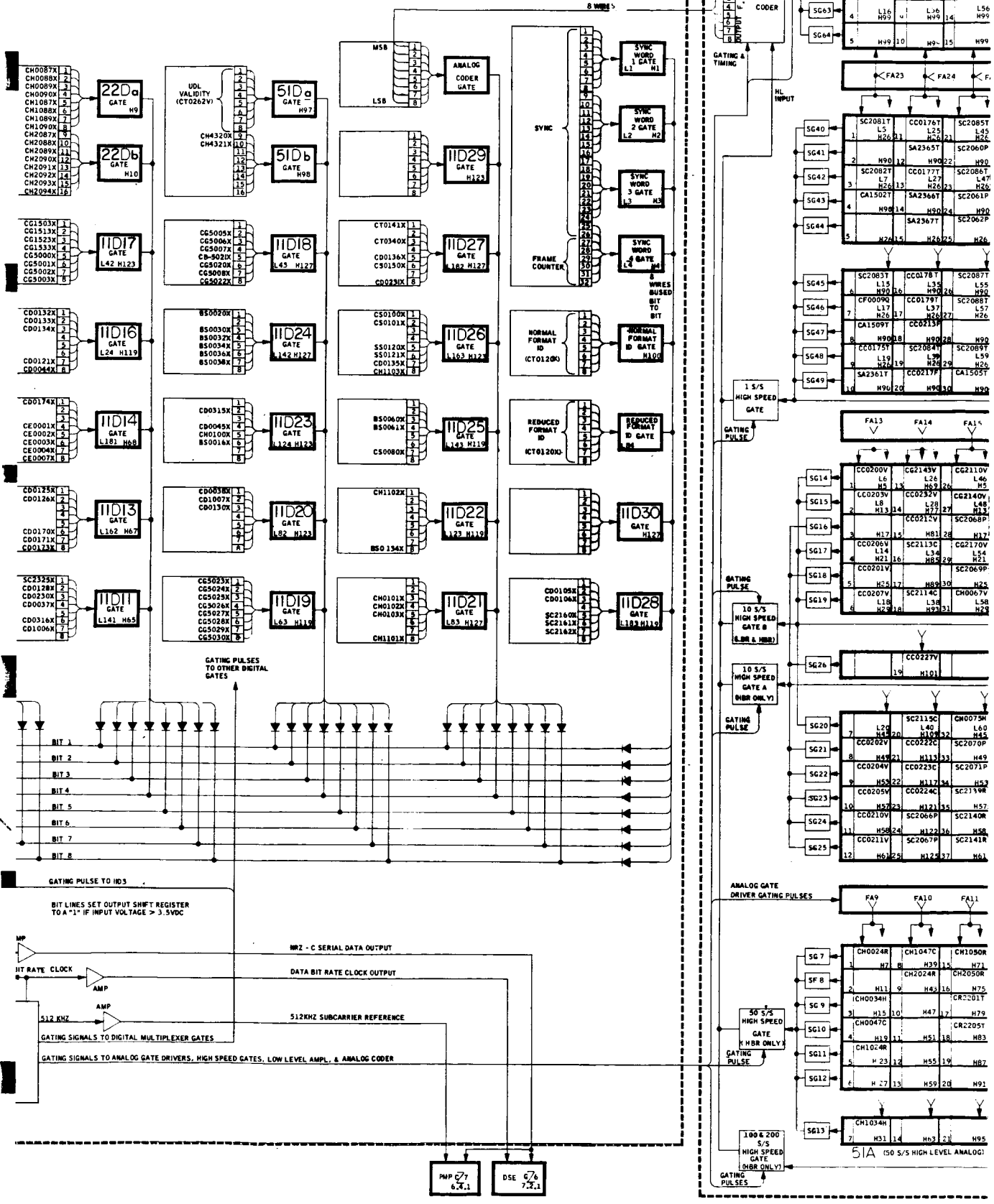
LBR FORMAT

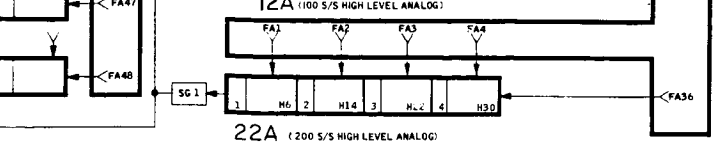
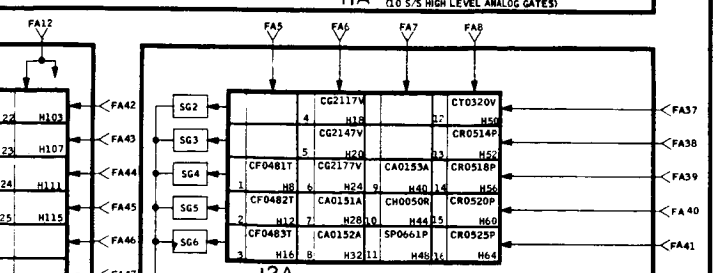
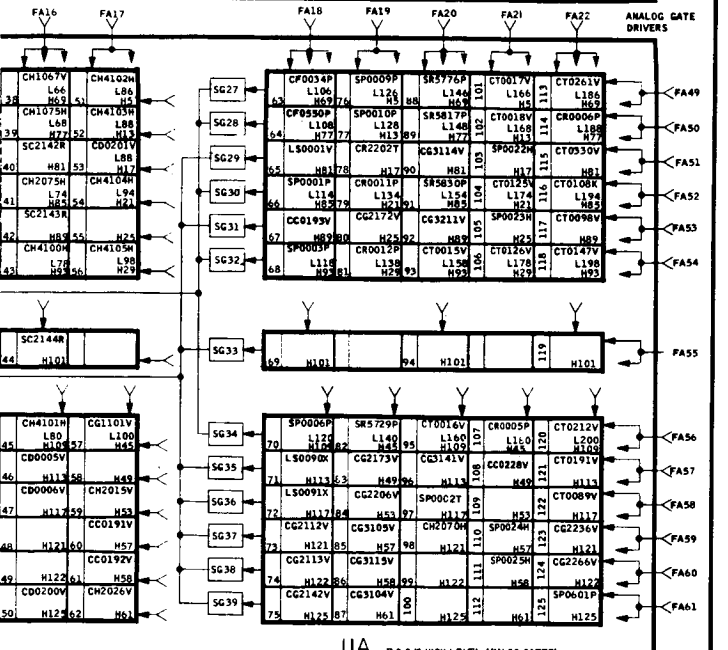
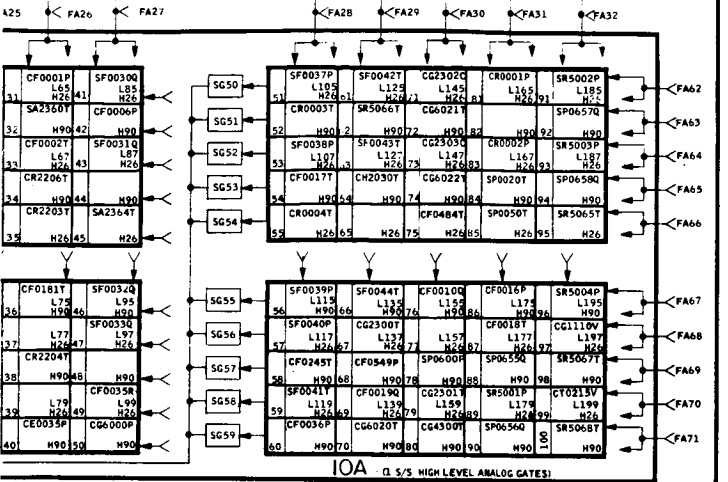
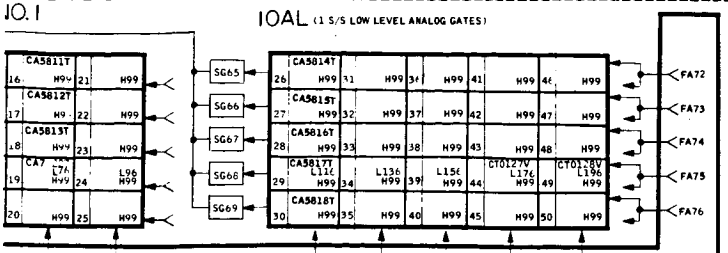
SYNCH	1	2	3	4
11D	5	21	11D	4
6	61	7	62	19
8	81	20	82	21
9	101	10	102	11
11	121	10	122	22
12	141	24	142	25
13	161	25	162	26
14	181	27	182	28
10A	1	5	11A	1
11	25	13	26	13
21	45	28	46	28
31	65	38	66	38
41	85	51	86	51
51	105	63	106	63
61	125	76	126	76
71	145	88	146	88
81	165	101	166	101
91	185	113	186	113
9	29	10	30	11
19	49	20	50	21
29	69	30	70	31
39	89	40	90	41
49	109	50	110	51
59	129	60	130	61
69	149	70	150	71
79	169	80	170	81
89	189	90	190	91
13	33	11A	4	14
14	53	29	54	26
15	73	41	74	36
16	93	54	94	46
17	113	66	114	56
18	133	79	134	66
19	153	91	154	76
20	173	104	174	86
21	193	116	194	96
10A	1	11A	1	10A
17	37	18	38	19
27	57	31	58	29
37	77	43	78	39
47	97	56	98	49
57	117	68	118	59
67	137	81	138	69
77	157	93	158	79
87	177	106	178	89
97	197	118	198	99



PCM NO.2

PCM N





NOTES:

- AMPLIFIER OUTPUT IS - 9VDC UNLESS GATED TO 0VDC.
- LOOK DESIGNATES LMR WORD NUMBER
- HOOK DESIGNATES HBR WORD NUMBER
- SGXX DESIGNATES SEQUENCER GATE NUMBER
- THE FOLLOWING LETTER CODE DESIGNATES HBR PRIME FRAMES FOR CHANNELS SAMPLED IN MORE THAN ONE PRIME FRAME:
 A - ALL PRIME FRAMES (1 THRU 50)
 B - PRIME FRAMES 1, 9, 11, 46
 C - PRIME FRAMES 2, 7, 12, 47
 D - PRIME FRAMES 3, 8, 13, 48
 E - PRIME FRAMES 4, 9, 14, 49
 F - PRIME FRAMES 5, 10, 15, 50
- HBR CHANNELS SAMPLED AT 1.5/5 WILL APPEAR IN WORDS 26, 90 AND 99. THE PRIME FRAME NUMBER FOR A PARTICULAR CHANNEL MAY BE FOUND BY THE FOLLOWING:
 FOR WORD 26 - $HBF = \frac{NCC-1}{2}$
 FOR WORD 90 - $HBF = \frac{NCC}{2}$
 FOR WORD 99 - $HBF = NCC$
 WHERE: HBF - PRIME FRAME NUMBER
 NCC - CHANNEL CODE NUMBER (AS 22 IN 10A22)

INSTR

SIGNATURES	DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION
DR <i>[Signature]</i>	<i>[Date]</i>	MANNED SPACECRAFT CENTER - HOUSTON, TEXAS
ENG <i>[Signature]</i>	<i>[Date]</i>	
CH		
APP		
AUTH		
INSTRUMENTATION PCM SIGNAL FLOW		
CSM	SIZE	OWG NO
MISSION	J	7.3.1
AS-501		
SCALE		SHEET 1 OF 1

CSM
AS-501

TABLE 7-2 PCM TELEMETRY - STRUCTURE

PARAMETER NO.	NOMENCLATURE	TM	CHANNEL CODE	INST BUS	SCE COND
CA0151	X AXIS ENTRY ACCEL HIGH	H1	12A7	V18	
CA0152	Y AXIS ENTRY ACCEL HIGH	H1	12A8	V18	
CA0153	Z AXIS ENTRY ACCEL HIGH	H1	12A9	V18	
CA1502	TEMP SIDE HS BOND LOC A	H1	10A4	V11	
CA1505	TEMP SIDE HS BOND LOC B	H1	10A30	V11	
CA1509	TEMP SIDE HS BOND LOC C	H1	10A8	V11	
SA2360	TEMP SEXT 3 IN SURF	H1	10A32	V14S	
SA2361	TEMP SEXT 6 IN SURF	H1	10A10	V14S	
SA2364	TEMP SEXT 3 FUEL TANK SURF	H1	10A45	V14S	
SA2365	TEMP SEXT 6 FUEL TANK SURF	H1	10A12	V14S	
SA2366	TEMP SEXT 4 IN SURF	H1	10A14	V14S	
SA2367	TEMP SEXT 1 IN SURF	H1	10A15	V14S	
CA5811	TEMP ASTRO SEXT AREA/STL LOC 1	L1	10AL16	V12	
CA5812	TEMP ASTRO SEXT AREA/STL LOC 2	L1	10AL17	V12	
CA5813	TEMP ASTRO SEXT AREA/AL LOC 1	L1	10AL18	V12	
CA5814	TEMP ASTRO SEXT AREA/AL LOC 2	L1	10AL26	V12	
CA5815	TEMP ASTRO SEXT AREA/AL LOC 3	L1	10AL27	V12	
CA5816	TEMP ASTRO SEXT AREA/AL LOC 4	L1	10AL28	V12	
CA5817	TEMP ASTRO SEXT AREA/AL LOC 5	L2	10AL29	V12	
CA5818	TEMP ASTRO SEXT AREA/AL LOC 6	L1	10AL30	V12	
CA7822	TEMP LH SIDE WINDOW IN FRAME	L2	10AL19	V18	

**

TABLE 7-3 PCM TELEMETRY - ELECTRICAL POWER SYSTEM

PARAMETER NO.	NOMENCLATURE	TM	CHANNEL CODE	INST BUS	SCE COND
CC0175	TEMP STATIC INV 1	H2	10A9		DBA
CC0176	TEMP STATIC INV 2	H2	10A11		DBA
CC0177	TEMP STATIC INV 3	H2	10A13		DBA
CC0178	TEMP BAT A CASE	H2	10A16	V12	
CC0179	TEMP BAT B CASE	H2	10A17	V12	
CC0191	DC VOLT AUX BAT 1	H1	11A60		AA
CC0192	DC VOLT AUX BAT 2	H1	11A61		AA
CC0193	DC VOLT AUX BAT 3	H1	11A67		AA
CC0200	AC VOLTS MN BUS 1 PHASE A	H2	11A1	VAC1	AC
CC0201	AC VOLTS MN BUS 1 PHASE B	H1	11A5	VAC1	AC
CC0202	AC VOLTS MN BUS 1 PHASE C	H1	11A8	VAC1	AC
CC0203	AC VOLTS MN BUS 2 PHASE A	H2	11A2	VAC2	AC
CC0204	AC VOLTS MN BUS 2 PHASE B	H1	11A9	VAC2	AC
CC0205	AC VOLTS MN BUS 2 PHASE C	H1	11A10	VAC2	AC
CC0206	DC VOLTS MN BUS A	H2	11A4	VMA	AA
CC0207	DC VOLTS MN BUS B	H2	11A6	VMB	AA
CC0210	DC VOLTS BAT BUS A	H1	11A11	VBA	AA
CC0211	DC VOLTS BAT BUS B	H1	11A12	VBB	AA
CC0212	DC VOLTS POST LNDG BAT	H1	11A15		AA
CC0213	FREQ AC BUS 1 PHASE A	H1	10A18	VAC1	FD
CC0217	FREQ AC BUS 2 PHASE A	H1	10A20	VAC2	FD
CC0222	DC CURRENT BAT A	H1	11A21		DA
CC0223	DC CURRENT BAT B	H1	11A22		DA
CC0224	DC CURRENT POST LNDG BAT	H1	11A23		DA
CC0227	DC VOLTAGE PYRO BATT A	H1	11A19		AA
CC0228	DC VOLTAGE PYRO BATT B	H1	11A108		AA
CC0232	DC VOLTS BAT RELAY BUS	H2	11A14	VBR	AA
CC0451	ESS AC LOAD TRANSFER	E2	11E5-08	VBR	AA
SC2060	N2 PRESS. F/C 1 REG	H1	10A22	V135	
SC2061	N2 PRESS. F/C 2 REG	H1	10A24	V135	

TABLE 7-3 PCM TELEMETRY - ELECTRICAL POWER SYSTEM (CONT'D)

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PARAMETER NO.	NOMENCLATURE	TM	CHANNEL CODE	INST BUS	SCE COND
SC2062	N2 PRESS. F/C 3 REG	H1	10A25	VI3S	
SC2066	O2 PRESS. F/C 1 REG	H1	11A24	VI3S	
SC2067	O2 PRESS. F/C 2 REG	H1	11A25	VI3S	
SC2068	O2 PRESS. F/C 3 REG	H1	11A28	VI3S	
SC2069	H2 PRESS. F/C 1 REG	H1	11A30	VI3S	
SC2070	H2 PRESS. F/C 2 REG	H1	11A33	VI3S	DBA
SC2071	H2 PRESS. F/C 3 REG	H1	11A34	VI3S	DBA
SC2081	TEMP F/C 1 COND EXH	H2	10A1		DBA
SC2082	TEMP F/C 2 COND EXH	H2	10A3		
SC2083	TEMP F/C 3 COND EXH	H2	10A6		
SC2084	TEMP F/C 1 SKIN	H2	10A19		DBA
SC2085	TEMP F/C 2 SKIN	H2	10A21		DBA
SC2086	TEMP F/C 3 SKIN	H2	10A23		DBA
SC2087	TEMP F/C 1 RAD OUT	H2	10A26	VI3S	
SC2088	TEMP F/C 2 RAD OUT	H2	10A27	VI3S	
SC2089	TEMP F/C 3 RAD OUT	H2	10A29	VI3S	
SC2113	DC CURRENT F/C 1 OUT	H2	11A16		DA
SC2114	DC CURRENT F/C 2 OUT	H2	11A18		DA
SC2115	DC CURRENT F/C 3 OUT	H2	11A20		DA
SC2120	F/C 1 BUS A DISC	E2	11E10-01	VBR	AA
SC2121	F/C 2 BUS A DISC	E2	11E10-02	VBR	AA
SC2122	F/C 3 BUS A DISC	E2	11E10-03	VBR	AA
SC2125	F/C 1 BUS B DISC	E2	11E10-04	VBR	AA
SC2126	F/C 2 BUS B DISC	E2	11E10-05	VBR	AA
SC2127	F/C 3 BUS B DISC	E2	11E10-06	VBR	AA
SC2139	FLOW RATE H2 F/C 1	H1	11A35	VI3S	
SC2140	FLOW RATE H2 F/C 2	H1	11A36	VI3S	
SC2141	FLOW RATE H2 F/C 3	H1	11A37	VI3S	
SC2142	FLOW RATE O2 F/C 1	H1	11A40	VI3S	
SC2143	FLOW RATE O2 F/C 2	H1	11A42	VI3S	

TABLE 7-3 PCM TELEMETRY - ELECTRICAL POWER SYSTEM (CONCLUDED)

PARAMETER NO.	NOMENCLATURE	TM	CHANNEL CODE	INST BUS	SCE COND
SC2144	FLOW RATE O ₂ F/C 3	H1	11A44	V13	
SC2160	PH FACTOR H ₂ O COND F/C 1	E2	11E28-05	ELECT	
SC2161	PH FACTOR H ₂ O COND F/C 2	E2	11E28-06	ELECT	
SC2162	PH FACTOR H ₂ O COND F/C 3	E2	11E28-07	ELECT	
SC2323	F/C 1 SHUTOFF MON	E2	11E10-07	VBR	AA
SC2324	F/C 2 SHUTOFF MON	E2	11E10-08	VBR	AA
SC2325	F/C 3 SHUTOFF MON	E2	11E11-01	VBR	AA

TABLE 7-4 PCM TELEMETRY - LAUNCH ESCAPE AND EARTH LANDING SYSTEMS

PARAMETER NO.	NOMENCLATURE	TM	CHANNEL CODE	INST BUS	SCE COND
CD0002	LES ABORT INITIATE SIG A	E2	11E12-01		
CD0005	DC VOLT PYRO BUS A	H1	11A46		
CD0006	DC VOLT PYRO BUS B	H1	11A47		
CD0023	CM-SM SEP RLY CLOSE A	E2	11E12-03		
CD0024	CM-SM SEP RLY CLOSE B	E2	11E12-04		
CD0037	ELS SEQ START RLY CLOSE A	E2	11E11-04		
CD0038	ELS SEQ START RLY CLOSE B	E2	11E20-01		
CD0044	BOOSTER CUTOFF SIG A	E2	11E16-08		
CD0045	BOOSTER CUTOFF SIG B	E2	11E23-04		
CD0062	LES ABORT INITIATE SIG B	E2	11E12-07		
CD0105	TWR JETT A	E2	11E28-02		
CD0106	TWR JETT B	E2	11E28-03		
CD0120	CANARD DEPLOY A	E2	11E15-05		
CD0121	CANARD DEPLOY B	E2	11E16-07		
CD0125	ADAPT/SM SEP INITIATE A	E2	11E13-01		
CD0126	ADAPT/SM SEP INITIATE B	E2	11E13-02		
CD0127	ADAPT SEP A	E2	11E12-02		
CD0128	ADAPT SEP B	E2	11E11-02		
CD0130	HAND CONTR IN A	E2	11E20-03		
CD0131	HAND CONTR IN B	E2	11E15-06		
CD0132	EDS ABORT LOGIC IN NO. 1	E2	11E16-01		
CD0133	EDS ABORT LOGIC IN NO. 2	E2	11E16-02		
CD0134	EDS ABORT LOGIC IN NO. 3	E2	11E16-03		
CD0135	EDS ABORT LOGIC OUT A	E2	11E26-07		
CD0136	EDS ABORT LOGIC OUT B	E2	11E27-05		
CD0140	DIRECT ULLAGE ON A	E2	11E12-06		
CD0141	DIRECT ULLAGE ON B	E2	11E12-08		
CD0170	RCS ACTIVATE SIG A	E2	11E13-06		
CD0171	RCS ACTIVATE SIG B	E2	11E13-07		
CD0173	CM RCS PRESS. SIG A	E2	11E13-08		

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TABLE 7-4 PCM TELEMETRY - LAUNCH ESCAPE AND EARTH LANDING SYSTEMS (CONCLUDED)

PARAMETER NO.	NOMENCLATURE	TM	CHANNEL CODE	INST BUS	SCE COND
CD0174	CM RCS PRESS. SIG B	E2	11E14-01		
CD0200	DC VOLTS LOGIC BUS A	H1	11A50		
CD0201	DC VOLTS LOGIC BUS B	H1	11A53		
CD0230	FWD HS JETT A	E2	11E11-03		
CD0231	FWD HS JETT B	E2	11E27-08		
CD0315	EDS ENABLE A	E2	11E23-02		
CD0316	EDS ENABLE B	E2	11E11-06		
CD1006	LES MOTOR INITIATE A	E2	11E11-07		
CD1007	LES MOTOR INITIATE B	E2	11E20-02		
CE0001	DRG DEPL RLY CLOSE A	E2	11E14-04	VSC5	
CE0002	DRG DEPL RLY CLOSE B	E2	11E14-05	VSC5	
CE0003	MN CHUTE DEPL-DRG REL RLY A	E2	11E14-06	VSC5	
CE0004	MN CHUTE DEPL-DRG REL RLY B	E2	11E14-07	VSC5	
CE0007	BARO SW LOCK-IN RLY CLOSE A	E2	11E14-08	VSC5	
CE0008	BARO SW LOCK-IN RLY CLOSE B	E2	11E15-01	VSC5	
CE0035	BARO PRESS. STATIC REF	H1	10A40	VI2	
CE0321	MN CHUTE DISC RLY A	E2	11E15-02	VSC5	
CE0322	MN CHUTE DISC RLY B	E2	11E15-03	VSC5	

TABLE 7-5 PCM TELEMETRY - ENVIRONMENTAL CONTROL SYSTEM

PARAMETER NO.	NOMENCLATURE	TM	CHANNEL CODE	INST BUS	SCE COND
CF0001	PRESS. CABIN	H2	10A31	V12	
CF0002	TEMP CABIN	H2	10A33		
CF0006	PRESS. SURGE TANK	H1	10A42		
CF0009	QUAN WASTE H ₂ O TANK	H2	10A7		
CF0010	QUAN POT. H ₂ O TANK	H2	10A76		
CF0016	PRESS. GLY PUMP OUT	H2	10A86		
CF0017	TEMP GLY EVAP OUT STEAM	H1	10A54		
CF0018	TEMP GLY EVAP OUT LIQUID	H2	10A87		
CF0019	QUAN GLY ACCUM	H2	10A69		
SF0030	QUAN H ₂ TANK 1	H2	10A41		
SF0031	QUAN H ₂ TANK 2	H2	10A43		
SF0032	QUAN O ₂ TANK 1	H2	10A46		
SF0033	QUAN O ₂ TANK 2	H2	10A47		
CF0034	BACK PRESS. GLY EVAP	H2	11A63		
CF0035	FLOW RATE ECS O ₂	H2	10A49		
CF0036	PRESS. OUT O ₂ REG SUP	H1	10A60		
SF0037	PRESS. O ₂ TANK 1	H2	10A51		
SF0038	PRESS. O ₂ TANK 2	H2	10A53		
SF0039	PRESS. H ₂ TANK 1	H2	10A56		
SF0040	PRESS. H ₂ TANK 2	H2	10A57	V13S	
SF0041	TEMP O ₂ TANK 1	H2	10A59		
SF0042	TEMP O ₂ TANK 2	H2	10A61		
SF0043	TEMP H ₂ TANK 1	H2	10A63		
SF0044	TEMP H ₂ TANK 2	H2	10A66		
CF0181	TEMP GLY EVAP INLET	H2	10A36		
CF0245	TEMP O ₂ REG IN	H1	10A58		
CF0481	TEMP CP BRANCH 1 IN	H1	12A1		
CF0482	TEMP CP BRANCH 1 OUT	H1	12A2		
CF0483	TEMP CP BRANCH 2 IN	H1	12A3		
CF0484	TEMP CP BRANCH 2 OUT	H1	10A75		

TABLE 7-5 PCM TELEMETRY - ENVIRONMENTAL CONTROL SYSTEM (CONCLUDED)

PARAMETER NO.	NOMENCLATURE	TM	CHANNEL CODE	INST BUS	SCE COND
CF0549 CF0550	DIFF PRESS. COLDPLATE BRANCH 1 DIFF PRESS. COLDPLATE BRANCH 2	H1 H2	10A68 11A64	V18 V18	

TABLE 7-6 PCM TELEMETRY - GUIDANCE AND NAVIGATION SYSTEM

PARAMETER NO.	NOMENCLATURE	TM	CHANNEL CODE	INST BUS	SCE COND
CG0001	COMP DIG. DATA 40 BITS	S2	51DS	G&N	
CG1101	-28 VDC SUPPLY	H2	11A57	G&N	
CG1110	2.5 VDC TM BIAS	H2	10A97	G&N	
CG1503	IMU +28 VDC OPERATE	E2	11E17-01	G&N	
CG1513	IMU +28 VDC STANDBY	E2	11E17-02	G&N	
CG1523	AGC +28 VDC	E2	11E17-03	G&N	
CG1533	OPTX +28 VDC	E2	11E17-04	G&N	
CG2110	IGA TORQUE MOTOR IN	H1	11A26	G&N	
CG2112	IGA 1X RES OUT SINE IN PHASE	H1	11A73	G&N	
CG2113	IGA 1X RES OUT COS IN PHASE	H1	11A74	G&N	
CG2117	IGA SERVO ERROR IN PHASE	H1	12A4	G&N	
CG2140	MGA TORQUE MOTOR IN	H2	11A27	G&N	
CG2142	MGA 1X RES OUT SINE IN PHASE	H1	11A75	G&N	
CG2143	MGA 1X RES OUT COS IN PHASE	H2	11A13	G&N	
CG2147	MGA SERVO ERROR IN PHASE	H1	12A5	G&N	
CG2170	OGA TORQUE MOTOR IN	H2	11A29	G&N	
CG2172	OGA 1X RES OUT SINE IN PHASE	H1	11A80	G&N	
CG2173	OGA 1X RES OUT COS IN PHASE	H1	11A83	G&N	
CG2177	OGA SERVO ERROR IN PHASE	H1	12A6	G&N	
CG2206	IGA CDU 1X RES ERROR IN PHASE	H1	11A84	G&N	
CG2236	MGA CDU 1X RES ERROR IN PHASE	H1	11A123	G&N	
CG2266	OGA CDU 1X RES ERROR IN PHASE	H1	11A124	G&N	
CG2300	PIPA TEMP	H2	10A67	G&N	
CG2301	IRIG TEMP	H2	10A79	G&N	
CG2302	IMU HEATER CURRENT	H2	10A71	G&N	
CG2303	IMU BLOWER CURRENT	H2	10A73	G&N	
CG3104	SXT TRUN MDA INPUT IN PH	H1	11A87	G&N	
CG3105	SXT TRUN TACH F/B IN PH	H1	11A85	G&N	
CG3114	SXT SHAFT MDA INPUT IN PH	H1	11A90	G&N	
CG3115	SXT SHAFT TACH F/B IN PH	H1	11A86	G&N	

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 TABLE 7-6 PCM TELEMETRY - GUIDANCE AND NAVIGATION SYSTEM (CONCLUDED)

PARAMETER NO.	NOMENCLATURE	TM	CHANNEL CODE	INST BUS	SCE COND
CG3141	TRUN CDU 16X RES ERR IN PH	H1	11A96	G&N	
CG3211	SXT SHAFT 16X RES ERR IN PH	H1	11A92	G&N	
CG4300	AGC TEMP MON	H1	10A80	G&N	
CG5000	PIPA FAIL	E2	11E17-05	VSC5	
CG5001	IMU FAIL	E2	11E17-06	VSC5	
CG5002	CDU FAIL	E2	11E17-07	VSC5	
CG5003	GIMBAL LOCK WARNING	E2	11E17-08	G&N	
CG5005	ERROR DETECT	E2	11E18-02	G&N	
CG5006	IMU TEMP LIGHT	E2	11E18-03	G&N	
CG5007	ZERO ENCODER LIGHT	E2	11E18-04	VSC5	
CG5008	IMU DELAY LIGHT	E2	11E18-07	G&N	
CG5020	AGC ALARM 1 (PROGRAM)	E2	11E18-06	VSC5	
CG5021	AGC ALARM 2 (AGC ACTIVITY)	E2	11E18-05	VSC5	
CG5022	AGC ALARM 3 (TM)	E2	11E18-08	VSC5	
CG5023	AGC ALARM 4 (PROG CK FAIL)	E2	11E19-01	VSC5	
CG5024	AGC ALARM 5 (SCALER FAIL)	E2	11E19-02	VSC5	
CG5025	AGC ALARM 6 (PARITY FAIL)	E2	11E19-03	VSC5	
CG5026	AGC ALARM 7 (COUNTER FAIL)	E2	11E19-04	VSC5	
CG5027	AGC ALARM 8 (KEY REL)	E2	11E19-05	VSC5	
CG5028	AGC ALARM 9 (RUPT LOCK)	E2	11E19-06	VSC5	
CG5029	AGC ALARM 10 (TC TRAP)	E2	11E19-07	VSC5	
CG5030	COMP PWR FAIL LIGHT	E2	11E19-08	G&N	
CG6000	IMU PRESS.	H1	10A50	G&N	
CG6020	PSA TEMP 1 TRAY 3	H1	10A70	G&N	
CG6021	PSA TEMP 2 TRAY 2	H1	10A72	G&N	
CG6022	PSA TEMP 3 TRAY 4	H1	10A74	G&N	

TABLE 7-7 PCM TELEMETRY - STABILIZATION AND CONTROL SYSTEM

PARAMETER NO.	NOMENCLATURE	TM	CHANNEL CODE	INST BUS	SCE COND
CH0024	PITCH RATE	H1	51A1	S&C	
CH0034	PITCH POS F/B IN	H1	51A3	S&C	
CH0047	PTV DIFF CLUTCH VOLTS COMB	H1	51A4	S&C	
CH0050	PITCH RATE ERR AMPL OUT	H1	12A10	S&C	
CH0067	PITCH INTEGRATOR/ATT ERR SUM	H2	11A31	S&C	
CH0075	PITCH SCS ATT ERR	H2	11A32	S&C	
CH0087	+P/+X SOL DR OUT	E1	22E-01	S&C	
CH0088	-P/+X SOL DR OUT	E1	22E-02	S&C	
CH0089	+P/-X SOL DR OUT	E1	22E-03	S&C	
CH0090	-P/-X SOL DR OUT	E1	22E-04	S&C	
CH0100	G&N ΔV MODE CONT	E2	11E23-05	S&C	
CH0101	G&N ATT MODE CONT	E2	11E21-03	S&C	
CH0102	G&N ENTRY MODE CONT	E2	11E21-04	S&C	
CH0103	MON MODE CONT	E2	11E21-05	S&C	
CH1024	YAW RATE	H1	51A5	S&C	
CH1034	YAW POS F/B IN	H1	51A7	S&C	
CH1047	YTV DIFF CLUTCH VOLTS COMB	H1	51A8	S&C	
CH1050	YAW RATE ERR AMPL OUT	H1	51A15	S&C	
CH1067	Y INTEGRATOR/ATT ERR SUM	H2	11A38	S&C	
CH1075	YAW SCS ATT ERR	H2	11A39	S&C	
CH1087	+Y/+X SOL DR OUT	E1	22E-05	S&C	
CH1088	-Y/+X SOL DR OUT	E1	22E-06	S&C	
CH1089	+Y/-X SOL DR OUT	E1	22E-07	S&C	
CH1090	-Y/-X SOL DR OUT	E1	22E-08	S&C	
CH1100	SCS ΔV MODE CONT	E2	11E15-08	S&C	
CH1101	SCS ATT MODE CONT	E2	11E21-08	S&C	
CH1102	SCS ENTRY MODE CONT	E2	11E22-01	S&C	
CH1103	SCS LOCAL VERT MODE CONT	E2	11E26-08	S&C	
CH2015	COMB AG SMRD	H1	11A59	S&C	
CH2024	ROLL RATE	H1	51A9	S&C	

TABLE 7-7 PCM TELEMETRY - STABILIZATION AND CONTROL SYSTEM (CONCLUDED)

PARAMETER NO.	NOMENCLATURE	TM	CHANNEL CODE	INST BUS	SCE COND
CH2026	COMBINED RG SMRD	H1	11A62	S&C	
CH2030	COMB ATT GYRO TEMP	H1	10A64	S&C	
CH2050	ROLL RATE ERR AMPL OUT	H1	51A16	S&C	
CH2070	ROLL ATT ERR AMP OUT	H1	11A98	S&C	
CH2075	ROLL SCS ATT ERROR	H2	11A41	S&C	
CH2087	+R/+Z SOL DR OUT	E1	22E-09	S&C	
CH2088	-R/+Z SOL DR OUT	E1	22E-10	S&C	
CH2089	+R/-Z SOL DR OUT	E1	22E-11	S&C	
CH2090	-R/-Z SOL DR OUT	E1	22E-12	S&C	
CH2091	+R/+Y SOL DR OUT	E1	22E-13	S&C	
CH2092	-R/+Y SOL DR OUT	E1	22E-14	S&C	
CH2093	+R/-Y SOL DR OUT	E1	22E-15	S&C	
CH2094	-R/-Y SOL DR OUT	E1	22E-16	S&C	
CH3185	0.05G MANUAL SW	E2	11E7-01	S&C	
CH4100	RES SIN OUT P ATT	H2	11A43		PD
CH4101	RES COS OUT P ATT	H2	11A45		PD
CH4102	RES SIN OUT Y ATT	H2	11A51		PD
CH4103	RES COS OUT Y ATT	H2	11A52		PD
CH4104	RES SIN OUT R ATT	H2	11A54		PD
CH4105	RES COS OUT R ATT	H2	11A56		PD
CH4320	SPS SOL DR OUT 1	E1	51E-09	S&C	
CH4321	SPS SOL DR OUT 2	E1	51E-10	S&C	

TABLE 7-8 PCM TELEMETRY - SERVICE PROPULSION SYSTEM

PARAMETER NO.	NOMENCLATURE	TM	CHANNEL CODE	INST BUS	SCE COND
SP0001	PRESS. HE TANK	H2	11A66	V14S	
SP0002	TEMP HE TANK	H1	11A97	V14S	
SP0003	PRESS. OXID TANKS	H2	11A68	V14S	
SP0006	PRESS. FUEL TANKS	H2	11A70	V14S	
SP0009	PRESS. MN VLV ENG OXID IN	H2	11A76	V14S	
SP0010	PRESS. MN VLV ENG FUEL IN	H2	11A77	V14S	DBA
SP0020	TEMP CHAMB OUTER SKIN 1	H1	10A84		
SP0022	POS FUEL/OXID VLV 1	H1	11A103	VSC5 S	
SP0023	POS FUEL/OXID VLV 2	H1	11A105	VSC5 S	
SP0024	POS FUEL/OXID VLV 3	H1	11A110	VSC5 S	
SP0025	POS FUEL/OXID VLV 4	H1	11A111	VSC5 S	
SP0050	TEMP NOZZLE OUTER SKIN 1	H1	10A85	V14S	
SP0600	ENG VLV ACT SYS TNK PRESS. PRI	H1	10A78	V14S	
SP0601	ENG VLV ACT SYS TNK PRESS. SEC	H1	11A125	V14S	
SP0655	QUAN SPS OXID TNK 1	H1	10A88		
SP0656	QUAN SPS OXID TNK 2	H1	10A90		
SP0657	QUAN SPS FUEL TNK 1	H1	10A92		
SP0658	QUAN SPS FUEL TNK 2	H1	10A94		
SP0661	PRESS. ENG CHAMB	H1	12A11	V14S	

PARAMETER NO.	NOMENCLATURE	TM	CHANNEL CODE	INST BUS	SCE COND
CR0001	PRESS. HE TNK A	H2	10A81	V11	
CR0002	PRESS. HE TNK B	H2	10A83	V11	
CR0003	TEMP HE TNK A	H1	10A52	V11	
CR0004	TEMP HE TNK B	H1	10A55	V11	
CR0005	PRESS. FUEL TNK A	H2	11A107	V11	
CR0006	PRESS. FUEL TNK B	H2	11A114	V11	
CR0011	PRESS. OXID TNK A	H2	11A79	V11	
CR0012	PRESS. OXID TNK B	H2	11A81	V11	
CR0514	CCW ROLL ENG PRESS. SYS A	H1	12A13	V19	
CR0518	-YAW ENG PRESS. SYS A	H1	12A14	V19	
CR0520	CCW ROLL ENG PRESS. SYS B	H1	12A15	V19	
CR0525	+YAW ENG. PRESS. SYS B	H1	12A16	V19	
CR2201	TEMP OX VLV CCW ENG SYS A	H1	51A17	V11	
CR2202	TEMP OX VLV -Y ENG SYS A	H1	11A78	V11	
CR2203	TEMP OX VLV +Y ENG SYS B	H1	10A35	V11	
CR2204	TEMP OX VLV -P ENG SYS B	H1	10A38	V12	
CR2205	TEMP OX VLV -P ENG SYS A	H1	51A18	V12	
CR2206	TEMP OX VLV CW ENG SYS B	H1	10A34	V11	
SR5001	PRESS. HE TNK A	H2	10A89	V13S	
SR5002	PRESS. HE TNK B	H2	10A91	V13S	
SR5003	PRESS. HE TNK C	H2	10A93	V14S	
SR5004	PRESS. HE TNK D	H2	10A96	V14S	
SR5065	TEMP ENG PKG A1	H1	10A95	V13S	
SR5066	TEMP ENG PKG B1	H1	10A62	V13S	
SR5067	TEMP ENG PKG C1	H1	10A98	V14S	
SR5068	TEMP ENG PKG D1	H1	10A100	V14S	
SR5729	PRESS. A HE MANIF	H2	11A82	V13S	
SR5776	PRESS. B HE MANIF	H2	11A88	V13S	
SR5817	PRESS. C HE MANIF	H2	11A89	V14S	
SR5830	PRESS. D HE MANIF	H2	11A91	V14S	

TABLE 7-10 PCM TELEMETRY - L/V EMERGENCY DETECTION SYSTEM

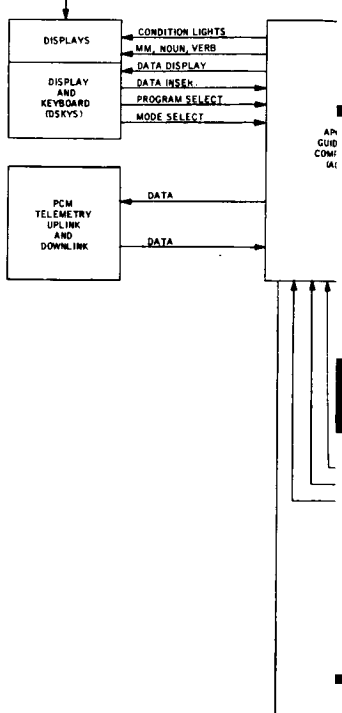
PARAMETER NO.	NOMENCLATURE	TM	CHANNEL CODE	INST BUS	SCE COND
LS0001	Q BALL VECTOR SUM OUT	H1	11A65		
BS0016	LV GUID FAIL A	E2	11E23-06		AA
BS0020	LV RATE EXCESSIVE A	E2	11E24-01		AA
BS0030	ENG NO. 1 OUT A	E2	11E24-03		AA
BS0032	ENG NO. 2 OUT A	E2	11E24-04		AA
BS0034	ENG NO. 3 OUT A	E2	11E24-05		AA
BS0036	ENG NO. 4 OUT A	E2	11E24-06		AA
BS0038	ENG NO. 5 OUT A	E2	11E24-07		AA
BS0060	LIFTOFF SIG A	E2	11E25-03		AA
BS0061	LIFTOFF SIG B	E2	11E25-04		AA
CS0080	EDS ABORT REQ A	E2	11E25-07		AA
LS0090	TMR PHYS SEP MON A	H1	11A71	VSC5	
LS0091	TMR PHYS SEP MON B	H1	11A72	VSC5	
CS0100	CM/SM PHYS SEP MON A	E2	11E26-01	VSC5	
CS0101	CM/SM PHYS SEP MON B	E2	11E26-02	VSC5	
SS0120	SM/ADAPT PHYS SEP MON A	E2	11E26-05	VSC5 S	
SS0121	SM/ADAPT PHYS SEP MON B	E2	11E26-06	VSC5 S	
BS0134	S-II SECOND PLANE SEP A	E2	11E22-08		AA
CS0150	MAST CAUT/WARN ON	E2	11E27-06		AA

PARAMETER NO.	NOMENCLATURE	TM	CHANNEL CODE	INST BUS	SCE COND
CT0012	TAPE MOTION MON OPER	E2	11E15-04	C&I	
CT0013	TAPE MOTION MON R&D	E2	11E15-07	C&I	
CT0015	SIG COND POS SUPPLY VOLTS	H2	11A93	C&I	
CT0016	SIG COND NEG SUPPLY VOLTS	H2	11A95	C&I	
CT0017	SNSR EXC 5 VOLTS	H2	11A101	C&I	
CT0018	SNSR EXC 10 VOLTS	H2	11A102	C&I	
CT0089	C-BAND XMTR OUT MON	H1	11A122	C&I	
CT0098	C-BAND DECODER OUT	H1	11A117	C&I	
CT0120	PCM BIT RATE CHANGE 8 BITS	D2	-	C&I	
CT0125	PCM HI LVL 85% REF	H2	11A104	C&I	
CT0126	PCM HI LVL 15% REF	H2	11A106	C&I	
CT0127	PCM LO LVL 85% REF	H2	10AL44	C&I	
CT0128	PCM LO LVL 15% REF	H2	10AL49	C&I	
CT0141	CTE TIMING MODE MON	E2	11E27-01	C&I	
CT0142	CEN TIMING GMT 32 BITS	D2	11D1	C&I	
CT0147	S-BAND RCVR AGC VOLTS	A2	11A118	C&I	
CT0191	VHF/AM RCVR AGC VOLTS	H1	11A121	C&I	
CT0212	S-BAND RCVR STATIC PH ERR	H2	11A120	C&I	
CT0215	S-BAND XMTR DETECTED RF OUT	H2	10A99	C&I	
CT0261	UDL RCVR SIG STRENGTH	H2	11A113	C&I	
CT0262	UDL SYS VALID SIG 8 BITS	D1	51D	C&I	
CT0320	VHF/AM XMTR DETECTED RF OUT	H1	12A12	C&I	
CT0330	VHF/FM XMTR PA DETECTED RF OUT	H1	11A115	C&I	
CT0340	PCM TIMING SOURCE EXT OR INT	E2	11E27-03	C&I	

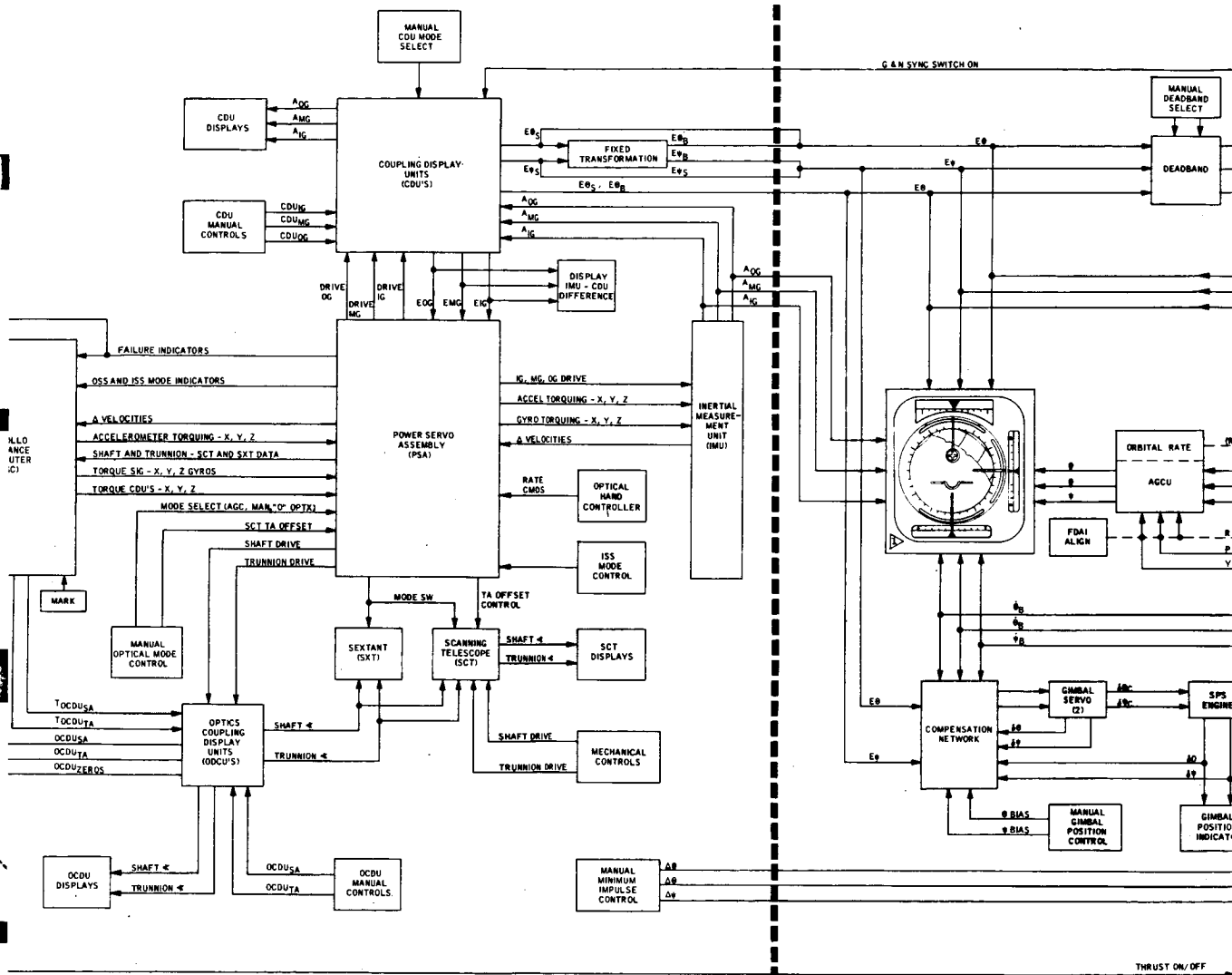
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SECTION 8
GUIDANCE

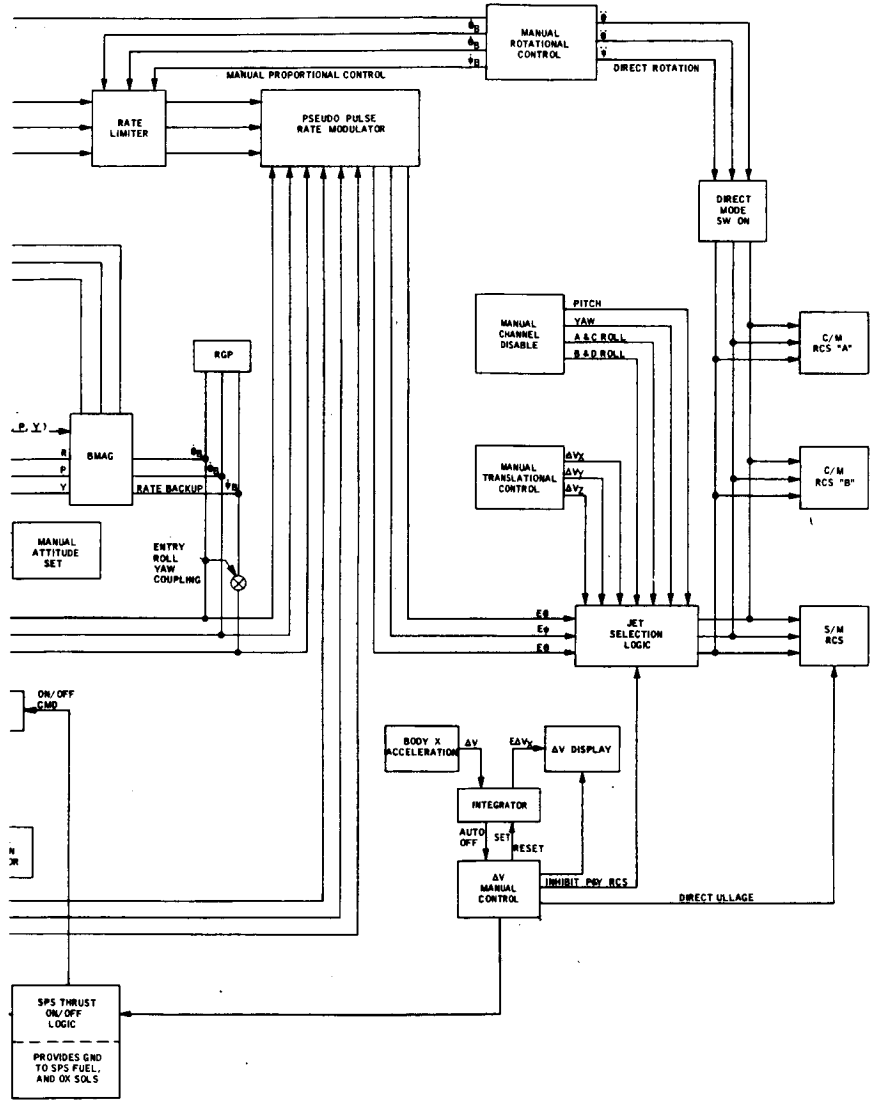
8.1 NOTES, SYSTEMS, GENERAL

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G AND N SCS





NOT APPLICABLE TO AS-501

SA = SHAFT ANGLE
 TA = TURNON ANGLE
 OG, MG, IG, = OUTER, MIDDLE, INNER GIMBAL
 R = ROLL
 P = PITCH
 Y = YAW
 ERG, EPG, EYG = ROLL, PITCH AND YAW STABILITY ERRORS
 AOG, AYG, AIG = OUTER, MIDDLE AND INNER GIMBAL ANGLE
 FDAI = FLIGHT DIRECTOR ATTITUDE INDICATOR
 AGCU = ATTITUDE GYRO COUPLING UNIT
 RCP = RATE GYRO PACKAGE
 A&C, A&P, A&Y = ENGINE GIMBALLING PITCH AND YAW
 ERG, EPG, EYG = ROLL, PITCH AND YAW BODY ERRORS
 BMAG = BODY MOUNTED ATTITUDE GYRO
 R = ROLL RATE
 A = ROLL ACCELERATION
 Δ = CHANGE
 ICDU = INERTIAL COUPLING DISPLAY UNIT

G&N

SIGNATURES		DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION MANNED SPACECRAFT CENTER - HOUSTON, TEXAS	
DR	<i>[Signature]</i>	10-27-64	GUIDANCE AND NAVIGATION BLOCK DIAGRAM	
ENG	<i>[Signature]</i>	1-11-65		
DR	<i>[Signature]</i>	1-11-65		
NAA	<i>[Signature]</i>	1-11-65		
AUTH	<i>[Signature]</i>	1-20-65		
CSM		SIZE	DWG NO	
MISSION		J	8.1.1	
AS-501		SCALE	SHEET 1 OF 1	

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8.2 INERTIAL SUBSYSTEM

The inertial subsystem, one of the three subsystems of the G&N system, consists of an IMU (which contains the inertial sensors) a, Coupling Display Unit (CDU), power supplies in the Power Servo Assembly, and the required controls for the operation of said equipment, all found in the lower equipment bay.

The inertial system is aligned before flight by gyrocompassing and since the system will be turned off for approximately 80 percent of the time, it will be aligned in flight by the flight crew using the optical subsystem. In addition to turning the system off completely, the gyros could drift over a prolonged period of use and thus require realignment.

The inertial subsystem is used in spacecraft guidance to determine the direction and magnitude of the required velocity corrections to be applied to the spacecraft. The Apollo stable member (IMU) is a three gimballed system containing three integrating gyros for stability and three orthogonally mounted pendulous accelerometers for velocity and position determination. Once the inertial subsystem is energized and aligned, any rotational motion of the spacecraft will be about the gimballed stable member, which will remain fixed in space. Resolvers mounted on the gimbal axis act as angular sensing devices and measure the attitude of the spacecraft with respect to the stable member. These angular measurements are displayed to the flight crew and are sent to the AGC via the CDU's.

The CDU's couple the IMU to the AGC and generate steering and alignment signals. The inertial subsystem contains three CDU's, one for each gimbal. Each CDU contains resolvers, which are positioned either manually by the astronaut or automatically by the AGC. One of the major signals generated by the CDU's is the Δ angle which is proportional to the angular difference between the IMU gimbal and CDU resolver positions. This signal can be used to control the

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position of the IMU or the CDU's, to display spacecraft attitude error, or to develop attitude error signals for steering during thrusting maneuvers or for spacecraft attitude control.

If the attitude of the spacecraft is to be changed by the AGC, the AGC drives the CDU's to the desired P, R, Y settings. The error (IMU vs CDU) is transmitted to the SCS and the appropriate RCS jets fire to null the error. In this manner the attitude of the spacecraft is under control of the AGC.

8.2.1 G&N Modes

There are six inertial modes of operation that are used in conjunction with the eight Stabilization and Control modes of operation. The eight SCS modes are:

- | | |
|-------------------------|-------------------------|
| A. G&N Attitude Control | B. SCS Attitude Control |
| G&N ΔV | SCS ΔV |
| G&N ENTRY | SCS ENTRY |
| Monitor | Local Vertical |

When any of the modes in Group A is selected, the IMU is the reference as displayed on the Flight Director Attitude Indicator (FDAI). When Group B is being utilized, the FDAI reflects the Body Mounted Attitude Gyro (BMAG) information as the prime attitude data.

Group A is utilized when the primary guidance system is in control of the spacecraft. That is, the inertial subsystem will interface with the above mentioned modes in the SCS. The IMU however, is the prime reference system. Group B is utilized when the guidance system is proven to be inoperative or has been turned OFF by the flight crew. These modes of operation will not interface with the prime system and will utilize the BMAG's as their reference system as opposed to the IMU.

The exception to this rule is the utilization of the SCS Attitude Control Mode (for spacecraft stability) for IMU alignment.

The following Table 8-1 shows the Inertial Subsystem modes and their associated SCS modes. A brief description of the inertial modes is included.

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TABLE 8-1 INERTIAL SUBSYSTEMS MODES AND ASSOCIATED SCS MODES

INERTIAL SUBSYSTEMS	SCS MODES OF OPERATION
1. Attitude Control	G&N Attitude Control G&N ΔV
2. Fine Align	SCS Attitude Control
3. Coarse Align	SCS Attitude Control
4. CDU Manual	SCS Attitude Control
5. Zero Encode	SCS Attitude Control
6. Entry	G&N Entry

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8.2.2 Attitude Control - 1X IMU and 1X CDU Resolvers Utilized (IG, MG, OG)

In the Attitude Control Mode of operation, velocity steering or attitude control signals are generated so that the IMU gimbal angles and the CDU shaft angles remain the same. Any movement of the spacecraft causing a change of gimbal position about the stable member will result in an error output from the CDU 1X resolver which will be applied (SCS in the Attitude Control, ΔV , or Entry mode) to the SCS for spacecraft corrective rotational thrusting.

The error signal which is used for attitude control and velocity steering is generated by the 1X CDU resolver and is sent to the Stabilization and Control system through the pitch-yaw resolver and fixed resolution transformer. The error signal results from the difference between the angular position of the IMU and CDU 1X resolvers. While in the attitude control mode, the CDU resolver can be positioned automatically by the AGC. If velocity steering is being performed, the AGC drives the CDU's to control the direction of the thrust vector and the CDU error signal (P&Y) is used to position the service propulsion engine.

8.2.3 Fine Align - 1X & 16X IMU and the 1X & 16X CDU Resolvers Utilized (IG, MG, OG)

Fine alignment will be accomplished by AGC pulsing of the stabilization gyro torque ducosyn to provide a stable reference from which the computer can track spacecraft attitude movements. The CDU's at this time are slaved to the IMU and will follow the IMU gimbal angles. The number of pulses required to fine align the stable member are calculated by the AGC based upon optical measurements. This mode may be selected by manual operation, computer control, and also by the G&N sync switch.

The fine align mode performs two tasks; (a) the gyro floats are torqued so the stabilization loops reposition the stable member (b) the CDU's are driven to repeat the IMU gimbal angles. The torquing is accomplished by the AGC plus and minus torquing pulses at a rate of 3,200 PPS, applied to the ternary current switch.

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The ternary current switch output pulses displace the stabilization gyro float from a null, and generate error signals in the stabilization loop. The error signal in the stabilization loop causes the torque motors to drive the gimbals to position the stable member. The CDU's follow the gimbal angles. The angular difference between the IMU and CDU 1X and 16X resolvers generates a CDU resolver error signal proportional to the sine of the angular difference. This signal is sent to the motor drive amplifier. The motor drive amplifier output excites the control winding of the CDU drive motor and drives the CDU shaft until the IMU and CDU angles are equal. Upon completion of the mode, the stable member is fine aligned to a reference coordinate system and the CDU readouts indicate the gimbal angles.

When the G&N sync switch is ON and the SCS relay is energized, the system will also be in fine align. Two conditions are required to energize the SCS relay. First, the SCS must be in the G&N attitude control mode. Second, the astronaut must be using the rotational hand controller to control the spacecraft. Thus, when a new attitude is established, the CDU's having been slaved to the gimbals will have the capability of providing the reference for holding the spacecraft at its new orientation.

8.2.4 Coarse Align - 1X IMU and 1X CDU Resolvers Utilized (IG, MG, OG)

The purpose of the Coarse Align Mode is to slave the IMU gimbals to an angular position as determined by the CDU. The mode is entered by one of four means: (a) pressing the coarse align pushbutton with the inertial subsystem in manual control, (b) AGC command of coarse align mode with the system in computer control, (c) IMU turned ON for less than 100 seconds (d) system in manual CDU mode and the manual align pushbutton pressed. The coarse align light will come on except in the case of condition (d) when the basic mode is CDU manual.

The gimbal 1X resolver is excited with an 800 CPS reference and the motor sine and cosine windings are connected to the CDU 1X resolver

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motor. When the two motor angles differ, an error signal proportional to the sine of the difference is generated by the CDU resolver. The signal is sent to the IMU-CDU difference meter and also to the coarse align amplifier where it is amplified and demodulated. The demodulated signal is sent to the gimbal servo amplifier which drives the IMU gimbal until the error between the IMU gimbal resolver and CDU shaft resolver is driven out.

Positioning of the CDU's is performed by the AGC's pulsing the digital-to-analog converter. When the AGC is used to position the IMU gimbals, a 3,200 PPS signal is applied to the digital-to-analog converter for a 1/12 second interval. The three digital-to-analog converters receive pulses sequentially, requiring 1/4 second to supply all the digital-to-analog converters with an input. The cycle is repeated until the required number of pulses has been issued by the AGC. For a small amount of shaft rotation, the digital-to-analog converter provides an 800 cps output proportional in amplitude to the number of pulses received. The output goes to the motor drive amplifier and drives the CDU shaft. The CDU encoder electronics provides pulses to the AGC and digital-to-analog converter. The pulses are generated by shaft rotation (approx 2,200 pps max). Each pulse is equal to approximately 40 arc seconds of rotation of the one-speed resolver. Theoretically, one pulse out of the AGC to the digital-to-analog converter should cause the encoder to generate one pulse of feedback to the AGC and digital-to-analog converter. The pulse input from the AGC to the digital-to-analog converter and the feedback from the encoder should cancel each other when CDU shaft angle equals the AGC commanded angle.

8.2.5 CDU Manual - No Resolvers Utilized (DACS Inhibited)

The manual CDU mode is used as a backup mode to provide the coarse align capability in the event of an AGC malfunction, since the CDU is positioned only by the AGC in the coarse align mode. For this mode, three methods of entry are possible:

- A. Pressing the CDU MANUAL pushbutton with the TRANSFER switch in MANUAL.
- B. By AGC command with the TRANSFER switch in COMPUTER
- C. By turning on the G&N SYNC switch on the main D&C panel during the attitude control mode. The G&N SYNC switch initiated manual CDU mode is used to lock the CDU's and hold the spacecraft in the previous attitude reference position obtained by pilot manipulation of the rotational hand controller. The CDU's are slewed to the desired shaft angle by the MANUAL SLEW switch located on the CDU. When the manual align pushbutton is depressed, the IMU gimbals are driven to the CDU shaft angles. At this time, the DAC is disabled.

8.2.6 Zero Encode - 1/2X & 16X CDU Resolvers Utilized (IG, MG, OG)

The purpose of the Zero Encoder mode of operation is to drive the CDU shaft angle to a zero position utilizing the CDU 16X and 1/2X resolvers. AGC CDU registers are cleared and encoder outputs indicative of CDU shaft angle changes are thereafter referenced to the zero position for use by the AGC, essentially referencing the computer and CDU to each other. The zero encoder mode is manually selected by pressing ZERO ENCODER on the IMU control panel. If the system is in manual control, has been on for 100 seconds minimum, and zero encoder is initiated, the following occurs: (a) the ZERO ENCODER lamp lights and (b) a signal is provided to disable the digital-to-analog converter (DAC) since it will be receiving pulses and could provide an input to the CDU motor drive amplifier.

In the CDU ZERO ENCODER loop, an 800 cps reference voltage is applied to the stators of the 16X and 1/2X CDU resolvers. The sine windings of the resolvers are applied through a limiter circuit or two speed switch to the motor drive amplifier inputs. The motor drive amplifier output signal is applied to the CDU servo motor which repositions

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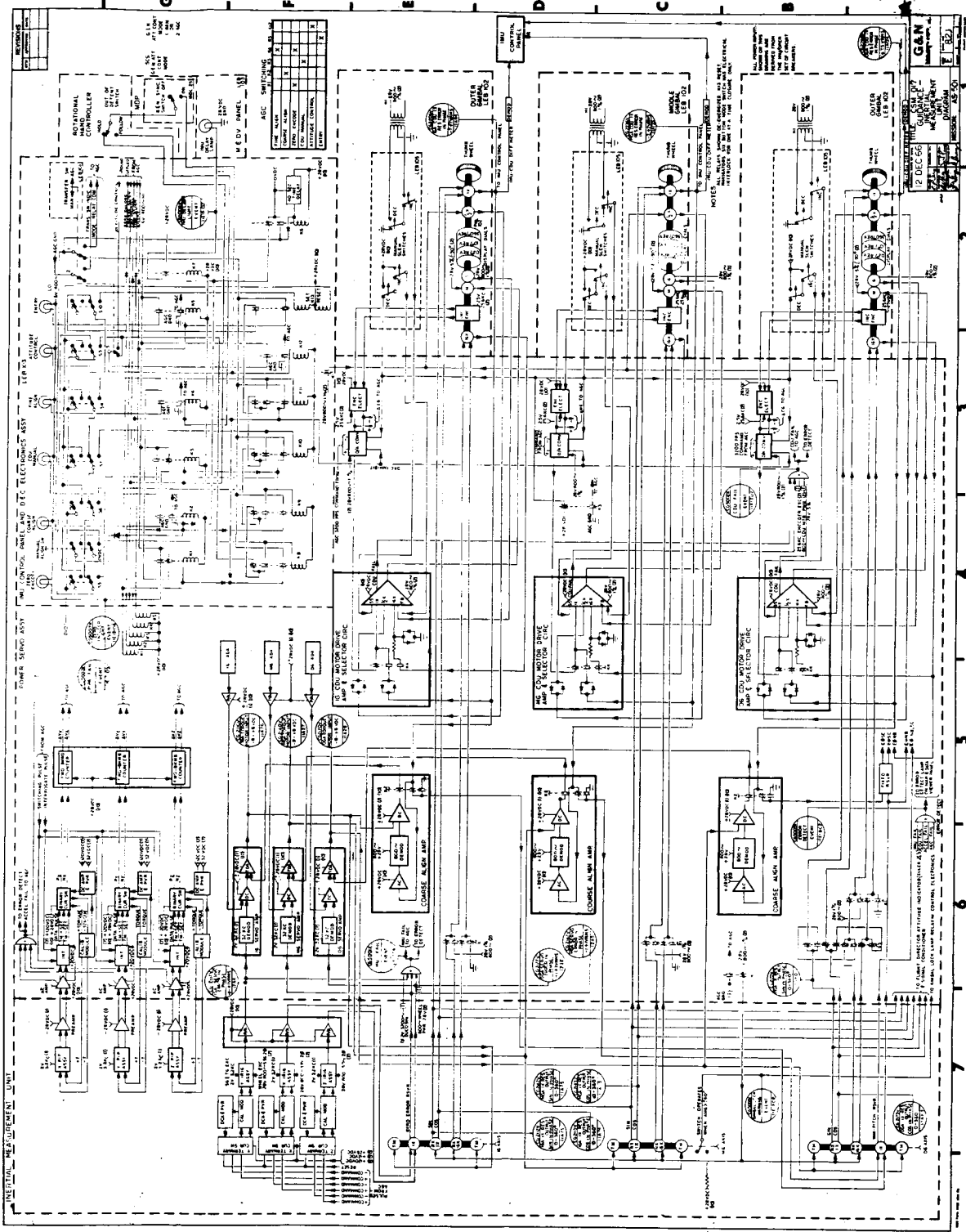
the CDU shaft until the shaft is at the zero angle. At this time the sine of the angle is zero and the resolver outputs are zero. The maximum time for CDU zeroing is approximately 20 seconds.

8.2.7 Entry - 16X CDU & 1X IMU Resolver Combination In OG (IG & MG_{1X} IMU = 1X CDU)

The purpose of the Entry mode is to reduce the response time required for generating an attitude error signal in the outer CDU which controls the roll of the command module during the entry phase. It is also necessary to provide ISS error output to the SCS in terms of the spacecraft entry axes.

The entry mode may be entered in manual control or in computer control. Mechanization of the entry mode is similar to mechanization of the attitude control mode, except that the output of the IMU outer gimbal 1X resolver is switched to the outer gimbal CDU 16X resolver. The roll commands to the Stabilization and Control System during entry are supplied by the outer gimbal CDU 16X resolver. By connecting the 1X IMU resolver to the 16X CDU resolver, the amount of angular rotation of the CDU shaft for a given IMU angle is reduced by a factor of 16. Therefore, when the AGC commands a roll maneuver of X degrees, the CDU is positioned at $X^\circ/16$.

In addition, the fixed resolution transformer is not being used at this time since the Navigation Base axes coincide with the spacecraft entry axes.



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8.3 OPTICAL SUBSYSTEM

8.3.1 Notes General - Optical Subsystem

The optical subsystem for the Apollo spacecraft consists of a scanning telescope (SCT) with a 60 degree field of view and a sextant (SXT) with a 1.8 degree field of view. The SCT has a single line of sight used for acquisition and orbit determination, while the SXT utilizes two lines of sight for angular measurement. A single line of sight of the SXT is used to align the IMU.

The optical instruments are physically attached to the navigation base to insure alignment; functionally they perform two services. First, they provide the AGC with data obtained by measuring angles between lines of sight to celestial objects and, secondly, they provide measurement for establishing an inertial reference.

The optics can be positioned by the flight crew utilizing the optics control stick or the AGC can position the optics. If the optics are to be positioned by the AGC, the Optical Coupling Display Unit (OCDU) is driven by the AGC to the desired shaft and trunnion settings. The SXT will follow as will the SCT depending upon the switch settings on the Optics control panel in the Lower Equipment Bay (LEB). The OCDU's function exactly as the ICDU's in that they both receive and transmit angular data to the AGC. In this manner the computer is cognizant of sighting data as performed by the flight crew. Selection as to which mode of operation is to be utilized is done manually from the optics control panel in the LEB. In addition, the LEB is equipped to receive a rotational hand controller on the cable should spacecraft orientation be required while performing navigation sightings.

At the instant the optical sighting is taken, the time of sighting, the angles of the optical instruments and the IMU gimbal angles if, the ISS is enabled, are recorded by the AGC. Data pertaining to the location of the celestial objects and programs for navigational calculations have been stored in the AGC. The navigational measurements will consist of earth orbit determination, midcourse navigation, and IMU alignment. The

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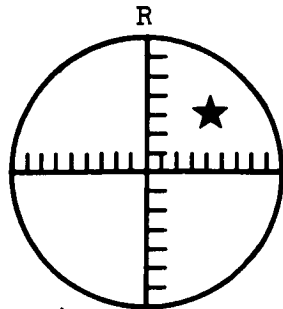
IMU is aligned during flight by measuring the angle between the navigation base and each of two stars with the sextant.

8.3.2 IMU Alignment

Since the Guidance and Navigation System will be turned OFF during approximately 80 percent of the mission, inflight alignment is required and is accomplished by utilizing the optics in conjunction with the AGC. The navigator will mark; using the SCT, on two coarse align stars which will in turn enable the AGC to determine the spacecraft orientation. With this data known, the AGC can now complete the coarse alignment process by driving the CDU's to the desired settings and the gimbal angles will in turn follow. After coarse alignment is completed, fine alignment is initiated and this time the navigator, utilizing the SXT, marks singularly on two fine align stars. The AGC, through the optical CDU's will record the angle the star line of sight makes with the stable member, and will in turn provide the necessary number of torquing pulses required to position the stable member to its exact orientation. After torquing, the stable member is inertially fixed, or fine aligned.

8.3.3 Optics Nav Sightings

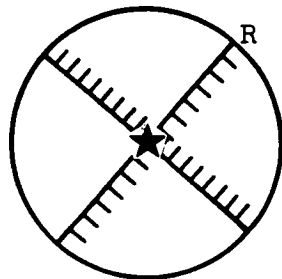
A.



Shaft } = 0, Trunnion } = 0

The navigator has found the desired star in the SCT 60 degree FOV and will now, utilizing the optics hand controller, center the star. The SLAVE TELESCOPE switch is in the star LOS position.

B.



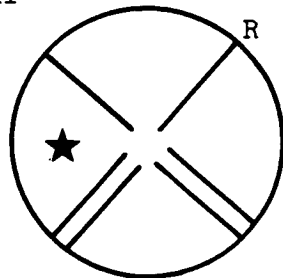
Shaft } $\approx 45^\circ$ Trunnion $\approx 12^\circ$

The star is now centered and the navigator will press the MARK button. The AGC will record the IMU gimbal angles, the shaft and trunnion settings of the OCDU's and the AGC time.

C.

The above process is repeated for a second star and after identifying the two stars, via the DSKY to the AGC, the computer now determines spacecraft orientation and completes coarse alignment.

D. SXT

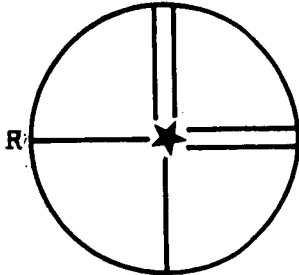


Shaft } $\approx 45^\circ$ Trunnion $\approx 12^\circ$

Fine alignment is accomplished using the SXT. The SCT is slaved to the SXT and will function as an acquisition aid for the SXT. While centering the star in the SCT FOV, it will not necessarily be centered in the SXT due to the smaller, thus more accurate, FOV.

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E.



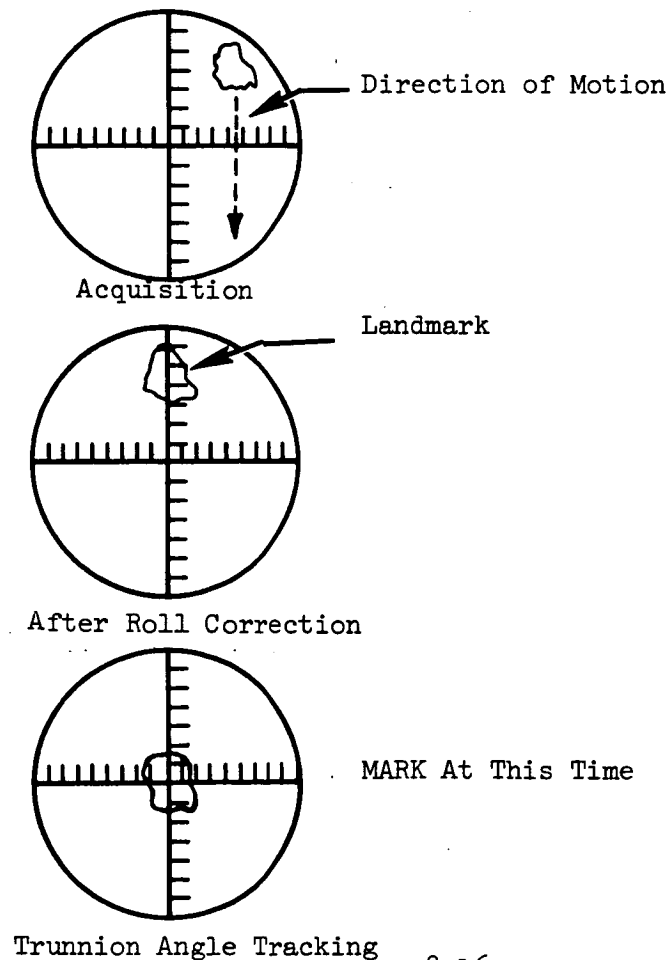
The SXT now has the star centered in its FOV, using the optics hand controller, and after identifying the star to the AGC, the MARK button is depressed and the shaft and trunnion angles, time, and IMU angles are recorded by the AGC.

Shaft $\angle \approx -90^\circ$ Trunnion $\angle \approx 10^\circ$

The above process is repeated, for a second star, and the computer initiates the required gyro torquing to complete fine alignment.

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8.3.4 Orbit Determination

The scanning telescope (SCT) with its 60 degree field of view is used for orbit determination since the 1.8 degree field of view of the sextant is too small. The IMU is aligned and the +X axis of the spacecraft is along the flight path. The object to be MARKED comes into view and if it is not traveling along the R line of the spacecraft (shaft $\dot{\phi} = 0$), the S/C will be rolled until this condition exists. When the landmark has traveled down the R line until it is centered in the crosshairs, the operator will press the MARK button, at which time the SCT shaft and trunnion angles, time, and the IMU angles will all be read by the AGC. A series of three or four sightings will determine the spacecraft orbit.



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G

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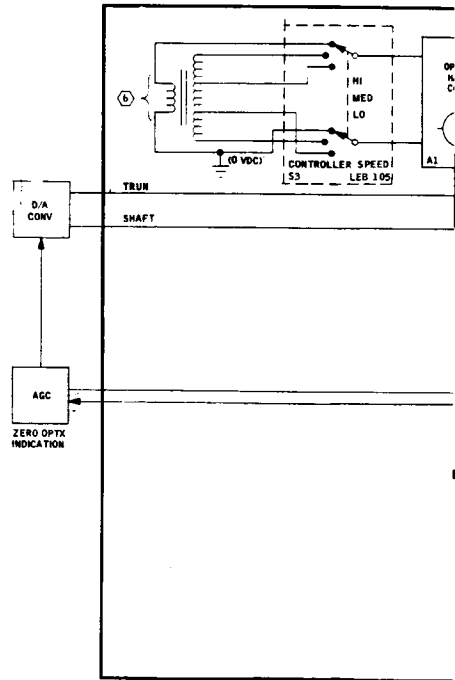
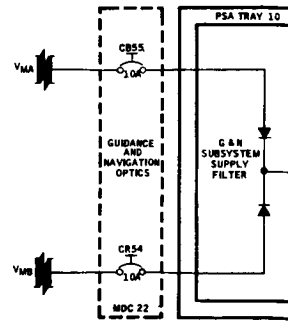
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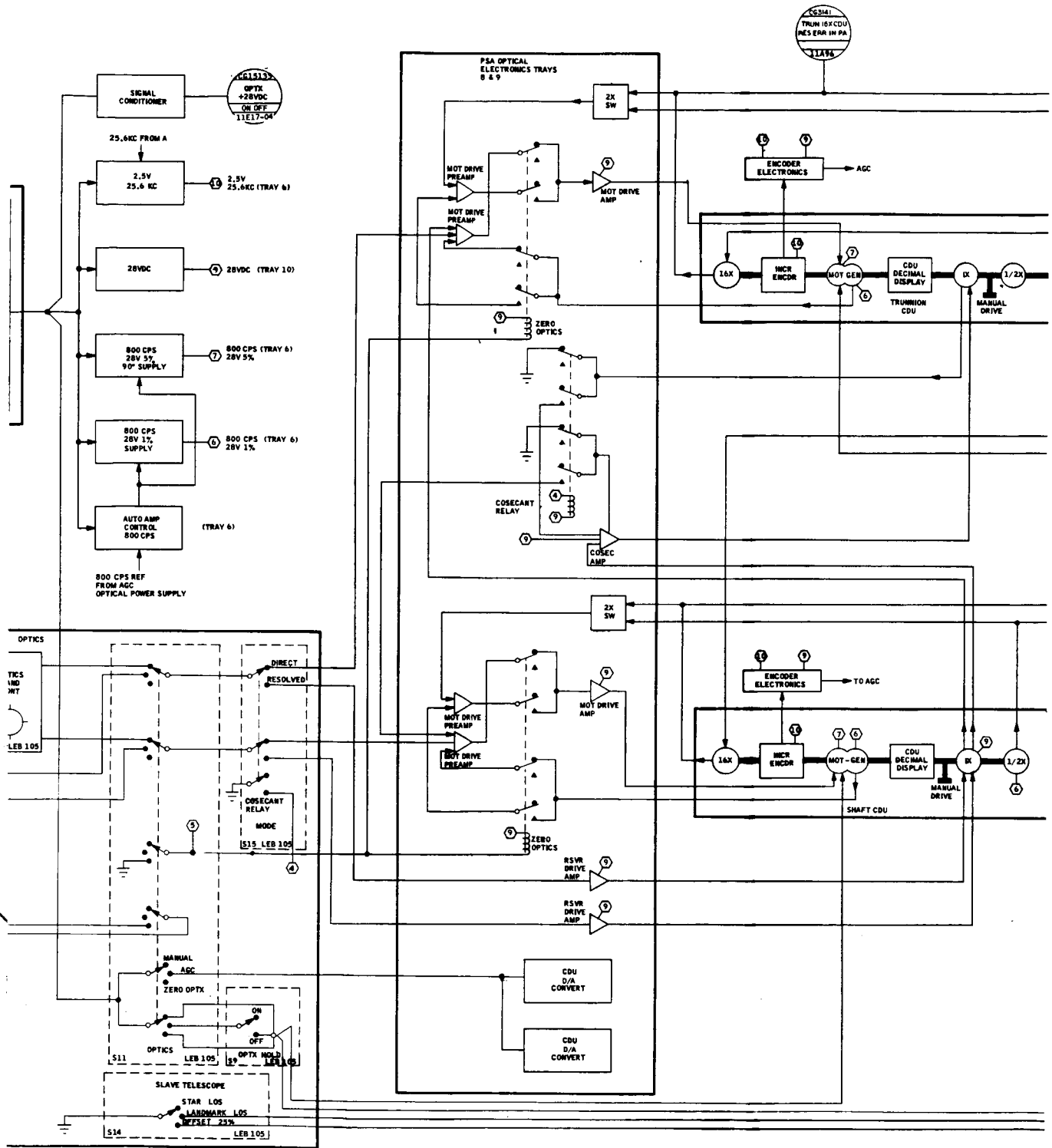
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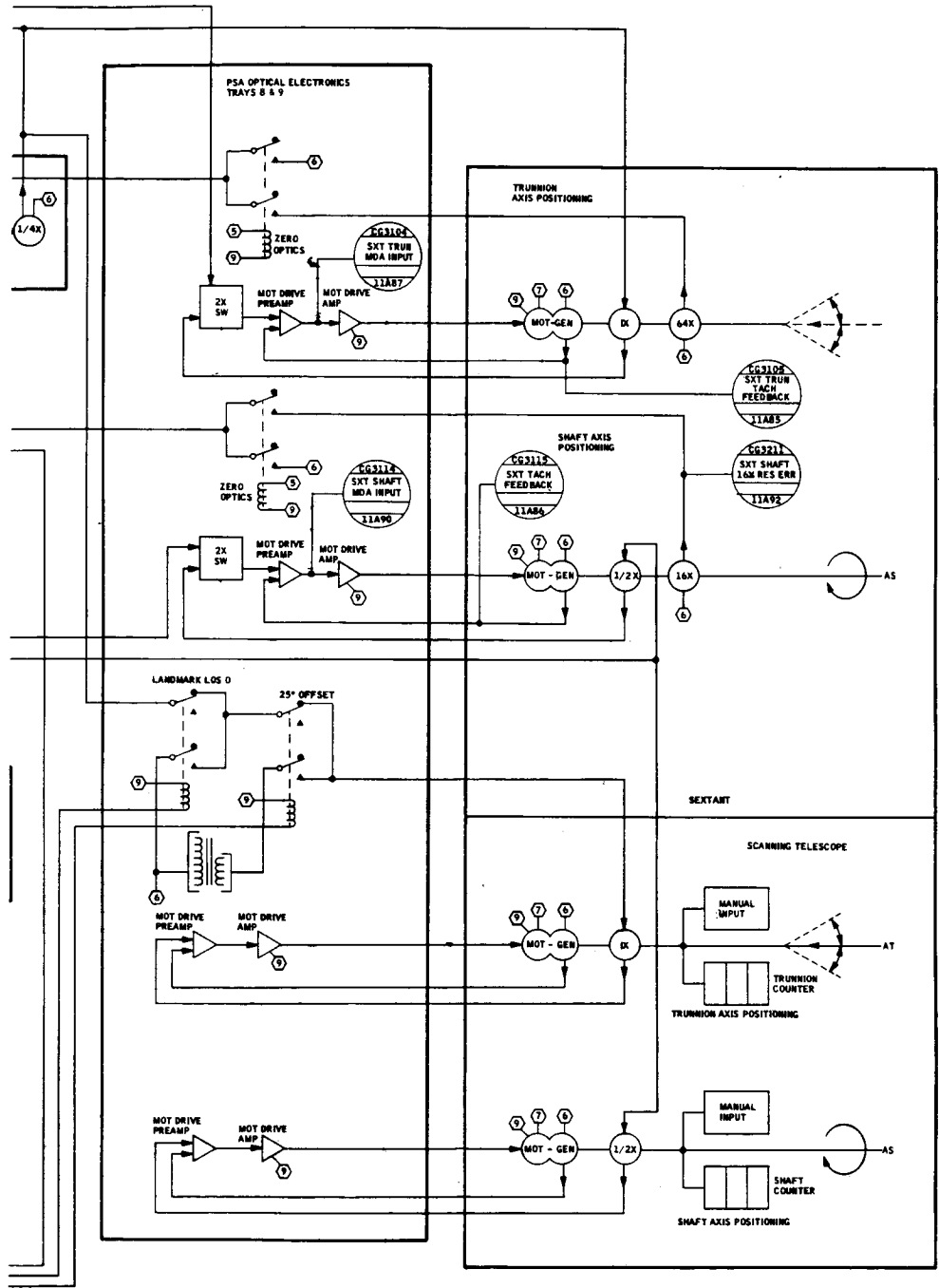
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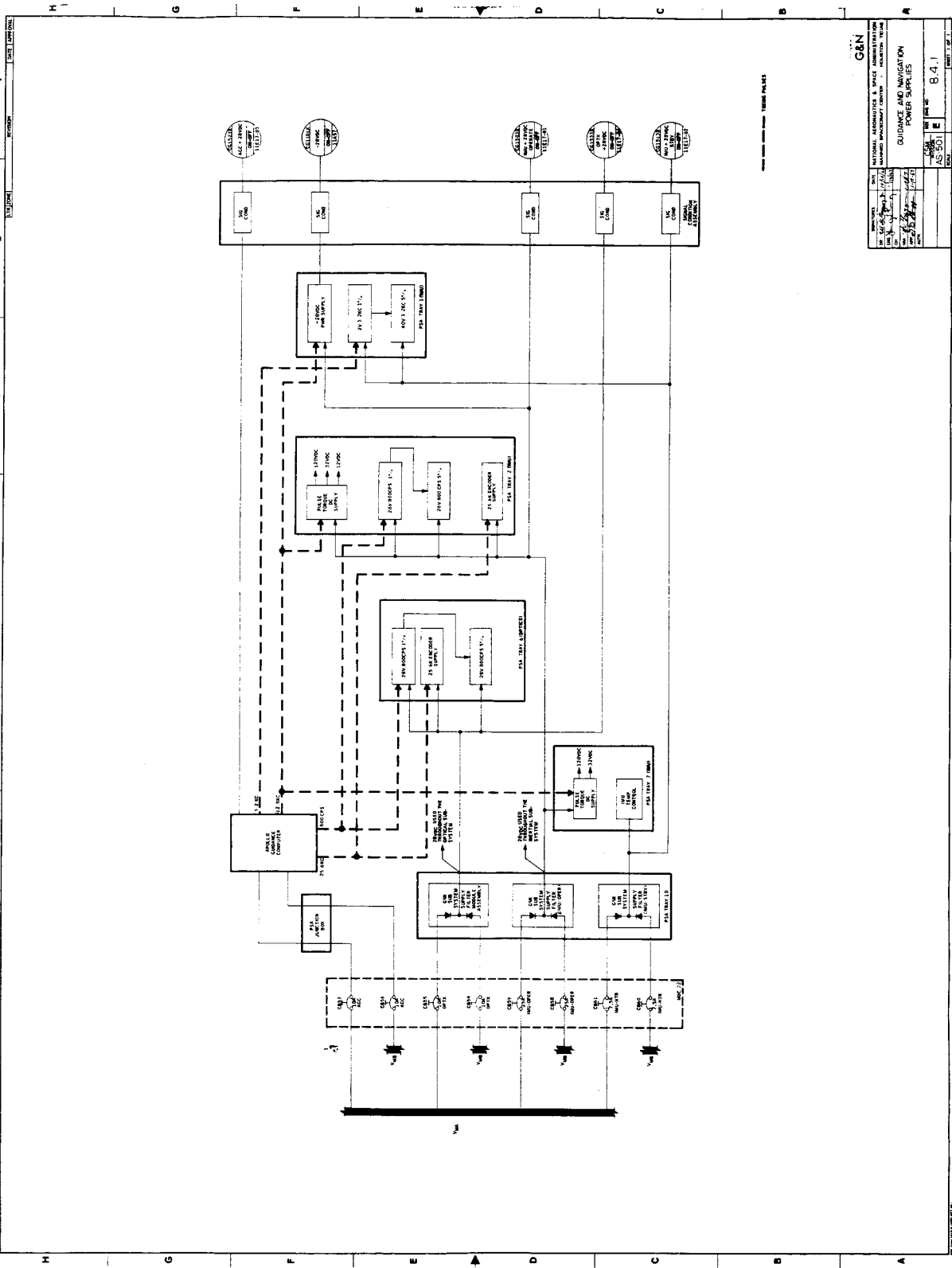






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DR <i>[Signature]</i>		<i>[Date]</i>	NATIONAL AERONAUTICS & SPACE ADMINISTRATION	
ENGR <i>[Signature]</i>		<i>[Date]</i>	MANNED SPACECRAFT CENTER - HOUSTON, TEXAS	
CH <i>[Signature]</i>		<i>[Date]</i>	OPTICAL SUBSYSTEM	
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MISSION AS-204		SCALE	SHEET 1 of 1	

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8.4 NOTES, ELECTRICAL POWER DIAGRAM



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GUIDANCE AND NAVIGATION POWER SUPPLIES	
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TESTED	
REVISIONS	

12VDC TO 5VDC CONVERTER

12VDC TO 15VDC CONVERTER

12VDC TO 24VDC CONVERTER

GROUNDING

ANALOG COMPUTER

DIGITAL COMPUTER

ANALOG SYSTEM

POWER SUPPLY

12VDC

24VDC

GROUND

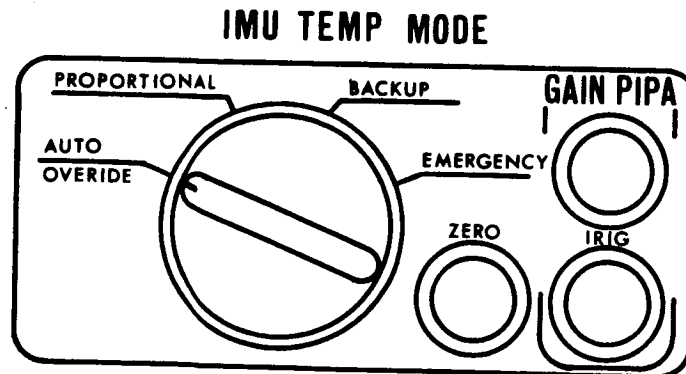
COMMON

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8.5 IMU TEMP MODE SELECTOR

8.5.1 Notes General - IMU TEMP MODE Selector

The IMU TEMP MODE Selector is a four-position rotary switch. The four positions and their functions are as follows:



A. Auto/Override

The AUTO/OVERRIDE switch position is the normal operating position. In this mode, both the temperature control circuit and temperature indicating circuit are utilized. Temperature control is furnished by the temperature control amplifier using the IRIG temperature control sensors. Temperature indication, utilizing the IRIG and PIPA temperature indicating sensors, may be obtained from the temperature indicating bridge (test point) or the temperature indicating bridge amplifier (telemetry).

Normally, heating is accomplished by the control heaters and emergency heaters operating in parallel. If the IMU exceeds normal temperature tolerances ($\pm 4^{\circ}\text{F}$), the system will automatically switch to the emergency mode and the IMU TEMP light will illuminate. When this occurs, the temperature alarm relays turn off the control heaters. The emergency heaters

continue to operate under the control of an emergency mercury thermostat. When the temperature returns to within $\pm 1^{\circ}\text{F}$ of normal, the IMU TEMP light will be extinguished and the system will switch back to the normal control mode. The system will continue to cycle between auto override and emergency modes with an attendant cycling of the IMU TEMP light as long as the malfunction exists and the selector switch remains in the AUTO/OVERRIDE position. In this event, the navigator should select another mode. The mode selected will depend on whether the malfunction exists in the control circuit or indicating circuit.

B. Proportional

The PROPORTIONAL mode is used if a malfunction occurs in the temperature indicating circuit causing undesirable cycling to the EMERGENCY mode. In the proportional mode, temperature control is furnished by the same heater control circuitry used in the AUTO/OVERRIDE mode. The temperature indicating circuitry is not used. Abnormal temperature will cause the IMU TEMP light to illuminate, but will not switch the system to the EMERGENCY mode.

C. Backup

The BACKUP mode is used if a malfunction occurs in the normal control circuit. Temperature control is then furnished by the temperature indicating circuits. In this mode, the IMU TEMP light will illuminate when the heaters are OFF and will extinguish when the heaters are ON.

D. Emergency

In the EMERGENCY switch position, IRIG temperature is controlled by means of an emergency safety mercury thermostat and the emergency heaters. The safety thermostat provides overheat protection for the IMU by opening the emergency heater circuit when the stable member temperature exceeds 134°F . When this temperature drops below 132°F the thermostat closes the circuit to reactivate the heaters.

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8.5.2 ZERO Button (S4)

The ZERO pushbutton is a momentary contact pushbutton used for checking the calibration of the temperature monitoring devices. Depressing this button replaces the IRIG and PIPA temperature indicating sensors in the bridges with standard resistances equal to the resistances of the indicating sensors at their normal operating temperature thus providing a calibration point for the condition of normal temperature.

8.5.3 IRIG GAIN Button (S1)

The IRIG GAIN pushbutton is similar in function to the ZERO button. Depressing the IRIG button replaces the IRIG temperature indicating sensor in the bridge with a standard resistance equal to the resistance of the temperature indication sensor when it is operating at 5°F below normal. Depressing the IRIG button also tests the temperature alarm circuits and will light the IMU TEMP light.

8.5.4 PIPA GAIN Button (S2)

The PIPA GAIN pushbutton performs the same function as the IRIG GAIN button with the exception that the resistance used is equivalent to PIPA indicating sensors operating at 5°F above normal.

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8.6 APOLLO GUIDANCE COMPUTER (AGC)

The computer subsystem (CSS) consists of the AGC, the navigation panel display, and keyboard (DSKY), and the main panel DSKY. The AGC is a digital computer and is the major unit of the CSS. The DSKY's provide two-way communications between the flight crew and the AGC.

The AGC is the processing center of the G&N system. It is both a general purpose and control computer. The AGC performs calculations and control functions according to a series of instructions which are a result of conditions both internal and external to the AGC.

The AGC provides the following capabilities for the Apollo missions:

- A. It solves the Guidance and Navigation problems required for all phases of the Apollo Mission. This falls under the general purpose category.
 1. Orbital Integration - Given pertinent data, the AGC can calculate, at time T_N , the state vector of the spacecraft at time T_X , where $X > N$.
 2. Thrust Vector Control Calculations - During a thrust maneuver, the AGC can calculate V_G (velocity to be gained), A_G (acceleration to be gained), and from their cross product. The cross product is then used by the G&N System and other spacecraft systems to steer the spacecraft to a given point in space at a given time.
- B. It controls the G&N system and other spacecraft systems. Under this control category would be items such as positioning the stable member, positioning the optical unit, turning on and off the SPS engine, and the generation of timing pulses which are used throughout the spacecraft for synchronization purposes.
- C. It maintains cognizance of its own operation, that is, it can detect many of its own malfunctions.

The AGC consists of a logic tray assembly and a memory tray assembly. A tray assembly consists of a tray, the modules, and the connectors mounted on it. The modules contain the AGC's circuitry.

The AGC is functionally divided into seven blocks:

Timer

Sequence Generator

Central Processor

Memory

Priority Control

Input-Output

Power

- A. TIMER - The Timer generates all the necessary synchronization pulses to ensure a logical data flow from one area to another within the AGC. It also generates timing waveforms which are used by the AGC's alarm circuitry and other areas of the spacecraft for control and synchronization purposes.
- B. SEQUENCE GENERATOR - The Sequence generator directs the execution of machine instructions. It does this by generating control pulses which logically sequence data throughout the AGC. The control pulses are formed by combining the order code of an instruction word with synchronization pulses from the timer.
- C. CENTRAL PROCESSOR - The central processor performs all arithmetic operations required of the AGC, buffers all information coming from and going to memory, checks for correct parity on all words coming from memory, and generates a parity bit for all words written into memory.
- D. MEMORY - Memory provides the storage for the AGC and is divided into two sections: erasable memory and fixed memory. Erasable memory can be written into or read from and its readout is destructive. Fixed memory cannot be written into and its readout is non-destructive.
- E. PRIORITY CONTROL - Priority control establishes a processing priority of operations which must be performed by the AGC. These operations are a result of conditions which occur both internally and externally to the AGC. Priority control consists of counter priority control and interrupt priority control. Counter priority control initiates actions which

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update counters in erasable memory. Interrupt priority control transfers control of the AGC to one of six interrupt subroutines (priority programs) stored in fixed memory.

- F. INPUT-OUTPUT - The input-output section routes and conditions signals between the AGC and other areas of the spacecraft.
- G. POWER - This section provides voltage levels necessary for the proper operation of the AGC.

8.6.1 AGC Characteristics

Computer Type	Automatic, electronic, digital, general purpose and control
Internal Transfer	Parallel
Memory	Random Access
Erasable	Core, Capacity = 1024 words
FIXED	Core, rope, capacity = 24,576
Word length	16 bits
Number System	Binary one's complement
Hardware registers	22 total
Machine Instruction	21 total
Memory Cycle Time (MCT)	11.7 μ seconds = 12 ACTION times
Basic Clock oscillator	2.048 mc
AGC power supplies	+3 VDC, +13 VDC
COUNTERS	20 total
Logic	Positive logic 1 = +3 VDC, logic 0 = 0 VDC
Parity	Odd

The following is a brief discussion of several AGC characteristics listed above.

- A. INTERNAL TRANSFER - Parallel internal transfer implies that all bits of a word are transferred simultaneously when a word is routed from one area to another within the AGC.
- B. HARDWARE REGISTERS - A hardware register is a flip-flop register. Most of the AGC's hardware registers consist of 16 flip-flops and their associated read and write gates.

- *
- C. MACHINE INSTRUCTIONS - A machine instruction is one the AGC can directly interpret and execute. Machine instructions are divided into three groups; regular, involuntary, and miscellaneous. Regular instructions consist of an order code and a relevant address. They are divided into two groups: basic groups; basic and extra code. Involuntary instructions are associated with priority control. Miscellaneous instructions are associated with testing the AGC on the ground. All machine instructions consist of one or more subinstructions. A subinstruction takes one MCT to perform.
 - D. COUNTER - A counter is a 16-bit (word) location in erasable memory which is updated when certain conditions (counter interrupts) occur. A counter is not a flip-flop register.
 - E. LOGIC - The AGC employs positive logic. Positive logic implies that the voltage level associated with a Logic 1 is algebraically higher than the voltage level associated with a Logic 0.
 - F. PARITY - The AGC uses odd parity, that is all words stored in memory containing an odd number of Logic 1's. This condition makes it possible for the AGC to detect a malfunction when a word is incorrectly transferred from memory.

8.6.2 AGC Updates

The following is a description of AGC updating utilizing the portions of the loop from the UPLINK XMITTER to the AGC downlink. For this description, we shall consider three bits of data (an octal five) starting at the remote site. The AGC however, receives data in terms of a keycode, which is a five bit code, recognizable by the computer.

8.6.3 Command Data Processor (CDP)

The CDP will take the three bits and convert it to a keycode (5 bits). To this is added the vehicle address, system address, and

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a "1" is added to bit 7. The three bits now have the following format:

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
X	X	X	X	X	X	1	0	0	1	0	1	1	1	0	1	0	0	0	1	0	1
VEHICLE ADDRESS			SYSTEMS ADDRESS			K						R									

The three bits have now grown to 22 bits. The 22 bits are now sub-bit encoded and now becomes 110 bits. The sub-bit encoding for the vehicle address is different than the sub-bit encoding for the systems address and data. A total of 110 bits will be transmitted to the spacecraft (via the uplink transmitter UHF or USB) to get three bits of data onboard.

8.6.4 S/C Receiver

The sub-bit encoding is stripped here and the vehicle address and systems address is checked. If all check satisfactorily, the data is transmitted serially to the uplink counter in the AGC, Bit 7 first. When Bit 7 overflows, the uplink counter is left with KKK where the K represents the keycode, its complement, and the keycode again. The overflow causes an interrupt alarm in the AGC and then the data (15 bits) is transferred to an area of AGC memory called KEYTEMP #1.

8.6.5 KEYTEMP 1

In the area of KEYTEMP 1, a check is made to see if the KKK conditions exist. If so, "K" (5 bits) of data is transferred to an area where keycode processing is performed which consists of interpreting keycodes. This keycode process is also used to interpret DSKY inputs since the DSKY utilizes the 5-bit Keycode also.

8.6.6 ASSEMBLY REGISTER

The keycode (now reduced to the original three bits) and these three bits are transferred to the assembly register. When five words are transmitted, (keycodes) the 15-bit assembly register is full and an ENTER command will transfer all 15 bits to an area called TEMP STORAGE. This is an area of core (14 regs) memory which is set

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aside for updating. When all the words associated with this type update, are into TEMP STORAGE, a FINAL ENTER command will enable the AGC to utilize this data in its computations. If no FINAL ENTER is received by the AGC, the data will remain in TEMP STORAGE and not be utilized.

8.6.7 OUT REGISTER 4

The OUT REGISTER 4 is the method whereby the data transmitted to the AGC is returned to the ground for verification purposes. The data is transmitted as a 40-bit word in the following manner:

1	Word 1	/	P	/	Word 2	/	P	/	WORD ORDER CODE	1				
1			15	16	17			31	32	33				40

Words 1 and 2 are identical and the word order code identifies the Words 1 and 2 as either marker, identification, or data words. The 40-bit word arrives via the TM system as 5, 8-bit words. On the ground, the data received is checked against the data transmitted. If it checks a FINAL ENTER it is transmitted to enable the AGC to utilize the update. If the data does not compare, corrective action is automatically initiated.

8.6.8 Program No. and Routines For AS-501

8.6.8.1 Program No. For AS-501

OX	<u>PRELAUNCH</u>
00	IDLING
01	G&N STARTUP AND CHECKOUT
02	INITIALIZATION
03	GYROCOMPASSING
04	OPTICAL VERIFICATION OF AZIMUTH
05	INERTIAL REFERENCE
07	SYSTEM TEST
1X	<u>BOOSTER MONITOR</u>
11	PRE-LET (LAUNCH ESCAPE TOWER) JETTISON

12 POST-LET JETTISON
17 LET ABORT
2X COASTING PHASE
22 LANDMARK TRACKING
23 STAR/LANDMARK SIGHTING
27 AGC UPDATE
3X PRE-THRUSTING PHASES
31 ORBIT CHANGE
32 RETURN TO EARTH
33 SPS MINIMUM IMPULSE
4X THRUSTING PHASES
41 ORBIT CHANGE
42 RETURN TO EARTH
43 SPS MINIMUM IMPULSE
5X ALIGNMENT
51 IMU ORIENTATION DETERMINATION
52 S-IVB/IMU ALIGNMENT
53 CSM/IMU ALIGNMENT
54 IMU REALIGNMENT PROGRAM
6X ENTRY
61 MANEUVER TO CM/SM SEPARATION ATTITUDE
62 CM/SM SEPARATION AND PREENTRY MANEUVER
63 INITIATE ENTRY STEERING
64 .05 G INDICATION
67 FINAL PHASE
7X ABORT PHASES
71 FIRST ABORT BURN

8.6.8.2 Mission AS-501 AGC

<u>ROUTINE NO.</u>	<u>ROUTINE TITLE</u>
1	ATTITUDE CONTROL MODE CHECK
2	THRUST CONTROL MODE CHECK
3	ENTRY CONTROL MODE CHECK
4	FINE ALIGNMENT

<u>ROUTINE NO.</u>	<u>ROUTINE TITLE</u>
21	ATTITUDE MANEUVER
22	SCS DISCRETE MONITOR
24	DELTA V MONITOR
25	COARSE ALIGNMENT
27	SIGHTING MARK
28	AUTO OPTICS POSITIONING
29	STAR DATA TEST
30	GYRO TORQUING
31	BACKUP DELTA V COUNTER
33	PRE-THRUST SPS MINIMUM IMPULSE DATA LOAD
34	ORBIT PARAMETER DISPLAY
35	PRE-THRUST ORBIT CHANGE DATA LOAD
36	PRE-THRUST RETURN TO EARTH DATA LOAD
37	SPS ENGINE IGNITION
38	SPS ENGINE THRUST FAIL

8.6.9 Verb Definitions AS-501

REGULAR VERBS

01	DISPLAY OCTAL COMP 1 (R1)
02	DISPLAY OCTAL COMP 2 (R1)
03	DISPLAY OCTAL COMP 3 (R1)
04	DISPLAY OCTAL COMP 1, 2 (R1, R2)
05	DISPLAY OCTAL COMP 1, 2, 3 (R1, R2, R3)
06	DECIMAL DISPLAY
07	DP DECIMAL DISPLAY (R1, R2)
10	REQUEST WAITLIST
11	MONITOR OCT COMP 1 (R1)
12	MONITOR OCT COMP 2 (R1)
13	MONITOR OCT COMP 3 (R1)
14	MONITOR OCT COMP 1, 2 (R1, R2)
15	MONITOR OCT COMP 1, 2, 3 (R1, R2, R3)

16 MONITOR DECIMAL
17 MONITOR DP DECIMAL (R1,R2)
20 REQUEST EXECUTIVE (NON-FLIGHT USE ONLY)
21 LOAD COMP 1 (R1)
22 LOAD COMP 2 (R2)
23 LOAD COMP 3 (R3)
24 LOAD COMP 1, 2 (R1, R2)
25 LOAD COMP 1, 2, 3 (R1, R2, R3)
26 SPARE
27 SPARE
30 SPARE
31 BANK DISPLAY (FIXED MEMORY)
32 SPARE
33 PROCEED WITHOUT DATA
34 TERMINATE CURRENT TEST OR LOAD REQUEST
35 RELEASE DISPLAY SYSTEM
36 FRESH START
37 CHANGE MAJOR MODE

END OF REGULAR VERBS

EXTENDED VERBS

40 ZERO (USED WITH NOUN ICDU OR OCDU)
41 COARSE ALIGN (USED WITH NOUN ICDU OR OCDU)
42 FINE ALIGN IMU
43 LOCK IMU
44 SET IMU TO ATTITUDE CONTROL
45 SET IMU TO REENTRY CONTROL
46 RETURN IMU TO COARSE ALIGN
47 OPTICAL TRACKER ON (NOT IN USE YET)
50 PLEASE PERFORM
51 PLEASE MARK
52 MARK REJECT (UNTIL BUTTON AVAILABLE)

53 FREE (USED WITH NOUN ICDU OR OCDU)
 54 PULSE TORQUE GYROS
 55 ALIGN TIME
 56 PERFORM BANKSUM
 57 DO SYSTEM TEST (NON-FLIGHT USE ONLY)
 60 PREPARE FOR STANDBY
 61 RECOVER FROM STANDBY
 62 ILLEGAL VERB
 63 ILLEGAL VERB
 64 DISPLAY ORBITAL PARAMETERS
 65 CALCULATE TIME OF ARRIVAL AT LONGITUDE
 66 CALCULATE LATITUDE AND LONGITUDE AT SPECIFIED TIME
 67 CALCULATE TIME OF ARRIVAL AT MAXIMUM DECLINATION
 70 PERFORM MANUAL ATTITUDE MANEUVER
 71 MTVC TAKEOVER
 72 UPDATE MINIMUM IMPULSE TARGETTING
 73 UPDATE RETURN TO EARTH TARGETTING
 74 UPDATE ORBITAL CHANGE TARGETTING
 75 PERFORM BACKUP LIFTOFF
 76 PERFORM STATE VECTOR (RVT) UPDATE
 77 UPDATE LIFTOFF TIME

8.6.10 Noun Definitions AS-501

<u>NORMAL NOUNS</u>	<u>COMPONENTS</u>	<u>SCALE & DECIMAL POINT</u>
00 NOT IN USE		
01 SPECIFY MACHINE ADDRESS (FRACTIONAL)	-	.XXXXX
02 SPECIFY MACHINE ADDRESS (WHOLE)	1COMP	XXXXX.
03 SPARE		
04 SPARE		
05 ANGULAR ERROR	1COMP	XXX.XX DEG
06 SPARE		
07 CHANGE OF PROGRAM (MAJOR MODE)	1COMP	OCTAL ONLY

<u>NORMAL NOUNS</u>	<u>COMPONENTS</u>	<u>SCALE & DECIMAL POINT</u>
(USED WITH PLEASE PERFORM ONLY)		
10 SPARE		
11 ENGINE ON ENABLE	-	INFORMATION CONVEYED BY NOUN CODE ONLY
(USED WITH PLEASE PERFORM ONLY)		
12 GIMBAL ANGLES	3COMP	XXX.XX DEG FOR EACH
13 DELTA VELOCITY MEASURED (VECTOR MAG)	1COMP	XXXXX. FT/SEC
14 DELTA VELOCITY COUNTER SETTING	1COMP	XXXXX. FT/SEC
15 INCREMENT MACHINE ADDRESS	1COMP	OCTAL ONLY
16 AGC CLOCK TIME (HRS, MIN, SEC)	3COMP	00XXX. HRS 000XX. MIN OXX.XX SEC
17 FINAL ICDU ANGLES	3COMP	XXX.XX DEG FOR EACH
20 ICDU	3COMP	XXX.XX DEG FOR EACH
21 PIPAS	3COMP	XXXXX. PULSES FOR EACH
22 NEW ANGLES I	3COMP	XXX.XX DEG FOR EACH
23 DELTA ANGLES I	3COMP	XXX.XX DEG FOR EACH
24 DELTA TIME FOR AGC CLOCK (HRS, MIN, SEC)	3COMP	00XXX. HRS 000XX. MIN OXX.XX SEC
25 CHECKLIST (USED WITH PLEASE PERFORM ONLY)	1COMP	XXXXX.
26 PRIO/DELAY	1COMP	XXXXX.
27 SELF TEST ON/OFF SWITCH	1COMP	XXXXX.
30 STAR NUMBERS	3COMP	XXXXX. FOR EACH
31 FAILURE INFORMATION (FAILREG, SFAIL, ERCOUNT)	3COMP	OCTAL ONLY FOR EACH
32 SPARE		
33 TIME OF IGNITION	3COMP	00XXX. HRS 000XX. MIN OXX.XX SEC

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<u>NORMAL NOUNS</u>	<u>COMPONENTS</u>	<u>SCALE & DECIMAL POINT</u>
34 EVENT TIME (HRS, MIN, SEC)	3COMP	00XXX. HRS 000XX. MIN 0XX.XX SEC
35 DELTA EVENT TIME (HRS, MIN, SEC)	3COMP	00XXX. HRS 000XX. MIN 0XX.XX SEC
36 DELTA EVENT TIME (MIN/SEC)	1COMP	XXBXX MIN/SEC
37 SIGHTING IDENTIFICATION	1COMP	OCTAL ONLY
<u>MIXED NOUNS</u>		
40 GAMMA, INERTIAL VELOCITY (VI), ALTITUDE ABOVE LAUNCH PAD (HPAD)	3COMP	XXX.XX DEG XXXXX. FT/SEC XXXX.X N.M.
41 MAX ACCELERATION (GMAX), PERIGEE ALTITUDE (HP), FREE-FALL TIME (T _{FF})	3COMP	XXX.XX G XXXX.X N.M. XXBXX MIN/SEC
42 MISS DISTANCE (DELTA R), PERIGEE ALTITUDE (HP), FREE-FALL TIME (T _{FF})	3COMP	XXXX.X N.M. XXXX.X N.M. XXBXX MIN/SEC
43 APOGEE ALTITUDE (HA), PERIGEE ALTITUDE (HP), FREE-FALL TIME (T _{FF})	3COMP	XXXX.X N.M. XXXX.X N.M. XXBXX MIN/SEC
44 LATITUDE, LONGITUDE, ALTITUDE (ABOVE FISCHER ELLIPSOID)	3COMP	XXX.XX DEG XXX.XX DEG XXXX.X N.M.
45 APOGEE ALTITUDE (HA), PERIGEE ALTITUDE (HP), DELTA VELOCITY REQUIRED (DELTA VREQ)	3COMP	XXXX.X N.M. XXXX.X N.M. XXXXX. FT/SEC
46 TIME TO EVENT, VELOCITY TO BE GAINED (VG), PERIGEE ALTITUDE (HP)	3COMP	XXBXX MIN/SEC XXXXX. FT/SEC XXXX.X N.M.

<u>MIXED NOUNS</u>		<u>COMPONENTS</u>	<u>SCALE & DECIMAL POINT</u>
47	GAMMA AT EI, MISS DISTANCE (DELTA R), INERTIAL VELOCITY (VI AT EI)	3COMP	XXX.XX DEG XXXX.X N.MI. XXXXX. FT/SEC
50	TIME TO EVENT, DELTA TIME BURN, DELTA VELOCITY MEASURED	3COMP	XXBXX MIN/SEC XXBXX MIN/SEC XXXXX. FT/SEC
51	TIME TO EVENT, VELOCITY TO BE GAINED (VG), MEASURED VELOCITY CHANGE ALONG XSC	3COMP	XXBXX MIN/SEC XXXXX. FT/SEC XXXXX. FT/SEC
52	TIME TO EVENT, VELOCITY TO BE GAINED (VG), FREE-FALL TIME (T_{ff})	3COMP	XXBXX MIN/SEC XXXXX. FT/SEC XXBXX MIN/SEC
53	MAX ACCELERATION (GMAX), GAMMA AT EI, FREE-FALL TIME (T_{ff})	3COMP	XXX.XX G XXX.XX DEG XXBXX MIN/SEC
54	COMMAND ROLL ANGLE (BETA), PRESENT ACCELERATION (G), RANGE TO TARGET	3COMP	XXX.XX DEG XXX.XX G XXXX.X N.MI.
55	OCDU X (SHAFT), Y (TRUNNION)	2COMP	XXX.XX DEG XXX.XX DEG OR XX.XXX DEG
56	MARK DATA X (SHAFT), Y (TRUNNION)	2COMP	XXX.XX DEG XXX.XX DEG OR XX.XXX DEG
57	NEW ANGLES OCDU X (SHAFT), Y (TRUNNION)	2COMP	XXX.XX DEG XXX.XX DEG OR XX.XXX DEG
60	IMU MODE STATUS (IN3, WASKSET, OLDERR)	3COMP	OCTAL ONLY FOR EACH
61	TARGET AZIMUTH, ELEVATION	2COMP	XXX.XX DEG XX.XXX DEG
62	IMPACT LATITUDE, IMPACT LONGITUDE, HEADS UP/DOWN	3COMP	XXX.XX DEG XXX.XX DEG +/-00001

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<u>MIXED NOUNS</u>	<u>COMPONENTS</u>	<u>SCALE & DECIMAL POINT</u>
63 LATITUDE, LONGITUDE/2, ALTITUDE (ABOVE FISCHER ELLIPSOID)	3COMP	XX.XXX DEG XX.XXX DEG XXX.XX N.MI.
64 PRESENT LATITUDE PRESENT LONGITUDE PRESENT ALTITUDE	3COMP	XXX.XX DEG XXX.XX DEG XXXX.X N.MI.
65 SAMPLED AGC CLOCK TIME (HRS,MIN,SEC) (FETCHED IN INTERRUPT)	3COMP	00XXX, HRS 000XX. MIN 0XX.XX SEC
66 SYSTEM TEST RESULTS	3COMP	XXXXX., .XXXXX, XXXXX.
67 DELTA GYRO ANGLES	3COMP	XX.XXX FOR EACH
70 PITCH TRIM YAW TRIM, DELTA TIME TAILOFF	3COMP	XXX.XX DEG XXX.XX DEG XXX.XX SEC
71 COMMAND ROLL ANGLE (BETA), PRESENT ACCELERATION (G) PREDICTED RANGE-RANGE TO TARGET	3COMP	XXX.XX DEG XXX.XX G XXXX.X N.MI.
72 DELTA POSITION	3COMP	XXXX.X KILOMETERS FOR EACH
73 DELTA VELOCITY	3COMP	XXXX.X METERS/ SEC FOR EACH
74 DELTA VELOCITY ALLOWABLE, DELTA TIME TAILOFF	2COMP	XXXXX. FT/SEC XXX.XX SEC
75 DELTA POSITION MAGNITUDE, DELTA VELOCITY MAGNITUDE, MULTIPLE MARK COUNTER	3COMP	XXXX.X N.MI. XXXXX. FT/SEC XXXXX.
76 SPARE		
77 SPARE		

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CHECKLIST FOR USE WITH NOUN 25

00001	SCS MODE - G&N ATT CONT
00002	SCS MODE - G&N DELTA V
00003	SCS MODE - G&N ENTRY
00004	SCS MODE - SCS ATT CONT
00007	ATT TRIM MANEUVER ENABLE
00011	AUTO OPTIC POS
00012	TARGET DATA ENTRY
00013	SW OSS TO COMPUTER CONT
00014	FINE ALIGN CHECK
00015	PERFORM STAR ACQ
00016	TERMINATE MARK SEQ
00031	ENGINE ON
00035	PREP AGC FOR THRUST
00036	THRUST TERMINATE
00041	CM/SM SEP
00051	FINAL IMU/FINAL VEH
00052	INTERIM IMU/FINAL VEH
00053	FINAL IMU/INTERIM VEH
00054	INTERIM IMU/INTERIM VEH
00060	IMU TURN-ON
00061	IMU POWER DOWN
00062	AGC POWER DOWN

DATE		COMPUTER WORKSHEET			PAGE
8.6.11 Computer Worksheet		VEHICLE	CSM	SYSTEM	MISSION
				C&N	501
NON-UPDATE DOWN LIST					
W.N.	NOMENCLATURE	REMARKS			UNITS
1	IDENTIFICATION	IDENTIFIES NON-UPDATE DOWNLIST			
	W.O. = 1	OCTAL CODE OUTPUT OF AGC = 62067			
2	DSPTAB+0	DISPLAY WORD +0			
	W.O. = 0	BIT 11 REGISTER 3 (-) SIGN			
		BIT 10-6 REGISTER 3 CHARACTER 4			
		BIT 5-1 REGISTER 3 CHARACTER 5			
3	DSPTAB+1	DISPLAY WORD +1			
	W.O. = 0	BIT 11 REGISTER 3 (+) SIGN			
		BIT 10-6 REGISTER 3 CHARACTER 2			
		BIT 5-1 REGISTER 3 CHARACTER 3			
4	DSPTAB+2	DISPLAY WORD +2			
	W.O. = 0	BIT 11 REGISTER 2 CHARACTER 5			
		BIT 5-1 REGISTER 3 CHARACTER 1			

DATE		COMPUTER WORKSHEET				PAGE
		VEHICLE	CSM	SYSTEM	C&N	MISSION
		NON-UPDATE				501
		DOWN LIST				2
W.N.	NOMENCLATURE	REMARKS	UNITS			
5	DSPTAB+3	DISPLAY WORD +3				
	W.O. = 0	REGISTER 2 (-) SIGN				
		REGISTER 2 CHARACTER 3				
		REGISTER 2 CHARACTER 4				
6	DSPTAB+4	DISPLAY WORD +4				
	W.O. = 0	REGISTER 2 (+) SIGN				
		REGISTER 2 CHARACTER 1				
		REGISTER 2 CHARACTER 2				
7	DSPTAB+5	DISPLAY WORD +5				
	W.O. = 0	REGISTER 1 (-) SIGN				
		REGISTER 1 CHARACTER 4				
		REGISTER 1 CHARACTER 5				
8	DSPTAB+6	DISPLAY WORD +6				
	W.O. = 0	REGISTER 1 (+) SIGN				
		REGISTER 1 CHARACTER 2				
		REGISTER 1 CHARACTER 3				

DATE		COMPUTER WORKSHEET				PAGE
		VEHICLE	CSM	SYSTEM	O&N	MISSION
		NON-UPDATE DOWN LIST				501
W.N.	NOMENCLATURE	REMARKS				UNITS
9	DSPTAB+7	DISPLAY WORD +7				
	W.O. = 0	BIT 11 UPLINK ACTIVITY				
		BIT 10-6				
		BIT 5-1 REGISTER 1 CHARACTER 1				
10	DSPTAB+8	DISPLAY WORD +8				
	W.O. = 0	BIT 10-6 HIGH OCTAL DIGIT OF NOUN				
		BIT 5-1 LOW OCTAL DIGIT OF NOUN				
11	DSPTAB+9	DISPLAY WORD +9				
	W.O. = 0	BIT 11 FLASH ACTIVITY				
		BIT 10-6 HIGH OCTAL DIGIT OF VERB				
		BIT 5-1 LOW OCTAL DIGIT OF VERB				
12	DSPTAB+10	DISPLAY WORD +10				
	W.O. = 0	BIT 10-6 HIGH OCTAL DIGIT OF MAJOR MODE				
		BIT 5-1 LOW OCTAL DIGIT OF MAJOR MODE				

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DATE		COMPUTER WORKSHEET				PAGE
		VEHICLE	CSM	SYSTEM	C&N	MISSION
		NON-UPDATE DOWN LIST				4
		NON-UPDATE DOWN LIST				501
W.N.	NOMENCLATURE	REMARKS				UNITS
13	DSPTAB+11	MODING RELAY WORD 1: -				
	W.O. = 0	BIT 1 - INITIATE ISS ZERO ENCODE MODE				
		BIT 2 - INITIATE ISS COARSE ALIGN MODE				
		BIT 3 - INITIATE ISS LOCK CDU MODE				
		BIT 4 - INITIATE ISS FINE ALIGN MODE				
		BIT 5 - ENCODER ZERO LAMP SET ON/OFF DISCRETE				
		BIT 6 - CDU FAIL LAMP SET ON/OFF DISCRETE				
		BIT 7 - PIPA FAIL LAMP SET ON/OFF DISCRETE				
		BIT 8 - IMU FAIL LAMP SET ON/OFF DISCRETE				
		BIT 10 - INITIATE ISS ATTITUDE CONT. MODE				
		BIT 11 - INITIATE ISS ROLL RE-ENTRY MODE				
14	DSPTAB+12 W.O. = 0	MODING RELAY WORD 2: - CAN BE IGNORED FOR MISSION 501.				
15	DSPTAB+13	MODING RELAY WORD 3: -				
	W.O. = 0	BIT 1 - SELECT C&N ATTITUDE CONT. IN SCS (TO MCP)				
		BIT 2 - SELECT C&N AV MODE IN SCS (TO MCP)				
		BIT 3 - SELECT C&N ENTRY MODE IN SCS (TO MCP)				
		BIT 4 - INITIATE CM/SI SEPARATION (TO MCP)				

COMPUTER WORKSHEET				PAGE
DATE	VEHICLE	SYSTEM	MISSION	5
	CSM	C&N	501	
NON-UPDATE DOWN LIST				
W.N.	NOMENCLATURE	REMARKS	UNITS	
		BIT 5 - INITIATE + X TRANSLATION (TO MCP)		
		BIT 7 - .05 G INDICATION (TO MCP)		
		BIT 8 - GIMBAL MOTOR POWER SET ON/OFF DISC. (TO MCP)		
		BIT 9 - FDAI ALIGN SET ON/OFF DISC. (TO MCP)		
		BIT 10 - TELECOMMUNICATION SET ON/OFF DISC. (TO MCP)		
		(BIT 10 NOT UTILIZED ON MISSION 501)		
16	TIME 2	CONTAINS MOST SIGNIFICANT BITS OF DOUBLE PRECISION REAL TIME		
		CLOCK OF ACC.		CENTISECONDS/28 (.01 SEC/228)
17	TIME 1	CONTAINS LEAST SIGNIFICANT BITS OF DOUBLE PRECISION REAL TIME		
		CLOCK OF ACC.		
18	IN REGISTER 0	STATUS WORD 1: -		
		BITS 1-5 - CONTAINS KEY CODE DATA		
		BIT 6 - UPLINK ACCEPT SWITCH INDICATION		
		(NO APPLICATION TO MISSION 501)		

MSC FORM 1230 (REV DEC 65)

DATE		COMPUTER WORKSHEET			PAGE
		VEHICLE	SYSTEM	MISSION	6
		CSM	G&N	501	
NON-UPDATE DOWN LIST					
W.N.	NOMENCLATURE	REMARKS	UNITS		
		BIT 7 - INHIBIT UPSYNC (WILL BE SET TO A 1 IF UNLINK BIT			
		RATE > 1600 BITS/SEC)			
		BIT 15 - MARK INDICATION (NO APPLICATION TO MISSION 501)			
19	IN REGISTER 2	STATUS WORD 2: -			
	W.O. = 0	BITS 1-4 - FINE TIME INFORMATION EMPLOYED IN ISS TESTING			
		BIT 5 - LIFTOFF INDICATION FROM EXTERNAL SOURCE			
		BIT 6 - GUID. REF. RELEASE INDICATION FROM EXTERNAL SOURCE			
		BIT 7 - SATURN ULLAGE (NO USE IS MADE OF THIS INFORMATION			
		IN MISSION 501 AGC)			
		BIT 8 - S/B SEPARATE INDICATION (TO AGC)			
		BIT 9 - S/W/CM SEPARATE INDICATION (TO AGC)			
		BIT 10 - CDU FAIL INDICATION TO AGC			
		BIT 11 - PIPA FAIL INDICATION TO AGC			
		BIT 12 - IMU FAIL INDICATION TO AGC			
		BIT 15 - PARITY FAIL INDICATION TO AGC			

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COMPUTER WORKSHEET				PAGE
DATE	VEHICLE	SYSTEM	G&N	MISSION
	C5M			501
NON-UPDATE				
DOWN LIST				
W.N.	NOMENCLATURE	REMARKS	UNITS	
20	IN REGISTER 3	STATUS WORD 3: -		
	W.O. = 0	BIT 1 - ZERO ENCODER INDICATION (ISS MODE) (TO ACC)		
		BIT 2 - COARSE ALIGN INDICATION (ISS MODE) (TO ACC)		
		BIT 3 - CDU MANUAL INDICATION (ISS MODE) (TO ACC)		
		BIT 4 - FINE ALIGN INDICATION (ISS MODE) (TO ACC)		
		BIT 5 - ATTITUDE CONT INDICATION (ISS MODE) (TO ACC)		
		BIT 6 - TRANSFER SWITCH MANIPULATION INDICATION		
		BIT 7 - ENTRY INDICATION (ISS MODE) (TO ACC)		
		BIT 10 - OPTIC MODE SW3		
		BIT 11 - STAR PRESENT (NOT APPLICABLE ON M-501)		
		BIT 12 - ZERO OPTICS INDICATION		
		BIT 13 - SEXTANT ON INDICATION (ALWAYS A ONE)		
		BIT 14 - OPTICS MODE SW2 INDICATION		
		BIT 15 - "OR" OF DSKY CONTROL (C) RELAYS		
21	OUT REGISTER 1	BIT 1 - PROGRAM ALARM INDICATION. (LITE ON/OFF DISC)		
	W.O. = 0	BIT 2 - COMPUTER ACTIVITY INDICATION. (LITE ON/OFF DISC)		
		BIT 3 - KEY RELEASE INDICATION. (LITE ON/OFF DISC)		

DATE		COMPUTER WORKSHEET			PAGE
		VEHICLE	SYSTEM	C&N	MISSION
		CSM			501
NON-UPDATE					
DOWN LIST					
W. N.	NOUENCLATURE	REMARKS			UNITS
		BIT 4 - T/M ALARM INDICATION. (LITE ON/OFF DISC)			
		BIT 5 - PROGRAM CHECK FAIL INDICATION (LITE ON/OFF DISC)			
		BIT 7 - RUPT TRAP RESET INITIATION (NOT APPLICABLE ON M-501)			
		BIT 9 - WORD ORDER INDICATION FOR DOWNLINK			
		BIT 10 - BLOCK END PULSE INITIATION. (STOP DOWNLINK IF DOWN- LINK RATE TO HIGH)			
		BIT 13 - ENGINE ON/OFF INITIATION			
22	STATE WORD	PROGRAM DATA WORD 1			
		W.O. = 0			
		BIT 1 - PROGRAM SWITCH INDICATION			
		BIT 1 - INRLSW			
		BIT 2 - UPLINK BLOCKED INDICATION ($K \neq \bar{K} \neq K$)			
		BIT 3 - EXTENDED VERB ACTIVITY INDICATION (INTERLOCK FOR VERBS 37).			
		BIT 4 - DISPLAY UTILIZED BY OPERATOR INDICATION (INTERLOCK) (NOT EMPLOYED ON 501 MISSION).			
		BIT 5 - DSKY FLAG			
		BIT 6 - VERIFLAG			

DATE		COMPUTER WORKSHEET			PAGE
		VEHICLE	CSM	SYSTEM	G&N
		NON-UPDATE			MISSION
		DOWN LIST			501
W. N.	NOMENCLATURE	REMARKS	UNITS		
	BIT 6 - HIND 2 SWITCH - ENTRY ROUTINE USE (INITIALLY = 1).				
	BIT 7 - HUNT SW-ENTRY ROUTINE USE (INITIALLY = 1).				
	BIT 8 - E G SW-ENTRY ROUTINE USE (INITIALLY = 1).				
	BIT 9 - RELATIVE VELOCITY SW - ENTRY ROUTINE USE.				
	BIT 10 - GONE PAST SW - ENTRY ROUTINE USE (INITIALLY = 1).				
	BIT 11 - NAV. BAS/STABLE MEMBER BIT (AFTER GRR SET TO 1).				
	BIT 12 - BIAS FLAG				
	BIT 13 - TFF2 FLAG				
	BIT 14 - ABORT SIG FLAG				
	BIT 15 - J SWITCH (NO APPLICATION FOR 501).				
23	FLAG WORD 1	PROGRAM DATA WORD 2: -			
	W.O. = 0	BIT 1 - TUMBLING INDICATION (CDU RATES $> 5^{\circ}/\text{SEC}$)			
		BIT 2 - LIFT OFF			
		BIT 3 - ENTRY PROGRAM INDICATION (SET TO ONE AFTER CM/SM MANVR)			
		BIT 4 - STEERING INDICATION (ACTIVE DURING A BURN).			
		BIT 5 - DV MONITOR PROGRAM ENABLE (ENABLE THRUST DETECTION)			
		BIT 6 - MONITOR (SET TO A ONE DURING SATURN PITCH OVER)			

DATE		COMPUTER WORKSHEET			PAGE
		VEHICLE	SYSTEM	C&N	MISSION
		CSM			501
NON-UPDATE					
DOWN LIST					
W.N.	NOBENCLATURE	REMARKS	UNITS		
		BIT 7 - INIT 1 FLAG (SET TO A 1 WHEN T _{FF} FIRST BECOMES LESS THAN 200 SECONDS - FREE FALL INTERRUPT MUST BE ENABLED)			
		BIT 8 - S4B SEPARATION (SET TO A 1 WHEN S4B SEPARATION IN-BIT IS SENSED)			
		BIT 9 - INITIAL (PRE-SPS1 BURN COMPUTATION FLAG)			
		BIT 10 - INTERRUPT FLAG (ENABLE FREE FALL SENSING)			
		BIT 11 - IMU ACTIVITY FLAG			
		BIT 12 - SHUTDOWN FLAG (ENTRY PREPARATION BASED ON T _{FF} OR SOME OTHER REASON, SUCH AS DELTA-V ALARM)			
		BIT 13 - SOAK FLAG			
		BIT 14 - UPDATE FLAG (SET TO A 1 IF SUCCESSFUL UPDATE COMPLETELY RECEIVED)			
		BIT 15 - COAST FLAG (IN COAST PHASE)			
24	FLAG WORD 2	PROGRAM DATA WORD 3: -			
	W.O. = 0	BIT 1 - ARREST BURN FLAG (SET IF TUMBLING)			
		BIT 2 - ABORT BURN FLAG			
		BIT 3 - TUMBLE ABORT BURN (OCCURS AFTER ARREST BURN)			

DATE		COMPUTER WORKSHEET			PAGE
		VEHICLE	CSM	SYSTEM	MISSION
					501
NON-UPDATE		DOWN LIST			UNITS
W.N.	NOMENCLATURE	REMARKS			
		BIT 4 - SPS1 BURN FLAG			
		BIT 5 - SPS2 BURN FLAG			
		BIT 6 - SPS3 BURN FLAG			
		BIT 7 - SPS4 BURN FLAG			
		BIT 8 - BEGIN ARC FLAG (CALCUL. OF ATT. MAN'R ROUTINE)			
		BIT 9 - NEGATIVE FLAG (CALCUL. OF ATT. MAN'R ROUTINE)			
		BIT 10 - DOING ATTITUDE MANEUVER FLAG			
		BIT 11 - CALCULATE ATT. MAN'R ROUTINE FLAG (ON DURING ENTIRE ROUTINE)			
		BIT 12 - ROLL TO BE PERFORMED FLAG (CAL OF ATT MAN'R ROUTINE)			
		BIT 13 - BACK ARC FLAG (CALCUL. OF ATT. MAN'R ROUTINE)			
		BIT 14 - CDUX INDICATION (MODIFICATION OF CDUX FOR ENTRY)			
		BIT 15 - DRIFT INDICATION (PLATFORM CORRECT. BY TIME BIAS MEANS DURING COAST PHASE.)			
25	CDUX W.O. = 0	ROLL AXIS GIMBAL ANGLE			15 BIT WORD, DECIMAL
26	CDUY W.O. = 0	PITCH AXIS GIMBAL ANGLE			FRACTION OF 360°
27	CDUZ W.O. = 0	YAW AXIS GIMBAL ANGLE			NO SIC

MSC FORM 1838 (REV DEC 85)

DATE		COMPUTER WORKSHEET			PAGE
		VEHICLE	SYSTEM	C&N	MISSION
		CSM			501
NON-UPDATE DOWN LIST					
W.N.	NOMENCLATURE	REMARKS	UNITS		
28	RE DO CTR W.O. = 0	ACCUMULATES NO. OF RESTARTS OCCURRING DURING A MISSION			
29	DELV X W.O. = 0	X PIPA COUNTER CONTENTS			
30	DELV Y W.O. = 0	Y PIPA COUNTER CONTENTS	5.85 CM/SEC ² /PULSE		
31	DELV Z W.O. = 0	Z PIPA COUNTER CONTENTS			
32	DESIRED CDUX W.O. = 0	DESIRED ROLL ANGLE	15 BIT WORD, DECIMAL		
33	DESIRED CDUY W.O. = 0	DESIRED PITCH ANGLE	FRACTION OF 360°		
34	DESIRED CDUZ W.O. = 0	DESIRED YAW ANGLE	NO SIGN		
35	RRECT+0(MOST SIG BITS OF X POS.) W.O. = 0	SPS1 TAILOFF STATE VECTOR COMPONENT TO BE USED IN ORBITAL INTEGRATION PROGRAM.			
36	RRECT+1(LEAST SIG BITS OF X POS.) W.O. = 0	SPS1 TAILOFF STATE VECTOR COMPONENT TO BE USED IN ORBITAL INTEGRATION PROGRAM.			
37	RRECT+2(MOST SIG BITS OF X POS.) W.O. = 0	SPS1 TAILOFF STATE VECTOR COMPONENT TO BE USED IN ORBITAL INTEGRATION PROGRAM.	KILOMETERS		
38	RRECT+3(LEAST SIG BITS OF Y POS.) W.O. = 0	SPS1 TAILOFF STATE VECTOR COMPONENT TO BE USED IN ORBITAL INTEGRATION PROGRAM.	216		
39	RRECT+4(MOST SIG BITS OF Z POS.) W.O. = 0	SPS1 TAILOFF STATE VECTOR COMPONENT TO BE USED IN ORBITAL INTEGRATION PROGRAM.			

DATE	COMPUTER WORKSHEET			PAGE	13
	VEHICLE	C&M	SYSTEM	MISSION	501
	NON-UPDATE DOWN LIST				

W.N.	NOMENCLATURE	REMARKS	UNITS
40	RRECT+5(LEAST SIG BITS OF Z POS.) W.O. = 0	SPSI TAILOFF VECTOR COMPONENT TO BE USED IN ORBITAL INTEGRATION PROGRAM.	KILOMETERS 16 2
41	VRECT+0(MOST SIG BITS OF X VEL.) W.O. = 0	SPSI TAILOFF STATE VECTOR COMPONENT TO BE USED IN ORBITAL INTEGRATION PROGRAM.	
42	VRECT+1(LEAST SIG BITS OF X VEL.) W.O. = 0	SPSI TAILOFF STATE VECTOR COMPONENT TO BE USED IN ORBITAL INTEGRATION PROGRAM.	METERS SEC (64 631350.3)
43	VRECT+2(MOST SIG BITS OF Y VEL.) W.O. = 0	SPSI TAILOFF STATE VECTOR COMPONENT TO BE USED IN ORBITAL INTEGRATION PROGRAM.	
44	VRECT+3(LEAST SIG BITS OF Y VEL.)	SPSI TAILOFF STATE VECTOR COMPONENT TO BE USED IN ORBITAL INTEGRATION PROGRAM.	
45	VRECT+4(MOST SIG BITS OF Z VEL.) W.O. = 0	SPSI TAILOFF STATE VECTOR COMPONENT TO BE USED IN ORBITAL INTEGRATION PROGRAM.	
46	VRECT+5(LEAST SIG BITS OF Z VEL.) W.O. = 0	SPSI TAILOFF STATE VECTOR COMPONENT TO BE USED IN ORBITAL INTEGRATION PROGRAM.	
47	Tff (MOST SIG BITS) W.O. = 0	TIME OF FREE-FALL.	CENTISECONDS/2 ²⁸
(

DATE		COMPUTER WORKSHEET				PAGE
		VEHICLE	CSM	SYSTEM	G&N	MISSION
		NON-UPDATE				14
		DOWN LIST				501
W.N.	NOMENCLATURE	REMARKS				UNITS
48	T _{FF} (LEAST SIG BITS)	TIME OF FREE-FALL.				CENTISECONDS/2 ²⁸
	W.O. = 0					
49	TM MARKER W.O. = 1	OCTAL 74000 DUMMY MARKERS IF ACTUAL MARKERS HAVE NOT OCCURRED ABOVE.				
50	TM MARKER W.O. = 1	OCTAL 74000 DUMMY MARKERS IF ACTUAL MARKERS HAVE NOT OCCURRED ABOVE.				
51	TM MARKER W.O. = 1	OCTAL 74000 DUMMY MARKERS IF ACTUAL MARKERS HAVE NOT OCCURRED ABOVE.				
52	DSPTAB+0 W.O. = 0	SEE WORD 2				
53	DSPTAB+1 W.O. = 0	SEE WORD 3				
54	DSPTAB+2 W.O. = 0	SEE WORD 4				
55	DSPTAB+3 W.O. = 0	SEE WORD 5				
56	DSPTAB+4 W.O. = 0	SEE WORD 6				
57	DSPTAB+5 W.O. = 0	SEE WORD 7				
58	DSPTAB+6 W.O. = 0	SEE WORD 8				
59	DSPTAB+7 W.O. = 0	SEE WORD 9				
60	DSPTAB+8 W.O. = 0	SEE WORD 10				
61	DSPTAB+9 W.O. = 0	SEE WORD 11				
62	DSPTAB+10 W.O. = 0	SEE WORD 12				
63	DSPTAB+11 W.O. = 0	SEE WORD 13				

NON-UPDATE		DOWN LIST		UNITS
W.N.	NOMENCLATURE	REMARKS		
64	DSPTAB+12 W.O. = 0	SEE WORD 14		
65=	DSPTAB+13 W.O. = 0	SEE WORD 15		
66	RN+0(X POSITION)W.O.=0	MOST SIGNIFICANT WORD (AVERAGE G RESULTS)		
67	RN+1(X POSITION)W.O.=0	LEAST SIGNIFICANT WORD (AVERAGE G RESULTS)		
68	RN+2(Y POSITION)W.O.=0	MOST SIGNIFICANT WORD (AVERAGE G RESULTS)		METERS
69	RN+3(Y POSITION)W.O.=0	LEAST SIGNIFICANT WORD (AVERAGE G RESULTS)		2 ²⁵
70	RN+4(Z POSITION)W.O.=0	MOST SIGNIFICANT WORD (AVERAGE G RESULTS)		
71	RN+5(Z POSITION)W.O.=0	LEAST SIGNIFICANT WORD (AVERAGE G RESULTS)		
72	VN+0 (X VEL.) W.O. = 0	MOST SIGNIFICANT WORD (AVERAGE G RESULTS)		
73	VN+1 (X VEL.) W.O. = 0	LEAST SIGNIFICANT WORD (AVERAGE G RESULTS)		
74	VN+2 (Y VEL.) W.O. = 0	MOST SIGNIFICANT WORD (AVERAGE G RESULTS)		METERS/C. S.
75	VN+3 (Y VEL.) W.O. = 0	LEAST SIGNIFICANT WORD (AVERAGE G RESULTS)		7 2
76	VN+4 (Z VEL.) W.O. = 0	MOST SIGNIFICANT WORD (AVERAGE G RESULTS)		
77	VN+5 (Z VEL.) W.O. = 0	LEAST SIGNIFICANT WORD (AVERAGE G RESULTS)		
78	PIPTIME W.O. = 0	MOST SIGNIFICANT WORD OF PIPA READING TIME		C.S./2 ²⁸
79	PIPTIME+1 W.O. = 0	LEAST SIGNIFICANT WORD OF PIPA READING TIME		

DATE		COMPUTER WORKSHEET			PAGE
VEHICLE		MISSION	SYSTEM	CS&N	501
NON-UPDATE		DOWN LIST			16
W.N.	NOMENCLATURE	REMARKS	UNITS		
80	TIME 2 G R W.O.= 0	MOST SIGNIFICANT WORD OF GUID. REF. REL. TIME	C.S./2 ²⁸		
81	TIME 1 G R W.O.= 0	LEAST SIGNIFICANT WORD OF GUID. REF. REL. TIME			
82	TCUTOFF(MOST SIGNIFI- CANT) W.O.= 0	LIFT OFF TIME, ENGINE CUTOFF TIME & ENGINE ON TIME	CENTISECONDS/2 ²⁸		
83	TCUTOFF+1(LEAST SIGNI- FICANT) W.O.= 0	LIFT OFF TIME, ENGINE CUTOFF TIME & ENGINE ON TIME			
84	RAVEGON+0 (MOST SIG. BITS OF X POS.) W.O.=0	POSITION FROM ORBITAL INTEGRATION PROGRAM TO BE USED FOR SPS2 BURN.			
85	RAVEGON+1(LEAST SIG. BITS OF X POS.) W.O.=0	POSITION FROM ORBITAL INTEGRATION PROGRAM TO BE USED FOR SPS2 BURN.			
86	RAVEGON+2 (MOST SIG. BITS OF Y POS.) W.O.=0	POSITION FROM ORBITAL INTEGRATION PROGRAM TO BE USED FOR SPS2 BURN.	METERS 26 2		
87	RAVEGON+3 (LEAST SIG. BITS OF Y POS.) W.O.=0	POSITION FROM ORBITAL INTEGRATION PROGRAM TO BE USED FOR SPS2 BURN.			
88	RAVEGON+4 (MOST SIG. BITS OF Z POS.) W.O.=0	POSITION FROM ORBITAL INTEGRATION PROGRAM TO BE USED FOR SPS2 BURN.			
(

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DATE	COMPUTER WORKSHEET			PAGE
	VEHICLE	SYSTEM	MISSION	17
	CSM	C&N	501	

NON-UPDATE		DOWN LIST	
W.N.	NOMENCLATURE	REMARKS	UNITS
89	RAVEGON+5 (LEAST SIG. BITS OF Z POS.) W.O.=0	POSITION FROM ORBITAL INTEGRATION PROGRAM TO BE USED FOR SPS2 BURN.	$\frac{26}{2}$ METERS
90	VAVEGON+0 (MOST SIG. BITS OF X VEL.) W.O.=0	VELOCITY FROM ORBITAL INTEGRATION PROGRAM TO BE USED FOR SPS2 BURN.	
91	VAVEGON+1 (LEAST SIG. BITS OF X VEL.) W.O.=0	VELOCITY FROM ORBITAL INTEGRATION PROGRAM TO BE USED FOR SPS2 BURN.	
92	VAVEGON+2 (MOST SIG. BITS OF Y VEL.) W.O.=0	VELOCITY FROM ORBITAL INTEGRATION PROGRAM TO BE USED FOR SPS2 BURN.	$\frac{7}{2}$ METERS/C.S.
93	VAVEGON+3 (LEAST SIG. BITS OF Y VEL.) W.O.=0	VELOCITY FROM ORBITAL INTEGRATION PROGRAM TO BE USED FOR SPS2 BURN.	
94	VAVEGON+4 (MOST SIG. BITS OF Z VEL.) W.O.=0	VELOCITY FROM ORBITAL INTEGRATION PROGRAM TO BE USED FOR SPS2 BURN.	
95	VAVEGON+5 (LEAST SIG. BITS OF Z VEL.) W.O.=0	VELOCITY FROM ORBITAL INTEGRATION PROGRAM TO BE USED FOR SPS2 BURN.	

DATE		COMPUTER WORKSHEET			PAGE
		VEHICLE	SYSTEM	C&N	MISSION
		CSM			501
NON-UPDATE DOWN LIST					
U. N.	NOMENCLATURE	REMARKS	UNITS		
96	TAVEGON (MOST SIG. BITS) W.O. = 0	TIME THAT AVERAGE G PROGRAM WILL BE ACTIVATED FOR SPS2 BURN.	CENTISECONDS/28		
97	TAVEGON+1 (LEAST SIG. BITS) W.O. = 0	TIME THAT AVERAGE G PROGRAM WILL BE ACTIVATED FOR SPS2 BURN.			
98	TM MARKER W.O. = 0	OCTAL 74000 DUMMY MARKERS IF ACTUAL MARKERS HAVE NOT OCCURRED ABOVE.			
99	TM MARKER W.O. = 0	OCTAL 74000 DUMMY MARKERS IF ACTUAL MARKERS HAVE NOT OCCURRED ABOVE.			
100	TM MARKER W.O. = 0	OCTAL 74000 DUMMY MARKERS IF ACTUAL MARKERS HAVE NOT OCCURRED ABOVE.			

DOWN LIST

NON-UPDATE POST BURN/ENTRY

W.N.	NOMENCLATURE	REMARKS	UNITS
1	IDENTIFICATION	IDENTIFIES NON-UPDATE DOWNLIST	
	W.O. = 0	OCTAL CODE OUTPUT OF AGC = 62067	
2	DSPTAB+0	DISPLAY WORD +0	
	W.O. = 0	REGISTER 3 (-) SIGN	
		REGISTER 3 CHARACTER 4	
		REGISTER 3 CHARACTER 5	
3	DSPTAB+1	DISPLAY WORD +1	
	W.O. = 0	REGISTER 3 (+) SIGN	
		REGISTER 3 CHARACTER 2	
		REGISTER 3 CHARACTER 3	
4	DSPTAB+2	DISPLAY WORD +2	
	W.O. = 0	REGISTER 2 CHARACTER 5	
		REGISTER 3 CHARACTER 1	

DATE		COMPUTER WORKSHEET			PAGE
		VEHICLE	GSM	SYSTEM	G&N
		MISSION			501
NON-UPDATE POST BURN/ENTRY					
DOWN LIST					
W.N.	NOMENCLATURE	REMARKS	UNITS		
5	DSPTAB+3	DISPLAY WORD +3			
	W.O. = 0	REGISTER 2 (-) SIGN			
		REGISTER 2 CHARACTER 3			
		REGISTER 2 CHARACTER 4			
6	DSPTAB+4	DISPLAY WORD +4			
	W.O. = 0	REGISTER 2 (+) SIGN			
		REGISTER 2 CHARACTER 1			
		REGISTER 2 CHARACTER 2			
7	DSPTAB+5	DISPLAY WORD +5			
	W.O. = 0	REGISTER 1 (-) SIGN			
		REGISTER 1 CHARACTER 4			
		REGISTER 1 CHARACTER 5			
8	DSPTAB+6	DISPLAY WORD +6			
	W.O. = 0	REGISTER 1 (+) SIGN			
		REGISTER 1 CHARACTER 2			
		REGISTER 1 CHARACTER 3			

COMPUTER WORKSHEET				PAGE
DATE	VEHICLE		SYSTEM	MISSION
	CSM		G&N	501
NON-UPDATE POST BURN/ENTRY DOWN LIST				
W. N.	NOMENCLATURE	REMARKS		UNITS
9	DSPTAB+7	DISPLAY WORD +7		
	W.O. = 0	BIT 11	UPLINK ACTIVITY	
		BIT 10-6		
		BIT 5-1	REGISTER 1 CHARACTER 1	
10	DSPTAB+8	DISPLAY WORD +8		
	W.O. = 0	BIT 10-6	HIGH OCTAL DIGIT OF NOUN	
		BIT 5-1	LOW OCTAL DIGIT OF NOUN	
11	DSPTAB+9	DISPLAY WORD +9		
	W.O. = 0	BIT 11	FLASH ACTIVITY	
		BIT 10-6	HIGH OCTAL DIGIT OF VERB	
		BIT 5-1	LOW OCTAL DIGIT OF VERB	
12	DSPTAB+10	DISPLAY WORD +10		
	W.O. = 0	BIT 10-6	HIGH OCTAL DIGIT OF MAJOR MODE	
		BIT 5-1	LOW OCTAL DIGIT OF MAJOR MODE	

COMPUTER WORKSHEET				PAGE
DATE	VEHICLE	CSM	SYSTEM	MISSION
NON-UPDATE POST BURN/ENTRY				4
DOWN LIST				501
W.N.	NOMENCLATURE	REMARKS	UNITS	
13	DSPTAB+11	MODING RELAY WORD 1: -		
	W.O. = 0	BIT 1 - INITIATE ISS ZERO ENCODE MODE		
		BIT 2 - INITIATE ISS COARSE ALIGN MODE		
		BIT 3 - INITIATE ISS LOCK CDU MODE		
		BIT 4 - INITIATE ISS FINE ALIGN MODE		
		BIT 5 - ENCODER ZERO LAMP SET ON/OFF DISCRETE		
		BIT 6 - CDU FAIL LAMP SET ON/OFF DISCRETE		
		BIT 7 - PIPA FAIL LAMP SET ON/OFF DISCRETE		
		BIT 8 - IMU FAIL LAMP SET ON/OFF DISCRETE		
		BIT 10 - INITIATE ISS ATTITUDE CONT. MODE		
		BIT 11 - INITIATE ISS ROLL RE-ENTRY MODE		
14	DSPTAB+12	MODING RELAY WORD 2: - CAN BE IGNORED FOR MISSION 501.		
15	DSPTAB+13	MODING RELAY WORD 3: -		
		BIT 1 - SELECT G&N ATTITUDE CONT. IN SCS (TO MCP)		
		BIT 2 - SELECT G&N ΔV MODE IN SCS (TO MCP)		
		BIT 3 - SELECT G&N ENTRY MODE IN SCS (TO MCP)		
		BIT 4 - INITIATE CM/SM SEPARATION (TO MCP)		

COMPUTER WORKSHEET			PAGE
DATE	VEHICLE	SYSTEM	MISSION
	CSM	G&N	501
DOWN LIST			
W.N.	NOMENCLATURE	REMARKS	UNITS
		BIT 5 - INITIATE + X TRANSLATION (TO MCP)	
		BIT 7 - .05 G INDICATION (TO MCP)	
		BIT 8 - GIMBAL MOTOR POWER SET ON/OFF DISC. (TO MCP)	
		BIT 9 - FDAI ALIGN SET ON/OFF DISC. (TO MCP)	
		BIT 10 - TELECOMMUNICATION SET ON/OFF DISC. (TO MCP)	
		(BIT 10 NOT UTILIZED ON MISSION 501)	
16	TIME 2	CONTAINS MOST SIGNIFICANT BITS OF DOUBLE PRECISION REAL TIME	CENTISECONDS/2 ²⁸ (.01 SEC/228)
		CLOCK OF ACC.	
17	TIME 1	CONTAINS LEAST SIGNIFICANT BITS OF DOUBLE PRECISION REAL TIME	
		CLOCK OF ACC.	
18	IN REGISTER 0	STATUS WORD 1: -	
		W.O. = 0	
		W.O. = 0	
		BIT 6 - UPLINK ACCEPT SWITCH INDICATION	
		(NO APPLICATION TO MISSION 501)	

MSC FORM 1039 (REV DEC 85)

COMPUTER WORKSHEET				PAGE	6
DATE	VEHICLE	CSM	SYSTEM	G&N	MISSION
NON-UPDATE POST BURN/ENTRY DOWN LIST					
W.N.	NOMENCLATURE	REMARKS	UNITS		
		BIT 7 - INHIBIT UPSYNC (WILL BE SET TO A 1 IF UNLINK BIT			
		RATE > 1600 BITS/SEC)			
		BIT 15 - MARK INDICATION (NO APPLICATION TO MISSION 501)			
19	IN REGISTER 2	STATUS WORD 2: -			
	W.O. = 0	BITS 1-4 - FINE TIME INFORMATION EMPLOYED IN ISS TESTING			
		BIT 5 - LIFT OFF INDICATION FROM EXTERNAL SOURCE			
		BIT 6 - GUID. REF. RELEASE INDICATION FROM EXTERNAL SOURCE			
		BIT 7 - SATURN ULLAGE (NO USE IS MADE OF THIS INFORMATION			
		IN MISSION 501 ACC)			
		BIT 8 - S4B SEPARATE INDICATION (TO ACC)			
		BIT 9 - SM/CM SEPARATE INDICATION (TO ACC)			
		BIT 10 - CDU FAIL INDICATION TO ACC			
		BIT 11 - PIPA FAIL INDICATION TO ACC			
		BIT 12 - IMU FAIL INDICATION TO ACC			
		BIT 15 - PARITY FAIL INDICATION TO ACC			

DATE	COMPUTER WORKSHEET			PAGE	7
	VEHICLE	GSM	SYSTEM	G&N	MISSION
					501

NON-UPDATE POST SPS BURN/ENTRY DOWN LIST

W.N.	NOMENCLATURE	REMARKS	UNITS
20	IN REGISTER 3	STATUS WORD 3: -	
	W.O. = 0	BIT 1 - ZERO ENCODER INDICATION (ISS MODE) (TO ACC)	
		BIT 2 - COARSE ALIGN INDICATION (ISS MODE) (TO ACC)	
		BIT 3 - CDU MANUAL INDICATION (ISS MODE) (TO ACC)	
		BIT 4 - FINE ALIGN INDICATION (ISS MODE) (TO ACC)	
		BIT 5 - ATTITUDE CONT INDICATION (ISS MODE) (TO ACC)	
		BIT 6 - TRANSFER SWITCH MANIPULATION INDICATION	
		BIT 7 - ENTRY INDICATION (ISS MODE) (TO ACC)	
		BIT 10 - OPTIC MODE SW3	
		BIT 11 - STAR PRESENT (NOT APPLICABLE ON M-501)	
		BIT 12 - ZERO OPTICS INDICATION	
		BIT 13 - SEXTANT ON INDICATION (ALWAYS A ONE)	
		BIT 14 - OPTICS MODE SW2 INDICATION	
		BIT 15 - "OR" OR DSKY CONTROL (C) RELAYS	
21	OUT REGISTER 1	BIT 1 - PROGRAM ALARM INDICATION. (LITE ON/OFF DISC)	
	W.O. = 0	BIT 2 - COMPUTER ACTIVITY INDICATION. (LITE ON/OFF DISC)	
		BIT 3 - KEY RELEASE INDICATION. (LITE ON/OFF DISC)	

DATE		COMPUTER WORKSHEET			PAGE
		VEHICLE	CSM	SYSTEM	MISSION
					501
DOWN LIST					
NON-UPDATE POST BURN/ENTRY					
W. N.	NOMENCLATURE	REMARKS			UNITS
		BIT 4 - T/M ALARM INDICATION. (LITE ON/OFF DISC)			
		BIT 5 - PROGRAM CHECK FAIL INDICATION (LITE ON/OFF DISC)			
		BIT 7 - RUPT TRAP RESET INITIATION (NOT APPLICABLE ON M-501)			
		BIT 9 - WORD ORDER INDICATION FOR DOWNLINK			
		BIT 10 - BLOCK END PULSE INITIATION. (STOP DOWNLINK IF DOWN- LINK RATE TO HIGH)			
		BIT 13 - ENGINE ON/OFF INITIATION			
22	STATE WORD	PROGRAM DATA WORD 1			
	W.O. = 0	BIT 1 - PROGRAM SWITCH INDICATION			
		BIT 1 - INRLSW			
		BIT 2 - UPLINK BLOCKED INDICATION ($K \neq \bar{K} \neq K$)			
		BIT 3 - EXTENDED VERB ACTIVITY INDICATION (INTERLOCK FOR VERBS 37).			
		BIT 4 - DISPLAY UTILIZED BY OPERATOR INDICATION (INTERLOCK)			
		(NOT EMPLOYED ON 501 MISSION).			
		BIT 5 - DSKY FLAG			
		BIT 6 - VERIFLAG			

COMPUTER WORKSHEET			PAGE
DATE	VEHICLE		9
NON-UPDATE POST BURN/ENTRY		SYSTEM	MISSION
DOWN LIST		CSM	501
W. N.	NOMENCLATURE	REMARKS	UNITS
		BIT 6 - HIND 2 SWITCH - ENTRY ROUTINE USE (INITIALLY = 1).	
		BIT 7 - HUNT SW-ENTRY ROUTINE USE (INITIALLY = 1).	
		BIT 8 - E G SW-ENTRY ROUTINE USE (INITIALLY = 1).	
		BIT 9 - RELATIVE VELOCITY SW - ENTRY ROUTINE USE.	
		BIT 10 - GONE PAST SW - ENTRY ROUTINE USE (INITIALLY = 1).	
		BIT 11 - NAV. BAS/STABLE MEMBER BIT (AFTER GRR SET TO 1).	
		BIT 12 - BIAS FLAG	
		BIT 13 - TFF2 FLAG	
		BIT 14 - ABORT SIG FLAG	
		BIT 15 - J SWITCH (NO APPLICATION FOR 501).	
23	FLAG WORD 1	PROGRAM DATA WORD 2: -	
	W.O. = 0	BIT 1 - TUMBLING INDICATION (CDU RATES > 5°/SEC)	
		BIT 2 - LIFT OFF.	
		BIT 3 - ENTRY PROGRAM INDICATION (SET TO ONE AFTER CM/SM MAN'R)	
		BIT 4 - STEERING INDICATION (ACTIVE DURING A BURN).	
		BIT 5 - DV MONITOR PROGRAM ENABLE (ENABLE THRUST DETECTION)	
		BIT 6 - MONITOR (SET TO A ONE DURING SATURN PITCH OVER)	

MSC FORM 1838 (REV DEC 65)

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		VEHICLE	CSM	SYSTEM	MISSION
					501
NON-UPDATE POST SPS BURN/ENTRY					
DOWN LIST					
W. N.	NON-ENCLATURE	REMARKS			UNITS
		BIT 7 - INIT 1 FLAG (SET TO A 1 WHEN TFF FIRST BECOMES LESS THAN 200 SECONDS - FREE FALL INTERRUPT MUST BE ENABLED)			
		BIT 8 - S4B SEPARATION (SET TO A 1 WHEN S4B SEPARATION IN-BIT IS SENSED)			
		BIT 9 - INITIAL (PRE-SFS1 BURN COMPUTATION FLAG)			
		BIT 10 - INTERRUPT FLAG (ENABLE FREE FALL SENSING)			
		BIT 11 - IMU ACTIVITY FLAG			
		BIT 12 - SHUTDOWN FLAG (ENTRY PREPARATION BASED ON TFF OR SOME OTHER REASON, SUCH AS DELTA-V ALARM)			
		BIT 13 - SOAK FLAG			
		BIT 14 - UPDATE FLAG (SET TO A 1 IF SUCCESSFUL UPDATE COMPLETELY RECEIVED)			
		BIT 15 - COAST FLAG (IN COAST PHASE)			
24	FLAG WORD 2	PROGRAM DATA WORD 3: -			
	W.O. = 0	BIT 1 - ARREST BURN FLAG (SET IF TUMBLING)			
		BIT 2 - ABORT BURN FLAG			
		BIT 3 - TUMBLE ABORT BURN (OCCURS AFTER ARREST BURN)			

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COMPUTER WORKSHEET

DATE				PAGE 11
	VEHICLE CSM	SYSTEM G&N	MISSION 501	
NON-UPDATE, POST BURN/ENTRY DOWN LIST				
W. N.	NOMENCLATURE	REMARKS	UNITS	
	BIT 4 - SPS1 BURN FLAG			
	BIT 5 - SPS2 BURN FLAG			
	BIT 6 - SPS3 BURN FLAG			
	BIT 7 - SPS4 BURN FLAG			
	BIT 8 - BEGIN ARC FLAG (CALCUL. OF ATT. MAN'R ROUTINE)			
	BIT 9 - NEGATIVE FLAG (CALCUL. OF ATT. MAN'R ROUTINE)			
	BIT 10 - DOING ATTITUDE MANEUVER FLAG			
	BIT 11 - CALCULATE ATT. MAN'R ROUTINE FLAG (ON DURING ENTIRE ROUTINE)			
	BIT 12 - ROLL TO BE PERFORMED FLAG (CAL OF ATT MAN'R ROUTINE)			
	BIT 13 - BACK ARC FLAG (CALCUL. OF ATT. MAN'R ROUTINE)			
	BIT 14 - CDUX INDICATION (MODIFICATION OF CDUX FOR ENTRY)			
	BIT 15 - DRIFT INDICATION (PLATFORM CORRECT. BY TIME BIAS MEANS DURING COAST PHASE.)			
25	CDUX W.O. = 0	ROLL AXIS GIMBAL ANGLE	15 BIT WORD, DECIMAL	
26	CDUY W.O. = 0	PITCH AXIS GIMBAL ANGLE	FRACTION OF 360°	
27	CDUZ W.O. = 0	YAW AXIS GIMBAL ANGLE	NO SIGN.	

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		VEHICLE	SYSTEM	MISSION	12
		GSM	G&N	501	
NON-UPDATE POST BURN/ENTRY					UNITS
W. N.	NOMENCLATURE	REMARKS			
28	RE DO CTR W.O.=0	ACCUMULATES NO. OF RESTARTS OCCURRING DURING A MISSION.			
29	DELV X W.O.=0	X PIPA COUNTER CONTENTS			
30	DELV Y W.O.=0	Y PIPA COUNTER CONTENTS	5.85 CM/SEC ² /PULSE		
31	DELV Z W.O.=0	Z PIPA COUNTER CONTENTS			
32	DESIRED CDUX W.O.=0	DESIRED ROLL ANGLE	15 BIT WORD,		
33	DESIRED CDUY W.O.=0	DESIRED PITCH ANGLE	DECIMAL FRACTION		
34	DESIRED CDUZ W.O.=0	DESIRED YAW ANGLE	OF 360°, NO SIGN		
35	F 3(V) W.O.=0	ONLY AVAILABLE IN MODE 67 (PARAMETER USED IN ENTRY PHASE)	NMI/2700		
36	-DREFR W.O.=0	ONLY AVAILABLE IN MODE 67 (PARAMETER USED IN ENTRY PHASE)	FPS ² /805		
37	RTOGO W.O.=0	ONLY AVAILABLE IN MODE 67 (PARAMETER USED IN ENTRY PHASE)	NMI/2700		
38	RDOTREF (V) W.O.=0	ONLY AVAILABLE IN MODE 67 (PARAMETER USED IN ENTRY PHASE)	FPS/(25766.1973X2 ⁻²)		
39	-F 2(V) W.O.=0	ONLY AVAILABLE IN MODE 67 (PARAMETER USED IN ENTRY PHASE)	25766.1973/(2700X4)		
			NMI/FPS ²		
40	F 1(V) W.O.=0	ONLY AVAILABLE IN MODE 67 (PARAMETER USED IN ENTRY PHASE)	2700/805 NMI/FPS ²		
41	PREDANGL W.O.=0	ONLY AVAILABLE IN MODE 67 (PARAMETER USED IN ENTRY PHASE)			
42	JJ W.O.=0	ONLY AVAILABLE IN MODE 67 (PARAMETER USED IN ENTRY PHASE)	2 ³ /21600 NMI		

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MISSION 501

VEHICLE CSM

SYSTEM C&N

NON-UPDATE POST BURN/ENTRY DOWN LIST

W. N.	NOMENCLATURE	REMARKS	UNITS
43	THETA (MOST SIG. BITS) W.O.=0	AVAILABLE EVERY 2 SEC IN MODES 63 THRU 67 (CENTRAL ANGLE TO RT.)	NMI/21600
44	THETA+1 (LEAST SIG. BITS) W.O.=0	AVAILABLE EVERY 2 SEC IN MODES 63 THRU 67 (CENTRAL ANGLE TO RT.)	
45	LATANG (MOST SIG. BITS) W.O.=0	AVAILABLE EVERY 2 SEC IN MODES 63 THRU 67 (OUT OF PLANE ANGLE)	
46	LATANG+1 (LEAST SIG. BITS) W.O.=0	AVAILABLE EVERY 2 SEC IN MODES 63 THRU 67 (OUT OF PLANE ANGLE)	SCALED/2 ²
47	T _{FF} (MOST SIG. BITS) W.O.=0	TIME OF FREE-FALL	CENTISECONDS/2 ²⁸
48	T _{FF} +1 (LEAST SIG. BITS) W.O.=0	TIME OF FREE-FALL	
49	TM MARKER W.O.=1	DUMMY MARKERS IF ACTUAL MARKERS HAVE NOT OCCURRED ABOVE.	OCTAL 74000
50	TM MARKER W.O.=1	DUMMY MARKERS IF ACTUAL MARKERS HAVE NOT OCCURRED ABOVE.	OCTAL 74000
51	TM MARKER W.O.=1	DUMMY MARKERS IF ACTUAL MARKERS HAVE NOT OCCURRED ABOVE.	OCTAL 74000
52	DSPTAB+0 W.O.=0	SEE WORD 2	
53	DSPTAB+1 W.O.=0	SEE WORD 3	

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		VEHICLE	CSM	SYSTEM	MISSION
		DOWN LIST			501
W.N.	NOMENCLATURE	REMARKS	UNITS		
71	RN+5 (Z POSITION) W.O.=0	LEAST SIGNIFICANT WORD (AVERAGE G RESULTS)			
72	VN+0 (X VEL.) W.O.=0	MOST SIGNIFICANT WORD (AVERAGE G RESULTS)			
73	VN+1 (X VEL.) W.O.=0	LEAST SIGNIFICANT WORD (AVERAGE G RESULTS)			
74	VN+2 (Y VEL.) W.O.=0	MOST SIGNIFICANT WORD (AVERAGE G RESULTS)	METERS/C.S.		
75	VN+3 (Y VEL.) W.O.=0	LEAST SIGNIFICANT WORD (AVERAGE G RESULTS)	7		
76	VN+4 (Z VEL.) W.O.=0	MOST SIGNIFICANT WORD (AVERAGE G RESULTS)	2		
77	VN+5 (Z VEL.) W.O.=0	LEAST SIGNIFICANT WORD (AVERAGE G RESULTS)			
78	PIPTIME W.O.=0	MOST SIGNIFICANT WORD OF PIPA READING TIME			
79	PIPTIME+1 W.O.=0	LEAST SIGNIFICANT WORD OF PIPA READING TIME		C.S./2 ²⁸	
80	TIME 2 GR W.O.=0	MOST SIGNIFICANT WORD OF GUID. REF. REL. TIME			
81	TIME 1 GR W.O.=0	LEAST SIGNIFICANT WORD OF GUID. REF. REL. TIME			
82	TCUTOFF (MOST SIGNIFICANT) W.O.=0	LIFT OFF TIME, ENGINE CUTOFF TIME & ENGINE ON TIME		CENTISECONDS/2 ²⁸	
83	TCUTOFF+1 (LEAST SIGNIFICANT) W.O.=0	LIFT OFF TIME, ENGINE CUTOFF TIME & ENGINE ON TIME			

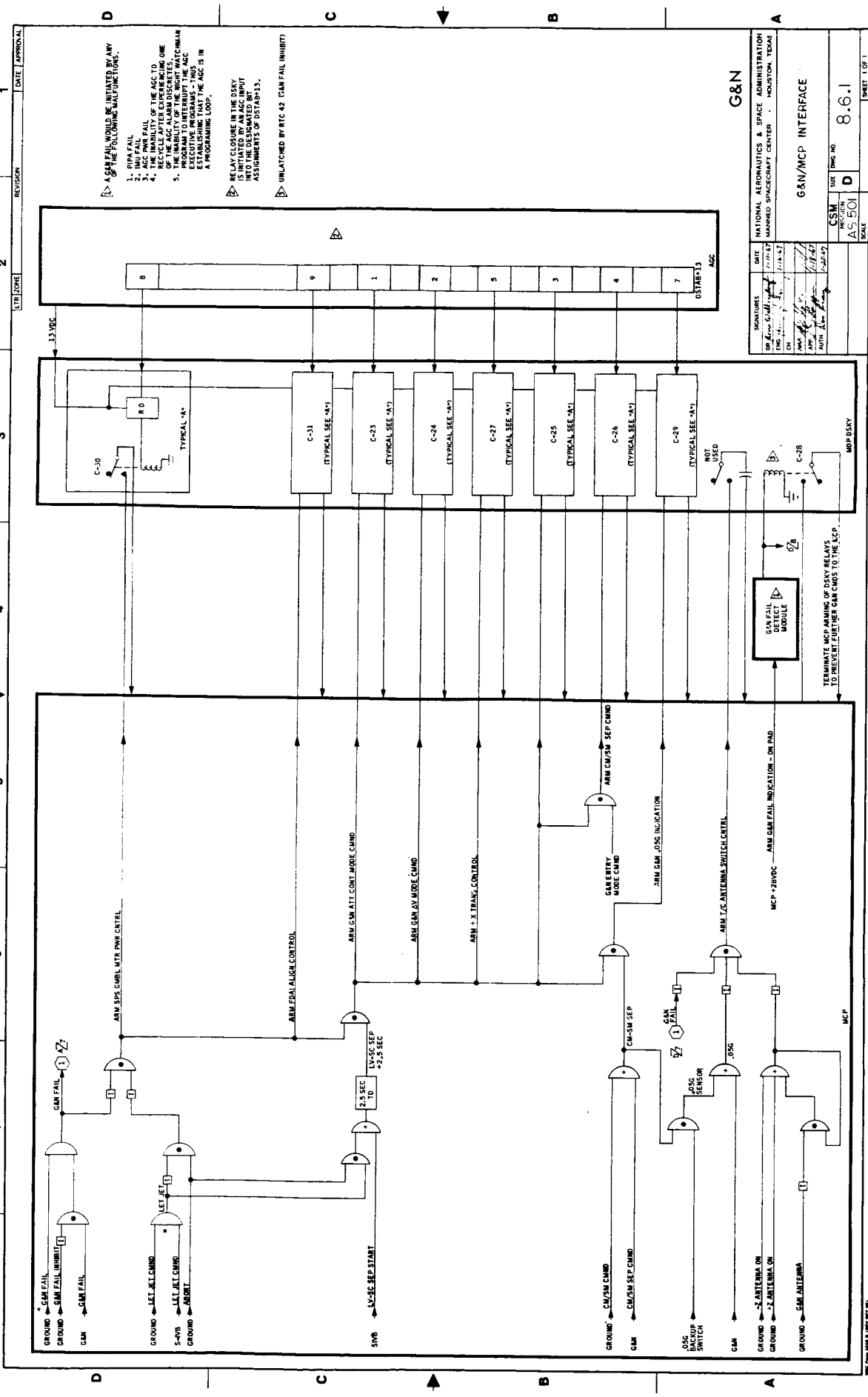
DOWN LIST

W. N.	NOMENCLATURE	REMARKS	UNITS
84	RT (MOST SIG BITS OF X POS) W.O.=0		
85	RT+1 (LEAST SIG BITS OF X POS) W.O.=0		
86	RT+2 (MOST SIG BITS OF Y POS) W.O.=0	CHANGED EVERY 2 SEC IN MODES 63 THRU 67, CURRENT ACC ESTIMATE OF IMPACT POINT, ALSO USED AS TEMP IN MODE 04 ENDING UP WITH RTATLANTIC IN IT AT LIFT OFF.	SCALED/2 ¹
87	RT+3 (LEAST SIG BITS OF Y POS) W.O.=0		
88	RT+4 (MOST SIG BITS OF Z POS) W.O.=0		
89	RT+5 (LEAST SIG BITS OF Z POS) W.O.=0		
90	1 - L/D (MOST SIG BITS) W.O.=0	CHANGED EVERY 2 SEC IN MODES 64 THRU 67, DESIRED CONTROL L/D.	1 - SCALED/2°
	2 - X PIP W.O.=0	ALSO USED TO RECORD CONTENTS OF X PIP ACCUMULATION REGISTER AT ENGINE OFF FOR ALL SPS BURNS.	2 - 5.85 CM/SEC ² / PULSE

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		CSM	C&N	501	
NON-UPDATE POST BURN/ENTRY					
W. N.	NOMENCLATURE	REMARKS	UNITS		
91	1 - L/D+1 (LEAST SIG BITS) W.O.=0	SAME AS ABOVE EXCEPT Y PIP.			
	2 - Y PIP W.O.=0				
92	1 - DIFF (MOST SIG BITS) W.O.=0	CHANGED IN MODE 64 AND THEN REQUIRING CONSTANT IN MODES 65 THRU 67, USED AS AN INTERMEDIATE PARAMETER IN ENTRY PHASE.	1 - NMI/(21600X2 ⁴)		
	2 - Z PIP W.O.=0	ALSO USED TO RECORD CONTENTS OF Z PIP ACCUMULATION REGISTER AT ENGINE OFF FOR ALL SPS BURNS.	2 - 5.85 CM/SEC ² / PULSE		
93	DIFF+1 (LEAST SIG BITS) W.O.=0	CHANGED IN MODES 64 THRU 67, USED AS AN INTERMEDIATE PARAMETER IN ENTRY PHASE.			
94	VAVEGON+4 (MOST SIG BITS OF Z VEL.) W.O.=0	VELOCITY FROM ORBITAL INTEGRATION PROGRAM TO BE USED FOR SPS2 BURN.	METERS/C.S. 7		
95	VAVEGON+5 (LEAST SIG. BITS OF Z VEL.) W.O.=0	VELOCITY FROM ORBITAL INTEGRATION PROGRAM TO BE USED FOR SPS2 BURN.	2		
96	TAVEGON (MOST SIG BITS) W.O.=0	TIME THAT AVERAGE G PROGRAM WILL BE ACTIVATED FOR SPS2 BURN.	CENTISECONDS/2 ²⁸		

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		VEHICLE	SYSTEM	G&N	18
		CSM			MISSION
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NON-UPDATE POST BURN/ENTRY					
DOWN LIST					
W. N.	NOMENCLATURE	REMARKS	UNITS		
97	TAVEGON+1 (LEAST SIG. BITS) W.O.=0	TIME THAT AVERAGE G PROGRAM WILL BE ACTIVATED FOR SPS2 BURN.			
98	TM MARKER W.O.=1	DUMMY MARKERS IF ACTUAL MARKERS HAVE NOT OCCURRED ABOVE. OCTAL	74000		
99	TM MARKER W.O.=1	DUMMY MARKERS IF ACTUAL MARKERS HAVE NOT OCCURRED ABOVE. OCTAL	74000		
100	TM MARKER W.O.=1	DUMMY MARKERS IF ACTUAL MARKERS HAVE NOT OCCURRED ABOVE. OCTAL	74000		

MSC FORM 1638 (REV DEC 65)



- REVISION**
- | REV | DATE | APPROVAL |
|-----|------|----------|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
- DATE APPROVAL**
- △ G&N FAIL WOULD BE INITIATED BY ANY OF THE FOLLOWING FAILURE CONDITIONS:
 1. DISENABLE FAIL
 2. DISENABLE FAIL
 3. AGC PWR FAIL
 4. RECICLE AFTER EXHAUSTING ONE OF THE AGC ALARM DISCRETES.
 5. PROGRAM TO INTERRUPT THE AGC EXECUTIVE PROGRAMS - THIS AGC IS IN A PROGRAMMING LOOP.
 - △ RELAY CLOSURE IN THE DSXY IS INITIATED BY AN AGC INPUT AND IS DESIGNATED BY ASSUMPTIONS 1 & 2 ON P-13.
 - △ UNLATCHED BY RTC 42 (G&N FAIL INHIBIT)

G&N

NATIONAL AERONAUTICS & SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER · HOUSTON, TEXAS

SIGNATURES	DATE
DESIGNED BY: [Signature]	1/21/67
CHECKED BY: [Signature]	1/21/67
APP. BY: [Signature]	1/21/67
AUTH. BY: [Signature]	1/21/67

CSM	SHEET	OF	NO.
A5501	D		8.6.1

G&N/MCP INTERFACE

LTD ZONE

1 2 3 4 5 6 7 8

D C B A

DATE APPROVAL

REVISION

CSM SHEET OF NO. A5501 D 8.6.1

NATIONAL AERONAUTICS & SPACE ADMINISTRATION MANNED SPACECRAFT CENTER · HOUSTON, TEXAS

G&N/MCP INTERFACE

SHEET TOP 1

NOT USED

TERMINATE AND ARMING OF DSXY RELAYS TO PREVENT BURSTING G&N CHDS TO THE MCP

0.5C BACKUP SWITCH

0.5C SENSOR

0.05C

MCP

*
8.7 DISPLAY AND KEYBOARD

The computer has two DSKY's associated with it, a navigation panel DSKY and a main panel DSKY. The navigation panel DSKY is mounted to the right and slightly above the G&N indicator control panel. The main panel DSKY is mounted on the Main Display and Control panel. Except for a few differences, the DSKY's are functionally identical.

The DSKY's provide the interface between the flight crew and the AGC. They enable the flight crew to load information into the AGC, request information from the AGC, initiate various programs stored in the AGC's memory, and perform tests on the AGC and other portions of the G&N system. The DSKY's also provide indications of failures and operational changes which may occur within the AGC and G&N system. The AGC can, under its own control, initiate a display of information or request the flight crew to perform an action.

The navigation panel DSKY keyboard consists of ten digit keys (0-9), nine operation keys (+, -, VERB, NOUN, ENTER, CLEAR, KEY RELEASE, ERROR RESET, TEST ALARM), and a brightness control.

Whenever a key, with the exception of the TEST ALARM key is pressed, +13 vdc is applied to a diode matrix which generates a unique five bit code (keycode) associated with that key. The keycode is inserted into bits five through one of the AGC's in 0 register. A key must be released before another key is pressed if information is to be properly processed by the AGC. The TEST ALARM key does not have a keycode associated with it. It is hard-wired into the AGC's circuitry. ERROR RESET has a key-code associated with it; however, it is also hard-wired directly to the AGC's alarm circuitry.

The main panel DSKY keyboard consists of ten digit keys, eight operation keys, a brightness control, and an UPTL switch. The main panel DSKY does not contain a TEST ALARM key.

The UPTL switch provides the flight crew with the capability of blocking or accepting uplink telemetry information. If this switch is placed in the BLOCK POSITION, a Logic 1 is inserted into Bit 6 of the IN 0 register.

*

The following is a brief functional description of the DSKY

keys.

KEY

- | | |
|-------------|--|
| 0-9 | Enters digital data into the DATA, VERB, NOUN, and PROGRAM display. |
| +and - | Enters the proper sign into the DATA displays for decimal data. |
| VERB | Blanks the VERB display and conditions the AGC to interpret the following two digital inputs as a verb code. |
| NOUN | Blanks the NOUN display and conditions the AGC to interpret the following two digital inputs as a noun code. |
| ENTER | Informs the AGC that the assembled data is complete and to execute the requested function. |
| CLEAR | Clears data contained in DATA display currently being used. Successive pressings clear the upper DATA displays |
| TEST ALARM | Lights the PARITY FAIL, COUNTER FAIL, RUPT LOCK, TC TRAP, and COMP FAIL alarm indicators to insure that they are properly working. |
| ERROR RESET | Tests for the presence of a transient or continuous alarm in the AGC. |
| KEY RLSE | Transfers control of the DSKY displays from the keyboard to the AGC program. |

8.8 LOWER EQUIPMENT BAY

The following is a description of the various controls and displays found in the Lower Equipment Bay (LEB).

The LEB is utilized by the flight crew for navigational sightings; however, it also functions as the physical housing for the guidance and navigation subsystems. The panel members listed herein are referenced to the LEB drawing included in this handbook.

<u>Panel</u>	<u>Switch/Button</u>	<u>Function</u>
100	Primary Rheostat	Provides flooding intensity
	Sec Switch	Provides floodlighting intensity for secondary floodlights.
	Clocks Switch	Provides integral lighting for the mechanical clocks in the LH LEB (GMT, TO EVENT, FROM EVENT)
	IMU/CDU DIFFERENCE INDICATOR	Displays the difference between the IMU gimbal angles and the CDU shaft angles in degrees. The signals applied to the meter are the demodulated outputs of the CDU single speed resolvers.

<u>Panel</u>	<u>Switch/Button</u>	<u>Function</u>
100 (Cont'd)	Computer Transfer Switch	Controls selection of ISS operating modes.
	Manual	Permits normal selection of ISS operating modes through the use of MODE switches.
	Computer	Enables AGC selection of ISS operating modes by setting mode relays directly.
	MODE Switches	Allow selection and display of ISS operating modes. Computer controlled when TRANSFER switch is in COMPUTER position. Manually controlled when TRANSFER switch is in MANUAL position.
	ZERO ENCODE	Selects zero encoder mode of ISS operation. This mode sets the shafts and encoders of the CDU's and CDU registers in the computer to zero.
	COARSE ALIGN	Selects coarse align mode of IMU operation. This mode positions the stable member of the IMU. This mode positions the stable member to within 1.5 degrees of desired inertial reference attitude.
	FINE ALIGN	Selects fine align mode of ISS operation. This mode completes stable member alignment to desired inertial reference attitude.
	CDU MANUAL	Selects manual CDU mode of ISS operation. This mode provides for backup-manual alignment of the stable member. Stable member drives to CDU angles when MANUAL ALIGN switch is depressed.
	ATT CONT	Selects attitude control mode of IMU operation. This mode provides attitude and velocity change sensing with respect to the space stabilized stable member.

<u>Panel</u>	<u>Switch/Button</u>	<u>Function</u>
100 (Cont'd)	ENTRY	Selects entry mode of IMU operation. This mode is similar to attitude control mode; however, the gain of the roll control loop is increased by a factor of 16 to increase roll rate and decrease response time.
102	CDU angle display readouts 2X TRUNNION, SHAFT ANGLE, OUTER GIMBAL (ROLL), INNER GIMBAL (PITCH), MIDDLE GIMBAL (YAW)	Provide visual representation of ICDU and OCDU angles. These are drum type readouts. The first cylinder represents 360°/rev, the second 10°/rev and the 3rd .2°/rev.
103	G&N condition lights	Warning lights denote detected malfunction.
	PGNS	Indicates an IMU, CDU, PIPA and/or AGC failure.
	AGC PWR FAIL	Indicates a failure in the Apollo guidance computer power supply.
	IMU FAIL	Indicates a failure in the inertial measurement unit.
	CDU FAIL	Indicates a failure in one or more of the coupling display units.
	ACCEL FAIL	Indicates a failure in one or more of the PIPA's.
	GIMBAL LOCK	Indicates a potential gimbal lock condition in the IMU (middle gimbal angle is greater than ± 60° with respect to outer gimbal).
	IMU TEMP	Indicates that the IMU temperature is out of tolerance, i.e., exceeds normal temperature by ±4°F (if IMU TEMP MODE switch is in AUTO OVERRIDE or PROPORTIONAL positions).

<u>Panel</u>	<u>Switch/Button</u>	<u>Function</u>
103 (Cont'd)	ZERO ENCODER	Indicates that the CDU encoders are being zeroed; lamp is extinguished after all encoders have been zeroed. (Remains illuminated for approximately 30 seconds. If AGC commanded zero encode mode, indicator may be illuminated for approximately 60 seconds).
	IMU DELAY	IMU coarse alignment to CDU angles taking place. Stable member is caged. Remains illuminated for approximately 100 seconds.
	MASTER ALARM	Red light illuminates to alert crew members at lower equipment bay of malfunction or out-of-tolerance condition. This is indicated by illumination of applicable system status lights on MDC 10 or 11. Upon illumination of MASTER ALARM light, the MASTER ALARM switch-lights on MDC 3 and 18 are simultaneously illuminated and an audio tone is sent to each headset. The MASTER ALARM light does not contain an integral switch. Light may be extinguished only by pressing the MASTER ALARM switch-light on MDC 3 or 18.
104	Sextant	Optical instrument for measuring the angle between two objects. The SXT is a dual line-of-sight instrument used to determine the following: a. The angle between a landmark and a star. b. The angle between a star line of sight and the navigation base. c. Tracking an unknown landmark. This information is used by the AGC for the following: a. Determine spacecraft position. b. Calculate required ΔV corrections c. To fine align the IMU The SXT has a 1.8 degree field of view with a magnification of 28.

*

<u>Panel</u>	<u>Switch/Button</u>	<u>Function</u>
104 (Cont'd)	Scanning Telescope	Optical instrument used for the following: a. Tracking a landmark in earth orbit. b. Identifying and centering a star within the sextant field of view. The scanning telescope has a 60 degree field of view and a 1X magnification.
	Trunnion and Shaft control	These controls are manually operated by means of a universal tool. They are used in the event of optics electronic failure. Enables manual positioning of the shaft and trunnion angles.
	Trunnion and Shaft Angle Display	Provides a mechanical readout and shaft of the SCT trunnion angle that is commanded manually or by the computer. Drum-type readouts in degrees, mechanically connected to the scanning telescope (SCT) trunnion and shaft drives, respectively. (SXT angles are identical).
105	Optics hand controller	Provides electrical commands to the optics shaft and trunnion drive motors. Five-position switch spring-loaded to center OFF position. Direction of target movement with respect to controller movement depends upon mode selected by CONTROLLER MODE switch. Rate of image movement is proportional to amount of hand controller movement.
	CHECK COOLANT switch	When pressed, applies power to floodlamps behind the display and control panel. Enables the crew to view the IMU quick-disconnect couplings through CHECK COOLANT windows.

*

<u>Panel</u>	<u>Switch/Button</u>	<u>Function</u>
105 (Cont'd)	CHECK COOLANT windows (two)	Permit observation of IMU coolant supply system quick-disconnect couplings for detecting leaks.
	MARK switch	Supplies an interrupt signal to the AGC which commands it to read the optics CDU angles, the time, and the IMU gimbal angles (if the IMU is operating).
	PANEL BRIGHTNESS Control	Provides adjustment of the illumination level of all integrally lighted G&N system controls and displays. In addition, the control provides power to the lamp in the THRUST ON switch.
	CHECK MODE LAMPS switch	Applies power to all MODE indicators on the IMU control panel LEB-101.
	CHECK CONDITION LAMPS switch	Applies power to all condition (caution and warning) lamps on panel LEB-103.
	Condition Lamps Switch	Provides dc power to G&N condition lamps.
	ATTITUDE IMPULSE group Attitude impulse control	A control stick used to apply small rotational thrust impulses to the spacecraft by means of the service module reaction jets. This seven-position switch is spring-loaded to center off. The control is used to apply one or any combination of pitch, roll, or yaw minimum thrust impulses to the S/C providing rate damping impulses of 2.4 arc-minutes/second/pulse or less. One pulse is produced each time the control is moved from the center position.
	ENABLE switch ON/OFF	Supplies a signal to the G&N and SCS systems which disables the active S/C attitude control mode, allowing the S/C to drift freely, and enables the attitude impulse control.

<u>Panel</u>	<u>Switch/Button</u>	<u>Function</u>
105 (Cont'd)	ENABLE switch (Cont'd)	Toggle-type, solenoid-held-to-on microswitch. The SCS must be in the G&N or SCS attitude control modes to enable solenoid holding. Attitude impulse is not enabled in the SCS local vertical mode. To enable the attitude impulses control circuit, the LIMIT CYCLE switch must also be ON.
	IMU TEMP MODE group Mode switch	Rotary, four-position, three-wafer switch. Enables the crew to select any one of the four modes of IMU temperature controls.
	AUTO OVERRIDE	Normal mode of temperature control. If IMU temperature exceeds normal tolerance by $\pm 4^{\circ}\text{F}$, system automatically switches to emergency mode and IMU TEMP light illuminates. When a malfunction occurs, the temperature alarm relays turn off the control heaters. Emergency heaters continue to operate under the control of an emergency mercury thermostat. When the temperature returns to within 1°F of normal, the IMU TEMP light extinguishes and the system switches back to the normal control mode.
	PROPORTIONAL	Temperature control is furnished by same control circuit used in AUTO/OVERRIDE mode. PROPORTIONAL mode is used if a malfunction occurs in the temperature indicating circuit, causing cycling to the EMERGENCY mode.
	BACKUP	Temperature control is furnished by temperature sensing circuits. BACKUP mode is used if a malfunction occurs in the normal control circuit. In this mode, the IMU TEMP light will illuminate when the heaters are off and will extinguish

<u>Panel</u>	<u>Switch/Button</u>	<u>Function</u>
105 (Cont'd)	BACKUP (Cont'd)	when the heaters are on. Manual switching to emergency mode is necessary if the temperature becomes excessive.
	EMERGENCY	A Mercury thermostat provides overheat protection for the IMU by opening the emergency heater circuit when the temperature exceeds 134°F. When this temperature drops below 132°F, the thermostat closes the circuit to reactivate the heaters.
	ZERO switch	Used to check calibration of IRIG and PIPA temperature monitoring devices.
	GAIN switch	Pushbutton, momentary-contact switch. When it is pressed, the IMU TEMP indicator (LEB-103) should be illuminated. If not, a malfunction exists in the system. Used to check temperature alarm circuit.
	IRIG	Simulates low temperature error (-5°F) to check IRIG temperature sensors and also tests alarm circuit.
	PIPA	Simulates high temperature error (+5°F) to check PIPA temperature sensors and also test alarm circuits.
	MAP AND DATA VIEWER group	Function deleted as a result of map and data viewer deactivation.
	OPTICS group SLAVE TELESCOPE switch	Single pole, three-position toggle switch.
	STAR LOS	Slaves SCT trunnion axis to SXT trunnion.
	LANDMARK LOS 0°	Drives SCT trunnion to zero independently of CDU trunnion. Zero position is parallel to SXT shaft axis.

<u>Panel</u>	<u>Switch/Button</u>	<u>Function</u>
105 (Cont'd)	OFFSET 25°	Drives telescope trunnion to 25° offset from shaft axis. This will bring the star and landmark within the 60° field-of-view of the SCT, while rotating about the shaft axis.
	OPTICS HOLD	Opens input to motors to prevent CDU creep.
	MODE SWITCH	Selects optics mode of operation.
	ZERO OPTICS	Optics and CDU resolvers are driven to zero. AGC register is set to all zeros. Completed in approximately 60 seconds.
	MANUAL	Normal operating position enabling crew to position optics by means of optics hand controller. In this position, the crew may select either the DIRECT or RESOLVED controller mode of operation.
	COMPUTER	Optics are automatically positioned by the AGC. Panel mounted controls are disabled.
	CONTROLLER SPEED switch	Provides attenuation of shaft and trunnion slew commands from optics hand controller. Direct Mode Maximum Drive Rates:
	HI	Trunnion 8.8°/sec Shaft 17.3°/sec
	MED	Trunnion 1.05°/sec Shaft 2.06°/sec
	LOW	Trunnion 0.105°/sec Shaft 0.206°/sec
	Resolved Mode Maximum Drive Rates:	
HI	Trunnion 8.8°/sec Shaft 8.8°/sec	
MED	Trunnion 1.05°/sec Shaft 1.05°/sec	
LOW	Trunnion 0.105°/sec Shaft 0.105°/sec	
	CONTROLLER MODE switch	Controls control stick output configuration.

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<u>Panel</u>	<u>Switch/Button</u>	<u>Function</u>
105 (Cont'd)	DIRECT	Applies control movements directly to CDU's. Right/left movement commands shaft rotation. Up/down movement commands trunnion angle increase/decrease. Target moves about arcs with speed of target movement varying with magnitude of angle.
	RESOLVED	Applies control stick movements to angular resolving circuits before applying commands to the CDU's. Target moves horizontally and vertically at a linear rate.
106	Alarm condition indicators	Indicate abnormal conditions of computer operation.
	PROG ALM	AGC program error detected.
	COUNTER FAIL	Counter increment instruction not executed or not completed within 10 msec of initiation.
	RUPT LOCK	No interrupt within 80 msec or interrupt not completed within 10 msec.
	TC TRAP	Transfer control not executed within 10 msec or not completed within 10 msec.
	SCALER FAIL	100-pps signal from scaler A of computer timing section failed.
	PARITY FAIL	Parity error exists in data word from memory.
	TM FAIL	Telemetry data rate incorrect or transmission incorrect.
	CHECK FAIL	Incorrect DSKY operation attempted.
	KEY RLSE	Computer program cannot proceed until operator releases DSKY control.

<u>Panel</u>	<u>Switch/Button</u>	<u>Function</u>
106 (Cont'd)	ACTIVITY lights	Indicates activity the computer is presently engaged in.
	UPTL	Computer is receiving information from telemetry updata link.
	COMP	Computer is engaged in computation.
	PROGRAM indicator	A two-digit display, indicating the number of the program (major mode) presently in progress.
	VERB indicator	A two-digit display, indicating verb code selected.
	NOUN indicator	A two-digit display, indicating noun code selected.
	REGISTER 1 indicator	Displays contents of selected register or memory location. First component of extended data word, if applicable.
	REGISTER 2 indicator	Displays contents of selected register or memory location. Second component of extended data word, if applicable.
	REGISTER 3 indicator	Displays contents of selected register or memory location. Third component of extended data word, if applicable.
	BRIGHTNESS control	Varies brightness of electro-luminescent data displays: REGISTER 1, REGISTER 2, and REGISTER 3.
	KEY RELEASE pushbutton	Enables program control of DSKY. Releases operator control of DSKY circuits.
	TEST ALARM push-button	Illuminates the alarm displays for bulb test.
	ERROR RESET pushbutton	Resets alarm light relays. AGC recycles to start of current operation. Verifies alarms. Alarms triggered by transients should not repeat.

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<u>Panel</u>	<u>Switch/Button</u>	<u>Function</u>	
106 (Cont'd)	Keyboard switches	Provides for entering data into or commanding operations of the AGC. Pushbutton-type switches (selectors). Each key generates a specific 5-bit keycode denoting the instruction or number being selected.	
	CLEAR	Places all zeros (logic 0's) in register being loaded.	
	VERB	Prepares computer to accept next two digits as verb code.	
	NOUN	Prepares computer to accept next two digits as noun code.	
	ENTER	Transfers contents of input register to central processor and initiates execution of instructions.	
	+	Denotes data to follow has positive decimal value.	
	-	Denotes data to follow has negative decimal value.	
	0 to 9	Enters binary equivalent of key pressed.	
	107	AGC MODE switch	Applies normal power to AGC
		ON	Applies power timing section of AGC
STANDBY		In STANDBY, AGC maintains timing signals and other circuits necessary to restart. STANDBY operation is used to conserve electrical power.	

9.1 NOTES, STABILIZATION AND CONTROL SUBSYSTEM

9.1.1 Introduction

The Stabilization and Control System (SCS) is mechanized within four subsystems. These subsystems are as follows:

- A. Attitude Reference Subsystem
- B. Altitude Control Subsystem
- C. Thrust Vector Control Subsystem
- D. Power Distribution Subsystem

These subsystems and their associated controls and displays in conjunction with the other spacecraft systems (Propulsion, Guidance and Navigation, Mission Control Programmer, and Electrical Power) provide the capability for the following:

- E. Automatic control of spacecraft attitude and inertial velocities
- F. Manual/semiautomatic control of spacecraft attitude and inertial velocities
- G. Manual/direct attitude control (ground initiated)

The intraconnections of the stabilization and control end items, or black boxes, and their interconnection with the other spacecraft systems are controlled by relays in the Mission Control Programmer. The following narrative describes the functions provided by each end item.

9.1.2 Rate Gyro Package

The rate gyro package contains three identical rate gyros, mounted orthogonally along the spacecraft body axes, and associated gyro electronics. No provision is made for heaters or temperature control of the gyros. Each gyro is a single-axis unit, with the input axis determined by the gyro mounting fixture. Self-test capabilities are provided by torquing coils, which enable the gyro to be displaced at a known rate and by spin motor rotation detection circuits, which allow monitoring of the gyro spin motor speed. All self-test circuits are completely isolated from operational circuits to prevent a failure in the former from affecting gyro operation. The function of the rate gyros is to

provide an indication on the FDAI of the rate of attitude change in pitch, roll, and yaw axes. An attitude change about any of the axes results in an output signal which is representative of the rate of displacement. The gyro outputs are used by the SCS as primary damping or stabilization signals and, in addition, as negative feedback to null rotational control commands and provide a proportional maneuver rate capability.

Each miniature rate gyro assembly consists of a spin motor, damping system, gimbal assembly, quadrilever spring, and self-check circuitry. The gyro spin motor is a 400-cps three-phase synchronous hysteresis motor powered by 26 volts ac. The maximum time allowed for the gyro to come up to operating speed is 17 seconds. Damping is accomplished by positive displacement of the damping fluid through temperature-controlled orifices. The quadrilever spring provides the torsional restraint required by the gyro, together with radial support for the gimbal assembly.

9.1.3 Attitude Gyro Accelerometer Package

9.1.3.1 General

The attitude gyro accelerometer package contains three body-mounted attitude gyros (BMAG's) and an accelerometer. Electronic control circuits for the gyros and accelerometer are contained in the display and attitude gyro accelerometer package electronic control assembly.

9.1.3.2 Body-Mounted Attitude Gyros

The three BMAG's are identical units, mounted orthogonally along the spacecraft body axes to sense attitude displacement along the pitch, roll, and yaw axes. Each gyro is a single-axis unit, with the input axis determined by the physical mounting in the spacecraft. The BMAG's have heaters and temperature control circuits which maintain the gyro temperature at $170^{\circ} \pm 2^{\circ}\text{F}$. If a single gyro exceeds the temperature limits, a light will be illuminated on the Caution Warning Panel MDC-10. A spin motor detection circuit is included in each gyro to allow monitoring of gyro spin motor speed. This parameter is on PCM.

The BMAG's provide information denoting the angular displacement of the spacecraft from a preset attitude. They are initially set to a specific space-stabilized orientation; thereafter, any displacement from this initial setting results in output signals which are representative of the amount of angular displacement. The output signals are used to produce attitude error signals for an attitude-hold mode or for display on the flight director attitude indicator. The outputs may also be applied to the attitude gyro coupling unit (AGCU) for conversion to inertial measurement unit (IMU) axes. (IMU axes differ from the spacecraft body axes.) The AGCU makes the transformation from body axes to IMU axes to allow the BMAG's to be used as a substitute or backup inertial guidance unit for the IMU during the periods when the IMU is turned off or malfunctioning. The BMAG's can also be used to provide spacecraft rotational velocity signals to back up any one or all of the rate gyros.

The BMAG's are single-degree-of-freedom, miniature integrating gyros contained in electrically heated individual packages. The heater will maintain individual BMAG temperature at $170^{\circ} \pm 2^{\circ}\text{F}$. Degraded gyro operation will result if this temperature is not maintained. The gyro spin motors are three-phase 24,000-rmp synchronous devices, powered by 13.6 volts 400 cps from a supply in the attitude gyro accelerometer package electronic control assembly. With C/M temperature at 80°F and the mounting plate temperature at 55°F , the maximum time allowed for the BMAG to reach operating limits is 40 minutes. If the BMAG Power Switch should be cycled and if the BMAG warm-up logic should fail or a single gyro should be out of the $\pm 2^{\circ}$ temperature band, none of the gyros will operate until the out of tolerance gyro reaches operating temperature; in the case of a logic circuit failure, none of the gyros can be used.

9.1.3.3 Accelerometer

The accelerometer is mounted along the spacecraft X-Axis and senses velocity changes along this axis. It is a pendulous type accelerometer with electronic null and balance. The temperature is maintained at $170^{\circ}\text{F} \pm 2^{\circ}\text{F}$ under normal operating conditions; however, it will operate

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with predictable, slightly reduced accuracy when the temperature is out of tolerance. A signal output is generated by an acceleration along the X-Axis. This acceleration causes the pendulous mass to move, resulting in a change of coupling between the primary and secondary windings of a signal generator. This results in an output signal which is demodulated and amplified to provide acceleration information in the form of digital signals to a counter in the Delta V display. The pendulous mass is returned to null by the balancing action of the electronic caging signal when the velocity change ceases.

9.1.4 Electronic Control Assemblies: Pitch, Roll, and Yaw

The pitch, yaw, and roll electronic control assemblies (ECA's) are nearly identical, with slight differences due to different requirements for each axis. The ECA's provide the circuitry for input control signal processing and SCS mode control and configuration. Input control signals consist of attitude error signals from the SCS BMAG's and from the G&N system, rate gyro angular velocity signals +X translational and direct rotation commands from the G&N and MCP respectively, Service Propulsion System (SPS) engine gimbal position, and rate feedback. Mode control inputs are received from relays in the MCP. These input signals are applied to logic-controlled relays which enable circuit configurations corresponding to the desired mode. ECA output signals consist of reaction jet firing commands and SPS gimbal position commands and SPS gimbal position commands. The reaction jet commands are generated in the jet selection logic portions of the ECA's. Preignition SPS engine gimbal position commands are generated manually at the AS/GPD by thumbwheels which provide input signals to the gimbal control circuits. Postignition gimbal control is provided by automatic thrust vector control (TVC) circuitry in the pitch and yaw ECA's.

9.1.5 Electronic Control Assembly, Auxiliary

The auxiliary electronic control assembly contains the Attitude Gyro Coupling Unit (AGCU) and service propulsion system thrust on/off

command circuitry. The AGCU portion of the auxiliary ECA receives BMAG signals from the DISP/AGAA ECA and transforms them from spacecraft body axes to IMU axes for display on the FDAI. It also transforms attitude set dial signals to body axes. The SPS engine on/off control circuitry in the AUX ECA receives engine on/off commands from the G&N system (G&N ΔV mode), and off commands from the Delta V display electronics. These commands are conditioned and applied through appropriate logic to the SPS engine solenoid valves.

9.1.6 Display and Attitude Gyro Accelerometer Assembly Electronic Control Assembly (D/AGAA ECA)

The display and attitude gyro accelerometer package electronic control assembly provides the electronic circuitry required to control and power the displays, BMAG's and accelerometer. The DISP ECA portion consists of the circuitry necessary to receive and condition the following:

- A. Attitude error signals from the G&N system or the BMAG's to the FDAI attitude error indicators
- B. Attitude rate-of-change signals from the rate gyros or BMAGS to the FDAI attitude rate indicators
- C. Feedback signals from the SPS engine gimbal position transducers to the gimbal position indicators
- D. Accelerometer signals from the AGAA to the Delta V display integrator
- E. Total attitude signals from the G&N subsystem or AGCU to the FDAI.

The AGAA ECA portion consists of circuitry necessary to accomplish the following:

- F. Accept and condition BMAG inputs for the AGCU.
- G. Accept and condition AGCU torquing commands to the BMAG's.
- H. Control BMAG and accelerometer temperature controls.
- I. Control and condition the accelerometer rebalance loop and inputs to the integrator.

J. Supply reference voltages to the BMAG's and accelerometer.

9.1.7 Displays and Controls

The Display and Control System provides optimum capability for the crew to monitor, evaluate automatic control maneuvers, and/or manually fly the spacecraft.

9.1.7.1 MCP RTC 44, 45, and 46 Backup Rate Commands (9.4.4)

A. Backup Rate Relays 1K4, 1K5, and 1K6 in the MCP

The Backup Rate Relays provide redundant contacts (two for each channel pitch, yaw, and roll) which are energized by ground initiated Real-Time Commands (RTC's) through the uplink telemetry receiver. When the command is sent and a relay energized, the selected BMAG provides rate information to the display and control electronics; otherwise the rate gyro performs this function.

B. Attitude Deadband Relay 2K69 (controlled by the G&N system)

The Attitude Deadband Relay selects minimum or maximum attitude deadband by energizing or de-energizing relay 2K69.

C. Limit Cycle Switch Relay 2K68 MCP

The Limit Cycle Relay is energized by a G&N command to simulate closure of the Limit Cycle switch and apply pseudo rate in all three channels.

D. 0.05G Switch (2K30 and 2K29)

During a G&N entry both 2K30 and 2K29 will be energized by a G&N 0.05G command. The programmer (MCP) provides a backup to the G&N at the 0.1G to 0.5G level. If G&N FAIL is transmitted by RTC 41, the flight controller has the additional option of selecting lifting entry RTC-10 which holds spacecraft roll attitude during entry using roll attitude gyro inputs and rate damping in the pitch and yaw axes. If RTC-10 is not transmitted, the SCS will perform a rolling entry upon receipt of the 0.05G backup from the MCP and a roll rate signal from the MCP, applied through the input normally used by the roll Rotation Controller Transducer.

E. Direct Mode Switch

The Direct Mode Switch is a two-position switch which provides power for direct rotation commands (RTC-13 through 21 inclusive) when in the ON position. Two Direct Mode Switch contacts are provided; one set uses power from direct Bus A and the other from direct Bus B; however, only Bus A inputs are used for direct control.

F. G&N/SCS Switch (Not Used)

The G&N/SCS Switch selects whether G&N system or the SCS system controls the displays and control electronics. The monitor configuration is an exception since this configuration can be selected from either the G&N or SCS switch position.

G. Attitude/Monitor/Entry Switch (In Monitor Position at Liftoff)

This three-position switch selects whether the system is in an attitude, monitor, or entry configuration. The functions obtainable when the switch is in the ATTITUDE position are explained in the switch sections, Delta V switch, and Local Vertical Switch. When the Attitude/Monitor/Entry Switch is in the ENTRY position, either G&N entry or SCS entry is selected, depending on the position of the G&N/SCS switch. When the Attitude/Monitor/Entry Switch is in the MONITOR position, monitor is selected.

H. Delta V Switch (Not Used)

I. Local Vertical Switch (Not Used)

J. Channel Enable Switches (Left in the ON or "UP" Position at Liftoff)

Four Channel Enable Switches are provided; one for the pitch channel, one for the yaw channel, and two for the roll channel. The A&C Roll Channel Enable Switch will be dead-faced after CM-SM separation. When the Channel Enable Switch is in the ON position, power is supplied to the reaction jet coils. The mission sequencer supplies power

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to enable the driver amplifiers through the Channel Enable Switches at launch vehicle separation or for abort conditions at altitudes greater than 25,000 feet. The mission sequencer removes this power during entry when the command module reaches an altitude of less than 25,000. The OFF function of the channel disable switches is provided by RTC 54, 55, 56, and 57 which grounds the 28U solenoid driver enable signal in the respective channel.

9.1.8 Flight Director Attitude Indicator (Not Implemented)

9.1.9 Attitude Set/Gimbal Position Display (AS/GPD) - MDC6

The Gimbal Position Display portion provides for control and display of the SPS gimbal angles. The attitude set portion provides for FDAI/AGCU alignment and provides a reference attitude for the spacecraft.

9.1.9.1 Gimbal Position Display

Provides indication of SPS engine gimbal position and allows for positioning of the gimbals.

- A. Gimbal Position Thumbwheels (Set to +3.6 degrees yaw and +0.4 degrees pitch at liftoff.)

Two thumbwheels, one each for pitch and yaw gimbal. Movement of the thumbwheels results in the generation of control and control logic, which drives the AGCU resolver shaft to the commanded position resulting in an output from an angle generator to the FDAI ball. The switch must be held until alignment is completed.

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9.1.10 Delta V Display (ΔV) - MDC 7 (Not Implemented)

9.1.10.1 AV Remaining (Not Implemented)

9.1.10.2 AV Set Switch (Not Implemented)

9.1.10.3 Thrust Control Switch (Not Implemented)

This is a three-position toggle switch (NORMAL-OFF-DIRECT ON). The NORMAL position permits the SPS engine to be ignited from the AGC through the SCS electronics or from the Thrust-On Momentary Switch (arms SPS). The OFF position provides a positive off command to the SPS. The DIRECT ON position provides a positive on command to the SPS.

9.1.10.4 Thrust-On Pushbutton Switch (Not Implemented)

This is a pushbutton momentary contact switch and is illuminated during engine firing sequences. After the SPS is armed and direct ullage has been commanded, this switch is used to ignite the engine in either SCS or G&N Delta V modes. After ignition, the engine continues to fire until the AV Remaining counter counts to zero or an engine off command is received from the AGC or a positive off command is generated by the manual OFF switch.

9.1.10.5 Direct Ullage Relay 1K31 and 1K72

The Direct Ullage Relay is commanded by RTC 22. Contacts of 1K31 applies 28 Vdc to the four +X reaction jet direct solenoids (1, 2, 5, and 6) for a ullage maneuver. Contacts of 1K72 energize the SPS gimbal motors.

9.1.11 Rotation Controller (Not Implemented)

9.1.12 Translation Controller (Not Implemented)

9.1.13 Attitude Impulse Switch LEB-4 (Not Implemented)

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9.2 SCS POWER DISTRIBUTION SUBSYSTEM

9.2.1 Introduction

The Electrical Power System supplies the SCS with 28 Vdc from two separate buses, V_{MNA} and V_{MNB} . In addition, it supplies 115 volt, three-phase, 400 cps power from a Y-Connected, four-wire source which also uses two separate buses, Vac_1 and Vac_2 . The two buses for ac and dc power distribution provide redundancy for critical SCS functions in case of a power failure on one bus relay. It will be energized to power the SCS electronics from the other bus. This power is supplied to the SCS through 18 circuit breakers located on the left-hand circuit breaker panel. From these circuit breakers, the power is distributed to the SCS components through six power switches on the sequence controller and SCS power panel. These six switches supply power to those SCS components which provide the backup (manual TVC) capability for controlling the spacecraft during the critical periods when the SPS engine is firing. The Group 1 power switches supply power to the rest of the SCS, except for 28 Vdc power which is not routed through the main power switches. This is termed the non-switched power.

9.2.2 28 Vdc Non-Switched Power

The 28 Vdc non-switched power is distributed to the SCS through 14 of the 18 circuit breakers on the left-hand circuit breaker panel. These 14 circuit breakers are labeled; Yaw, Pitch, A&C Roll, B&D Roll, Group 1, Direct Cont, and Group 2. This power is called non-switched power since its availability to the SCS is independent of the state of the six SCS power switches. The power distribution from these circuit breakers will now be considered according to the functions provided.

9.2.3 Reaction Jet Circuit Breakers

The Yaw, Pitch, A&C Roll, and B&D Roll circuit breakers apply 28 volts to the high side of the automatic coils for the indicated jets in the reaction control system. The jets can be activated by the SCS

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CSM
AS-501

jet drivers, which supply a ground when the jet should be on. The power from the circuit breakers goes through the Channel Enable Switches on the control panel. Any of the four channels can be enabled separately by means of these switches. Power to the reaction jets will enable half the reaction jets with V_{ma} and the other half with V_{mb} .

9.2.4 Group 1 Circuit Breakers

The two Group 1 dc circuit breakers supply 28 volts to the reaction jet drivers, translation controllers, and control panel. They also supply dc power through two of the SCS power switches. The power to the reaction jet drivers goes through a set of relays in the two Master Event Sequence Controllers (which are not part of the SCS), through the Channel Enable Switches on the control panel, through a set of relays in the SCS, and finally to the jet drivers. This power does not turn on the drivers. It is merely an enable signal. Thus, it can be seen that the Channel Enable Switches on the control panel disable a given channel both by removing the power from the high side of the coils, and also by disabling the jet drivers for that particular channel. Notice that in any given channel, half the jets get their power from Bus A and half from Bus B. This means that if power on one bus is lost, disabling half the jets, the rest of the jets on the remaining bus are sufficient to provide positive or negative rotation in all three axes but cannot provide translation.

The power which is used for commanding normal translation maneuvers by means of the translation controls is routed through the CM/SM Separation Switch (C19A1 and C19A2) so that translation control is deactivated after CM/SM separation. Prior to separation, however, the outputs of the two controllers are routed to the jet select logic to provide three-axis translation capability. Two isolation diodes feed the power from both Group 1 dc buses to the indicated switches on the control panel. Finally, it can be seen that dc power from the Group 1 circuit breakers is also routed to the SCS power switches. The distribution from these switches

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will be covered under the section dealing with the Group 1 power switches.

9.2.5 Group 2 Circuit Breakers

In reference to Figure 9.1.1, it can be seen that the two Group 2 dc circuit breakers supply power to the BMAG power switch. The distribution from the BMAG power switch will be covered in the section dealing with the Group 2 power switches.

9.2.6 Direct Control Circuit Breakers

The direct control circuit breakers are used to provide two redundant sources of power for direct ullage, direct rotation, and the SPS solenoid valves. Either one of the two buses is sufficient to provide a ullage maneuver, three axis rotational control, and turn-on of the SPS engine when the proper sequence of ground commands has been sent.

Manual direct rotation can be used any time the direct control circuit breakers are in and the Direct Mode Switch is ON. Direct ullage is available whenever the circuit breakers are in. As a backup capability, the SPS engine could be turned on simply by putting the Thrust Control Switch in the DIRECT ON position. Thus, it can be seen that the power from direct control circuit breakers provides a backup means for the critical maneuvers of ullage, rotation, and SPS engine thrust on. These backup capabilities are independent of the SCS power switches and would be available even if the rest of the SCS were to lose power.

9.2.7 Group 1 Power Switches

There are three SCS Group 1 power switches which supply 28 Vdc and 115 Vac power to the SCS. These three switches are shown in the upper half of Drawing 9.2.1 (SCS Power Distribution Subsystem).

- A. Partial SCS Power
- B. TVC No. 1
- C. Rate Gyro Power

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9.2.7.1 Partial SCS Power

The Partial SCS Power Switch distributes power to seven units in the SCS; the roll, pitch, yaw, auxiliary, and D/AGAA ECA's as well as the Delta V Indicator and Attitude Set/Gimbal Position Display. Each of the five ECA's contains rectifiers and voltage regulators for generating dc voltages from the 115 Vac supply. Unless it is indicated otherwise, the various voltages are generated using all three phases of the source.

The dc voltages generated in the pitch and yaw ECA's are used to power the control electronics within those units. The roll ECA generates power for its control electronics as well as the power for the signal conditioning circuits which are used in telemetering SCS information to the ground stations.

The power supply in the auxiliary ECA is used for the electronics in the AGCU and in the SPS engine on-off electronics. The FDAI and gimbal position display electronics receive their power from the D/AGAA ECA.

9.2.7.2 TVC No. 1 Power

The TVC No. 1 Power Switch feeds 115 Vac to the pitch and yaw TVC power supplies as well as 28 Vdc and 115 Vac to a power supply in the D/AGAA ECA. The pitch TVC power supply is used for operating the pitch SPS gimbal drive mechanism which consists of a servo amplifier, gimbal position and rate transducers, demodulators, and gimbal trim potentiometer. Similarly, the yaw power supply feeds power to the yaw channel.

The power supply in the D/AGAA ECA generates the voltages necessary for operating the accelerometer and Delta V indicator electronics.

9.2.8 Group 2 Power Switches

The Group 2 switches supply power to those components of the SCS which are necessary for manual thrust vector control. The three Group 2 switches are shown in the lower half of Drawing 9.2.1 as follows:

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- A. BMAG Power
- B. TVC No. 2 Power
- C. Rotation Control Power

9.2.8.1 BMAG Power Switch

This switch supplies 115 Vac and 28 Vdc to the roll, pitch, yaw, and D/AGAA ECA's. The voltages generated in the D/AGAA ECA are used for operating the BMAG's together with the torquing amplifiers and preamplifiers in the AGAA. One hundred fifteen Vac, Phase A power is also supplied to the yaw, pitch, and roll ECA's for demodulator references.

9.2.8.2 TVC No. 2 Power Switch

This switch supplied only 115 Vac power to the redundant set of TVC power supplies in the pitch and yaw ECA's. This second set of TVC power supplies in the pitch and yaw ECA's is used for operating a second gimbal drive mechanism which consists of servo amplifiers, summing amplifiers, gimbal position and rate transducers, demodulators, and gimbal trim potentiometers. If an improper high or low gimbal drive clutch current is sensed in either servo Amp No. 1 during an SPS engine firing, there is an automatic switchover to the TVC 2 mechanism. This switchover is accomplished in both channels if a manual thrust vector control signal is given by twisting the translation control handle clockwise.

9.2.8.3 Rotation Control Power Switch

From this switch, 115 Vac (Phase A only) power is distributed to the roll to provide an ac reference for the rotation control demod.

9.2.9 Additional Circuit Breakers and Switches

The following are circuit breakers and switches which are not considered part of the SCS but which must function properly if the SCS is to function properly.

*
9.2.9.1 Crew Safety Control Panel - MDC 16

Those switches pertaining to SCS functions are as follows:

A. Transfer CM/SM RCS Switch

Two-position toggle switch, CM/SM, provides backup capability for transfer of power from the SM to the CM RCS after CM/SM separation.

B. CM RCS Pressurization Switch

Two-position toggle switch which functions as a backup to the normal automatic pressurization of the CM Reaction Control System after CM/SM separation.

C. CM/SM Separation Switch

Two-position toggle switch which functions as the command for CM/SM separation transferring power (RCS Transfer Switch) from SM to CM.

D. RCS Command Switch

The three-position toggle switch (ON/NORM/OFF) which functions as a backup to the automatic enabling of the RCS solenoid drivers. The center position permits the MESC to permit its normal function of enabling the RCS solenoid drivers. The ON position provides a manual backup for enabling the RCS solenoid drivers. The OFF position inhibits activation of the RCS solenoid drivers.

9.2.9.2 Master Caution Warning - MDC 10 and 11

A. SPS Gimbal Drive Failure Indicator

The indicator illuminates indicating failure of a gimbal drive motor.

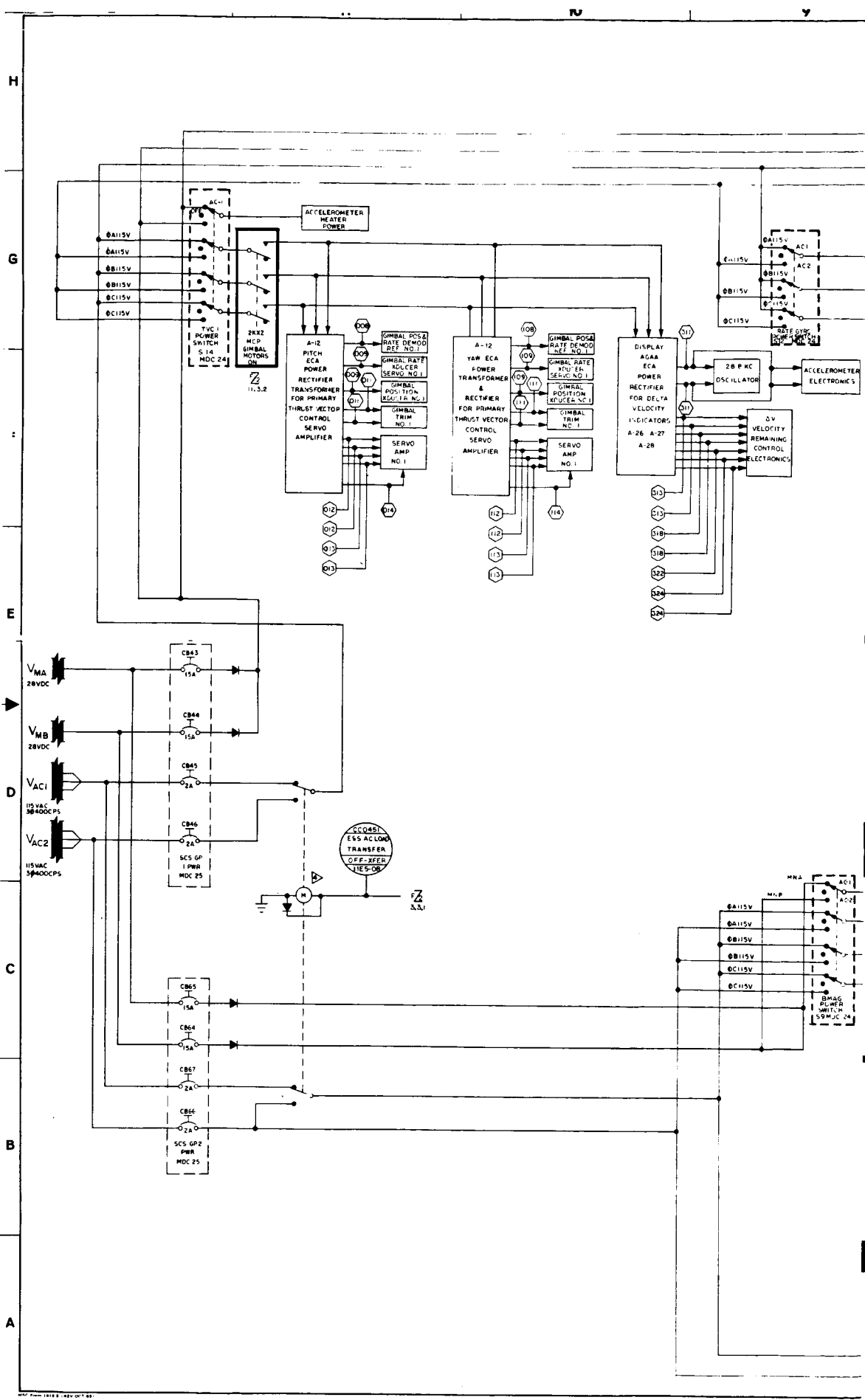
B. AGAA Temperature Failure Indicator

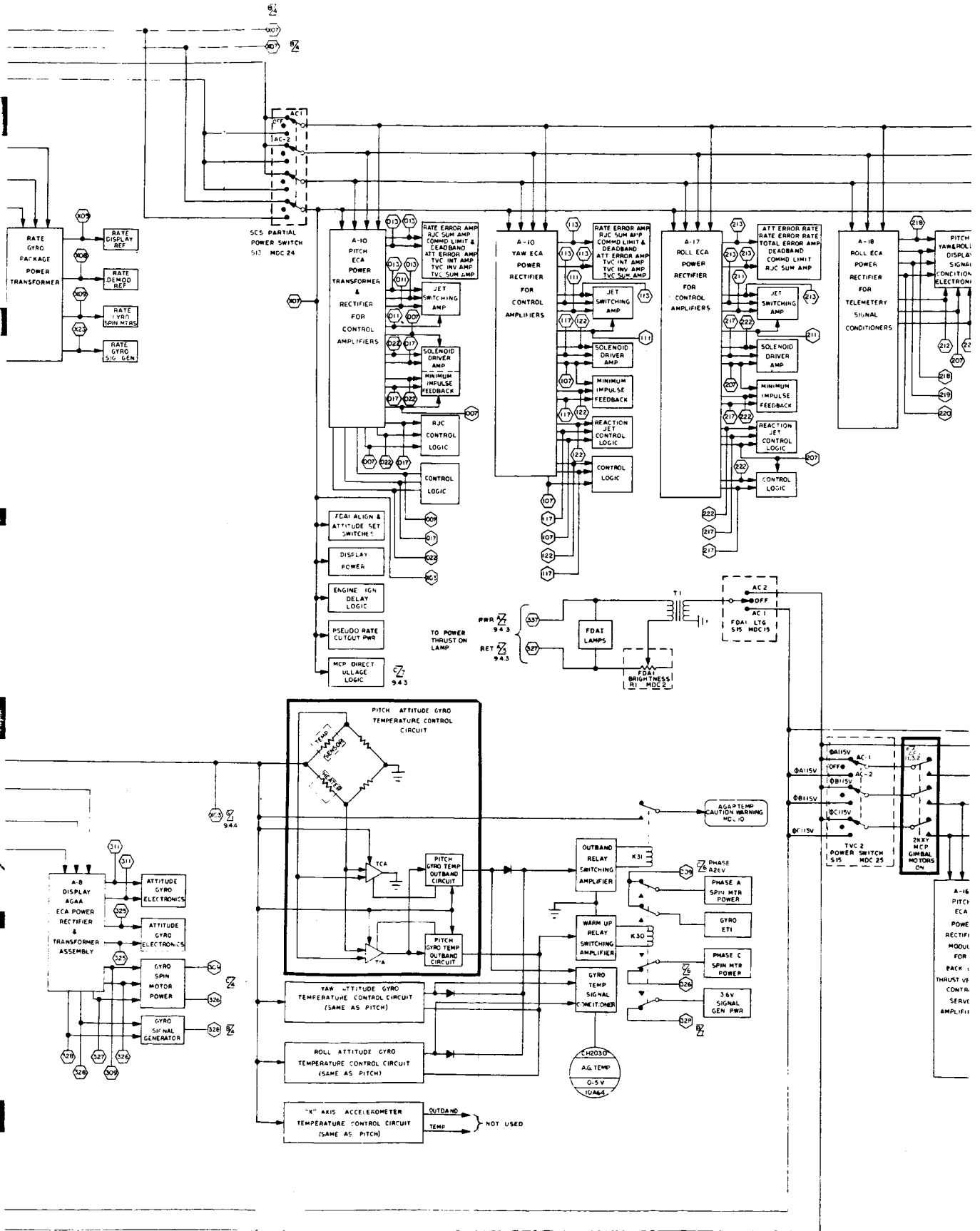
The indicator illuminates indicating failure of one of the three BMAG heaters, signifying gyro temperature in excess of the design band width of $170 \pm 2^{\circ}\text{F}$.

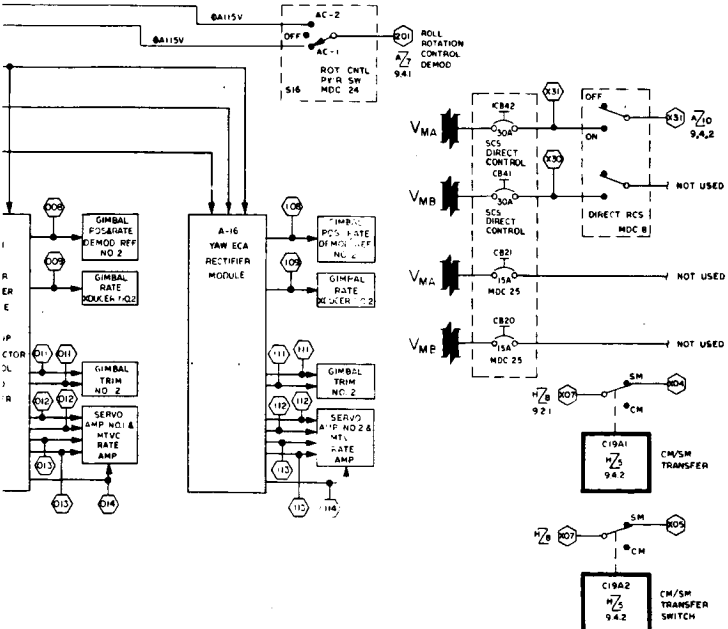
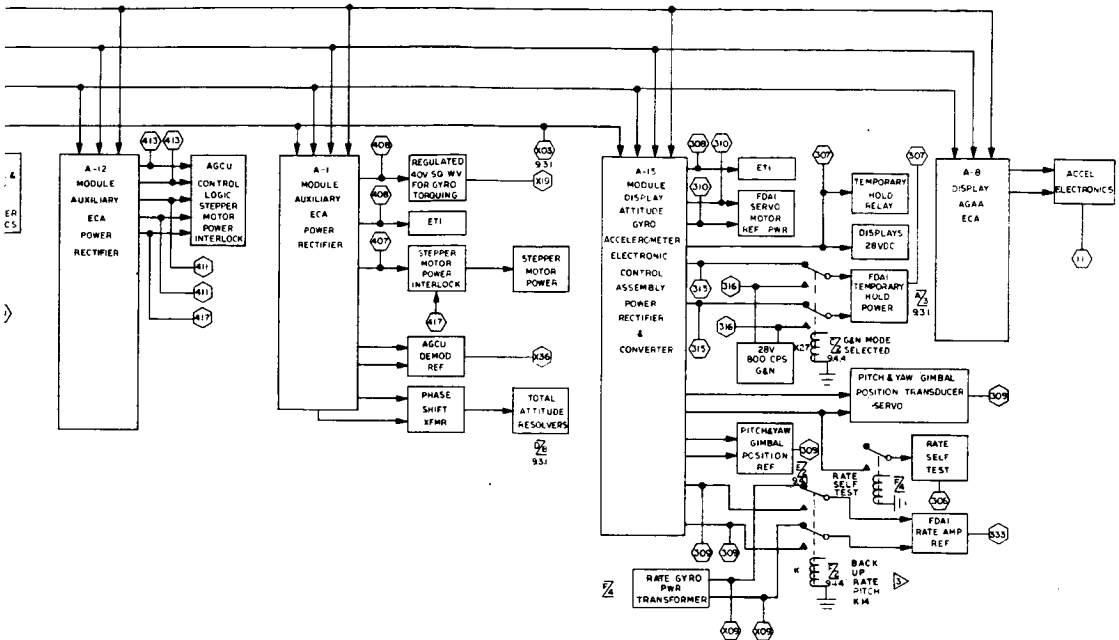
*
9.2.9.3 Gimbal Drive Control Panel - MDC 3

A. SPS Gimbal Drive Motor Switches

The SPS Gimbal Drive Motor Switches are three-position toggle switches (ON/AUTO/OFF). The ON position is spring-loaded and momentarily used for engine start. The AUTO position is normal and serves to maintain power for actuation of the gimbal motors. The OFF position removes power from the gimbal motors. Number 1 denotes primary system; Number 2 denotes secondary (redundant system).







- ▶ ALL AC CIRCUIT CB-45-46-46-67 ARE GANGED TO PROVIDE A BREAKER ON EACH OF THE THREE PHASES
- ▶ RLVT-ROTATIONAL LINEAR VARIABLE DIFFERENTIAL TRANSFORMER
- ▶ THIS CIRCUIT IS REPEATED FOR EACH AXIS
- ▶ ACTUAL CIRCUIT IS COMPOSED OF THREE SWITCHES PER BUSS

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DR <i>[Signature]</i>		12/1/68	NATIONAL AERONAUTICS & SPACE ADMINISTRATION	
ENG <i>[Signature]</i>		11/16/68	MANNED SPACECRAFT CENTER - HOUSTON, TEXAS	
CH <i>[Signature]</i>		11/16/68	STABILIZATION AND CONTROL POWER DISTRIBUTION SUBSYSTEM	
APP <i>[Signature]</i>		11/16/68		
AUTH <i>[Signature]</i>		11/16/68	CSM	SIZE
SCALE		AS-501	J	DWG NO. 92.1
				SHEET 1 OF 1

*

9.3 ATTITUDE REFERENCE SUBSYSTEM (ARS)

The Attitude Reference Subsystem consists of electronics, controls, and displays which provide a backup inertial attitude reference to facilitate manual spacecraft attitude control in the event of IMU failure.

9.3.1 Operation

The subsystem has five operational configurations: Caged, Uncaged, Backup Rate, Alignment, and Attitude Set (not used). These configurations are established by the operation of panel switches on the Main Display Console, lower equipment bay, and MCP which provide inputs to the logic circuits on the SCS Logic Diagram.

9.3.1.1 Caged

In the Caged configuration of the ARS attitude error outputs from the three body axes attitude gyros are summed and converted to a navigation axes reference. The signals are then applied to resolvers in the AGCU, where a pseudo navigation to Euler rate transformation is accomplished and the resolved errors are applied to level detectors in the AGCU electronics. Each time the Euler rate inputs rise above 1.5 Vdc, The level detector causes a stepper motor in the affected axes to step one quarter turn, 0.2 degrees of attitude change, and generates a second pulse which is applied first to a Euler-to-navigation transformation, then to a navigation-to-body axes transformation and then back to the attitude gyro torquer amplifiers to null outputs of the gyros. In this mode (Caged), the AGCU computes spacecraft body rotations and provides three attitude outputs, pitch, yaw, and roll which are identical, neglecting drift and other errors to the outputs of the inner, middle, and outer gimbal angles of the G&N inertial subsystem.

9.3.1.2 Uncaged

In the uncaged configuration, the attitude gyro outputs are applied to the Attitude and Thrust Vector Control Electronics and the Attitude Error Display on the Flight Director Attitude Indicator.

*

9.3.1.3 Backup Rate

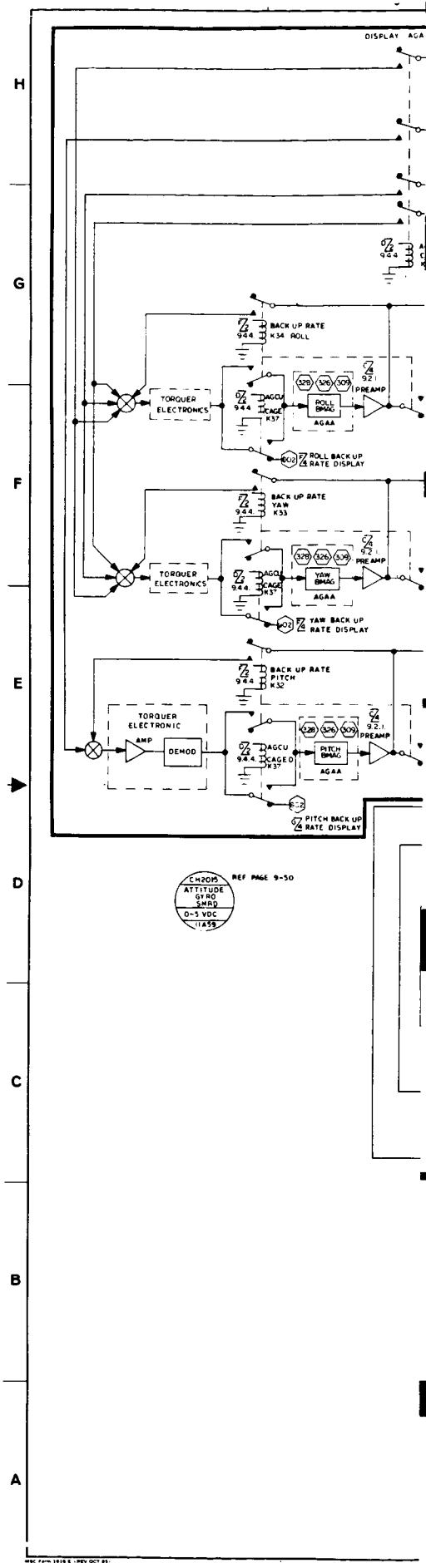
If any of the rate gyro switches are placed in the BMAG position, the output of that gyro is applied to its torquer amplifier. This output is now equivalent to spacecraft rotational velocity and is applied to the command rate display and the Attitude and Thrust Vector Control Electronics. If the AGCU is Caged when Backup Rate is selected, logic circuits in the D/AGAA ECA will configure the other two attitude gyros into rate gyros; however, only the gyro selected by the Rate Gyro Switches on MDC-8 will be applied to the control circuitry and display.

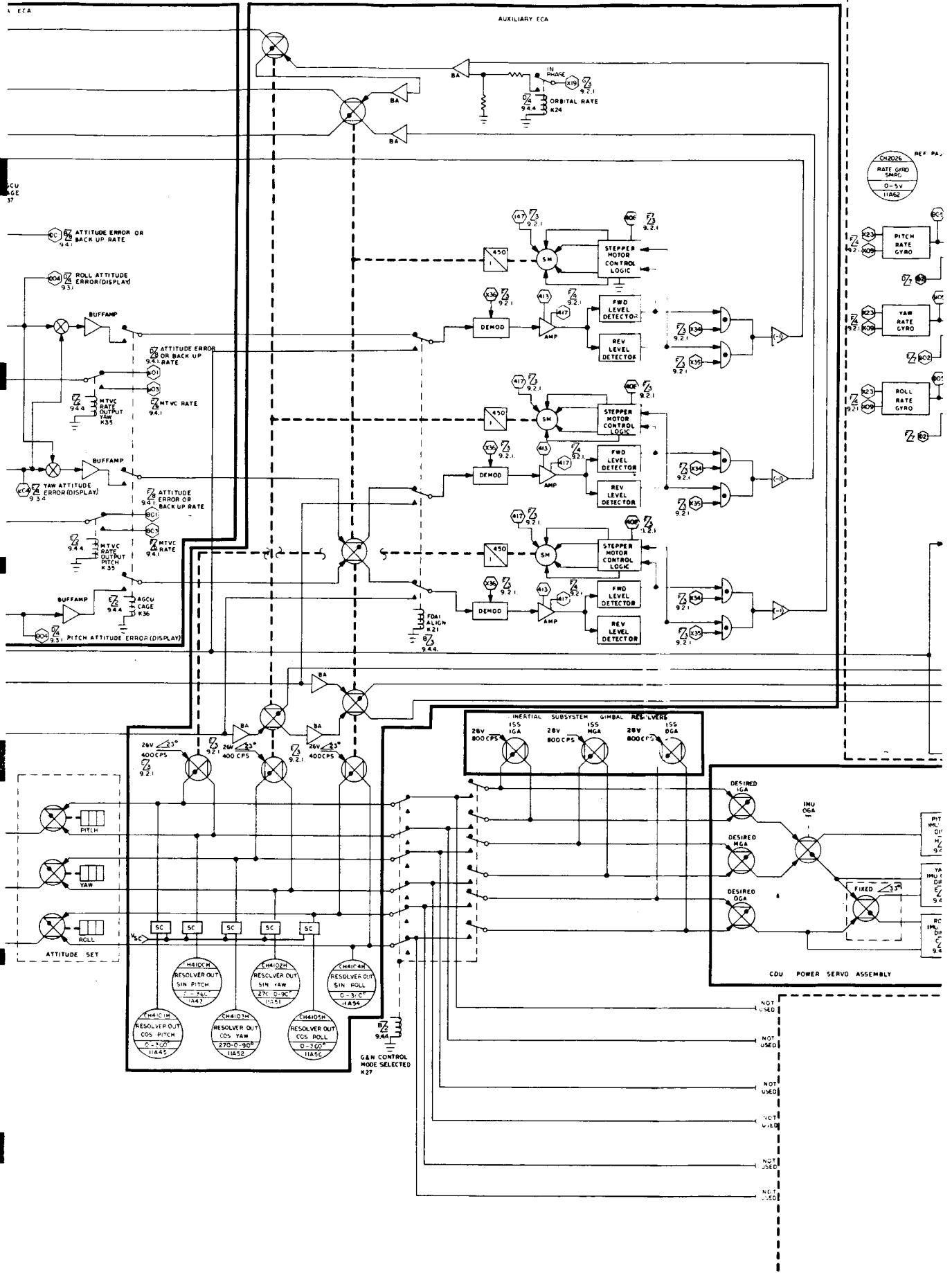
9.3.1.4 FDAI Align MDC-6

This term is in reality a misnomer since the alignment is strictly a function of the AGCU. The FDAI may or may not indicate the alignment, depending upon whether or not an SCS control mode has been selected. Any time the FDAI Align button is pressed, the AGCU will align itself to the Euler angles indicated on the readout windows adjacent to the Attitude Set thumbwheels on MDC-6. If the SCS is in a mode which connects the AGCU outputs to the FDAI, the angles in the readout windows will be indicated by the FDAI under the Navigation Axes Index (cross-hair symbol) and the roll bug of the FDAI when the alignment is complete.

9.3.1.5 Attitude Set Switch MDC-6

The Attitude Set Switch provides a means of manually orientating the vehicle from one inertial attitude to another using the FDAI Attitude Error Display, Attitude Display, and the Attitude Set thumbwheels. When the Attitude Set Switch is in the ATT SET position, the body axes equivalent of the difference between the attitude set resolver shaft angle and the shaft angle of the AGCU Attitude Resolvers is displayed by the FDAI Attitude Error Needles. These needles will null when the spacecraft has been rotated to the proper attitude.

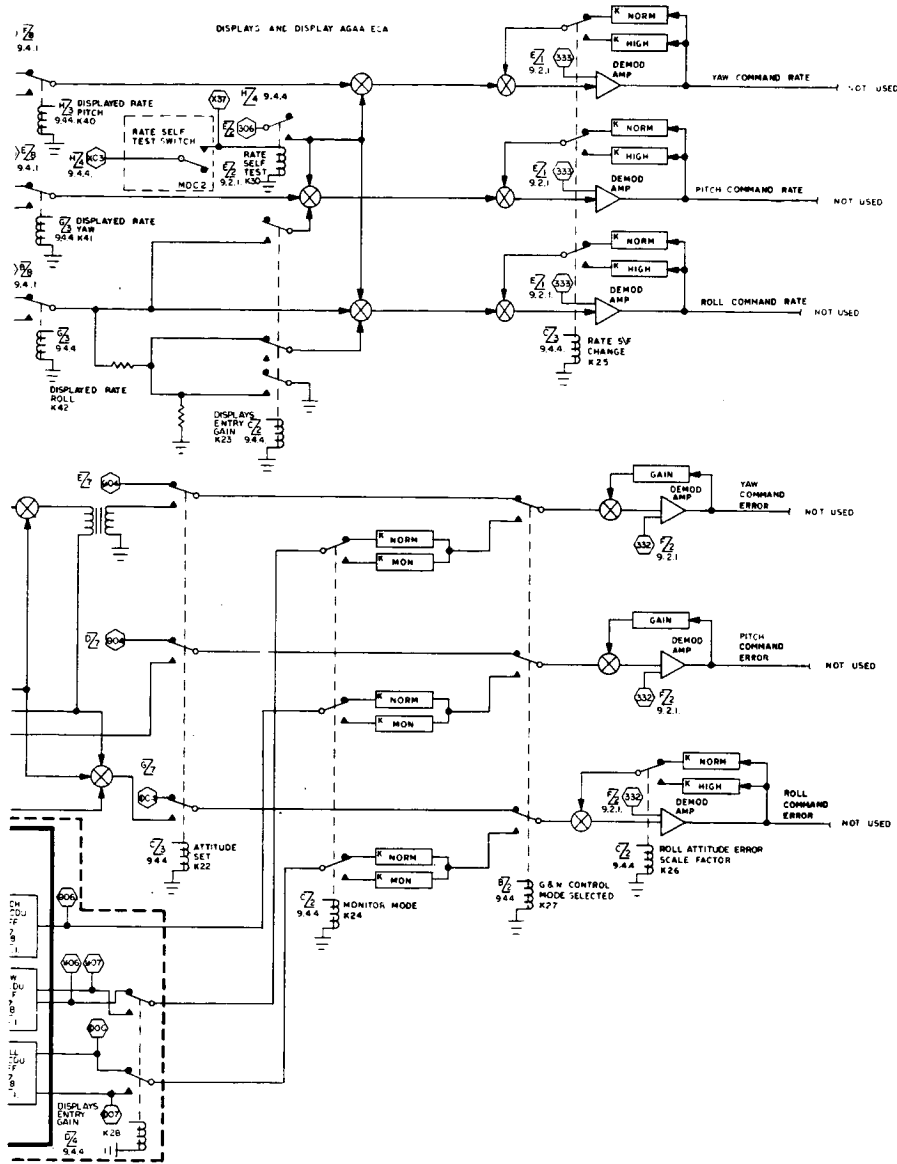




COMMAND RATE SCALE FACTOR			
MODE	PITCH	YAW	ROLL
SCS OP G & N DELTA V	± 5%	± 5%	± 5%
LCL VERT ATT CNTL	± 1%	± 1%	± 1%
MONITOR SCS ENTRY GEN ENTRY	± 5%	± 5%	± 25%

COMMAND ERROR SCALE FACTOR			
MODE	PITCH	YAW	ROLL
MONITOR	± 15°	± 15°	± 25°
SCS OP GEN ENTRY	± 5°	± 5°	± 25°
ALL OTHER MODES	± 5°	± 5°	± 5°

E 9-50



▷ FDAI 1GA IS THE EULER PITCH AXIS. FDAI MGA IS THE EULER YAW AXIS. FDAI OGA IS THE EULER ROLL AXIS (ROLL BUG)

▷ FDAI 1GA IS THE EULER PITCH AXIS. FDAI MGA IS THE EULER YAW AXIS. FDAI OGA IS THE EULER ROLL AXIS (ROLL BUG)



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DR. <i>[Signature]</i>		1/17/67	STABILIZATION AND CONTROL ATTITUDE REFERENCE SUBSYSTEM	
ENGR. <i>[Signature]</i>		1/19/67		
APPR. <i>[Signature]</i>		1/18/67	CSM MISSION AS-501 E 931	
AUTH. <i>[Signature]</i>		1/20/67		
SCALE		SIZE	SHEET 1 OF 1	

*

CSM
AS-501

9.4 ATTITUDE AND THRUST VECTOR CONTROL ELECTRONICS

The electronics depicted on Drawings 9.4.1 and 9.4.2 represent the mechanization required for control of the SPS engine gimbal angle and the CM/SM reaction jets. Control of the gimbaleed engine and reaction jets is obtained through the utilization of a combination of any of the four input devices to obtain one of the three basic control configurations.

- A. Monitor
- B. Automatic Control
- C. Manual Control

The electronics are configured by logic inputs from switches on the Main Display Console MDC-25 and lower equipment bay. These logic inputs modify the basic electronic configuration into control modes which are each suited to a particular mission phase, i.e., Launch, ΔV , Attitude Control or Entry.

9.4.1 Monitor

The monitor configuration (also a control mode) provides the capability of observing outputs of the G&N Inertial Subsystem (G&N ISS) while having manual control of spacecraft attitude and rate damping. G&N ISS outputs are monitored on the FDAI Attitude and Attitude Error Displays.

9.4.2 Automatic Control

The automatic control configuration enables automatic control of the spacecraft attitude or thrust vector direction and velocity during orbital non-atmospheric flight phases and to guide the spacecraft through atmospheric entry to a preselected landing site. This control capability is exercised when G&N Attitude Control, G&N ΔV , G&N Entry Mode has been selected.

9.4.3 Manual Control

When a Manual Control configuration is selected, direct manual inputs from the ground are required to control spacecraft attitude.

*

These functions may or may not be augmented by rate damping. This control configuration is present at any time ground commands are transmitted.

9.4.4 Modes of Operation

9.4.4.1 Monitor Mode

This is the normal SCS mode for the boost phase and is not normally used for orbit or entry. When the CSM/LV separate and the monitor mode has been selected, the FDAI Attitude and Attitude Error Displays are driven by either G&N or SCS inputs and the angular velocity display is driven by the rate gyros. The vehicle may be rate stabilized at ± 0.2 degree/second in all three axes, however, normally cannot be used after using CSM/S-IVB separation.

9.4.4.2 G&N Attitude Control Mode

The G&N System inputs control the spacecraft attitude automatically with the SCS Rate Gyro. Rotational maneuver rates are fixed by the AGC program at 0.5 degrees/second. The attitude deadband at this time may be selected by the crew at a maximum of 0.5 degrees or 5.0 degrees, according to the position of the deadband switch MDC-8 (Min-Max, respectively). Manual attitude control can be exercised during this mode but will not be effective as the G&N will command the vehicle to the CDU desired attitude when the Rotation Control is returned to detent. The computer attitude control can be inhibited by the G&N Sync Switch MDC-25. As long as the G&N Sync is ON, the G&N will hold the attitude selected by crew command, however, when the G&N Sync Switch is turned OFF, the computer will command the vehicle to the CDU desired attitude. When the vehicle is being maneuvered by CDU inputs to the reaction jets, the vehicle can respond to inputs which command spacecraft rotational velocities of 10 degrees/second in all three axes. Normally, automatic maneuver velocity will be a maximum of approximately 4 degrees per second in all axes controlled by the AGC program.

*
9.4.4.3 SCS Attitude Control Mode (Not Used)

9.4.4.4 G&N Delta V Mode

During G&N Delta V Mode, prior to SPS engine ignition, configured similar to its configuration for G&N Attitude Control Mode, the one significant departure from the attitude control configuration is in the AGCU which is Uncaged so the attitude gyros can follow spacecraft attitude changes during the burn. After SPS engine ignition, the pitch and yaw reaction jet solenoid drivers are disabled to conserve RCS fuel and are not enabled until one second after SPS engine shutdown. At SPS engine ignition, the G&N Control inputs are applied to the SPS Gimbal Electronics where they are summed with rate signals from the RCS Rate Gyros. Signals to the SCS Electronics are generated by the Apollo Guidance Computer through the coupling display unit of the G&N Subsystem. During the burn, the computer generates steering commands which are sent to the CDU's to adjust the CDU shaft angles, resulting in an angular difference between the IMU gimbal angle and CDU shaft angle. (See Drawing 9.3.1.) The sine of the difference angle is applied to the SCS Electronics as an error signal. The magnitude and phase of the error signal is a function of the computer program and is designed to provide a solution to the cross-product steering laws and accomplish multi-axis velocity changes. The SPS Gimbal can be driven at a maximum rate of 0.3 radians per second. Servo Amplifier No. 1 is used at all times to control the SPS gimbal angle unless Servo No. 2 is switched online by over/under current sensing or Manual Thrust Vector Control is selected. (See SCS Mode Logic, Drawing 9.4.4.)

A. G&N MTVC (Not Used)

9.4.4.5 SCS Delta V Mode (Selected Automatically at G&N FAIL Discrete)

In this mode, prior to SPS engine ignition, the SCS is configured similar to the SCS Attitude Control Mode and has identical control capability. At engine ignition, just as in G&N Delta V Mode, the pitch and yaw reaction jets solenoid drives are disabled. SPS gimbal angle is

*

controlled by attitude gyros and the integrators in the pitch and yaw electronic control assemblies. These integrators compute cg location with error inputs from the attitude gyros and gimbal position from the SPS gimbals. The gimbal position input is the form of a positive feedback to the Integrator and enables the mechanization of a very tight servo loop. The integrator output and attitude error amplifier output are summed and applied to the gimbal servo electronics. The output of this summing point is equivalent to SPS gimbal position.

A. SCS MTVC Mode (Not Used)

9.4.4.6 G&N Entry Mode

Prior to 0.05G sensing, this mode is identical to G&N Attitude Control Mode except that the G&N System is outputting navigation axes referenced attitude error rather than body axis referenced attitude errors, and the Command Service Module has separated. The systems will cause the spacecraft to deadband ± 2 degrees/second within the five-degree deadband and may be maneuvered at ± 10 degrees/second pitch, yaw, and roll. After 0.05G switching pitch and yaw axis attitude control are inhibited by the pitch and yaw RJC attitude relays and roll angular velocity is summed with yaw angular velocity for entry roll maneuvering. The summing gain for roll is equivalent to the $\tan < 21.5$ degrees and provides a coordinated lift vector roll. The G&N and SCS will maintain the lift vector to within ± 50 degrees of the selected (by roll CDU desired) attitudes deadband at a maximum rate of two degrees/second and maneuver at a maximum rate of 17 degrees/second.

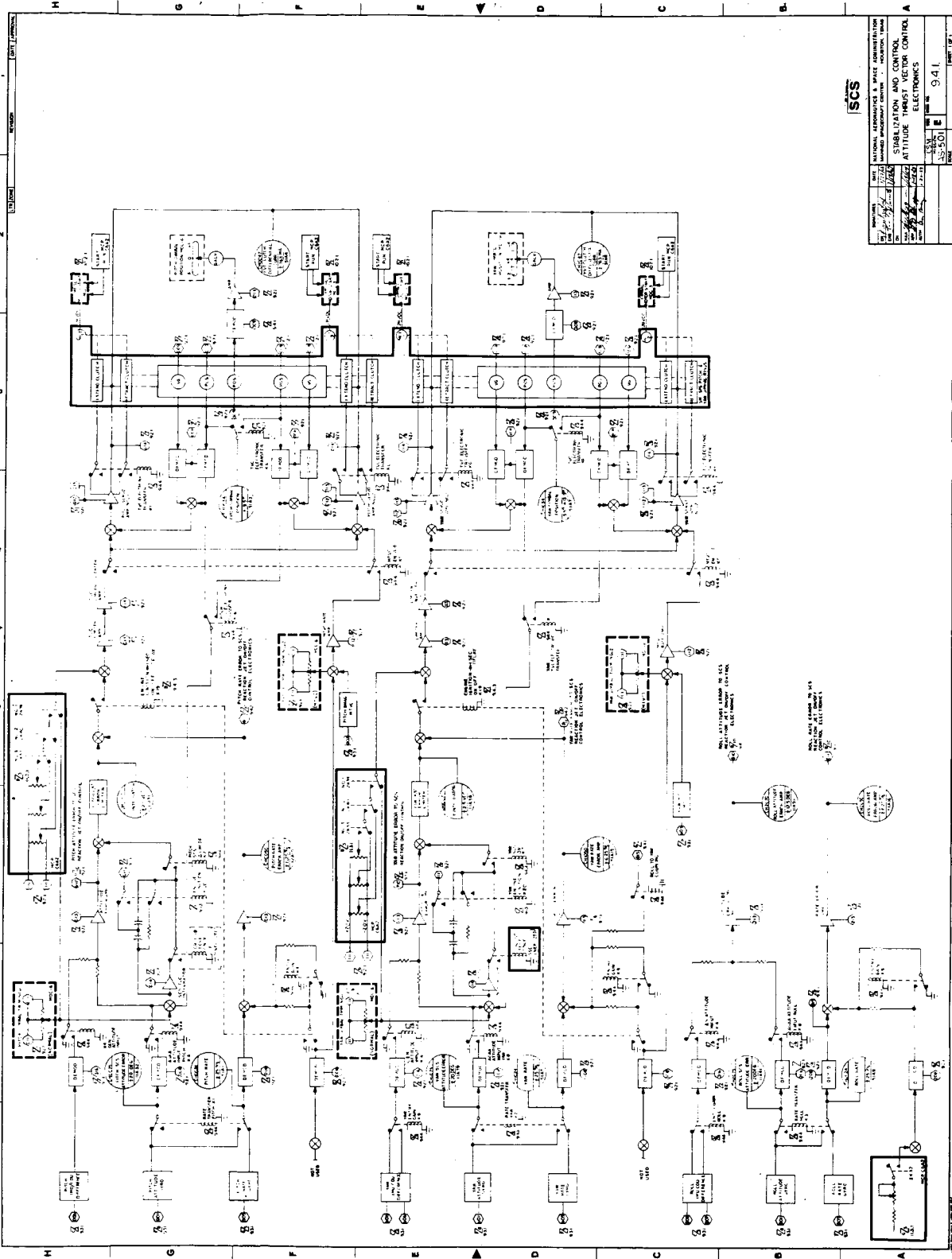
Crew displays for spacecraft attitude, attitude the IMU, CDU/IMU difference and rate gyro package respectively. The AGCU is caged and can provide an inertial attitude reference should the G&N fail, providing a BMAG has not been switched into Backup Rate Mode.

9.4.4.7 SCS Entry Mode (Selected at CM/SM Separation and G&N Fail)

SCS Entry provides an alternate to G&N Entry Mode. Prior to

*

0.05G Switch activation, the control functions are similar to the control functions provided by SCS attitude control mode, except that there is no translation capability. After 0.05G Switch activation, pitch and yaw attitude control are inhibited by RJC attitude relays and roll rate is coupled into the yaw axis after passing through a gain change. This signal (roll rate $\tan < 21.5$ degrees) insures that entry lift attitude display on the FDAI. All rotational maneuvers must be accomplished manually with proportional or direct reaction jet control. Maneuver rates are ± 5 degrees/second in pitch and yaw, ± 17 degrees/second in roll before 0.05G, and ± 17 degrees/second in roll after 0.05G. The rate deadband is ± 20 degrees/second in all axes before or after 0.05G and the attitude deadband is ± 5.0 degrees before 0.05G and inactive after 0.05G.



SCS

DESIGNATION	STABILIZATION AND CONTROL ATTITUDE THRUST VECTOR CONTROL ELECTRONICS
PROJECT	AS-501
REV.	941
DATE	
BY	
CHECKED BY	
APPROVED BY	

REVISIONS

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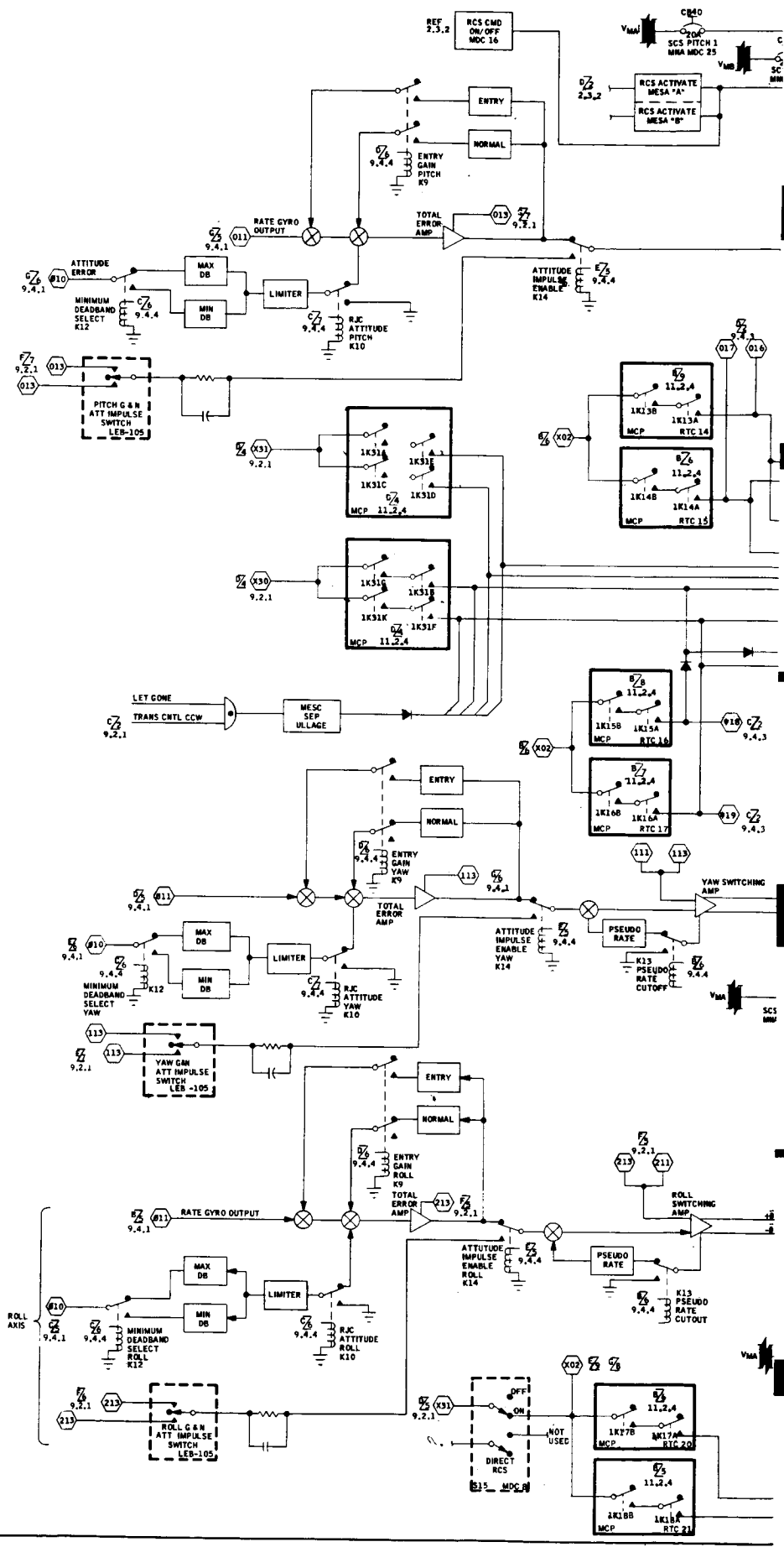
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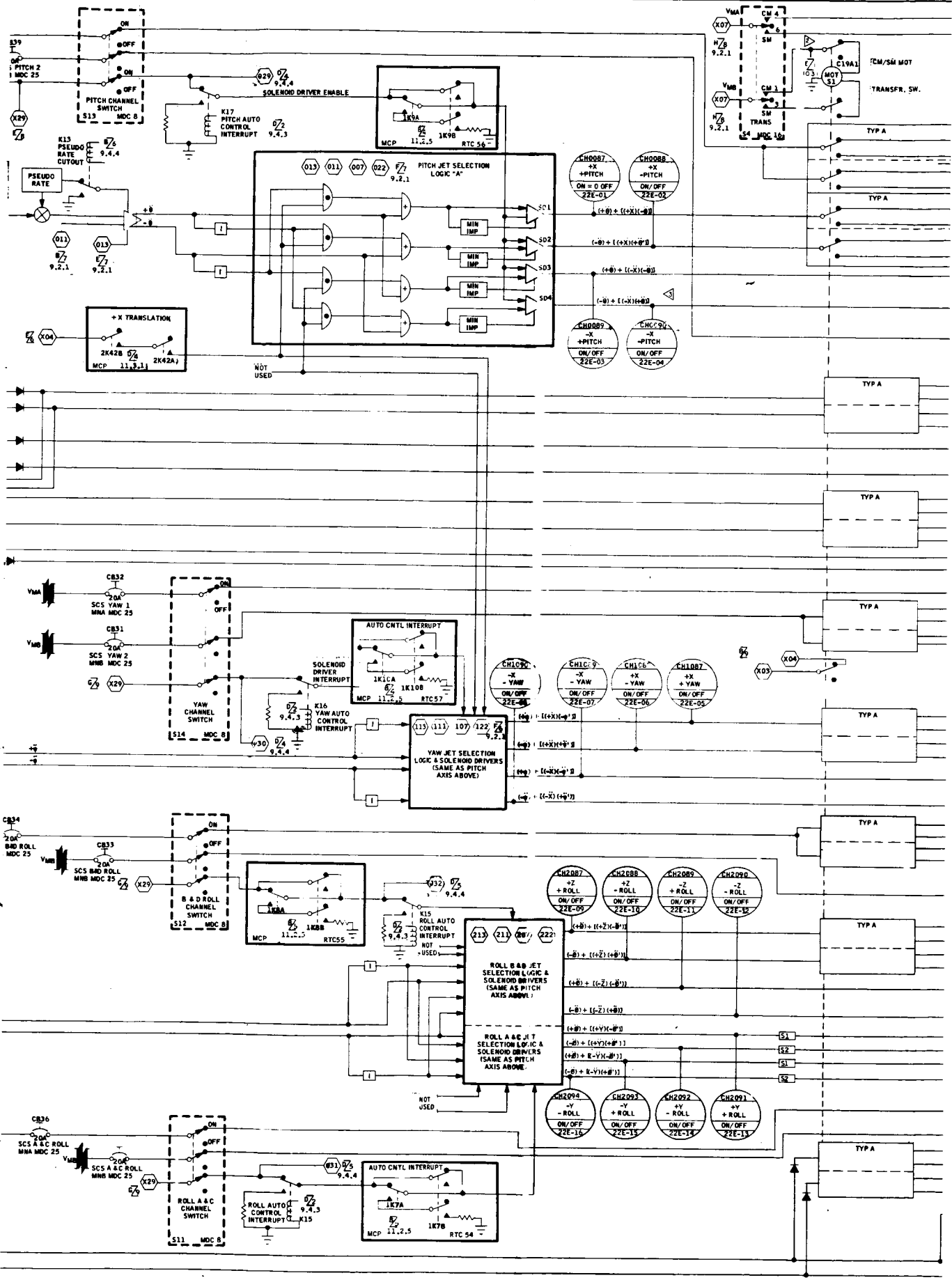
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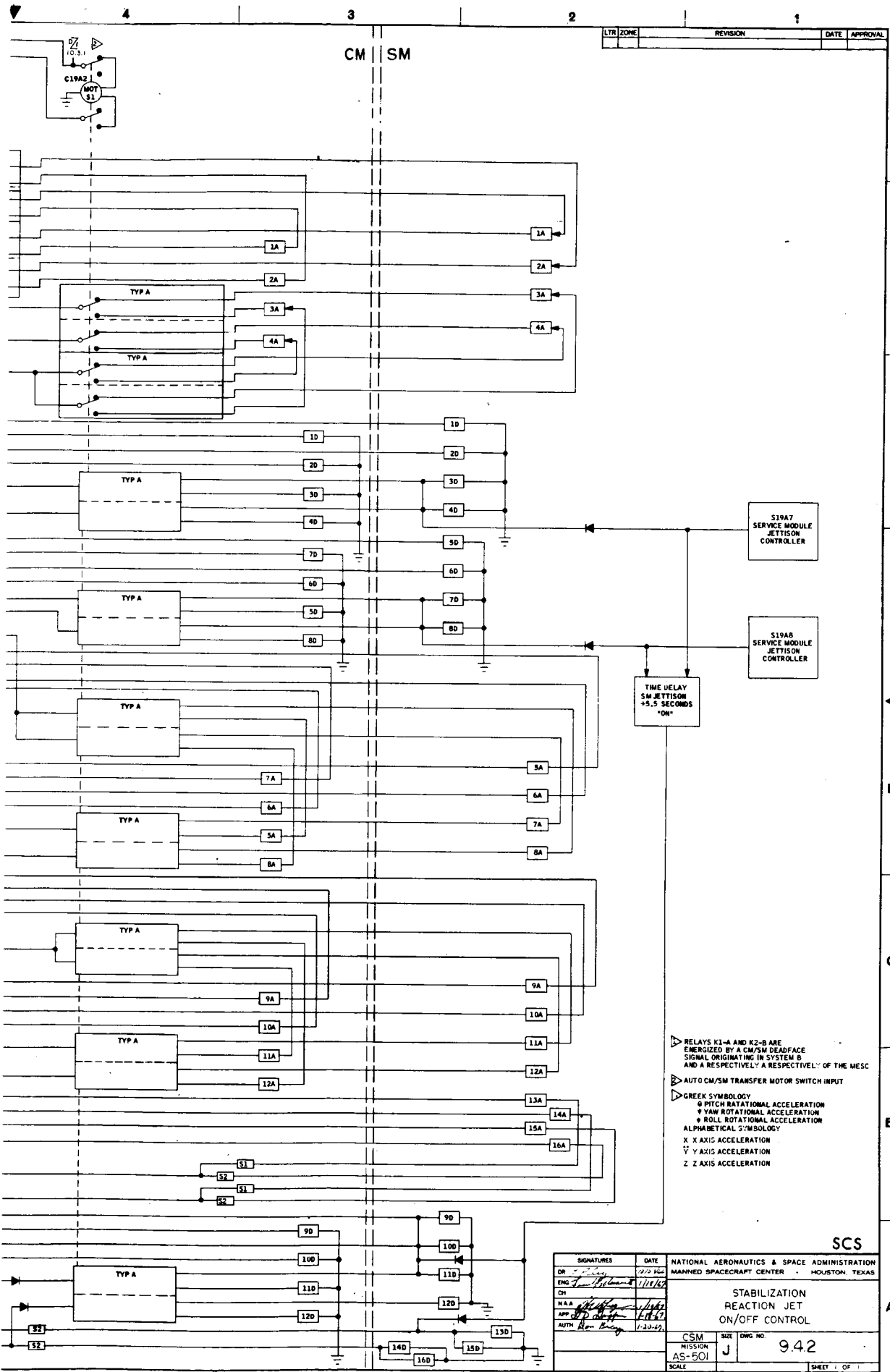
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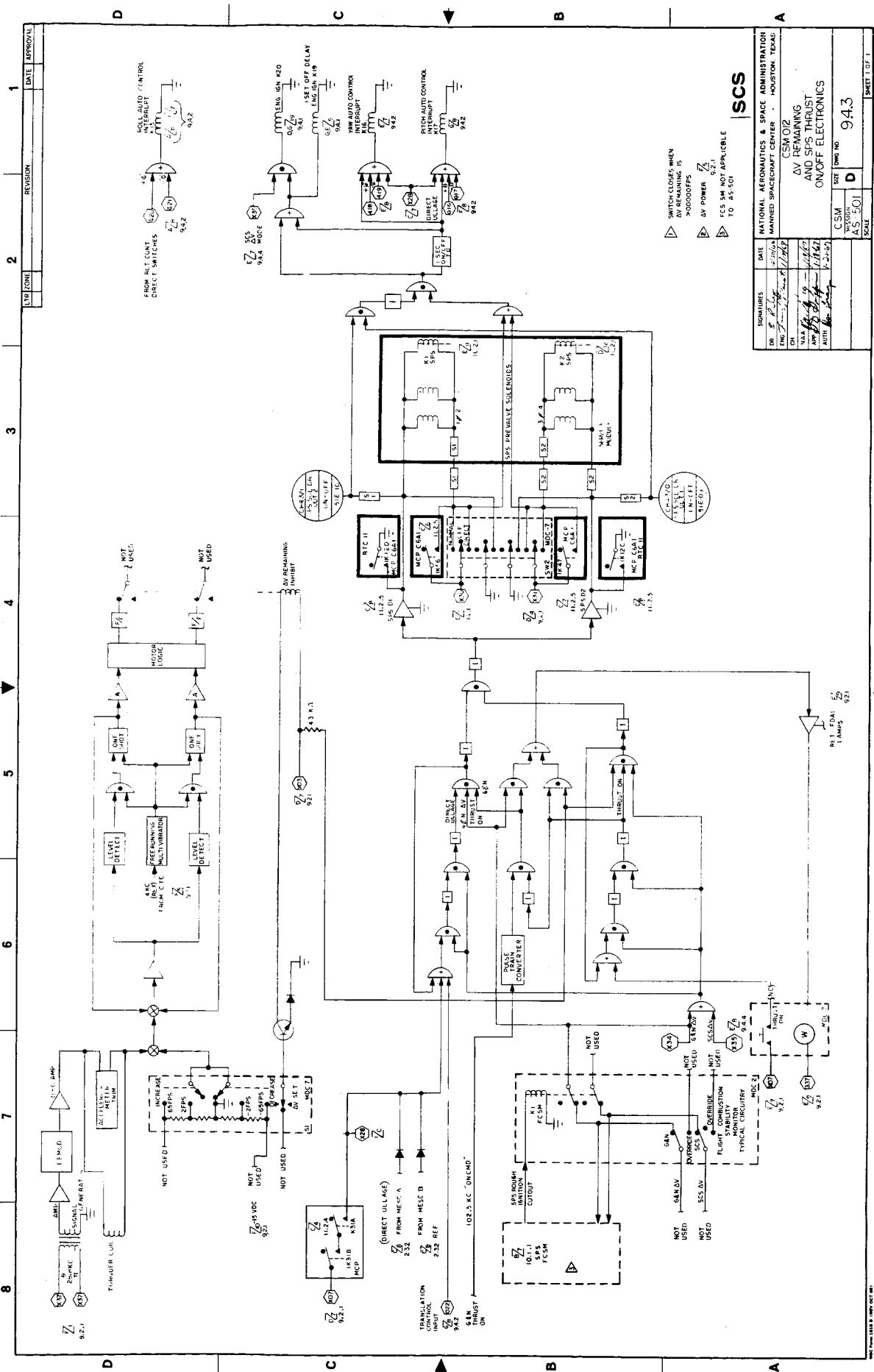
LTR	ZONE	REVISION	DATE	APPROVAL
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- ▷ RELAYS K1-A AND K2-B ARE ENERGIZED BY A CM/SM DEADFACE SIGNAL ORIGINATING IN SYSTEM B AND A RESPECTIVELY. A RESPECTIVELY OF THE MSC
- ▷ AUTO CM/SM TRANSFER MOTOR SWITCH INPUT
- ▷ GREEK SYMBOLLOGY
 - ◊ PITCH ROTATIONAL ACCELERATION
 - ◊ YAW ROTATIONAL ACCELERATION
 - ◊ ROLL ROTATIONAL ACCELERATION
- ALPHABETICAL SYMBOLLOGY
 - X X AXIS ACCELERATION
 - Y Y AXIS ACCELERATION
 - Z Z AXIS ACCELERATION

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DR		12/10/62	MANNED SPACECRAFT CENTER - HOUSTON, TEXAS	
ENG		1/11/63		
CH				
N.A.A.		1/11/63		
APP		1/11/63		
AUTH		1-20-63		
CSM		SIZE	OWG NO.	
MISSION		J	9.42	
AS-501				
SCALE				SHEET 1 OF 1

SCS

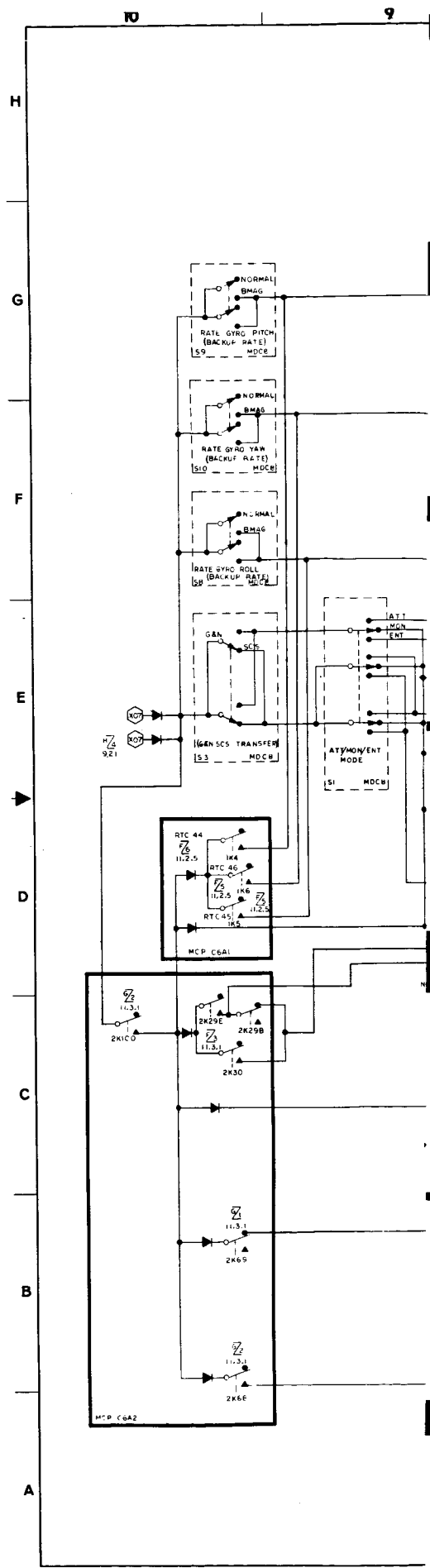
STABILIZATION
REACTION JET
ON/OFF CONTROL



SCS

- △ SWITCH CLOSES WHEN POWER IS 200000PPS
- △ AV POWER 9.2
- △ FCS SM NOT APPLICABLE TO A5-501

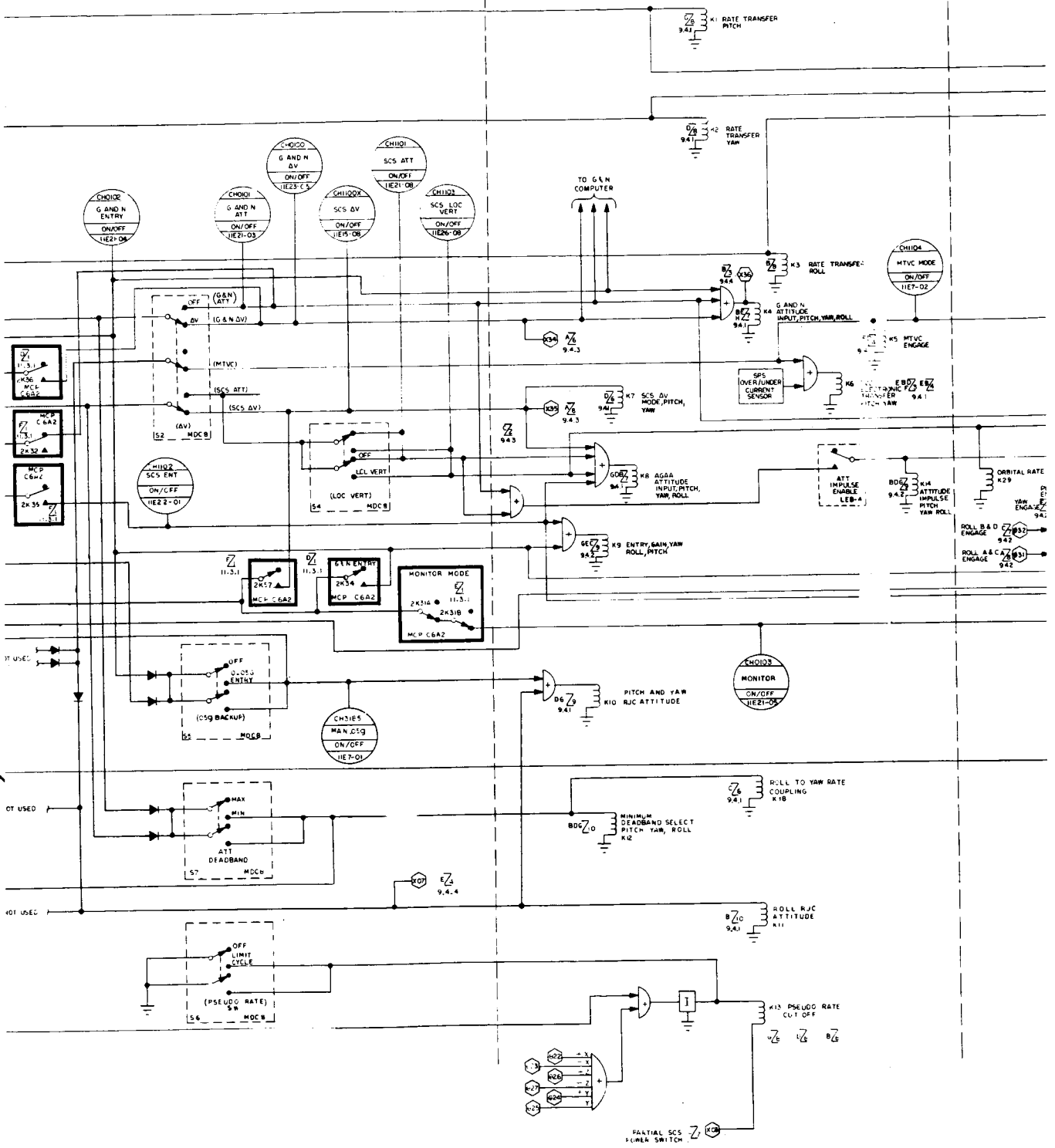
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DR	ENG	2/22/69	2/22/69	MANAGED SPACECRAFT SERVICES	HOUSTON, TEXAS
SA	AP	1/18/67	1/18/67	CSM/012	
AUT		1-20-50		AV REMAINING AND SPS THRUST ON/OFF ELECTRONICS	
				CSM	SIZE
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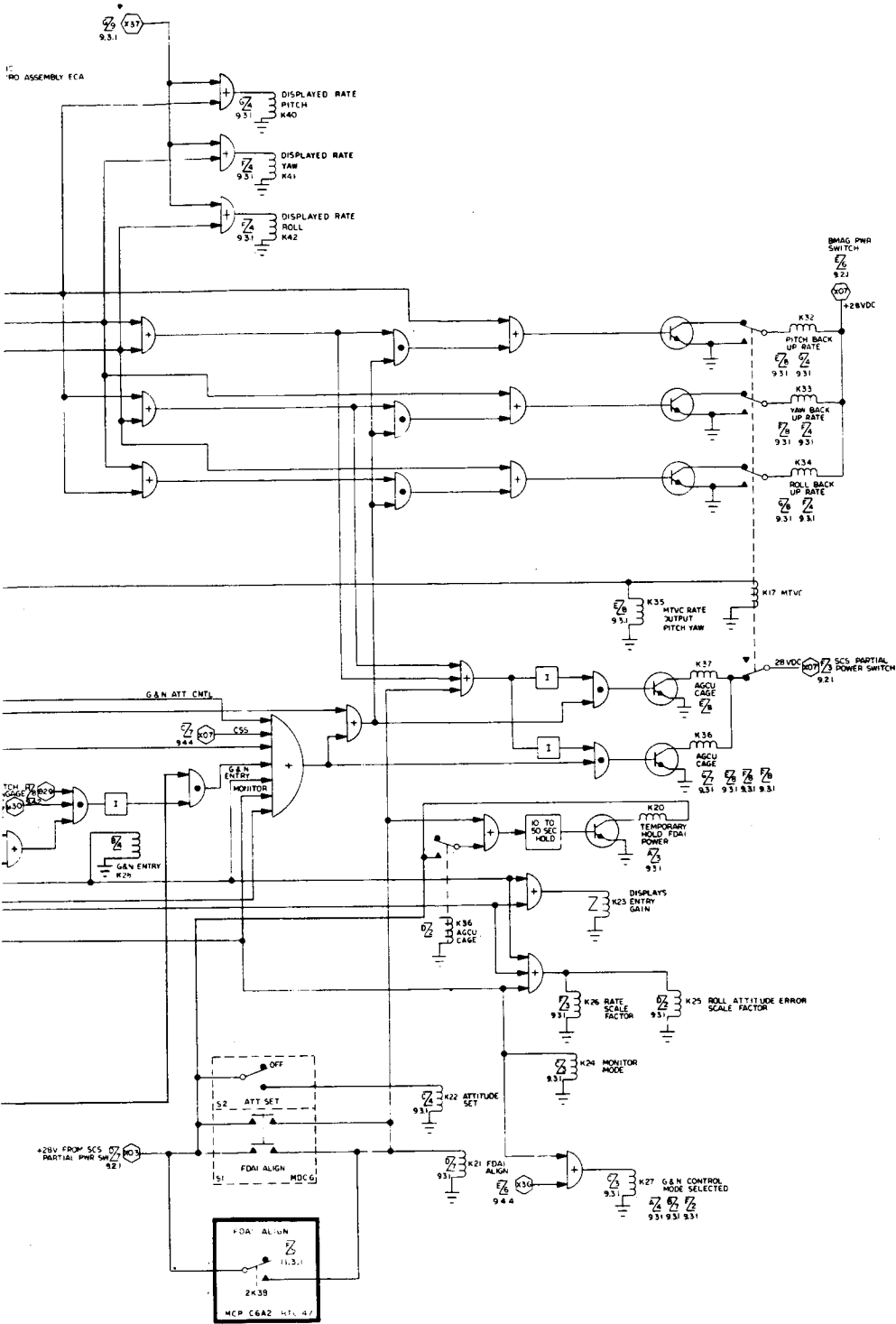


CONTROL PANEL

FUNCTIONAL ATTITUDE AND TOC LOGIC PITCH, YAW, OR ROLL ECA

FUNCTIONAL SYSTEM LOGIC DISPLAY AND ATTITUDE G





SIGNATURES		DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION MANNED SPACECRAFT CENTER - HOUSTON, TEXAS	
DR	<i>[Signature]</i>	11/14/67	STABILIZATION AND CONTROL MODE LOGIC	
ENR	<i>[Signature]</i>	11/14/67		
CH	<i>[Signature]</i>	11/14/67		
N-A	<i>[Signature]</i>	11/14/67		
APP	<i>[Signature]</i>	11/14/67		
AUTH	<i>[Signature]</i>	11/14/67	CSM WSPC: AS-50 SCALE: J SHEET: 94.4 SHEET: 2 OF 2	

*
9.5 NOTES: SCS SIGNAL LIST

The SCS signal list, Table 9-1, indicates all the signals, analog or discrete, which are generated in or used by the SCS. These signals are identified by a three-digit code:

FIRST DIGIT	NOMENCLATURE
θ	Pitch axis control signal
ψ	Yaw axis control signal
ϕ	Roll axis control signal
χ	Not identified by axis

The last two digits are a numerical identification.

EXAMPLE: $\phi 15$ is explained as follows:

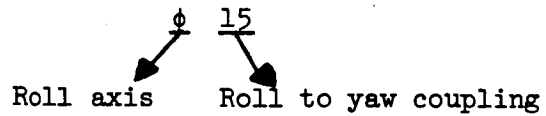


TABLE 9-1 SCS SIGNAL LIST

* $\theta, \psi, \phi 01$	Attitude Error or Backup Rate
$\theta, \psi, \phi 02$	Backup Rate Display
$\theta, \psi 03$	MTVC Rate
$\theta, \psi, \phi 04$	Attitude Error Display
$\theta, \psi, \phi 05$	Rate Gyro Output
$\theta, \psi, \phi 06$	CDU Body Error Command Output
$\psi, \phi 07$	CDU Entry Mode Error Command Output
$\theta, \psi, \phi 08$	Rotation Control #1
$\theta, \psi, \phi 09$	Rotation Control #2
$\theta, \psi, \phi 10$	Command Error
$\theta, \psi, \phi 11$	Command Rate
$\chi 12$	Translation Control CCW
$\chi 13$	Translation Control CW
$\theta, \psi, \phi 14$	Rotation Control B0
$\phi 15$	Roll to Yaw Coupling
$\theta 16$	+ $\ddot{\theta}$ Direct Rotation
$\theta 17$	- $\ddot{\theta}$ Direct Rotation
$\psi 18$	+ $\ddot{\psi}$ Direct Rotation
$\psi 19$	- $\ddot{\psi}$ Direct Rotation
$\phi 20$	+ $\ddot{\phi}$ Direct Rotation
$\phi 23$	- $\ddot{\phi}$ Direct Rotation
$\phi 22$	+ \ddot{X} Translation
$\phi 23$	- \ddot{X} Translation
$\theta 24$	+ \ddot{Y} Translation
$\theta 25$	- \ddot{Y} Translation
$\psi 26$	+ \ddot{Z} Translation
$\psi 27$	- \ddot{Z} Translation
$\chi 28$	Direct Ullage
$\theta 29$	Pitch Axis Engage
$\psi 30$	Yaw Axis Engage
$\phi 31$	Roll A&C Engage
$\phi 32$	Roll B&D Engage

*
TABLE 9-1 SCS SIGNAL LIST (CONT'D)

X33	Attitude Control Mode
X34	G&N ΔV Mode
X35	SCS ΔV Mode
X36	G&N Attitude Input

*

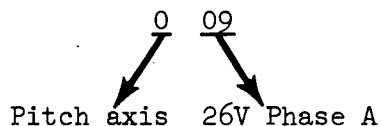
9.6 NOTES: SCS POWER LIST

The SCS power list, Table 9-2, indicates all the power which is generated in and used by the SCS electronics. The power is identified by a three-digit code. The first digit identifies the SCS end item, from which this power originates, that is:

FIRST DIGIT	NOMENCLATURE
0	Pitch ECA
1	Yaw ECA
2	Roll ECA
3	Displays ECA
4	Auxiliary ECA
X	Not identified with an ECA

The second two digits are simply a numerical identification.

EXAMPLE: 009 is explained as follows:



*
TABLE 9-2 SCS POWER LIST

01	Rotation Controller Demod
02	Pilot Direct
03	Co-Pilot Direct
04	Translation Control #1
05	Translation Control #2
06	5 Vac Rate Self Test
07	28 Vdc
08	115V ϕ A
09	26V ϕ A
10	17V $< 90^\circ$
11	± 20 Vdc
12	± 30 Vdc
13	± 40 Vdc
14	± 40 Vdc
15	28V 400cps
16	28V 800cps
17	-4 Vdc
18	± 15 Vdc
19	10V pp sq wave
20	-2.5 Vdc
21	-10 Vdc
22	31.5 Vdc
23	11.4 Vac 400cps
24	± 12 Vdc
25	± 25 Vdc
26	26 Vac ϕ C
27	ϕ B Ret.
28	3.6 Vac
29	RCS Enable
30	VMB Direct Power
31	VMA Direct Power
32	Reference Power, Servo Mtr & Att Error Amp
33	Reference Power, Rate Amp
36	AGCU Demod Reference

*

9.7 RELAY IDENTIFICATION

9.7.1 Attitude Control and Thrust Vector Control

K1	Rate Transfer Pitch
K17	Pitch Auto Control Interrupt
K2	Rate Transfer Yaw
K16	Yaw Auto Control Interrupt
K3	Yaw Auto Roll
K15	Roll Auto Control Interrupt
K4	G&N Attitude Input
K14	Attitude Impulse Enable
K5	MTVC Engage
K6	TVC Electronic Transfer
K7	SCS Delta Velocity Mode
K8	AGAA Attitude Input
K9	Entry Gain
K10	RJC Attitude; Pitch and Yaw
K11	RJC Roll Attitude
K12	Minimum Deadband, Select
K13	Pseudo Rate Cutout
K18	Roll to Yaw Rate Coupling
K10	Yaw Engine Ignition
K20	Pitch Engine Ignition

9.7.2 Attitude Reference System Logic

K32	Backup Rate Pitch
K33	Backup Rate Yaw
K34	Backup Rate Roll
K35	MTVC Rate Output
K36	AGCU Cage
K37	AGCU Cage
K38	Temporary Hold FDAI Power

*

K21	FDAI Align
K22	Attitude Set
K23	Displays Entry Gain
K24	Monitor Mode
K25	Roll Attitude Error Scale Factor
K26	Rate Scale Factor
K27	G&N Control Mode Selected
K28	G&N Entry Mode
K29	Orbit Rate
K30	Warmup
K31	Outband

MEASUREMENT IDENTIFICATION

DESCRIPTION	LOCATION				INPUT	OUTPUT (VOLTS DC)	SAMPLING RATE (S/S)
	PITCH ECA	YAW ECA	ROLL ECA	D/AGAA ECA			
Combined AG SMRD			CH2015V		Gyro Yaw Roll X X X X X 0 0 0 0 0 X X X X X 0 0 0 0 0	4.84 4.24 3.63 2.95 2.28 1.55 0.8 0.0	10
Rate	CH0024V	CH1024V	CH2024V		- 25.0 D/S 0.0 D/S + 25.0 D/S	0.0 2.5 5.0	50
Combined RG SMRD			CH2026V		SAME AS CH2015V		10
			CH2030V				
Combined AG TEMP					SAME AS CH2015V		10
Pitch Pos. Feedback In	CH0034H				- 9.5 D 0.0 D (null) + 9.5 D	0.0 2.5 5.0	50
Yaw Pos. Feedback In		CH1034H			- 5.5 D + 4.0 D (null) + 13.5	0.0 2.5 5.0	50
TV Diff Clutch Current Comb.	CH0047C	CH1047C			- 763.0 m.a. 0.0 m.a. + 763.0 m.a.	0.0 2.5 5.0	50

NOTE
 X means:
 AG speed = 24000 + 1950 rpm
 RG speed = 24000 + 195 rpm
 AG temp = 170° + 2°F
 0 = Not in above range

9.8 SCS TELEMETRY MEASUREMENT POINTS (CONT'D)

CSM
AS-501

MEASUREMENT IDENTIFICATION

DESCRIPTION	LOCATION				INPUT	OUTPUT (VOLTS DC)	SAMPLING RATE (S/S)	
	PITCH 0 ECA	YAW 1 ECA	ROLL 2 ECA	D/AGAA 3 ECA				AUX 4 ECA
Rate Error Amp Out	CH0050V	CH1050V	CH2050V		-6.25 D/S 0.0 D/S +6.25 D/S	0.0 2.5 5.0	50	
Integrator/Att. Error Summing	CH0067V	CH1067V			- 2.8 D Att. Error	1.0	10	
					- 3.5 V Integ. Output			
					-30.8 D/S Rate			
Roll Att. Error Amp Out	CH2070V				0.0 D Att. Error	2.5	10	
					0.0 V Integ. Output			
					0.0 D/S Rate			
					+ 2.8 D Att. Error			
					+ 3.5 V Integ. Output			
					+30.8 D/S Rate			
Rate Error Amp Out	CH0050V	CH1050V	CH2050V		-14.9 D Att. Error	1.0	50	
					-18.0 V Integ. Output			
					- 3.5 D Att. Error			
					- 4.2 V Integ. Output			
					0.0 Att. Error			
					0.0 V Integ. Output			
					+ 3.5 D Att. Error			
					+ 4.2 V Integ. Output			
					+14.9 D Att. Error			
					+18.0 V Integ. Output			
					-12.6 D	0.0		10
					0.0 D			
+12.6 D								
	2.5	10						
	4.0		10					
	5.0			10				

9.8 SCS TELEMETRY MEASUREMENT POINTS (CONT'D)

MEASUREMENT IDENTIFICATION

DESCRIPTION	LOCATION							INPUT	OUTPUT (VOLTS DC)	SAMPLING RATE (S/S)
	PITCH 0 ECA	YAW 1 ECA	ROLL 2 ECA	D/AGAA 3 ECA	AUX 4 ECA					
SCS Att. Error	CH0075V	CH1075V	CH2075V				- 20.0 D 0.0 D + 20.0 D	0.0 2.5 5.0	10	
RCS Solenoid Driver Out	CH0087X	CH1087X	CH2087X				Jet ON Jet OFF	0.0 → 0.5 3.5 → 5.0	200	
	CH0088X	CH1088X	CH2088X				} SAME AS ABOVE		200	
	CH0089X	CH1089X	CH2089X						200	
	CH0090X	CH1090X	CH2090X						200	
			CH2091X						200	
			CH2092X					200		
			CH2093X					200		
			CH2094X					200		
G&N Delta V Mode	CH0100X						Mode OFF Mode ON	0.0 → 0.5 3.5 → 5.0	10	
G&N Att. Mode	CH0101X						} SAME AS ABOVE		10	
G&N Entry Mode	CH0102X								10	
Monitor Mode	CH0103X								10	
SCS Delta V Mode		CH1100X							10	
SCS Att. Mode		CH1101X						10		
SCS Entry Mode		CH1102X						10		
SCS LCL Vert. Mode		CH1103X						10		
MTVC Mode Control		CH1104X					Mode OFF Mode ON	0.0 → 0.5 3.5 → 5.0	10	

9.8 SCS TELEMETRY MEASUREMENT POINTS (CONT'D)

MEASUREMENT IDENTIFICATION

DESCRIPTION	LOCATION				INPUT	OUTPUT (VOLTS DC)	SAMPLING RATE (S/S)
	PITCH 0 ECA	YAW 1 ECA	ROLL 2 ECA	D/AGAA 3 ECA			
Resolver Sin Out Pitch	Euler Angles				SIN 270° SIN 0° or SIN 180° SIN 90°	0.0 2.5 5.0	10
Resolver Cos Out Pitch					COS 180° COS 90° or COS 270° COS 0°	0.0 2.5 5.0	10
Resolver Sin Out Yaw					SAME AS CH4100H		10
Resolver Cos Out Yaw					SAME AS CH4101H		10
Resolver Sin Out Roll					SAME AS CH4100H		10
Resolver Cos Out Roll					SAME AS CH4101H		10
0.05g Reentry Sw. Mon.			CH3185X		0.05g Sw. OFF 0.05g Sw. ON	0.0 → 0.5 3.5 → 5.0	10
Delta V Remaining Pot Out			CH3186V		Delta V Rem. = -1000 Ft/S Delta V Rem. = 12999 Ft/S	0.0 5.0	10
SPS Solenoid Driver Out 2				CH4320X	Engine ON Engine OFF	0.0 → 0.5 3.5 → 5.0	50
SPS Solenoid Driver Out 1				CH4321X	SAME AS ABOVE		50

10.1 NOTES, SERVICE PROPULSION

10.1.1 SPS Engine

The SPS is composed of a rocket engine, propellant storage tanks, propellant distribution system, helium pressurization system, and a propellant utilization and gaging system.

- A. Fuel -- Aerozine 50, Unsymmetrical Dimethylhydrazine (UDMH) and Hydrazine ($N_2 H_4$) (50:50 blend)
- B. Oxidizer -- Nitrogen Tetroxide ($N_2 O_4$)
- C. O/F Ratio -- $2:1 \pm .05$
- D. Engine Life -- 500 seconds
- E. Nominal Thrust -- 21,500 lb.

10.1.2 Propellant Quantity

The total propellant supply is contained within four tanks: an oxidizer storage tank, oxidizer sump tank, fuel storage tank, and fuel sump tank. The storage and sump tanks for each propellant supply are connected in series by a single transfer line. Each sump tank contains a propellant retention reservoir. Propellant quantity is measured by two separate sensing systems; primary and auxiliary. The primary quantity sensors are cylindrical capacitance probes, mounted axially in each tank. In the oxidizer tanks, the probes consist of a pair of concentric electrodes with the oxidizer used as the dielectric. In the fuel tanks, a Pyrex glass probe, coated with silver on the inside, is used as one conductor of the capacitor. Fuel on the outside of the probe is the other conductor. The Pyrex glass itself forms the dielectric. The auxiliary system utilizes point sensors mounted at intervals along the primary probes to provide a step function impedance change when the liquid level passes their location centerline (see Table 10-1). Comparator circuits monitor propellant quantity and ratio unbalance information from both gaging systems. The SENSOR switch will be in the NORM position. The propellant quantity gaging system is operational only during engine firing. A 4.5 second firing period is required before

TABLE 10-1 SPS POINT SENSOR LOCATION

SENSOR STATION	HEIGHT (INCHES)	TANK	WEIGHT LB ABSOLUTE	WEIGHT LB GAGEABLE
8	14.55	OX SUMP	804.2	691.2
7	26.84	OX SUMP	2066.6	1858.1
6	33.83	OX SUMP	2817.0	2554.1
5	42.20	OX SUMP	3715.2	3387.3
4	80.00	OX SUMP	7772.5	7327.1
3	102.39	OX SUMP	10174.5	9729.1
2	116.38	OX SUMP	11676.0	11230.5
1	138.76	OX SUMP	14077.9	13632.4
MAX LEVEL	153.26	OX SUMP	15481.0	15035.5
7	22.87	OX STORAGE	17130.1	16684.6
6	59.12	OX STORAGE	21033.5	20588.0
5	94.90	OX STORAGE	24887.0	24441.6
4	117.21	OX STORAGE	27289.0	26843.5
3	131.06	OX STORAGE	28780.8	28335.3
2	133.84	OX STORAGE	29080.9	28635.5
1	137.47	OX STORAGE	29471.4	29025.9
MAX LEVEL	145.70	OX STORAGE	30343.4	29897.2
8	14.22	FUEL SUMP	415.5	345.6
7	26.89	FUEL SUMP	1061.2	929.0
6	34.28	FUEL SUMP	1445.6	1277.0
5	43.00	FUEL SUMP	1894.8	1693.6
4	81.08	FUEL SUMP	3881.2	3663.5
3	104.16	FUEL SUMP	5082.1	4864.5
2	118.59	FUEL SUMP	5832.9	5615.2
1	141.67	FUEL SUMP	7033.9	6816.2
MAX LEVEL	156.72	FUEL SUMP	7738.1	7520.3
7	22.22	FUEL STORAGE	8342.3	8342.3
6	59.62	FUEL STORAGE	10512.0	10244.3
5	96.53	FUEL STORAGE	12438.5	12220.8
4	119.54	FUEL STORAGE	13639.6	13421.9
3	133.83	FUEL STORAGE	14385.3	14167.6
2	136.70	FUEL STORAGE	14534.4	14317.7
1	140.47	FUEL STORAGE	14730.6	14512.9
MAX LEVEL	140.01	FUEL STORAGE	15171.2	14953.8

*

propellant quantity information is updated, when the SENSOR switch is in the NORM position. Ground display drops to zero.

- A. Total Fuel capacity 15,300 pounds
- B. AS-501 loading 10,333
- C. Total oxidizer capacity 30,600 pounds
- D. AS-501 loading 20,667

10.1.3 Propellant Utilization

A propellant utilization valve is installed to the oxidizer supply line between the heat exchanger unit and the engine oxidizer main orifice assembly. The fuel supply line connects directly from the heat exchanger unit to the engine main fuel orifice assembly. The propellant utilization valve is only manually controlled from the CM by the OXID FLOW switch (MDC 20) and is for adjustments in oxidizer flow which may be necessary to insure simultaneous propellant depletion. The propellant utilization valve consists of a motor-operated, redundant, double-blade valve assembly providing increased, decreased, or normal oxidizer flow rates. The PU valve primary or secondary gage servo operation is selected manually by the VALVE switch (MDC 20). The valve flow area is controlled by a three-position OXID FLOW switch, Increased (47.74 lb/sec), Normal (46.06 lb/sec), and Decreased (44.48 lb/sec). There is no ground TM on the PU valve positions. There will be no ground control of the PU valve. It will be manually placed in the NORM position prior to CM closeout and remain in that position for the entire flight.

10.1.4 Gimbal Actuators

Thrust vector control of the service propulsion engine is effected by two servo-controlled electromechanical actuators. Each actuator is a sealed unit and contains a primary and secondary motor, a primary and secondary set of extend and retract electromagnetic particle clutches, a bull gear and a ball nut, a jackscrew, three position transducers, and two rate transducers. The actuator control limits in the Y - Y axis

*

(pitch) allow engine deflections of 6 (+1/2, -0) degrees in either direction from a zero degree null offset and 7 (+ 1/2, -0) degrees in the Z -Z axis (yaw), about a +4 degree null offset. A snubbing device limits the actuator overtravel to one degree beyond the control limits. Actuator maximum rates are 0.13 radians/sec (8 degrees/sec). An overcurrent/undercurrent relay is connected between the actuator drive motor and Master Control Programer. The relay provides for drive motor starting and current monitoring during actuator operation. The relay will automatically trip (50 amps over, 5 amps under), removing power from the actuator drive motor in the event of either an overcurrent or undercurrent condition. The secondary system is protected by a 70 amp circuit breaker only. During normal operations, both the primary and secondary gimbal drive motors are operating, but only the primary set of clutches is commanded (two pitch, two yaw). If a malfunction occurs in the primary drive, the overcurrent relay removes power and provides a signal to the SCS to switch clutch commands to the secondary channel. The gimbal motors are turned on normally by a signal from the G&N to the MCP, which in turn, activates the four motors ON at 1/2 second intervals. The gimbal motors may also be turned on by sending RTC 22 (direct ullage) and RTC 11 (direct thrust ON). Prior to thrusting, the engine is initially aligned by the MCP gimbal position set discrete. When an extend or retract clutch command is received, the corresponding clutch shaft rotates, driving the ball gear and ball nut, which causes the jackscrew to reposition the engine gimbal. The velocity generators and position transducers provide feedback to the SCS summing logic and thereby controls the jackscrew. One position transducer in each actuator provides a signal to drive the applicable gimbal position indicator on MDC 6.

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10.1.5 Helium Isolation Valves

There are two helium isolation valves which are solenoid-actuated poppet valves. The control of these valves is either manual or automatic. The control method is selected from two three-position switches (AUTO, OFF, ON) on MDC 20. Normal switch position is in AUTO. This allows the valves to be opened at the SPS fire command signal and closed at removal of the fire command. The ON position is a manual override position which will open the valve at any time. The switch will be in the AUTO position for this flight.

10.1.6 Gaseous Nitrogen (GN₂) Tanks

Two GN₂ tanks are mounted on the engine injector assembly. GN₂ pressure is used to overcome the actuator spring pressure upon SPS fire command. There are two manually operated solenoid valves (INJECT PRE-VALVE, MDC 3) installed downstream on each GN₂ tank. The prevalues will be energized open by the MCP when gimbal motors are commanded ON. In the ON position, the valves allow GN₂ pressure to flow to two pilot control valves, which in turn control the pneumatic actuators. When the SPS fire signal is received by the pilot control valves, GN₂ pressure overcomes the actuator spring pressure and opens the main propellant ball valves. At removal of the fire command, the GN₂ is vented overboard through the pilot control valve and the spring pressure closes the main propellant ball valves. Each GN₂ tank is capable of 30 SPS ENGINE starts.

10.1.7 NORMAL, OFF, DIRECT-ON Switch

This switch supplies dc power to the control solenoid valves through the MCP. The control solenoid valves are armed by the MCP at LV/SC SEP plus 2.5 seconds by the closure of latching relays 1k47 and 1k56. This arming supplies +28 Vdc to the control valves enabling the SPS engine to be fired by either the thrust vector control logic or RTC 11 (DIRECT THRUST ON). If RTC 11 (DIRECT THRUST ON) is transmitted, RTC 13 (RESET CMDS 10-12) or RTC 12 (DIRECT THRUST OFF) must be sent in order to shutdown the SPS ENGINE. When RTC 12 (DIRECT THRUST OFF) C 11

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is transmitted, the SPS Arm Relays Reset (unlatch) thus removing +28 Vdc to the control valves thereby shutting down the SPS ENGINE. The NORMAL, OFF, DIRECT-ON Switch will be placed in the NORMAL position prior to CM closeout and remain there throughout the flight.

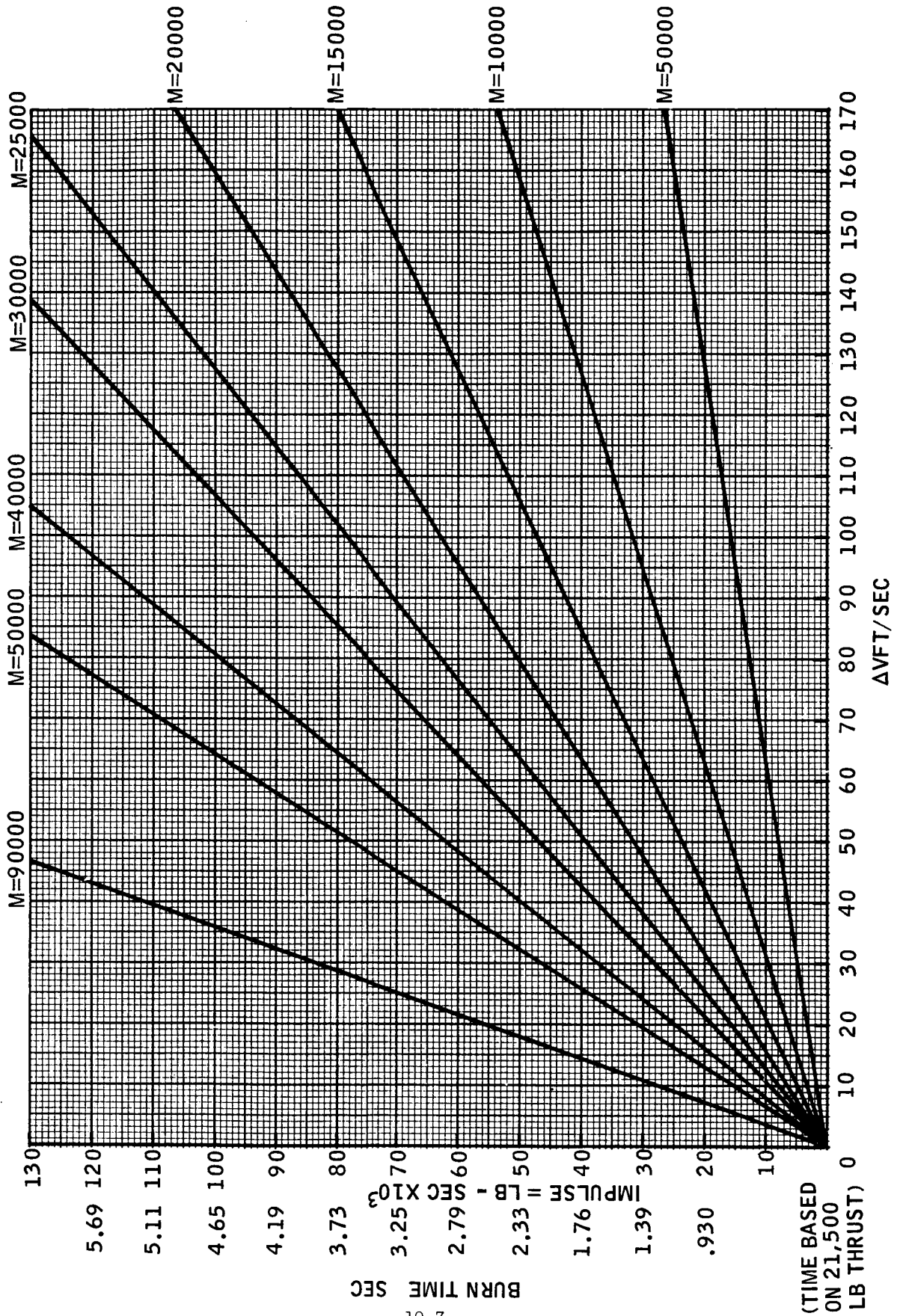


FIGURE 10.1 PROPULSION - SPS TOTAL IN PULSE VS ΔV

M-WT OF C/SM

- A. NORMAL SETTLING WITH 4 RCS ENGINES
- B. 2 RCS ENGINES

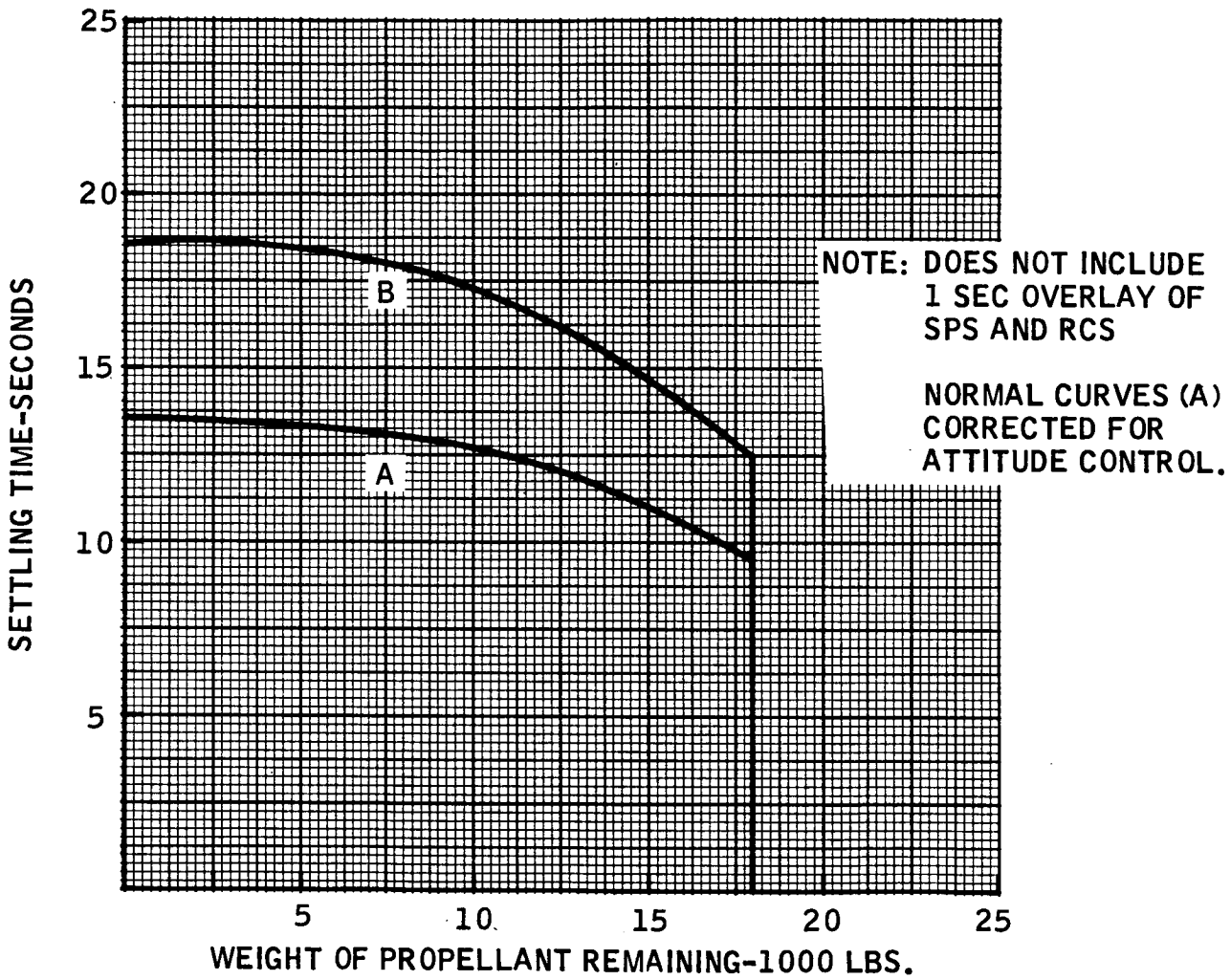
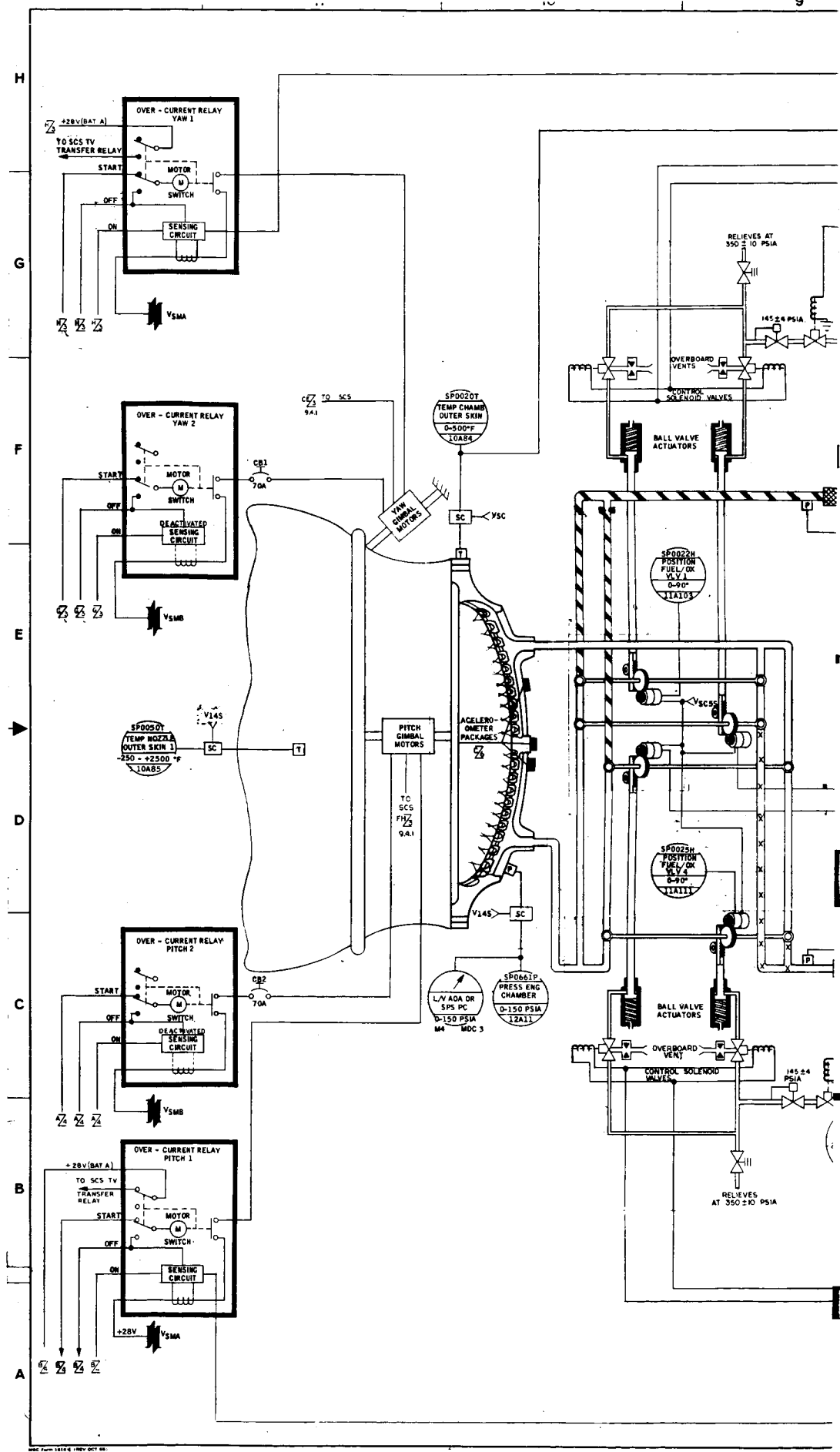
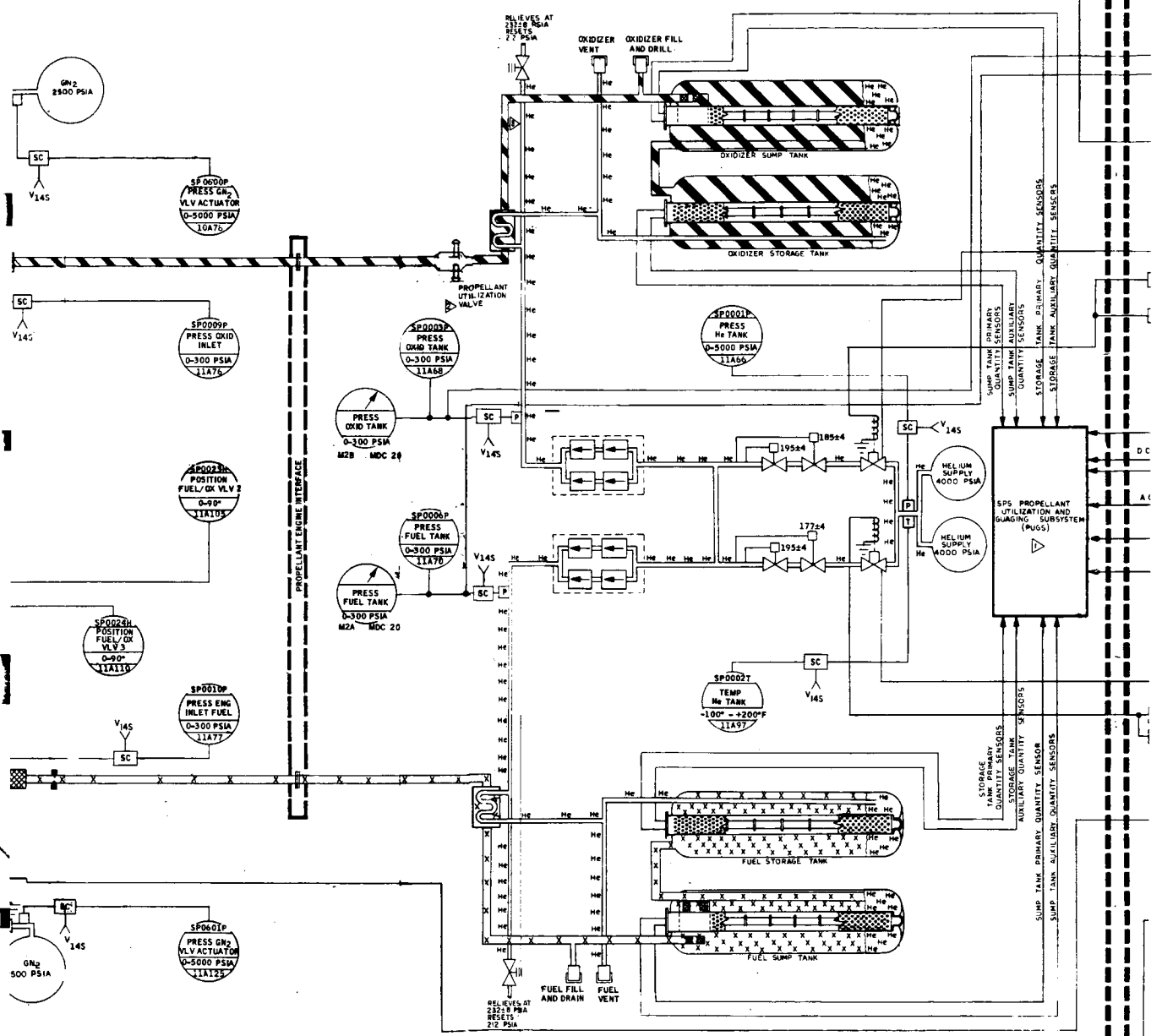
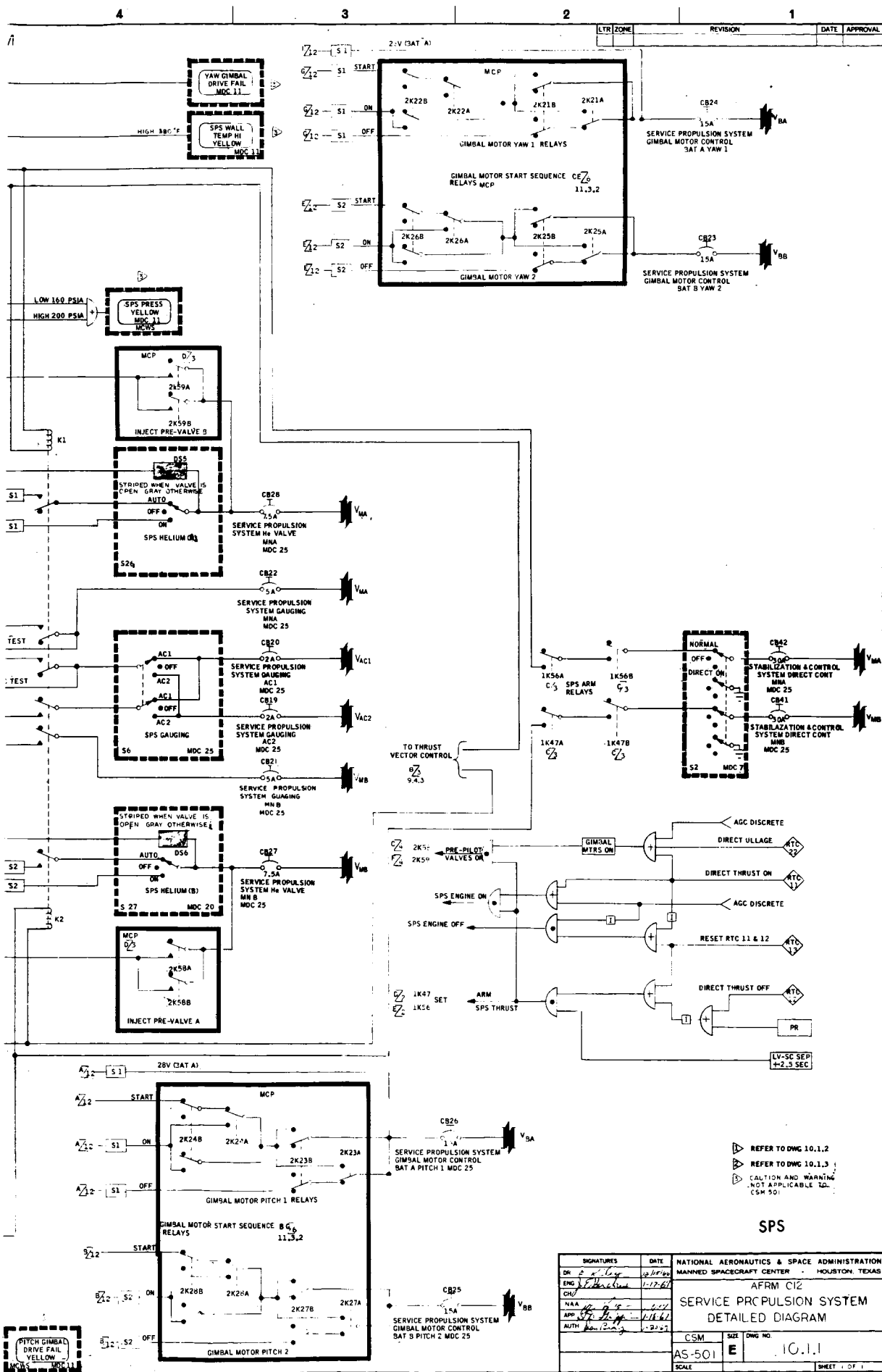


FIGURE 10.2 PROPULSION - SETTLING TIME VS PROPELLANT REMAINING.



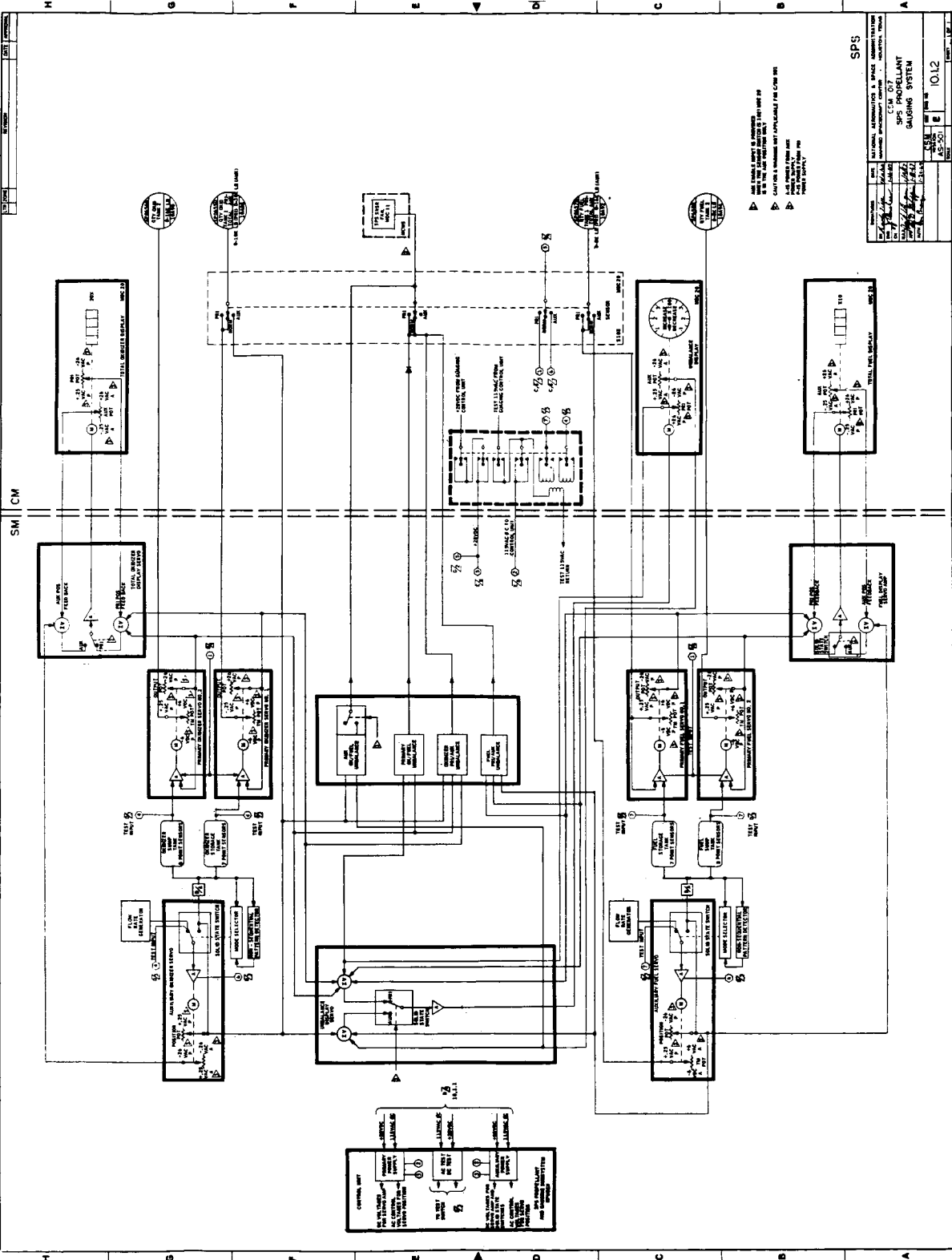




REFER TO DWG 10.1.2
 REFER TO DWG 10.1.3
 CAUTION AND WARNING
 NOT APPLICABLE TO
 CSM 501

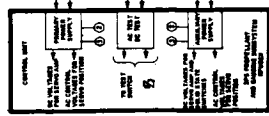
SPS

SIGNATURES		DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION	
DR	<i>[Signature]</i>	12/10/68	MANNED SPACECRAFT CENTER - HOUSTON, TEXAS	
ENG	<i>[Signature]</i>	1-12-69	AFRM C12	
CHK			SERVICE PROPUSSION SYSTEM	
NAA			DETAILED DIAGRAM	
APP	<i>[Signature]</i>	1-16-69	CSM	
AUTH	<i>[Signature]</i>	1-20-67	SIZE	DWG NO.
			AS-501	E 10.1.1
			SCALE	SHEET 1 OF 1

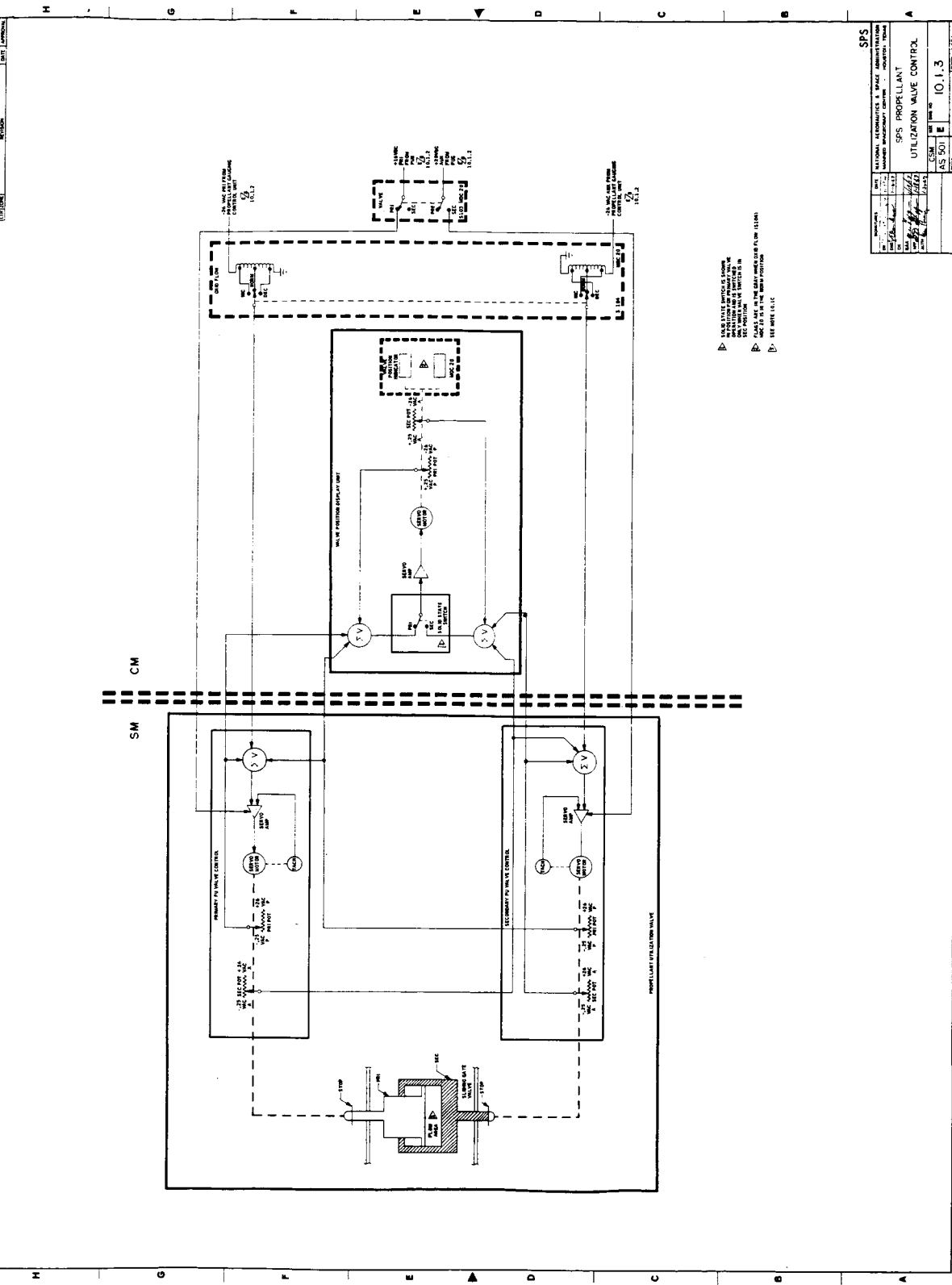


SPS NATIONAL AERONAUTICS & SPACE ADMINISTRATION SPACE OPERATIONS DIVISION SPS PROPELLANT GAUGING SYSTEM	
DRAWING NO. 10.12 DATE 10-1-68 BY [Signature] CHECKED [Signature]	PROJECT NO. 10.12 DRAWING NO. 10.12

- ▲ USE THIS SYMBOL TO INDICATE THE LOCATION OF THE GAUGE OR SWITCH ON THE PROPELLANT GAUGING SYSTEM
- ▲ USE THIS SYMBOL TO INDICATE THE LOCATION OF THE GAUGE OR SWITCH ON THE TOTAL FUEL DISPLAY
- ▲ USE THIS SYMBOL TO INDICATE THE LOCATION OF THE GAUGE OR SWITCH ON THE TOTAL PROPELLANT DISPLAY
- ▲ USE THIS SYMBOL TO INDICATE THE LOCATION OF THE GAUGE OR SWITCH ON THE TOTAL PROPELLANT DISPLAY



SM | CM



1. UNLESS OTHERWISE SPECIFIED, ALL PARTS AND MATERIALS SHALL BE OF THE QUALITY AND GRADE SPECIFIED IN THIS DRAWING.
 2. CHECK DATE OF THE DRAWING AND OF THE REV. 10.1.3.
 3. SEE NOTE 1.1.1.

SPS	
NATIONAL AERONAUTICS & SPACE ADMINISTRATION	
SPS PROPELLANT UTILIZATION VALVE CONTROL	
AS 501	10.1.3
REV	DATE
1	10/1/68
2	10/1/68
3	10/1/68
4	10/1/68
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10.2 NOTES, SERVICE MODULE, REACTION CONTROL SYSTEM

10.2.1 General

The SM/RCS consists of four individual, functionally identical packages located 90 degrees apart around the SM periphery (forward +X Axis) and offset from the S/C Y and Z axes by 7.25 degrees (CCW) and canted 10 degrees from the SM surface. Each quad incorporates a pressure feed positive-expulsion, pulse-modulated, bi-propellant system to produce the reaction thrust required. The reaction engines may be pulse or continuously fired.

10.2.2 RCS Engines

- A. Fuel -- Monomehtylhydrazine (MMH)
- B. Oxidizer -- Nitrogen Tetroxide (N₂O₄)
- C. O/F Ration -- $2.1 \pm .05$
- D. Thruster Life -- 1000 seconds pulse mode
500 seconds continuous burn
- E. Nominal Thrust -- 100 ± 5 lb

10.2.3 Propellant Quantity

- A. Fuel -- 65 each quad usable
- B. Oxidizer -- 121 each quad usable
- C. Total usable (4 quads) -- 790 lb

10.2.4 SM/RCS Propellant Quantity Computation

SM/RCS propellant quantity will be computed by a PVT method with pressures and temperatures using the RTCC and the Offline Computer for computations.

10.2.5 Helium Isolation Valves

The helium supply flows from the helium tank into two parallel helium isolation valves. The valves are a two-solenoid valve and are mechanically latched open and spring-loaded close. The normal valve position is open. No ground commands (RTC) for the helium isolation valves.

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10.2.6 Propellant Isolation Valves

Propellant isolation valves are two-solenoid valves which are magnetically latched open and spring-loaded closed. A fuel and oxidizer valve is controlled by a real-time command, both open and closed commands (one command for each quad).

Real-Time Commands

Quad	Open	Closed
A	32	24
B	33	25
C	34	26
D	35	27

10.2.7 RCS Quad Heaters

Each SM/RCS quad engine housing contains an electrical strip heater. Control of these heaters is automatic through thermostatic switches; range 115°F minimum and 134°F maximum. Power is supplied by Main Bus A +28 Vdc, for Quads B and D, and Main Bus B +28 Vdc for quads A and C. Circuit breakers are located on MDC 21. Heater operation is monitored by TM. (Engine package temp.)

10.2.8 Service Module RCS Jettison Controller (SMJC)

At CM/SM separation, the SMJC will command continuous firing of the -X jets (manual coils). This function is to provide an adequate separation distance between the CM and SM. After two seconds, the +roll jet will fire for 5.5 seconds for spin stabilization. The -X jets will fire until propellant depletion or electrical power loss. The SMJC consists of two complete redundant systems.

10.2.9 Propellant Solenoid Injector Control Valves (Fuel and Oxidizer)

The solenoid injector valves utilize two coaxially wound coils; one for automatic and one for direct manual operation. The automatic coil is utilized when the command is generated within the jet selection logic (SCS). The manual coils are used for commands originating from the

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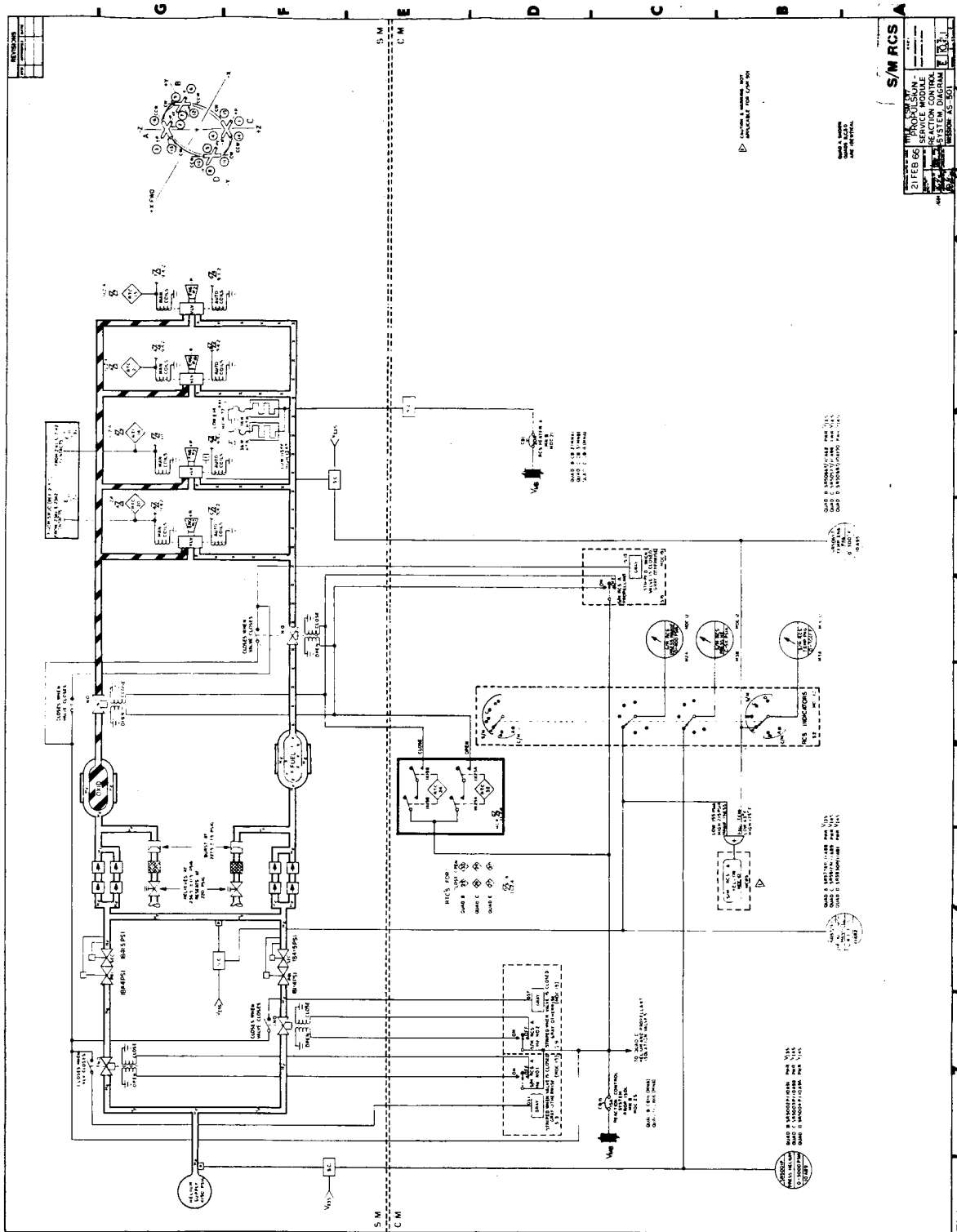
real-time commands and direct ullage. The valves are spring-loaded closed and electrically energized open. The fuel injector valves reach the full OPEN position in approximately 7 milliseconds and the oxidizer in approximately 9 milliseconds, giving a 2-millisecond fuel lead. The automatic coils (fuel and oxidizer) are connected in parallel, while the manual coils are connected in series. Auto coils are connected in parallel to prevent mismatch between opening and closing of the valves due to heat soak back. The series connection of the fuel manual coils (positive to negative) to the oxidizer coil (negative to positive) then to ground, increases the arc suppression, reducing the arc at the rotation controller in the DIRECT RCS MODE.

Real-Time Commands

<u>Direction</u>	<u>RTC</u>
+ Pitch	14
- Pitch	15
+ Yaw	16
- Yaw	17
+ Roll	20
- Roll	21

10.2.10 Attitude Control Maneuvers

Attitude control of the spacecraft can be accomplished by any two adjacent quads, either using the automatic mode (SCS) or direct mode (real-time commands). The ullage maneuver (SPS propellant settling) is accomplished by four jets (+X).



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10.3 NOTES, COMMAND MODULE, REACTION CONTROL SYSTEM

10.3.1 General

The CM/RCS consists of two separate independent systems, with one system capable of complete control. In low altitude (L/O to less than L/O +42 seconds) abort operation, provisions have been incorporated to automatically dump the oxidizer supply overboard, followed by a helium purge of the remaining helium supply. Normal reentry and after L/O +42 seconds, remaining propellants are dumped and then purged manually by the crew. Tanks will be pressurized to lesser value (60 psia, normal 291 psia) until system activation.

10.3.2 RCS Engines

- A. Fuel -- Monomethylhydrazine (MMH)
- B. Oxidizer -- Nitrogen Tetroxide (N₂O₄)
- C. O/F Ratio -- 2:1 ± .05
- D. Thruster Life -- 200 seconds
- E. Nominal Thrust -- 93 lb

10.3.3 Propellant Quantity Gaging

No propellant quantity gaging system on the CM/RCS.

10.3.4 Propellant Isolation Valves (Fuel And Oxidizer)

The isolation valves are two solenoid valves and are magnetically latched open and spring loaded closed. These valves allow fuel and oxidizer to flow to the injector valves and are controlled by a three-position (ON, HOLD, OFF) toggle switch (one switch per system) on MDC 15. The two propellant isolation valves will be placed in the open position, by MCP command, prior to CM/SM SEP to insure that the valves remain open upon system pressurization. No ground commands (RTC) for the CM/RCS propellant valves.

10.3.5 CM/RCS Pressurization

The CM/RCS will remain in STANDBY condition until CM/SM SEP. This is accomplished by isolating the high pressure helium with pyro

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squib valves. Each RCS system incorporates two squib valves which are blown one second prior to CM/SM SEP by the MESC. The MESC receives the signal for pressurization from the MCP. The RCS Tank pressures will be approximately 60 psia until system activation, at which time the pressures will increase to nominal regulated pressures.

10.3.6 CM/RCS Dump/Burn and Purge

There are two sequences for propellant jettison. One sequence is employed in event of an abort from launch pad to T+42 seconds. The second sequence is for a normal reentry or abort after T+42 seconds.

10.3.6.1 Sequence of Events For An Abort, Pad to T+42 Seconds:

(PROP JETT LOGIC Switch ON at L/O)

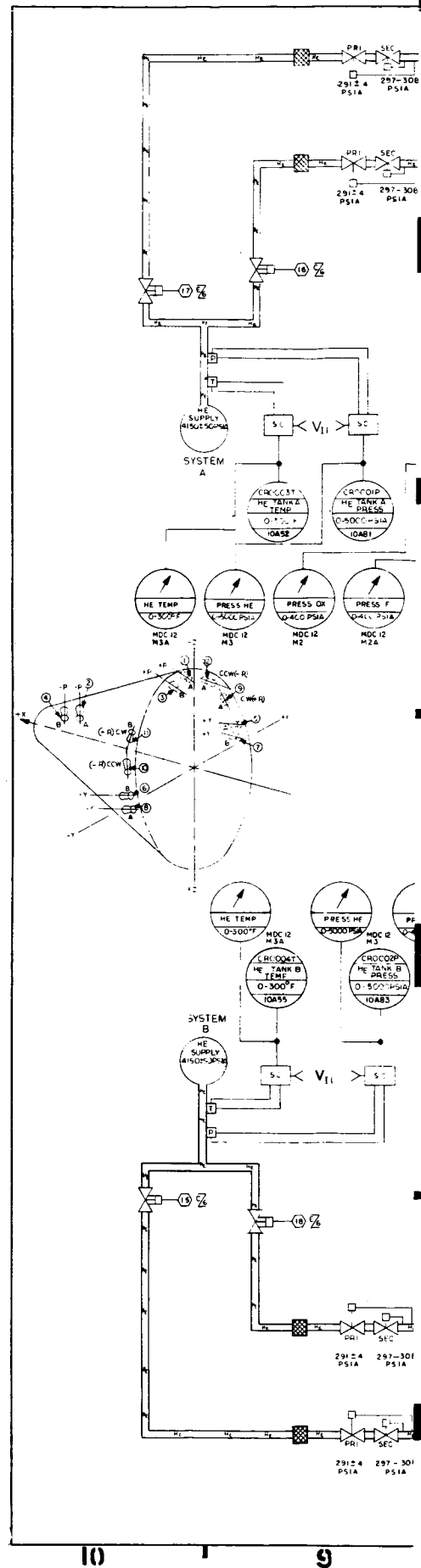
- A. At abort signal reception (LES ABORT), the four helium isolation squibs are initiated open (by closure of C/SM deadface relay), pressurizing A and B systems.
- B. Simultaneously, the oxidizer helium interconnect valve is initiated open, the propellant isolation valves (both fuel and oxidizer) are closed, and the oxidizer propellant interconnect is initiated open. The oxidizer overboard blowout plus is opened, dumping the oxidizer through the aft heat shield. The entire oxidizer supply is dumped in 13 to 15 seconds.
- C. At abort plus 18 seconds, the helium interconnect squib valve and the helium overboard dump is opened, dumping helium into the aft equipment compartment thus relieving the high-pressure helium. The oxidizer tank bypasses are also initiated open, allowing a complete oxidizer purge. The fuel remains onboard at impact, with no pressure on the fuel tanks.

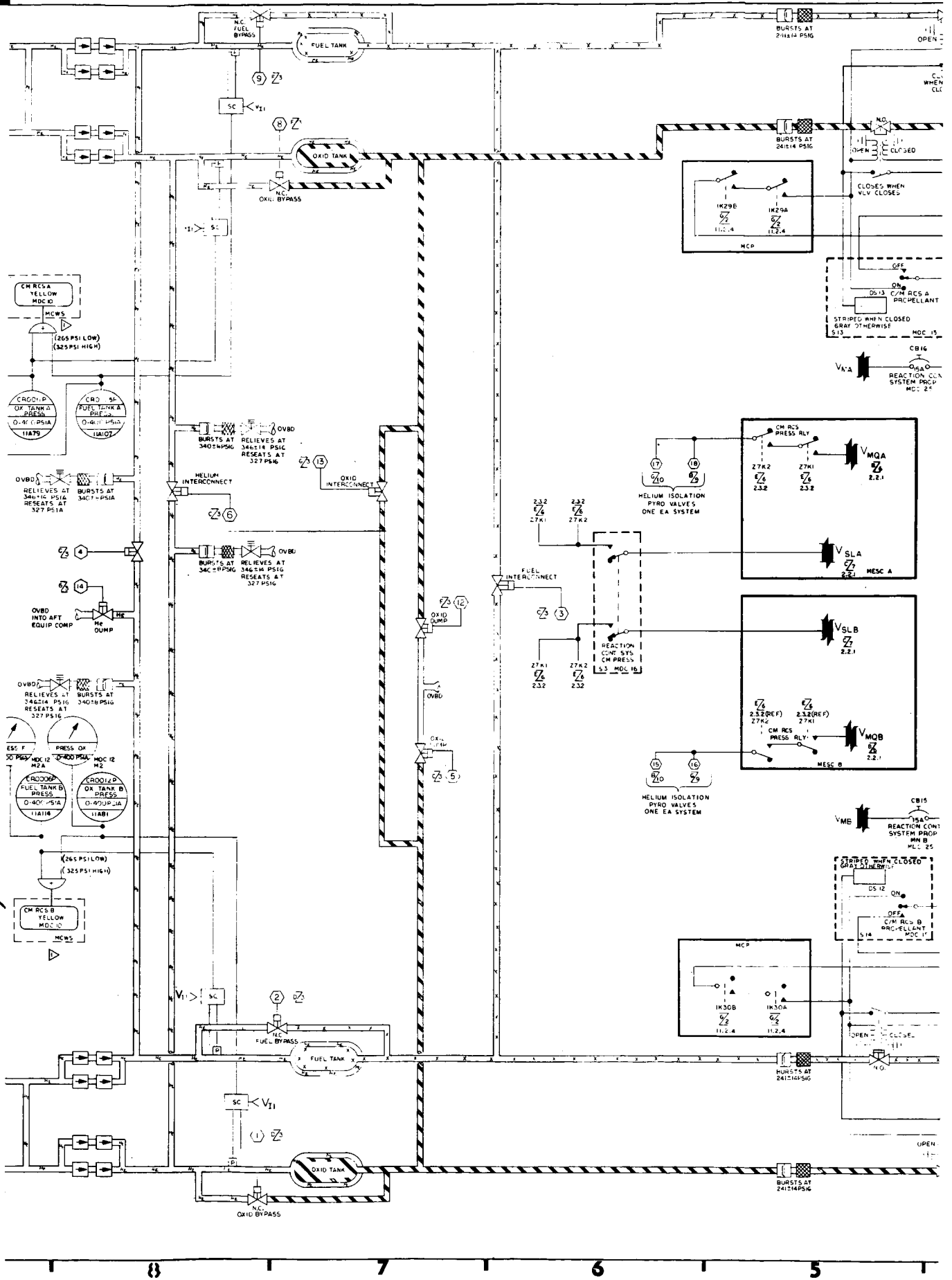
At abort plus 80 seconds, the RCS purge is activated, thus giving a redundant method of reducing the high-pressure helium. At T+42 seconds, the OX DUMP AUTO is disabled which inhibits auto oxidizer dump. Any abort after T+42 is the same as the normal reentry procedure.

*
10.3.6.2 Sequence of Events For A Normal Reentry or Abort Above T+42

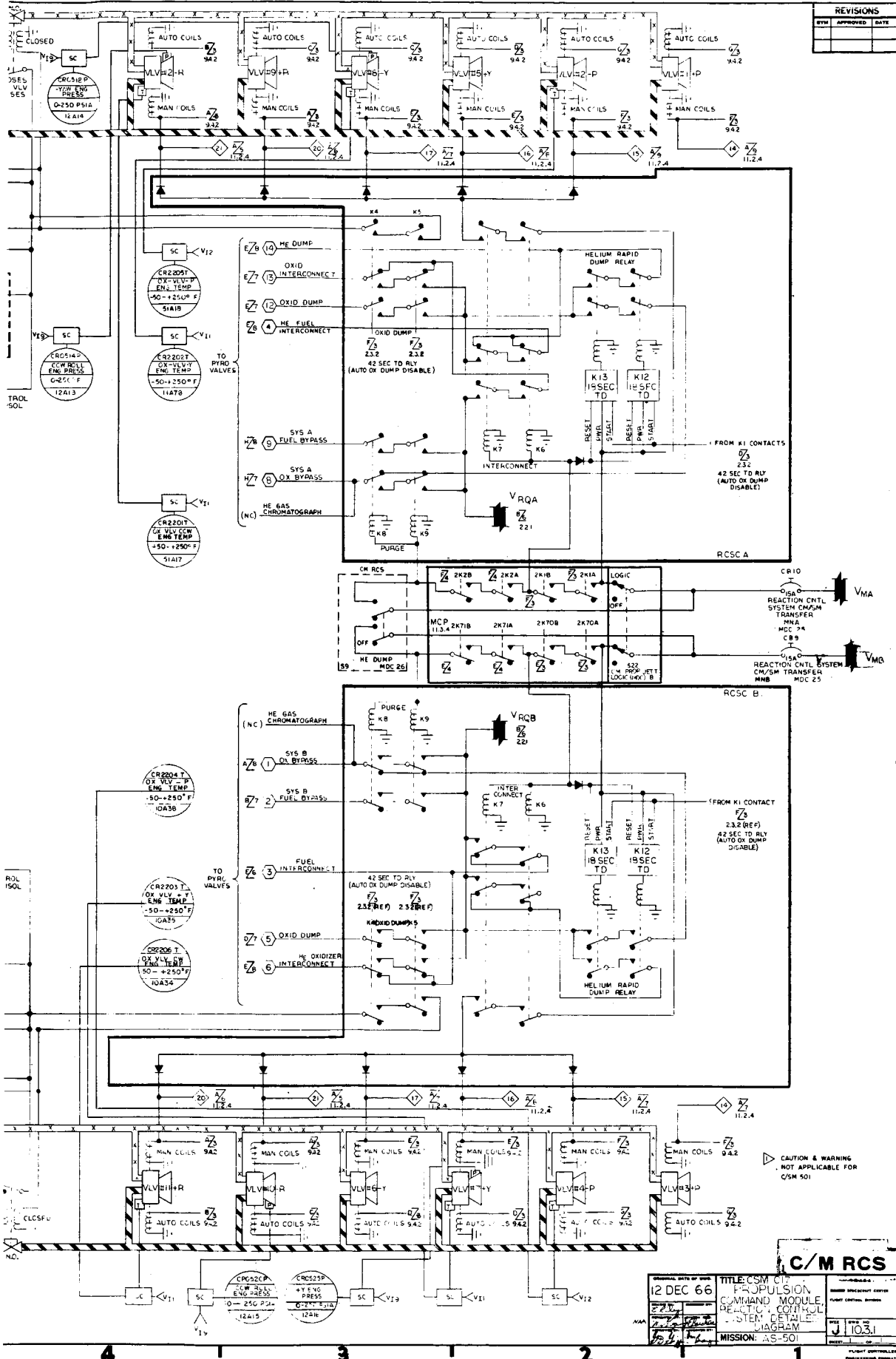
Seconds: (PROP JETT LOGIC Switch ON Prior to L/O)

- A. After the spacecraft is on the main chutes (12k baro + 20 seconds), RCS DUMP is activated. This simultaneously initiates OPEN two helium interconnect squib valves, fuel and oxidizer squib valves, and the injector valves of ten of the twelve engines (+ pitch jets not energized) burning the remaining propellants through the engines.
- B. Upon completion of propellant burn (250 second time delay), the PROP JETT PURGE is activated. This function will initiate the four helium bypass squib valves allowing helium pressure to bypass around the fuel and oxidizer tanks and out of the ten engines.





REVISIONS	
BY	DATE



CAUTION & WARNING
NOT APPLICABLE FOR
C/SM 501

12 DEC 66		TITLE: C/M RCS PROPULSION COMMAND MODULE REACTION CONTROL SYSTEM - DETAIL WIRING DIAGRAM	
MISSION: AS-50		SCALE: 100:1	
DESIGNED BY: [Signature]		CHECKED BY: [Signature]	
DRAWN BY: [Signature]		APPROVED BY: [Signature]	

4 1 3 1 2 1 1

SECTION 11

MISSION CONTROL PROGRAMER

CSM
AS-501

*

11.1 MISSION CONTROL PROGRAMER (MCP), GENERAL

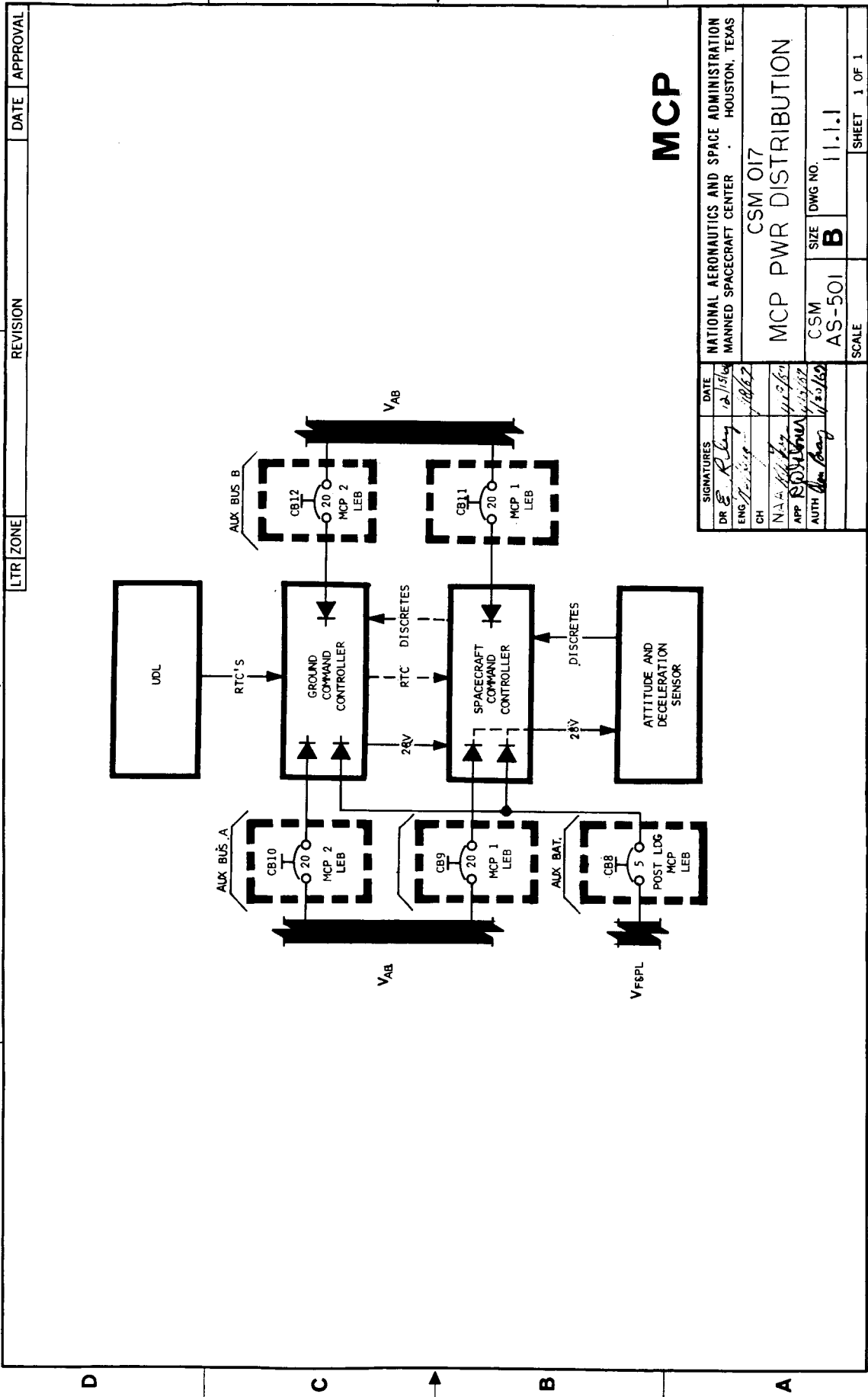
11.1.1 MCP Components

The MCP is comprised of three major components:

- A. Ground Command Controller (GCC)
- B. Spacecraft Command Controller (SCC)
- C. Attitude and Deceleration Sensor (ADS)

The equipment is mounted on a platform that replaces the crew couches. Coolant is provided by the ECS glycol coolant loop. MCP internal power is derived from the Auxiliary Battery Buses A and B. The postlanding power is provided by the Flight and Postlanding Bus. Upon impact, the auxiliary batteries are transferred to the F&PL Bus, deactivating a portion of the MCP. The SCC and GCC have independent internal power distribution, with crossovers for isolated functions. The ADS derives its power from the SCC.

4	3	2	1

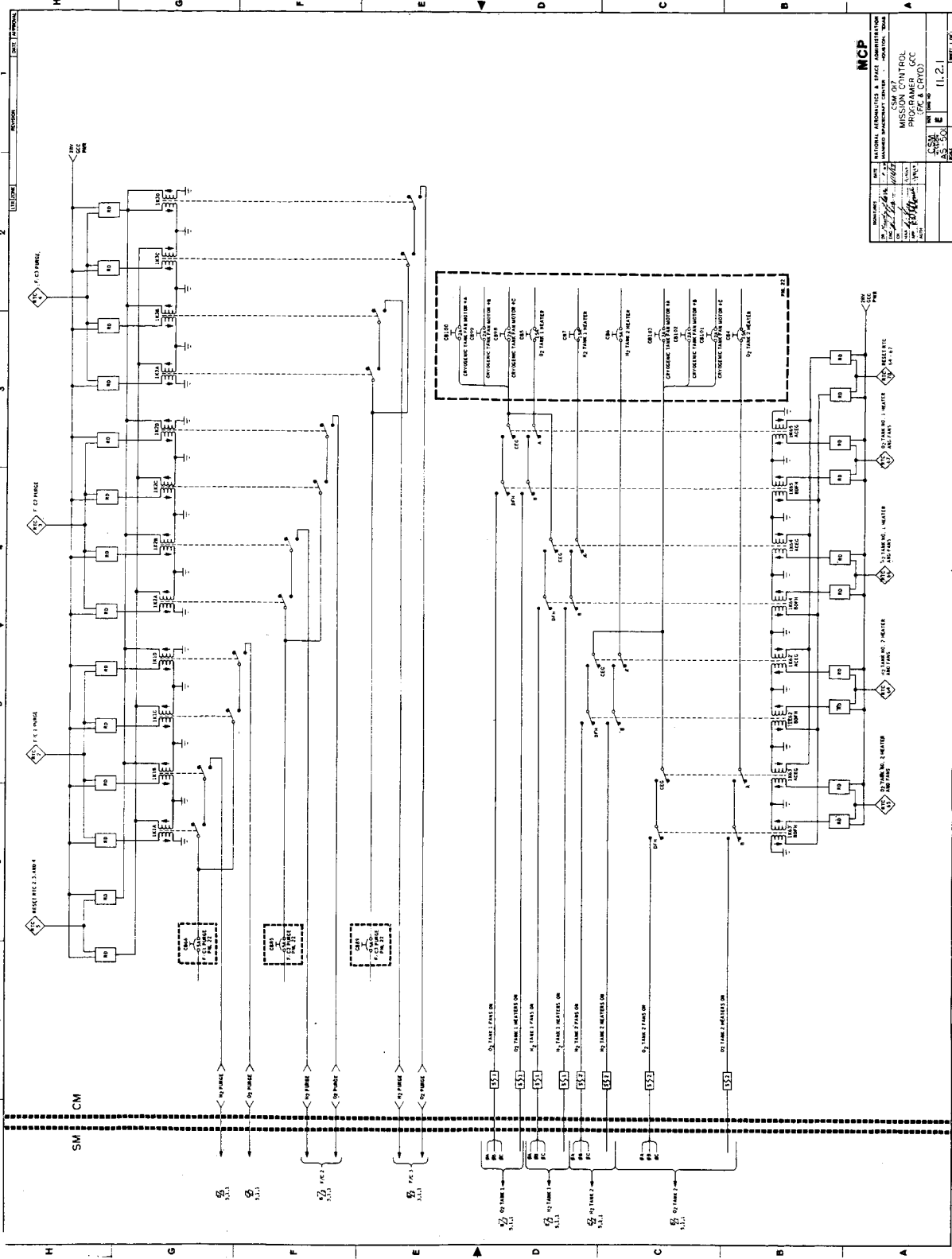


MCP

SIGNATURES		DATE	NATIONAL AERONAUTICS AND SPACE ADMINISTRATION	
DR E. R. Riley	12/19/64	MANNED SPACECRAFT CENTER HOUSTON, TEXAS		
ENG. J. J. ...	1/18/67	CSM 017		
CH		MCP PWR DISTRIBUTION		
N.A.S.A.	1/18/67	CSM	SIZE	DWG NO.
APP. J. J. ...	1/18/67	AS-501	B	11.1.1
AUTH. J. J. ...	1/18/67	SCALE		
			SHEET 1 OF 1	

*
11.2 GROUND COMMAND CONTROLLER (GCC)

All RTC's are received from the UDL through the GCC. Upon receipt of a given RTC, the required logic is set up in the GCC to perform the given function. In some incidences, the RTC is converted to a discrete and routed directly from the GCC to the SCC where the logic is set up to perform the function.



MCP		
DESIGNER	DATE	REV
APPROVED	DATE	REV
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C/S & CRYO.		
CSM		
AS-500		
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II.2.1		
REV. 1		

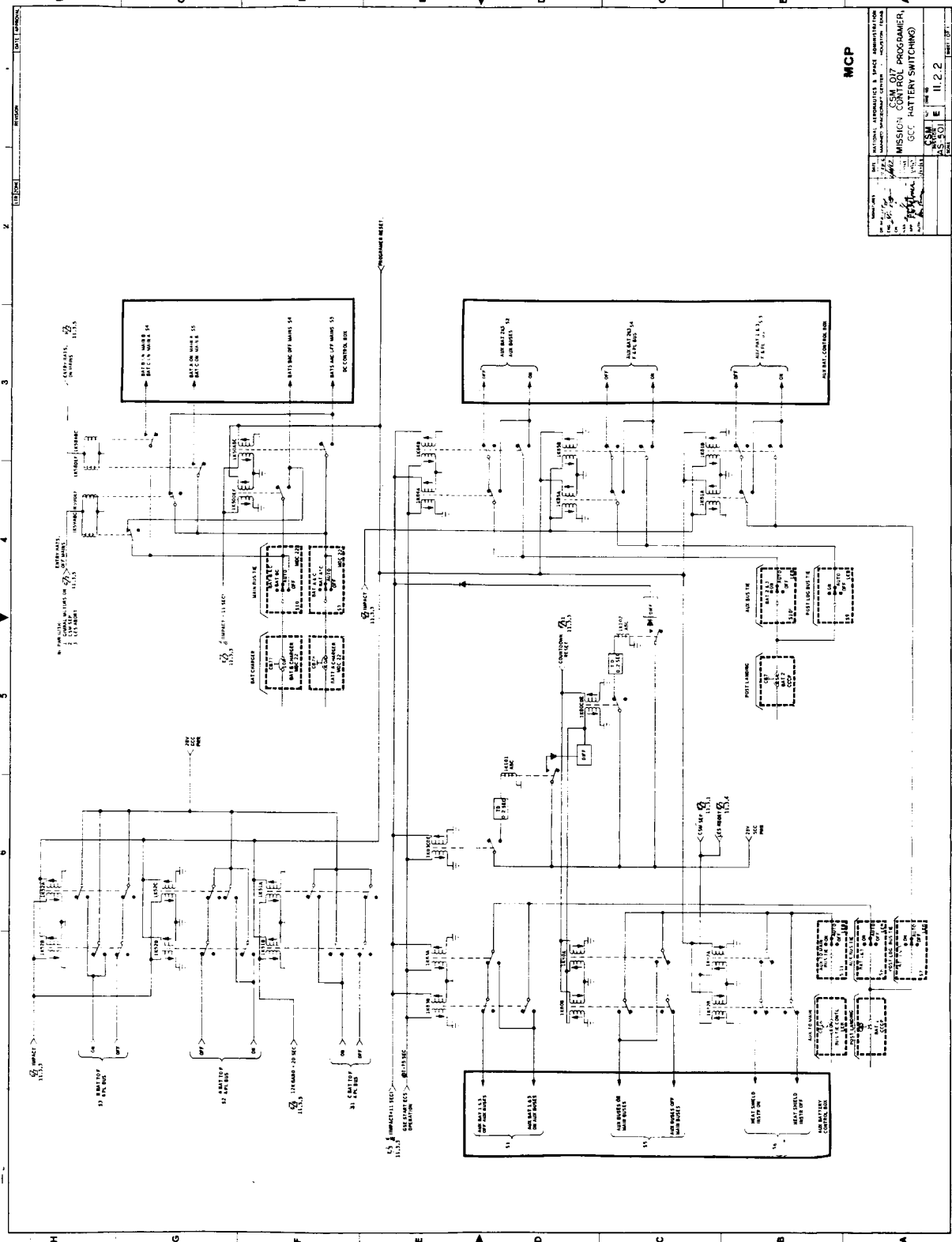
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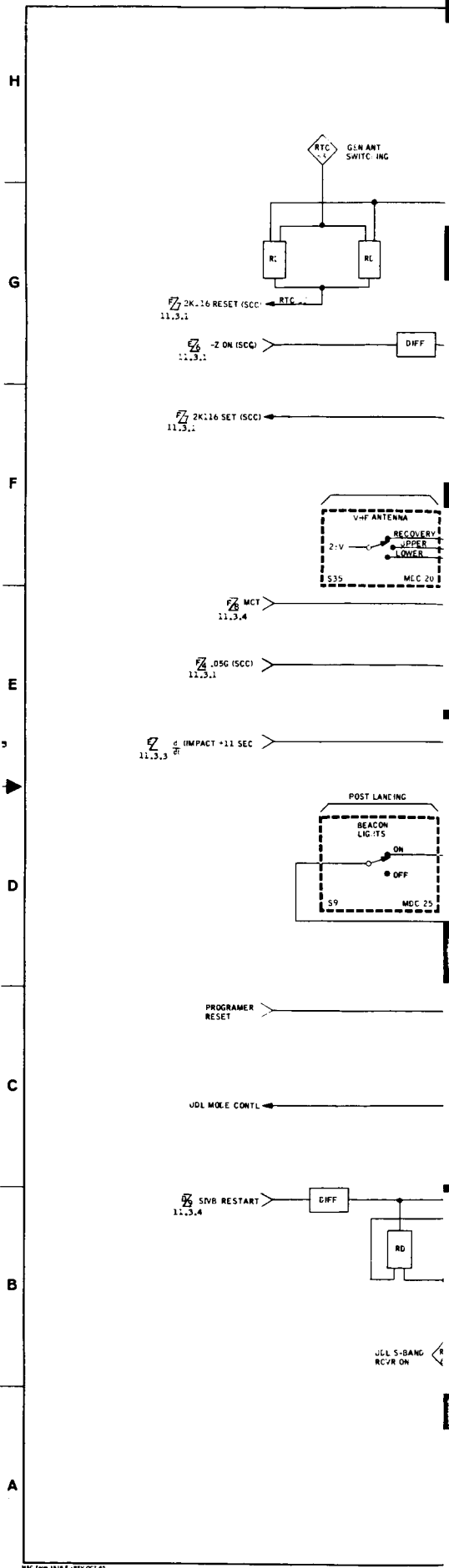
PROJECT: NATIONAL AERONAUTICS & SPACE ADMINISTRATION
PROGRAM: Manned Space Program
SUBPROGRAM: Gemini
MISSION: GEMINI 11
FUNCTION: MCC BATTERY SWITCHING
FORM NO. 34-8901 E 11.2

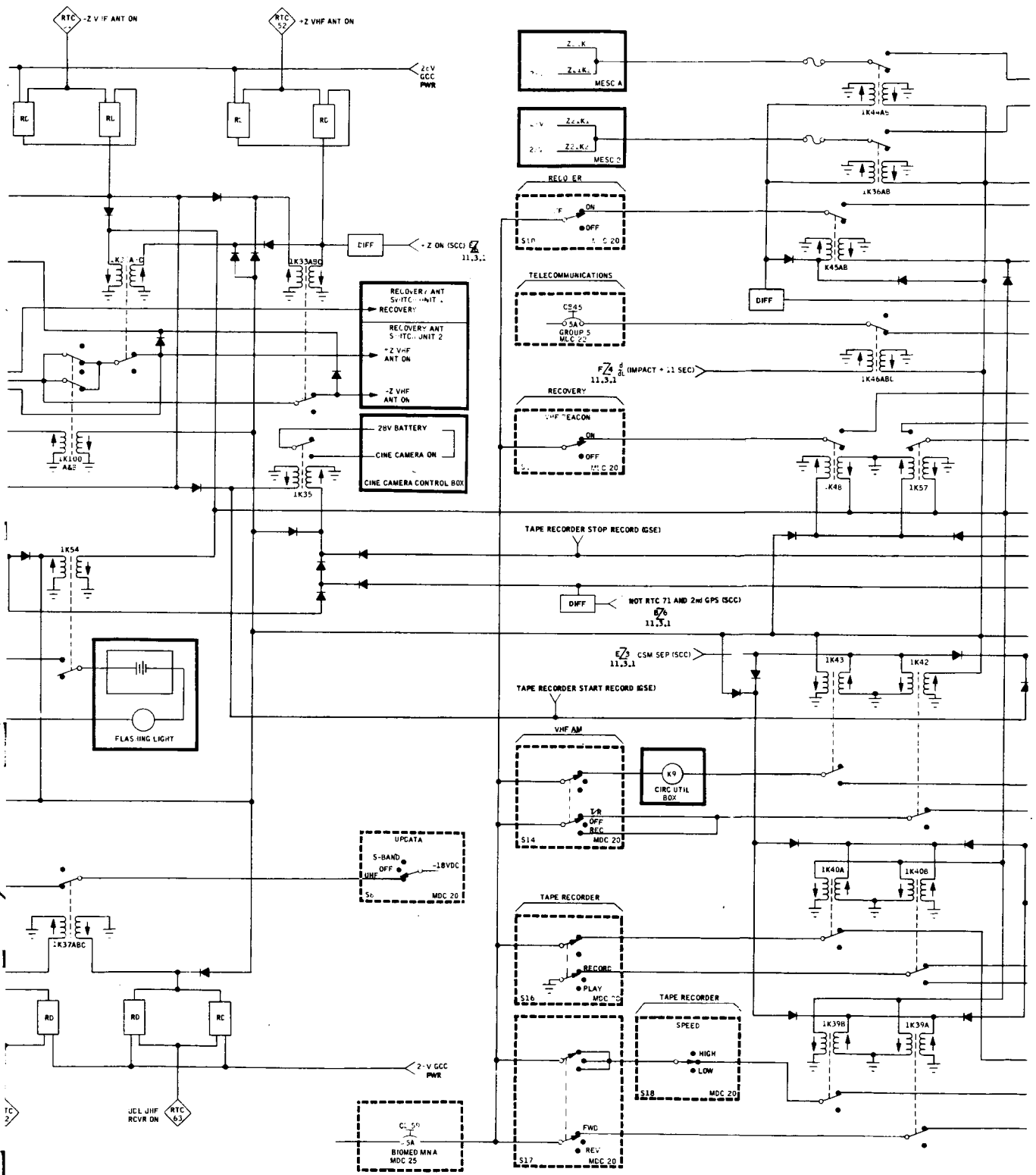


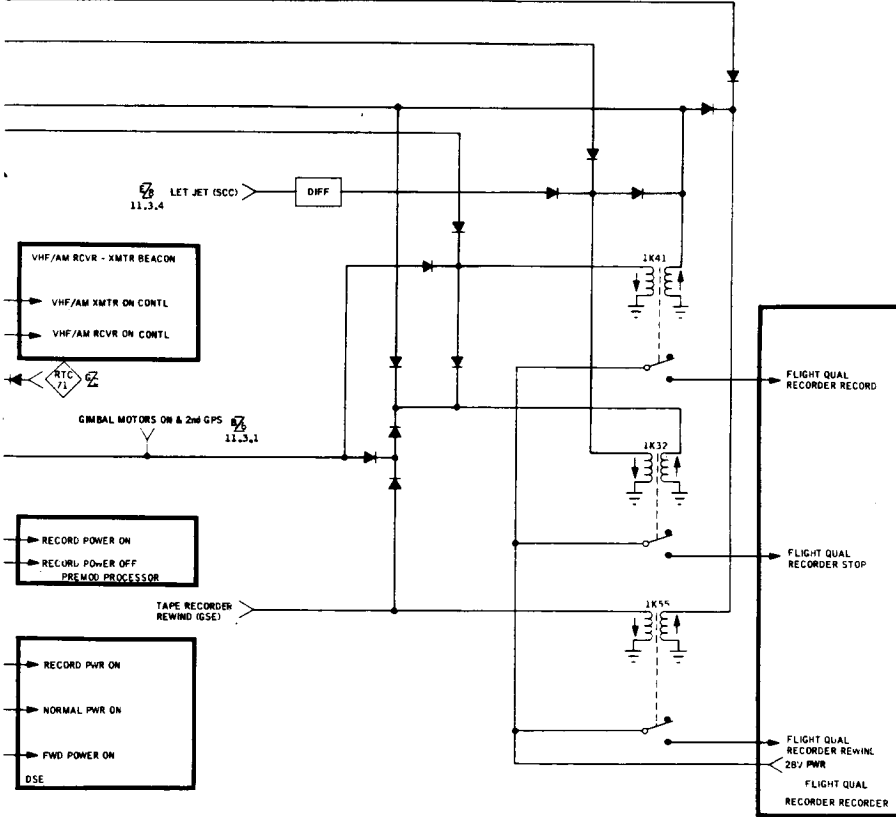
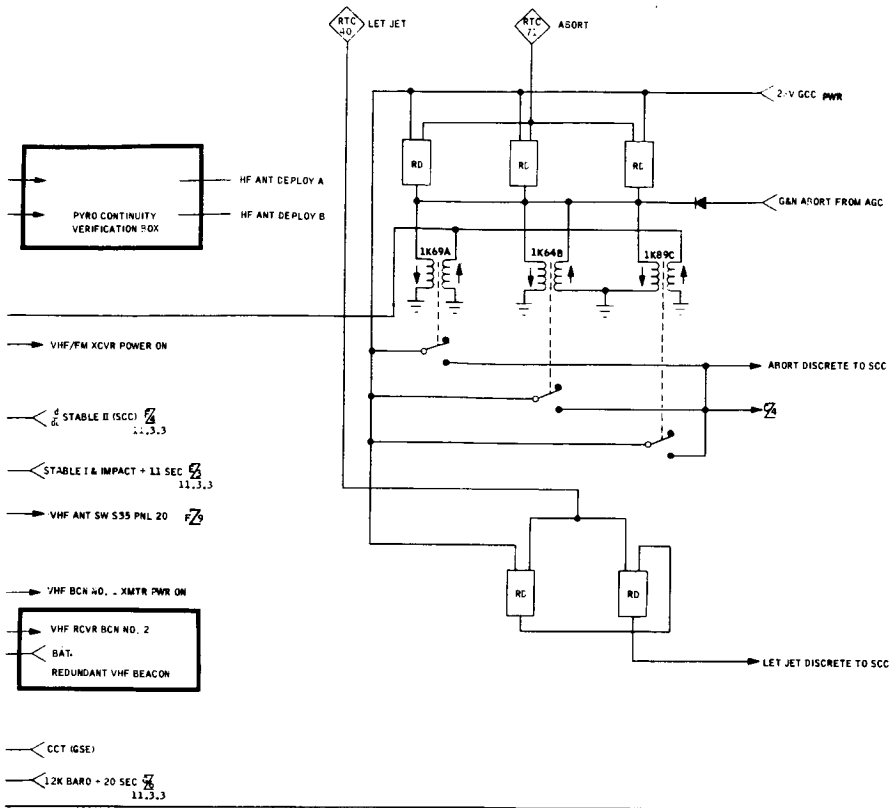
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VHF/AM XCVR - XMTR BEACON
 VHF/AM XMTR ON CONTRL
 VHF/AM XCVR ON CONTRL

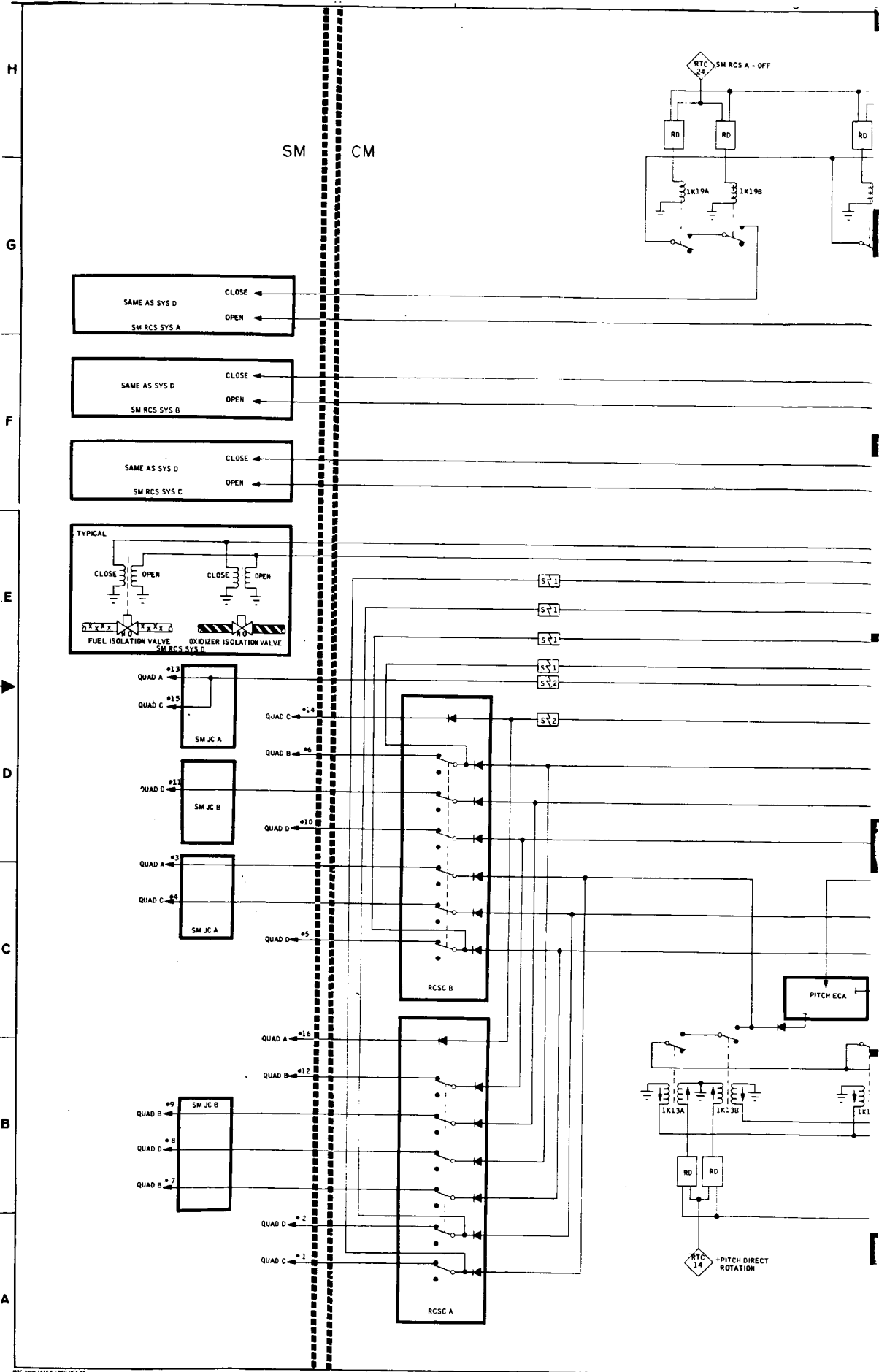
RECORD POWER ON
 RECORD POWER OFF
 PREMOD PROCESSOR

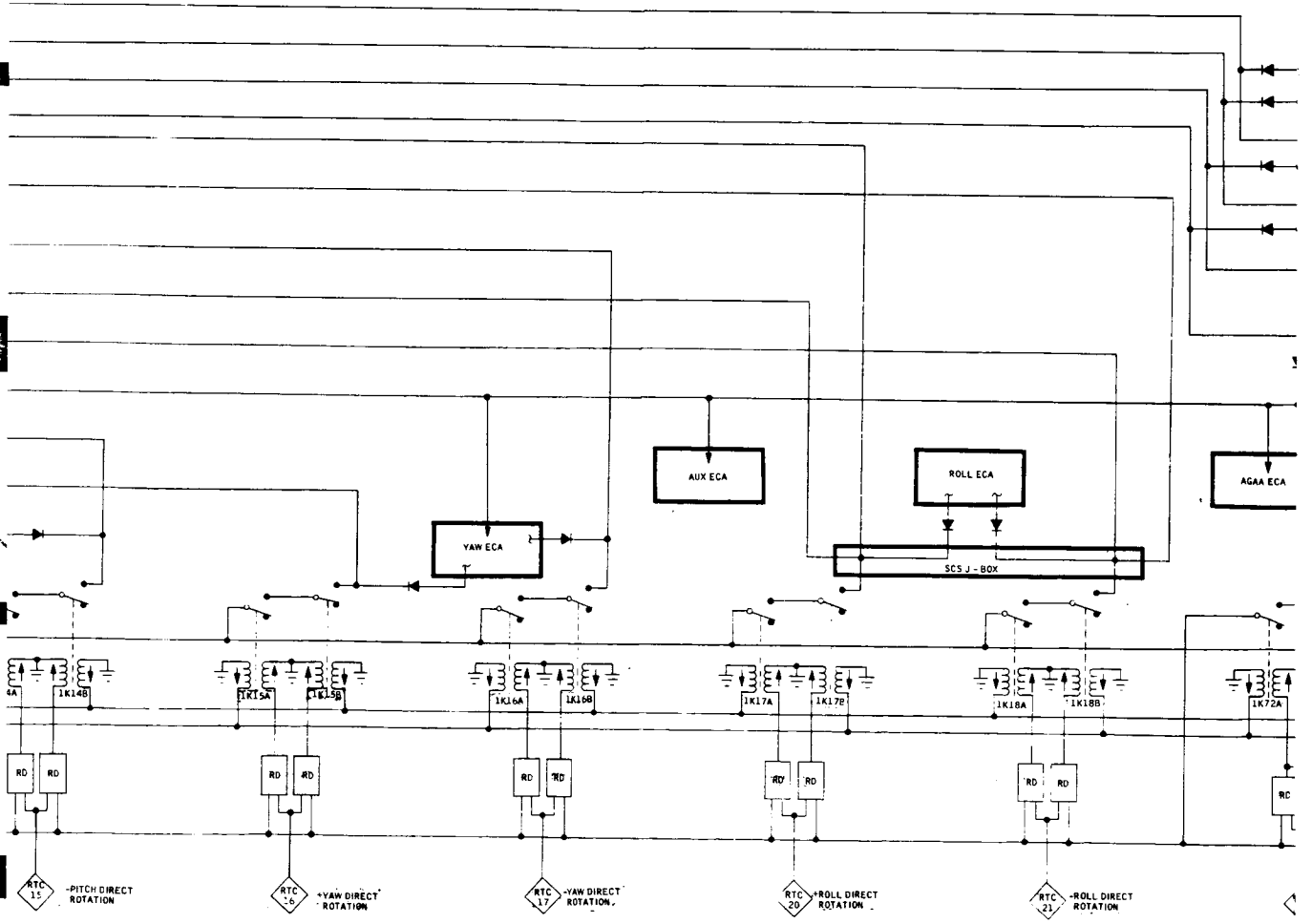
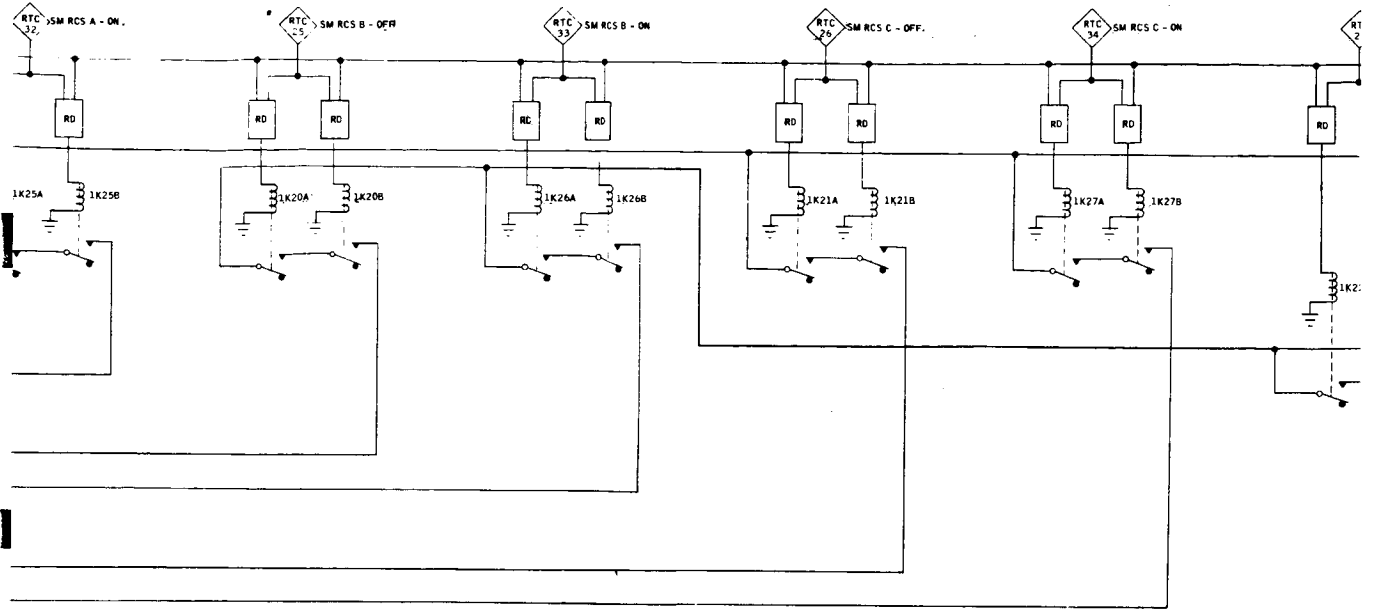
RECORD PWR ON
 NORMAL PWR ON
 FWD POWER ON
 DSE

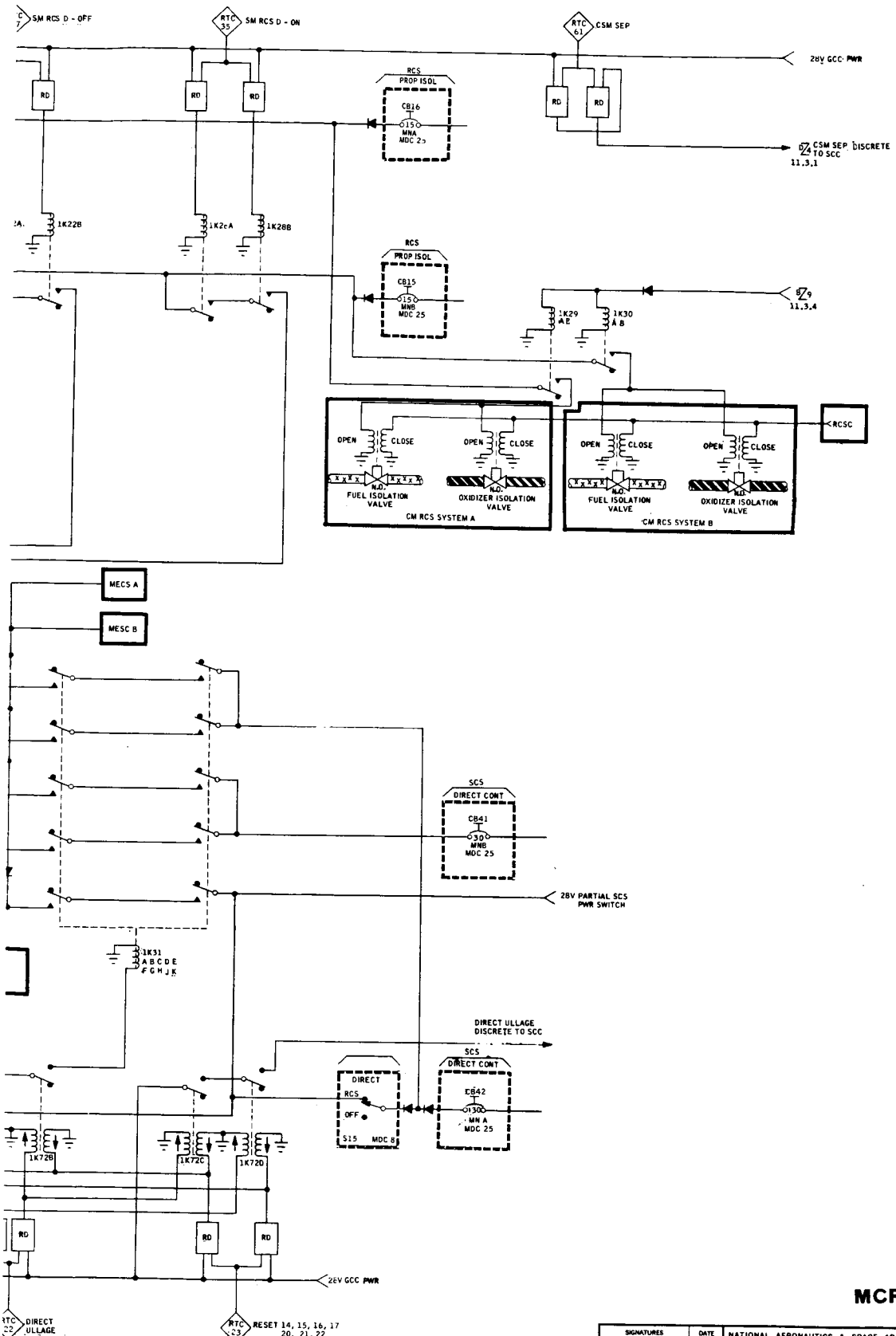
FLIGHT QUAL RECORDER RECORD
 FLIGHT QUAL RECORDER STOP
 FLIGHT QUAL RECORDER REWIND
 28V PWR
 FLIGHT QUAL RECORDER RECORDER

MCP

SIGNATURES		DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION MANNED SPACECRAFT CENTER - HOUSTON, TEXAS	
DR		11/27		
ENG		11/27		
CH		11/27		
TITLE			CSM 017 MISSION CONTROL PROGRAMMER, GCC (COMM & INSTR).	
APP				
AUTH		1/24/69		
CSM MISSION AS-501		SIZE	DWG NO	11.2.3
SCALE		E	SHEET 1 OF 1	



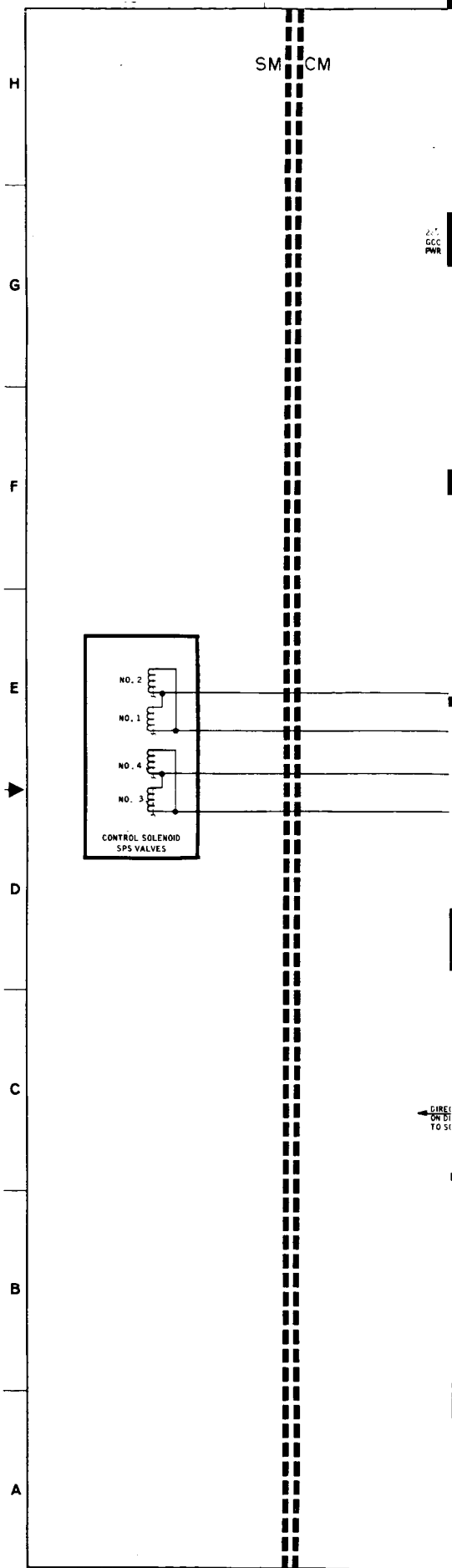


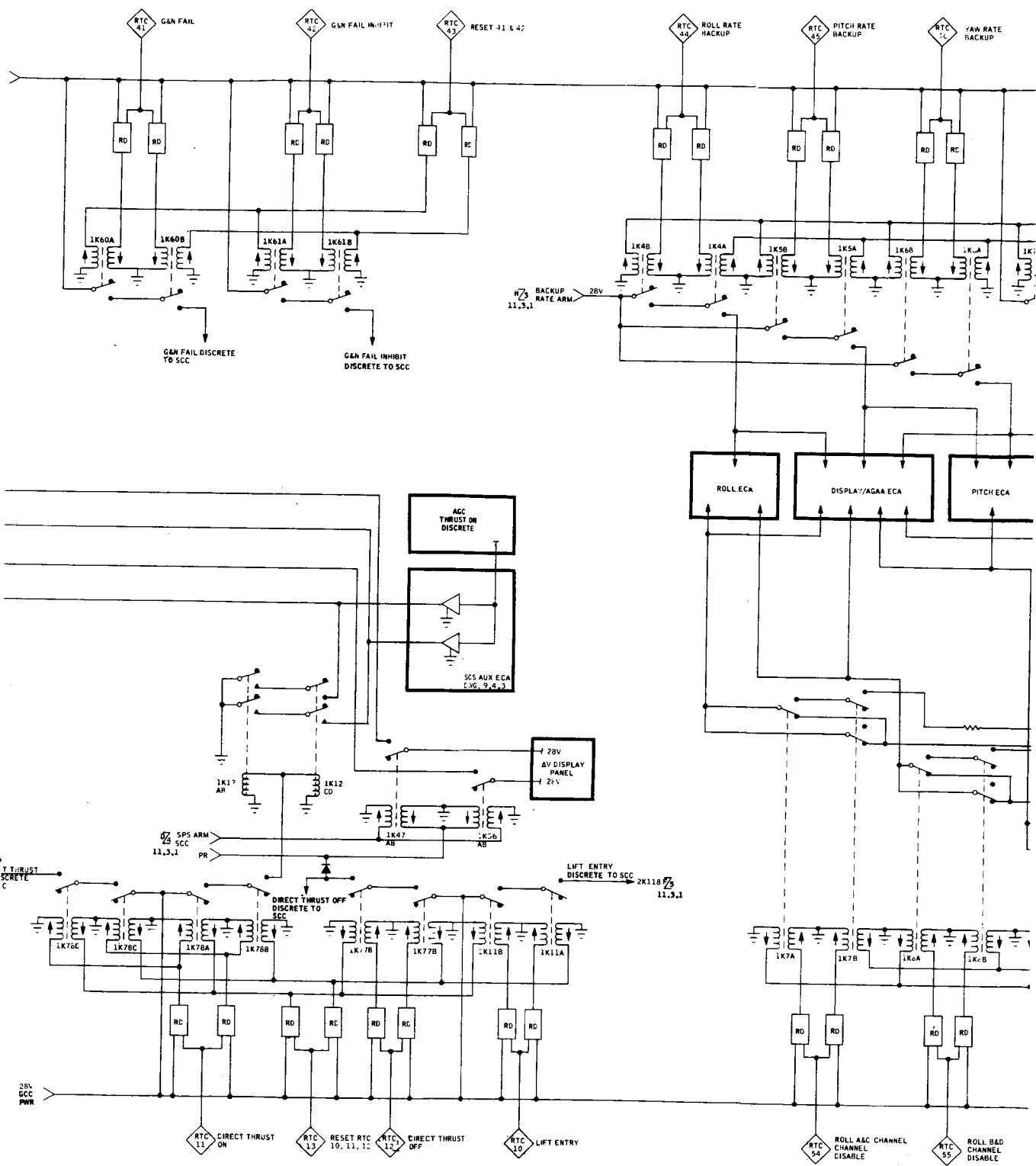


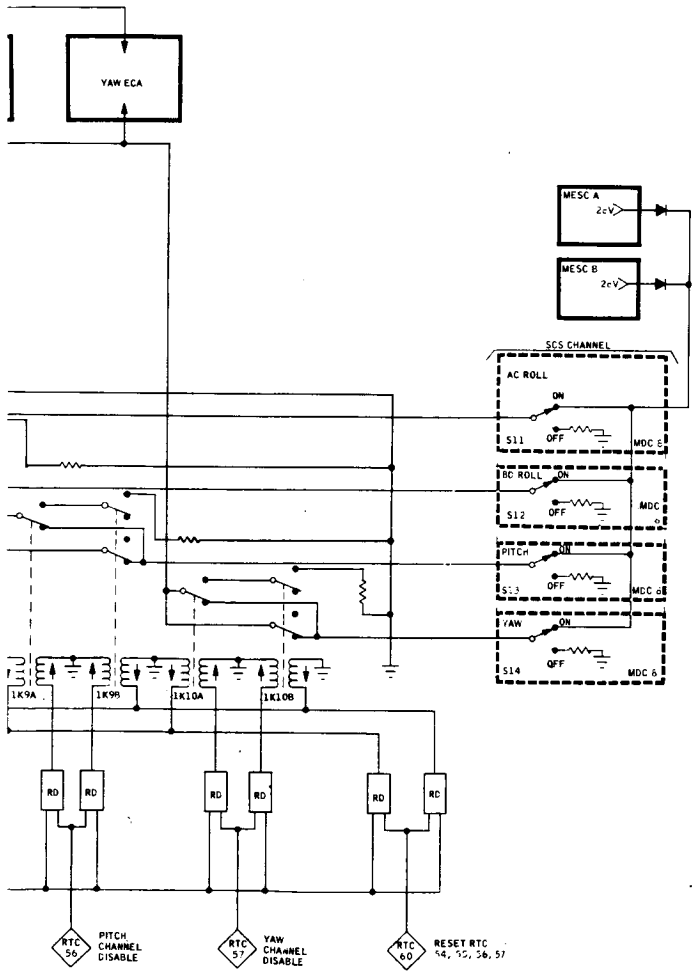
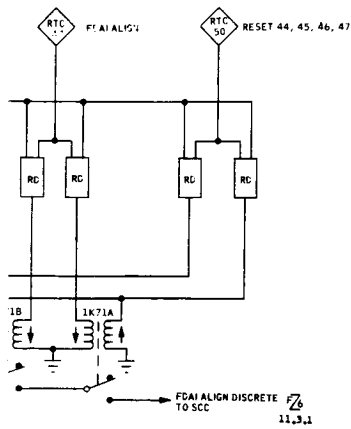
MCP

SIGNATURES		DATE		NATIONAL AERONAUTICS & SPACE ADMINISTRATION	
DR <i>[Signature]</i>		1/19/67		MANNED SPACECRAFT CENTER - HOUSTON, TEXAS	
ENGR <i>[Signature]</i>		1/18/67		<p align="center">CSM 017 MISSION CONTROL PROGRAMMER, GCC (RCS)</p>	
CH <i>[Signature]</i>		1/18/67			
NAA <i>[Signature]</i>		1/18/67			
APP <i>[Signature]</i>		1/18/67			
AUTH <i>[Signature]</i>		1/18/67		<p>CSM SIZE DWG NO MISSION AS-501 J 11.2.4</p>	
		SCALE		SHEET 1 OF 1	

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NOTES:
PR: PROGRAMMER RESET

MCP

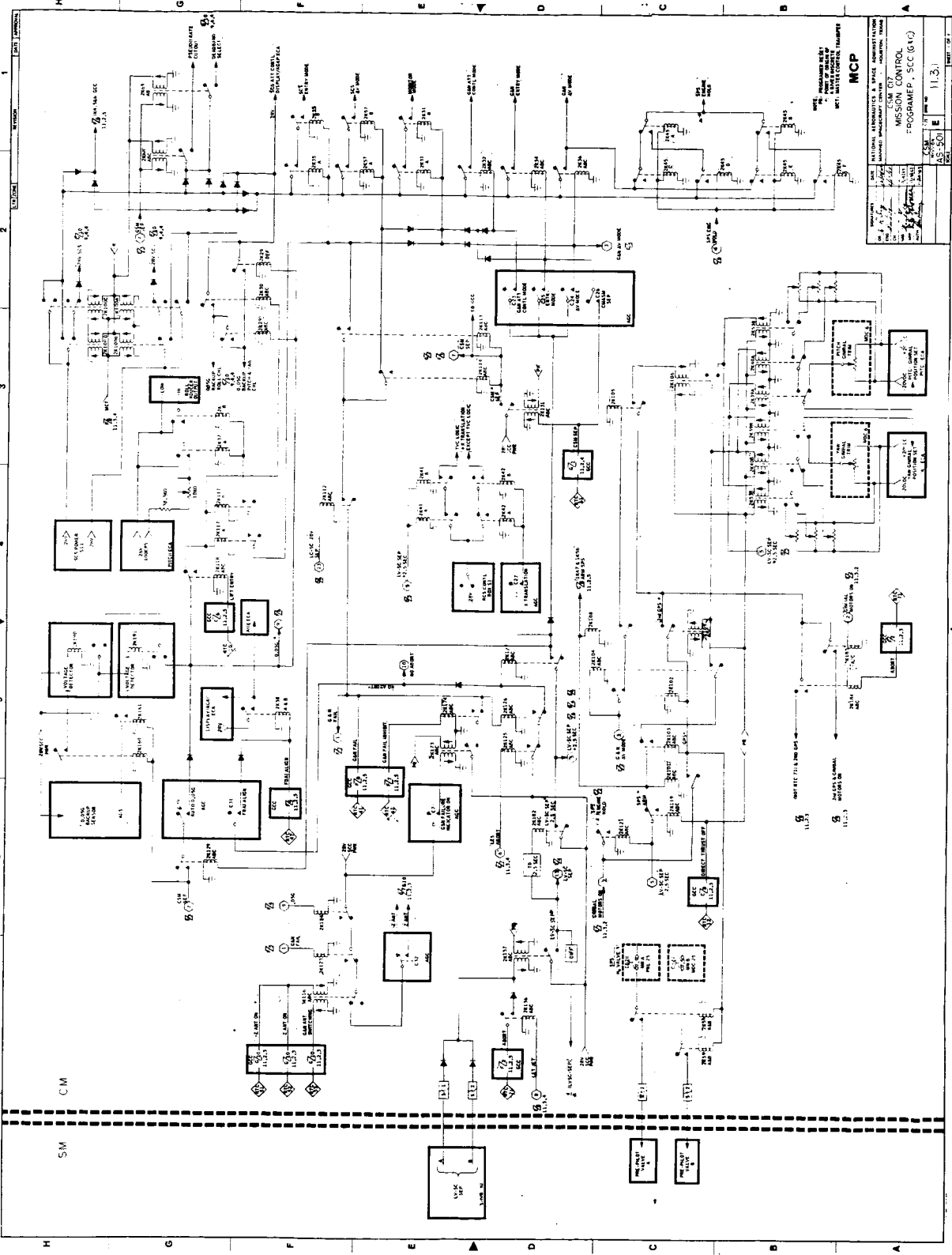
SIGNATURES		DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION MANNED SPACECRAFT CENTER HOUSTON, TEXAS	
DR	<i>Frank Flannery</i>	<i>11/21/67</i>	CM 017 MISSION CONTROL PROGRAMMER GCC (PROP AND G&C)	
ENG	<i>W. J. ...</i>	<i>11/21/67</i>		
CH	<i>...</i>	<i>...</i>		
APP	<i>...</i>	<i>...</i>		
AUTH	<i>...</i>	<i>11/21/67</i>		
CSM		MISSION	SIZE	DWG NO
AS-501		J		11.25
SCALE		SHEET 1 OF 1		

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11.3 SPACECRAFT COMMAND CONTROLLER (SCC)

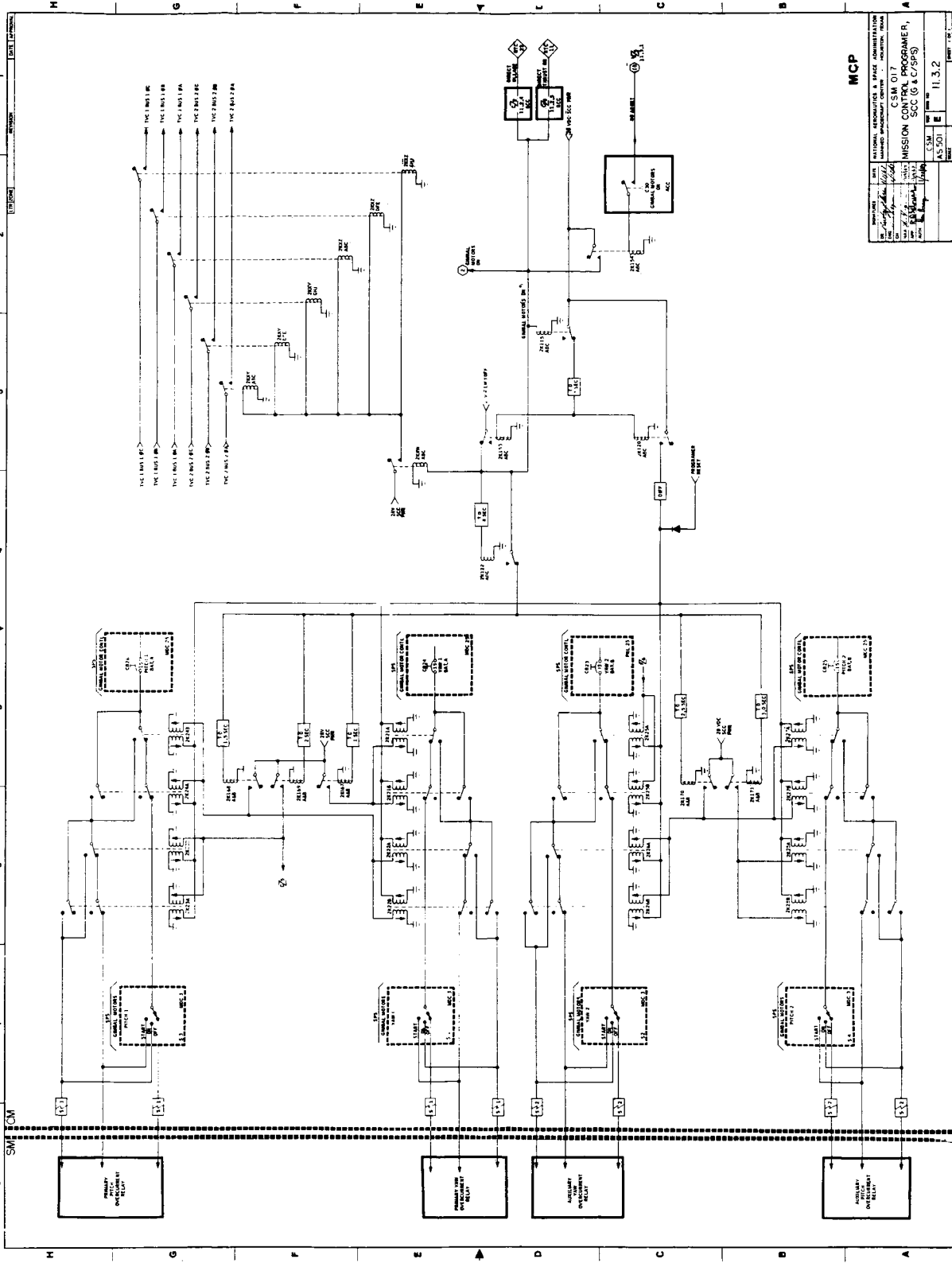
The SCC interfaces primarily with the MDC to replace the manual functions of the crew. Spacecraft discretes setup the necessary circuit logic to perform a given function. Discretes are also routed from the SCC to the GCC to perform various spacecraft functions, thru the GCC relay logic.



NATIONAL AERONAUTICS & SPACE ADMINISTRATION COMMUNICATIONS & INSTRUMENTATION DIVISION TELECOMMUNICATIONS SECTION WASHINGTON, D.C. 20546	
MISSION CONTROL PROGRAM - SEC (G-1)	
DRAWING NO. 11.3	SHEET NO. 11.3
DATE: 11.3	

SM

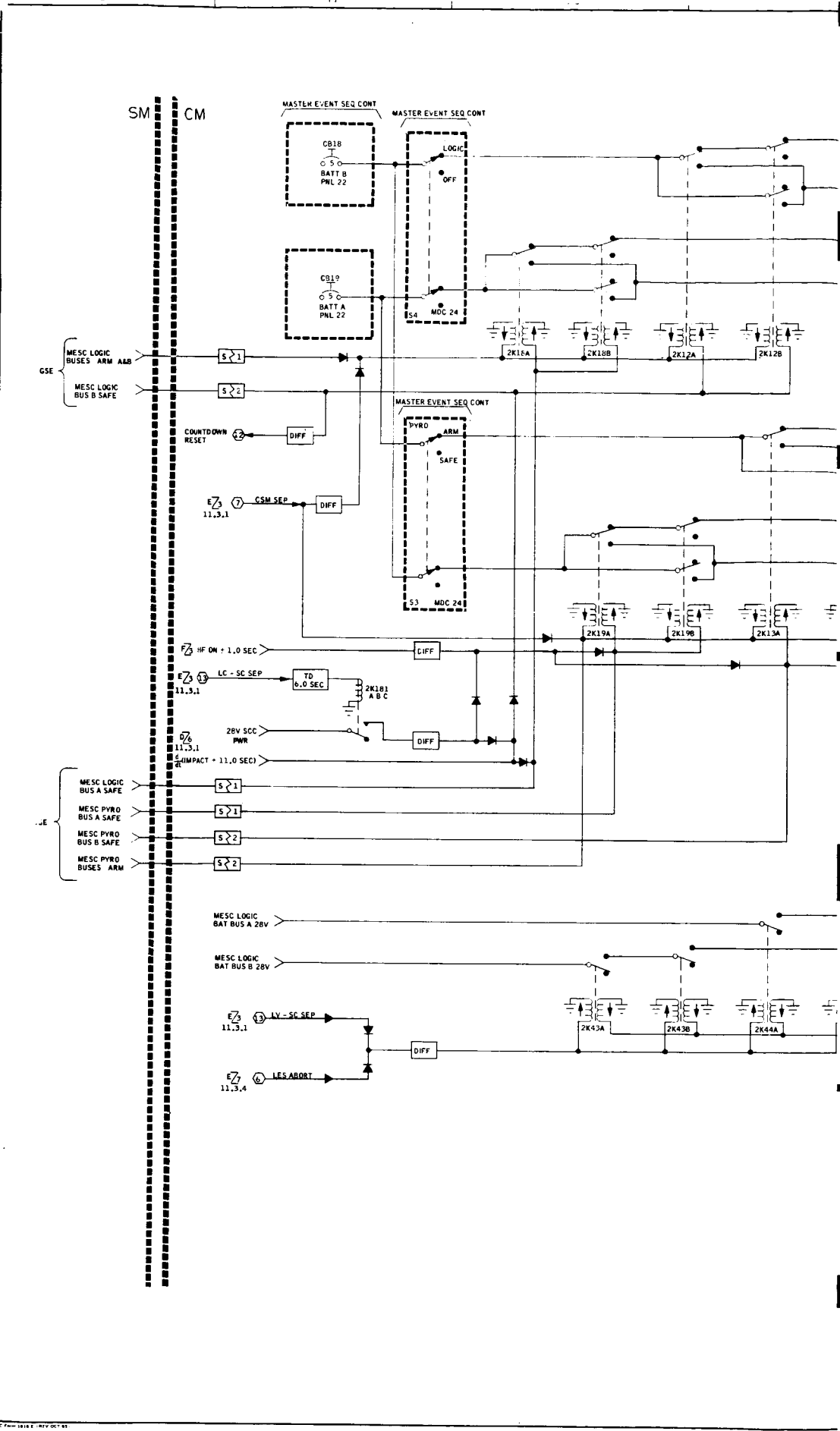
CM

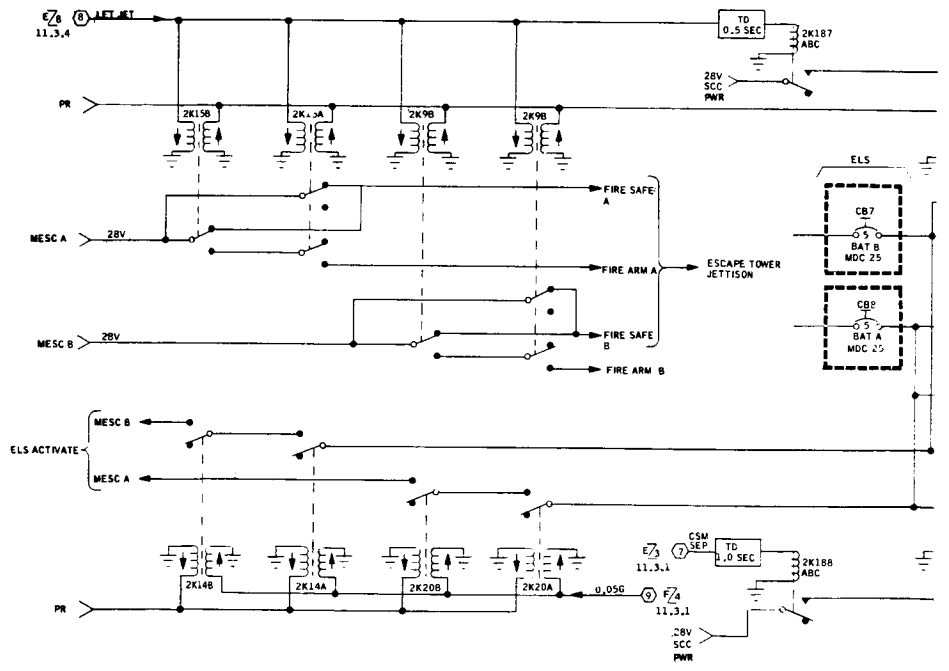
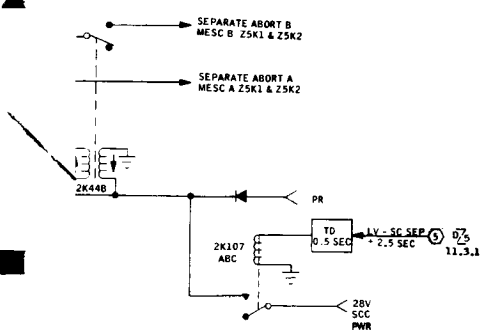
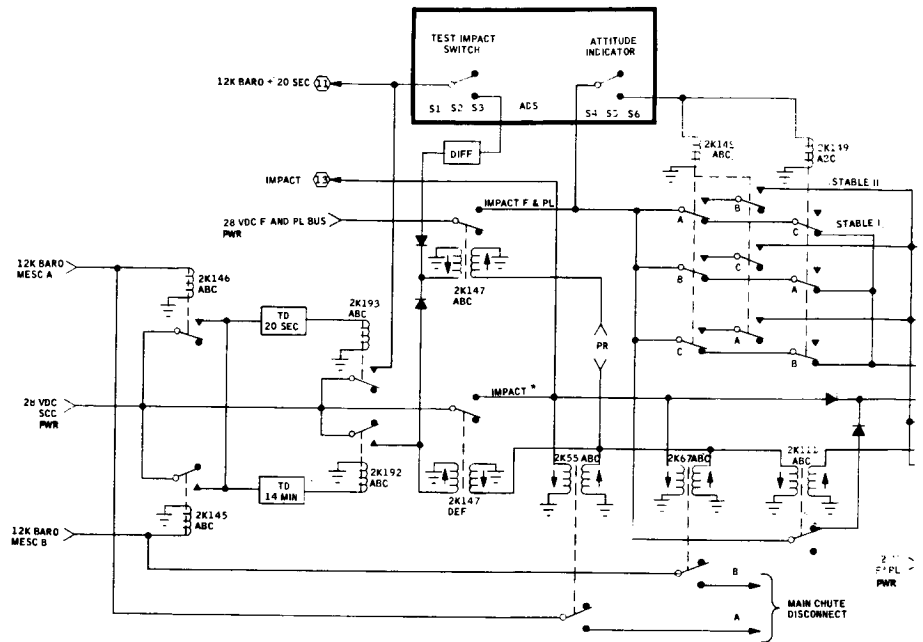
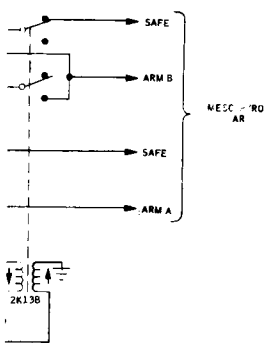
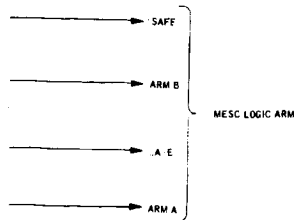


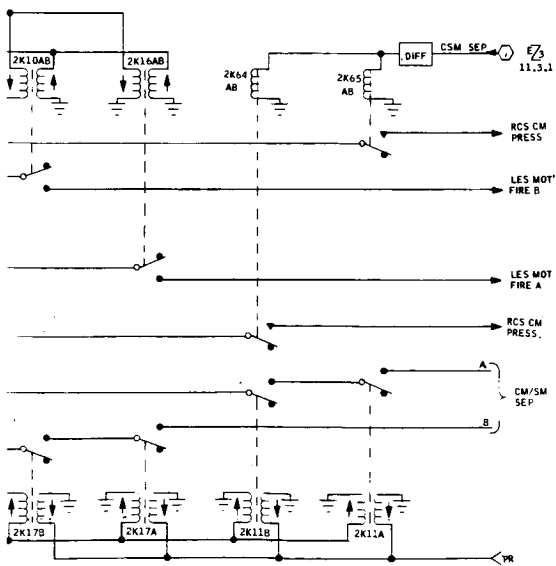
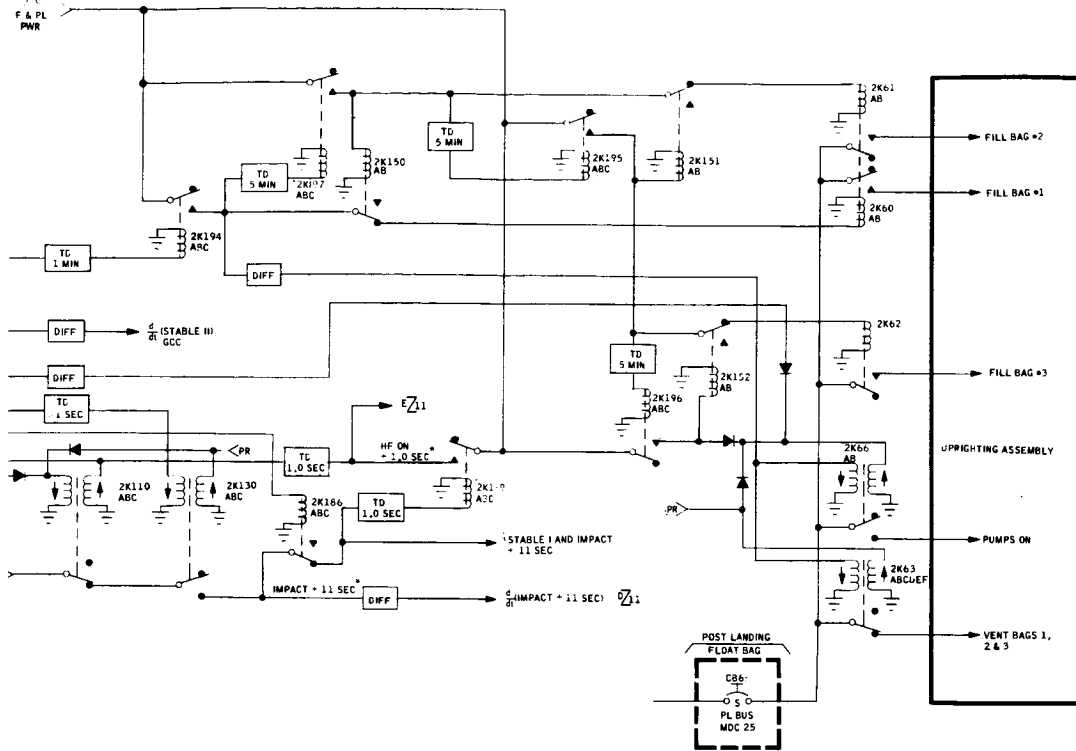
MCP

DESIGN NO.	CSM 017
ISSUED BY	MISSION CONTROL PROGRAMMER, SCC (G & C/SFS)
DATE	11.3.2
REV.	AS 501
BY	
CHECKED BY	
APPROVED BY	
SCALE	
FIGURE NO.	

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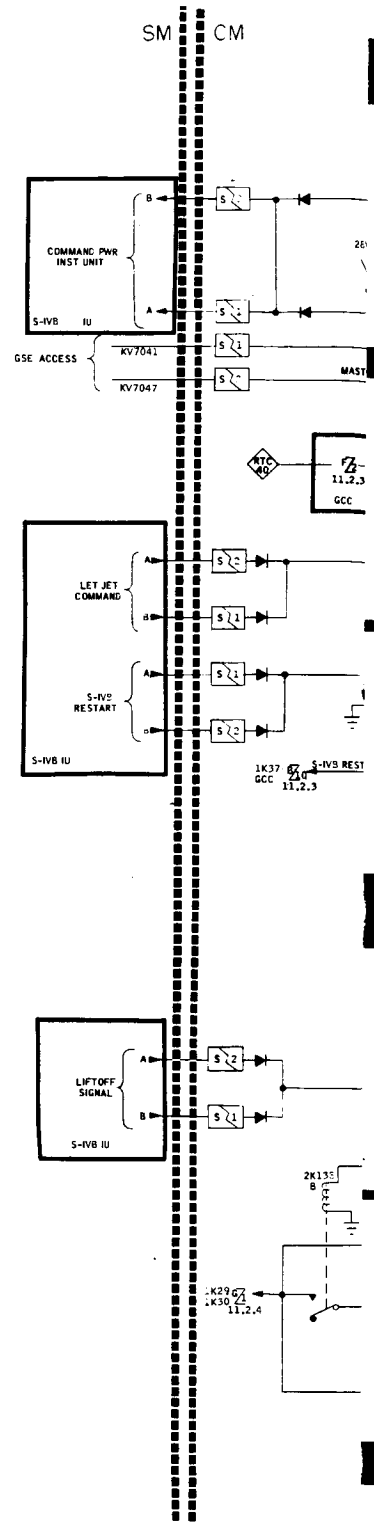


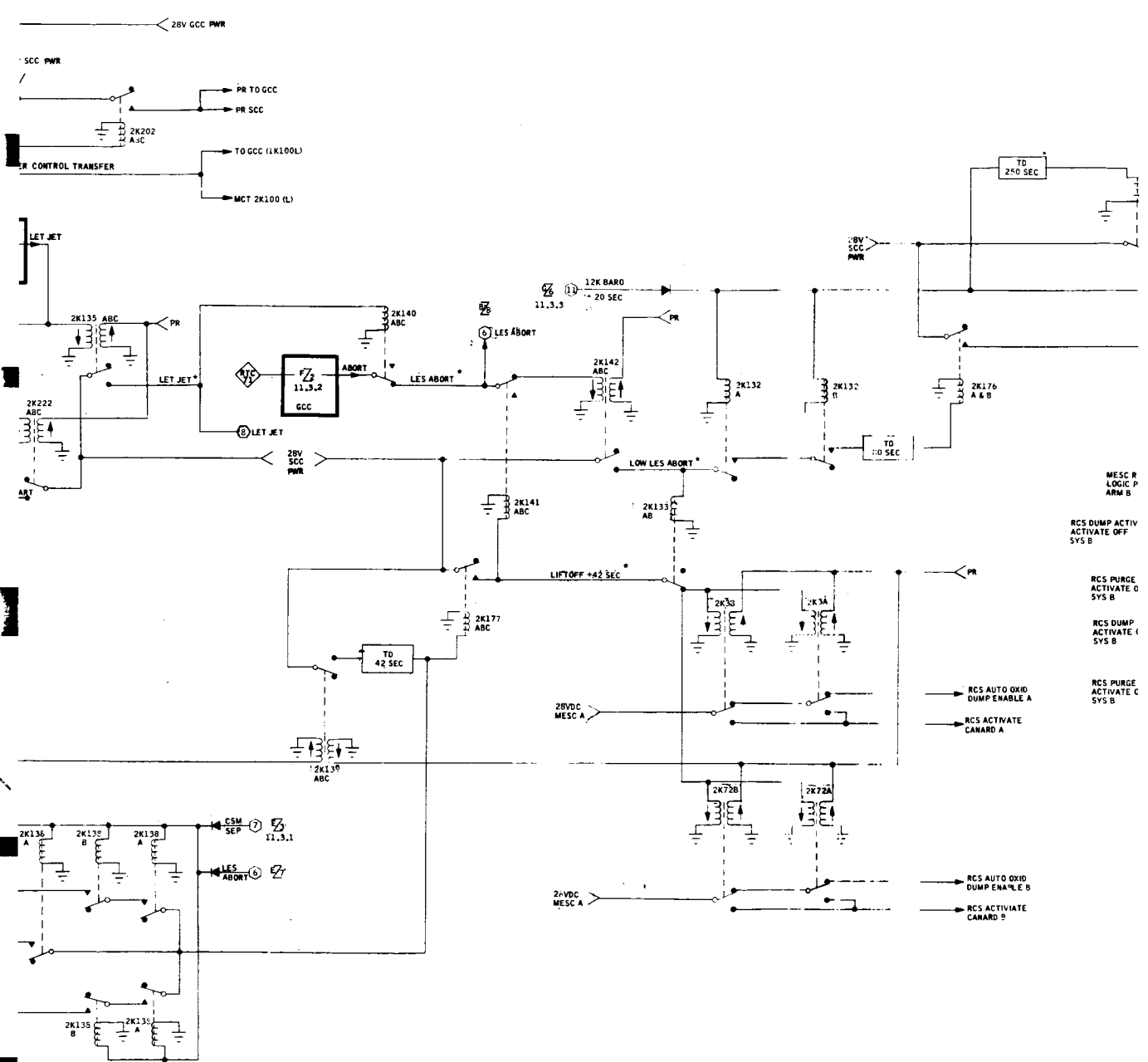
NOTE:
 PR: PROGRAMMER RESET
 * (ASTERISKS): POINT OF ORIGIN
 OF A GIVEN DISCRETE

MCP

SIGNATURES		DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION MANNED SPACECRAFT CENTER HOUSTON, TEXAS	
DR	MALIFF	7-27	CSM 017 MISSION CONTROL PROGRAMMER SCC (SEQ'L)	
ENG				
CHK				
APP	<i>[Signature]</i>	7-27		
AUTH	<i>[Signature]</i>	7-27		
SCALE	J	113.3	SHEET 1 OF 1	

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RCS PURGE
ACTIVATE
SYS A

RCS DUMP
ACTIVATE
SYS A

RCS PURGE
ACTIVATE
SYS A

RCS DUMP
ACTIVATE
SYS A

MESC RCS LOG
PWR ARM A

MESC R
LOGIC P
ARM B

RCS DUMP ACTIV
ACTIVATE OFF
SYS B

RCS PURGE
ACTIVATE O
SYS B

RCS DUMP
ACTIVATE I
SYS B

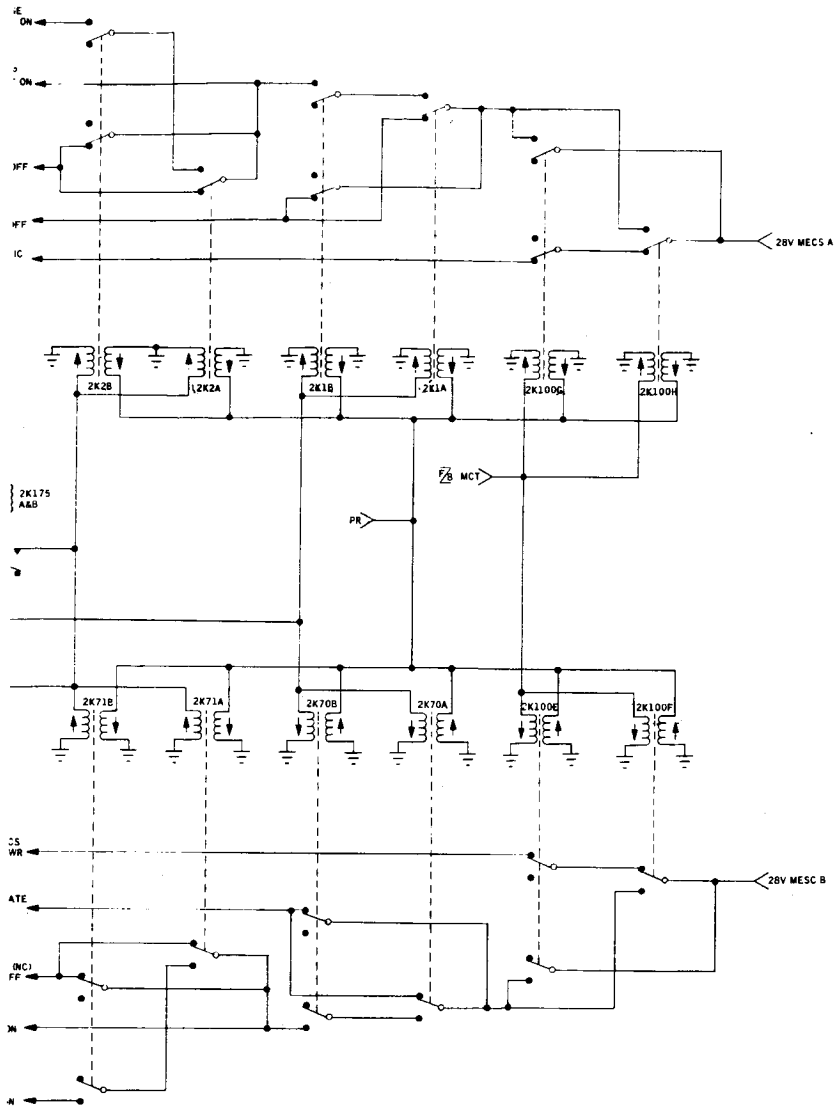
RCS PURGE
ACTIVATE C
SYS B

RCS AUTO OXID
DUMPERABLE A

RCS ACTIVATE
CANARD A

RCS AUTO OXID
DUMPERABLE B

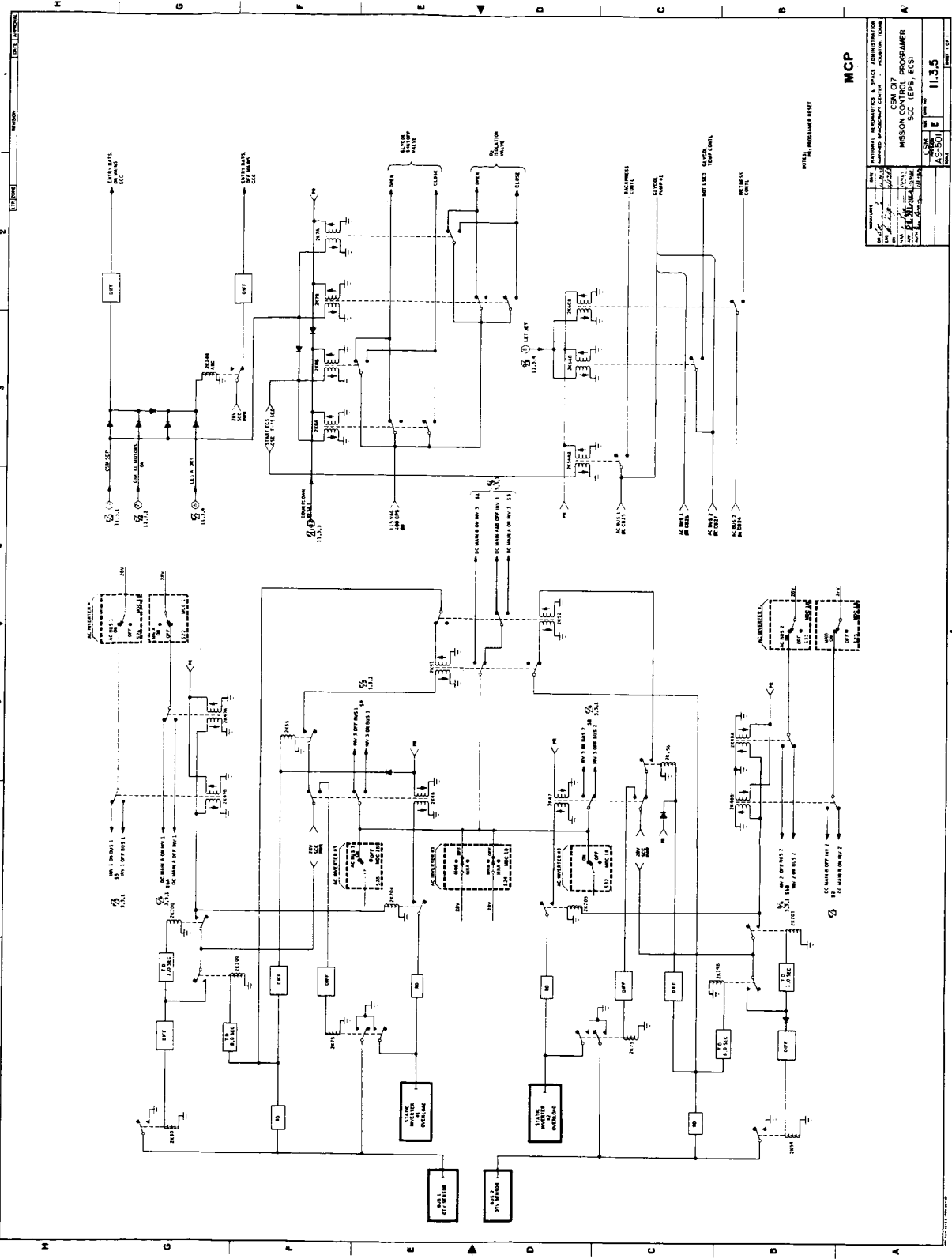
RCS ACTIVATE
CANARD B



NOTE:
 PR: PROGRAMER RESET
 * (ASTERISKS): POINT OF ORIGIN OF A GIVEN DISCRETE

MCP

SIGNATURES		DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION MANNED SPACECRAFT CENTER - HOUSTON, TEXAS	
DR	<i>B. P. King</i>	12/1/68		
ENC	<i>S. J. ...</i>	11/22/68		
CH				
NAA			CSM 017 MISSION CONTROL PROGRAMER, SCC (SEQ)	
APP	<i>R. W. ...</i>	11/22/68		
AUTH	<i>de Kraw</i>	11/22/68		
		MISSION	SIZE	DWG NO.
		AS-501	E	11.3.4
		SCALE	SHEET 1 OF 1	



MCP

REV.	DATE	BY	DESCRIPTION
1	11/22/54	W. J. MURPHY	MISSION CONTROL PROGRAMMER
2	11/22/54	W. J. MURPHY	REVISION
3	11/22/54	W. J. MURPHY	REVISION
4	11/22/54	W. J. MURPHY	REVISION
5	11/22/54	W. J. MURPHY	REVISION
6	11/22/54	W. J. MURPHY	REVISION
7	11/22/54	W. J. MURPHY	REVISION
8	11/22/54	W. J. MURPHY	REVISION
9	11/22/54	W. J. MURPHY	REVISION
10	11/22/54	W. J. MURPHY	REVISION
11	11/22/54	W. J. MURPHY	REVISION
12	11/22/54	W. J. MURPHY	REVISION
13	11/22/54	W. J. MURPHY	REVISION
14	11/22/54	W. J. MURPHY	REVISION
15	11/22/54	W. J. MURPHY	REVISION
16	11/22/54	W. J. MURPHY	REVISION
17	11/22/54	W. J. MURPHY	REVISION
18	11/22/54	W. J. MURPHY	REVISION
19	11/22/54	W. J. MURPHY	REVISION
20	11/22/54	W. J. MURPHY	REVISION
21	11/22/54	W. J. MURPHY	REVISION
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23	11/22/54	W. J. MURPHY	REVISION
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28	11/22/54	W. J. MURPHY	REVISION
29	11/22/54	W. J. MURPHY	REVISION
30	11/22/54	W. J. MURPHY	REVISION
31	11/22/54	W. J. MURPHY	REVISION
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38	11/22/54	W. J. MURPHY	REVISION
39	11/22/54	W. J. MURPHY	REVISION
40	11/22/54	W. J. MURPHY	REVISION
41	11/22/54	W. J. MURPHY	REVISION
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44	11/22/54	W. J. MURPHY	REVISION
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49	11/22/54	W. J. MURPHY	REVISION
50	11/22/54	W. J. MURPHY	REVISION

MISSION CONTROL PROGRAMMER
 SEC. (ECP, ECI)
 11.3.5

*

11.4 ATTITUDE AND DECELERATION SENSOR (ADS)

The ADS provides a Stable I-Stable II Attitude Sensor, a 0.05G backup sensor, and an impact switch.

*

11.5 MCP CIRCUIT LOGIC

Figures 11.5.1 thru 11.5.7 are the logic circuits associated with the MCP and Spacecraft Systems. Relays numbered LKX are in the GCC. Relays numbered 2KX are in the SCC. ADS interfaces are noted.

Relays that are reset (or set) by the programmer reset discrete (sent at T-5 hrs by GSE) are not shown in the logic where no other discrete is involved in the reset (or set). Table 11-1 lists all relay numbers and functions involved in a programmer reset discrete.

The following terms and symbols are used in the logic circuit:


A. S: SET OR LATCH

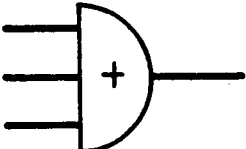
B. R: REST OR UNLATCH

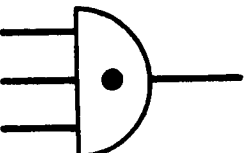
C.

SOME*
WORD

: A flag, origin of a discrete. This flag is common with all other identical flags shown without asterisk.

D. INPUT —  — OUTPUT: An inverter. The output is the logical inverse of the input.

E. INPUTS  OUTPUT: A standard "OR" gate.

F. INPUTS  OUTPUT: A standard "AND" gate

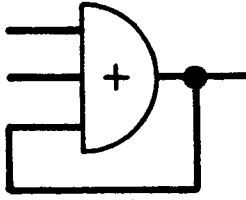
G. INPUTS  OUTPUT: A latching or gate. The output is logically 1 if either input is 1 and continues to be 1 even if the input becomes logically 0. (Note: A programmer reset discrete is required to reset the output to 0.)

TABLE 11-1 MCP RELAY LOGIC FOR A PROGRAMER RESET

SYSTEM	CONTACT LOCATION		CONTACT NUMBER	SET	RESET	FUNCTION
	SCC	GCC				
SEQ	X		2K100EFGH		X	MESC A&B LOGIC PWR
	X		2K9		X	E/T JET
	X		2K10		X	LES MOTOR FIRE B
	X		2K11		X	CSM SEP B
	X		2K14		X	ELS ACTIVATE B
	X		2K15		X	E/T JET A
	X		2K16		X	LES MOTOR FIRE A
	X		2K17		X	CSM SEP A
	X		2K20		X	ELS ACTIVATE A
	X		2K55		X	MN CHUTE DISCONNECT A
	X		2K63		X	VENT BAGS ON, UPRIGHTING CONTL
	X		2K66		X	PUMPS OFF, UPRIGHTING CONTL
	X		2K67		X	MN CHUT DISCONNECT B
EPS	X		2K46		X	INV 3 OFF BUS 1
	X		2K47		X	INV 3 OFF BUS 2
	X		2K48		X	ISOLATE INV 2
	X		2K49		X	ISOLATE INV 1
	X		2K51		X	MN B OFF INV 3
	X		2K52		X	MN A OFF IVN 3
		X	1K50		X	ENTRY BATTS OFF MAINS
		X	1K51		X	C BATT ON F&PL BUS
		X	1K52		X	A&B BATTS ON F&PL BUS
		X	1K81		X	AUX BATTS 1 & 3 ON F&PL BUS
		X	1K82		X	HEAT SHIELD INSTR ON
		X	1K85		X	AUX BATTS 2 & 3 F&PL BUS
ECS	X		2K6		X	GLYCOL WETNESS CONTROL
	X		2K7		X	O ₂ ISOLATION VALVE OPEN
	X		2K8		X	GLYCOL SHUTOFF VALVE OPEN
	X		2K56		X	BACKPRESSURE CONTROL
CRYO					NONE	
TELECOMM		X	1K100		X	Z ANTENNA SWITCHING
		X	1K32		X	FQ RECORDER STOP OFF
		X	1K33		X	-Z ANTENNA ON
		X	1K34		X	+Z ANTENNA ON
		X	1K35		X	CINE CAMERA CONTROL (OFF)
		X	1K36		X	HF ANT DEPLOY B OFF
		X	1K37		X	UHF RCVR ON
		X	1K38		X	VHF/FM XMTR ON
		X	1K39		X	DSE FWD-NML ON
		X	1K40		X	DSE RECORD ON
		X	1K41		X	FQ RECORDER OFF
		X	1K42		X	VHF/AM RCVR ON

* TABLE 11-1 MCP RELAY LOGIC FOR A PROGRAMER RESET (Cont'd)

SYSTEM	CONTACT LOCATION		CONTACT NUMBER	SET	RESET	FUNCTION
	SCC	GCC				
TELECOMM		X	1K44		X	HF ANTENNA DEPLOY A OFF
		X	1K46		X	PWR TO CB45 OFF
		X	1K54		X	FLD SWING LIGHT ON
		X	1K55		X	FQ RECORDER REWIND OFF
		X	1K43	X		VHF XMITTER ON
		X	1K45	X		HF XCVR ON
		X	1K48	X		VHF SURVIVAL BEACON ON
		X	1K57	X		VHF SURVIVAL BEACON ON
G&C	X		2K39		X	GIMBAL POSITION SET
	X		2K40		X	GIMBAL POSITION SET
	X		2K43		X	SEP/ABORT A OFF
	X		2K44		X	SEP/ABORT B OFF
	X		2K53		X	GIMBAL POSITION SET
	X		2K68		X	PSEUDO RATE OUT
	X		2K69		X	DEADBAND SELECT
		X	1K47		X	DIRECT THRUST OFF
	X	1K56		X	DIRECT THRUST OFF	
PROP	X		2K21		X	YAW 1 START
	X		2K22		X	YAW 1 ON
	X		2K23		X	PROP ISOLATION VALVE (N.C)
	X		2K24		X	PROP ISOLATION VALVE (N.C)
	X		2K25		X	YAW 2 START
	X		2K26		X	YAW 2 ON
	X		2K27		X	PITCH 2 START
	X		2K28		X	PITCH 2 ON
	X		2K1		X	RCS DUMP A
	X		2K2		X	RCS PURGE ACTIVATE
	X		2K3		X	OXID DUMP A
	X		2K70		X	RCS DUMP B
	X		2K71		X	RCS PURGE ACTIVATE
	X		2K72		X	OXID DUMP B
	X		2K100ABCD		X	PITCY, YAW, & ROLL BACKUP

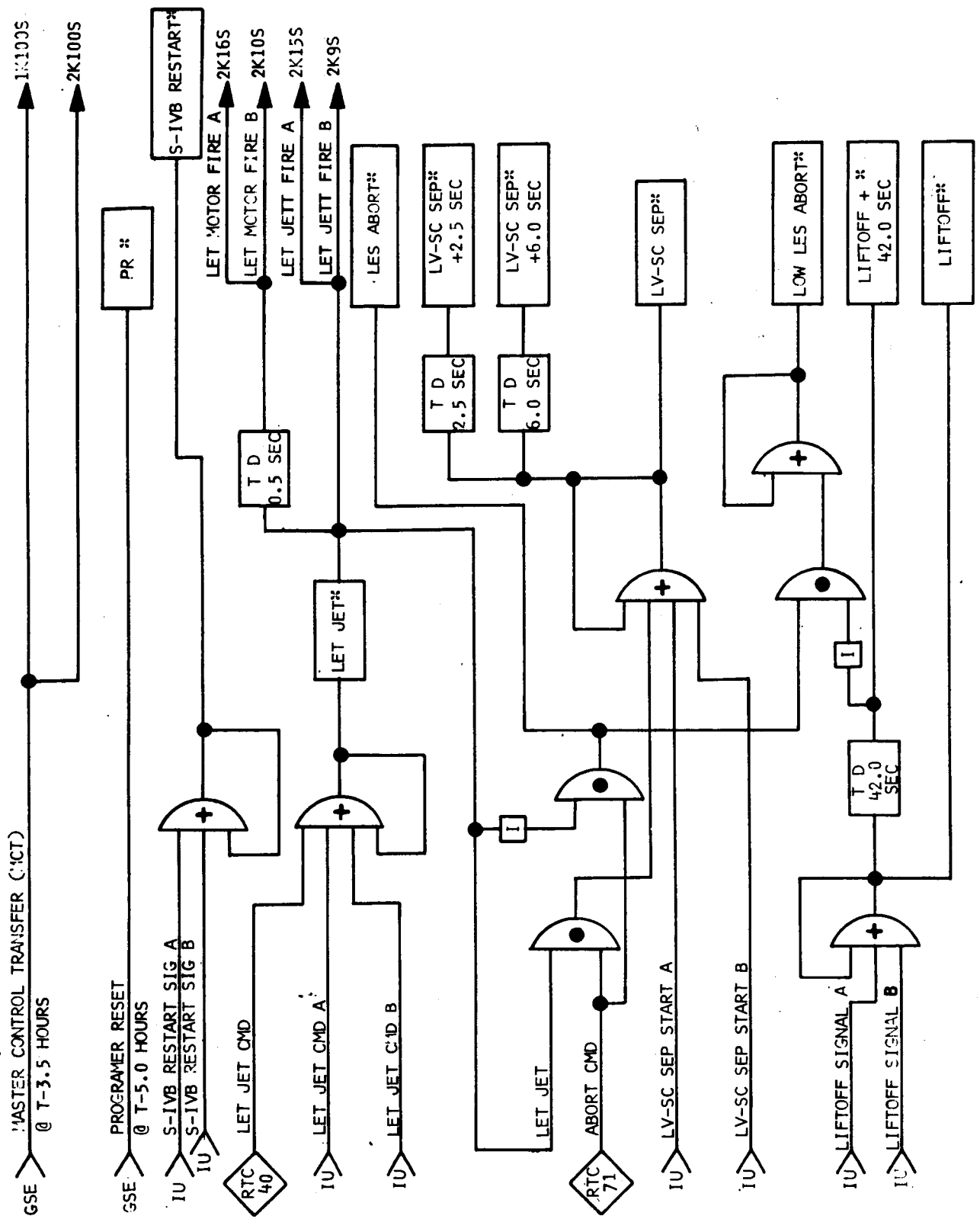


FIGURE 11.5.1A MCP/S-IVB IU LOGIC

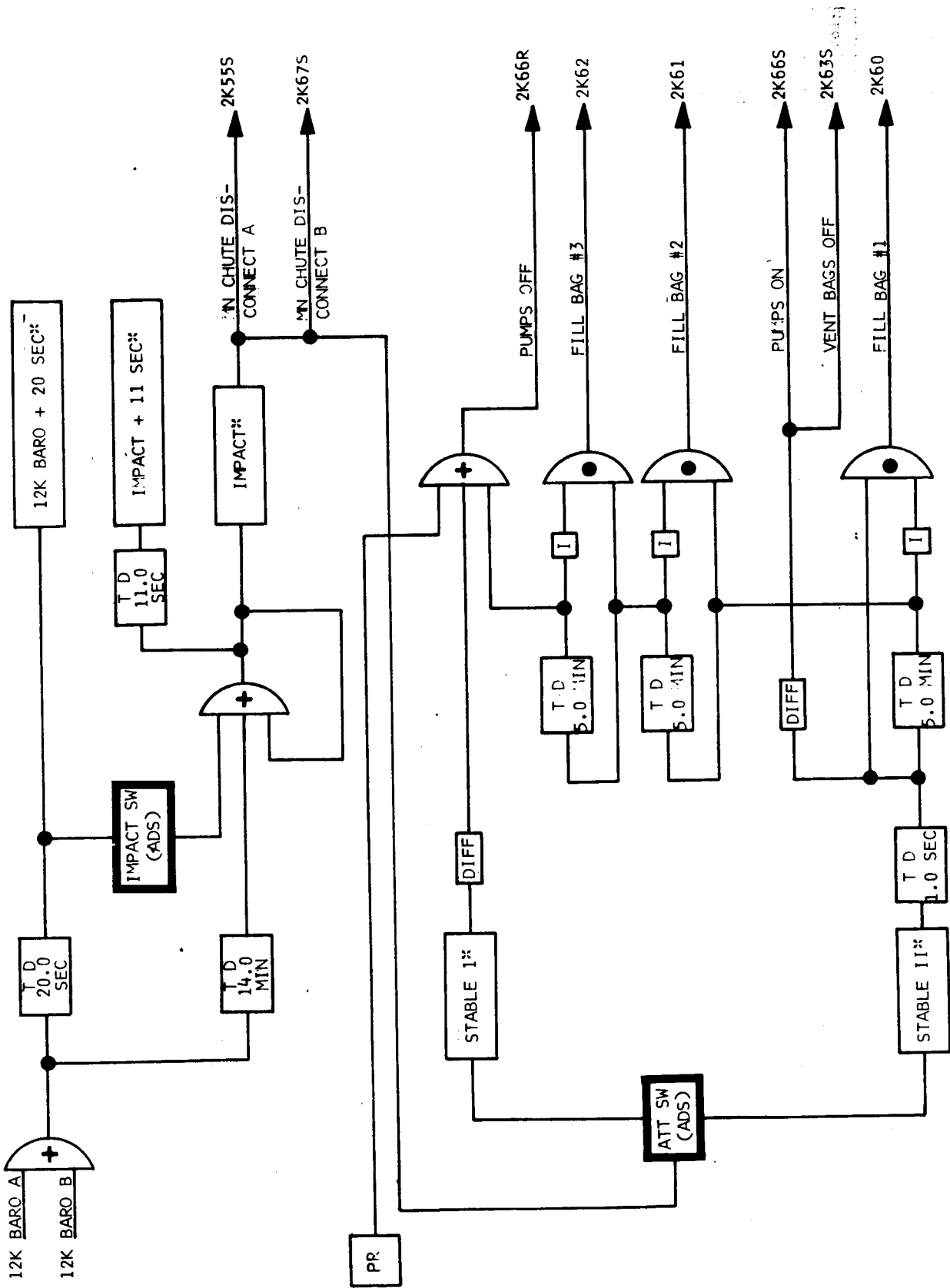


FIGURE 11.5.1B MCP/SEQ (RECOVERY) LOGIC

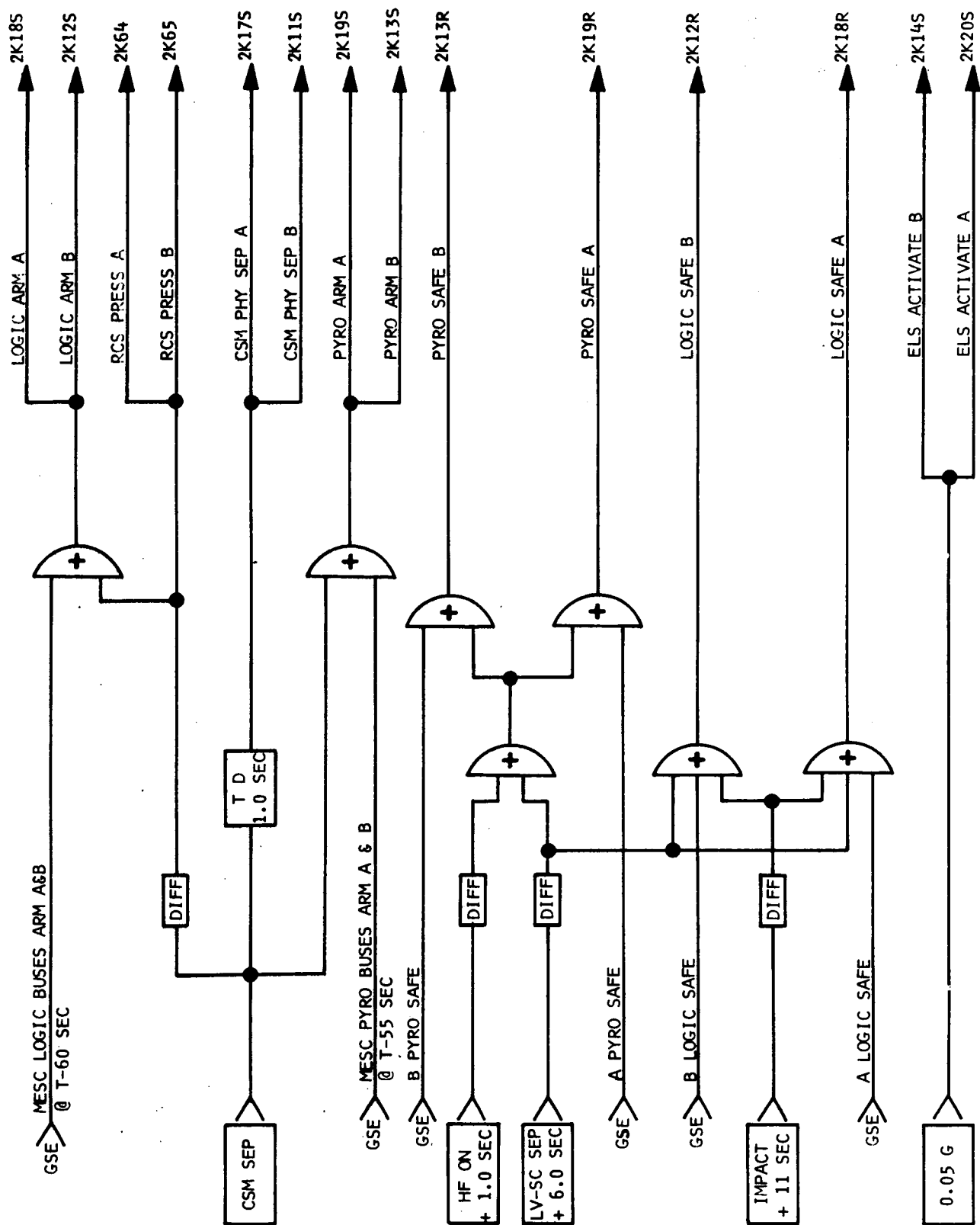


FIGURE 11.5.1C MCP/MESC LOGIC

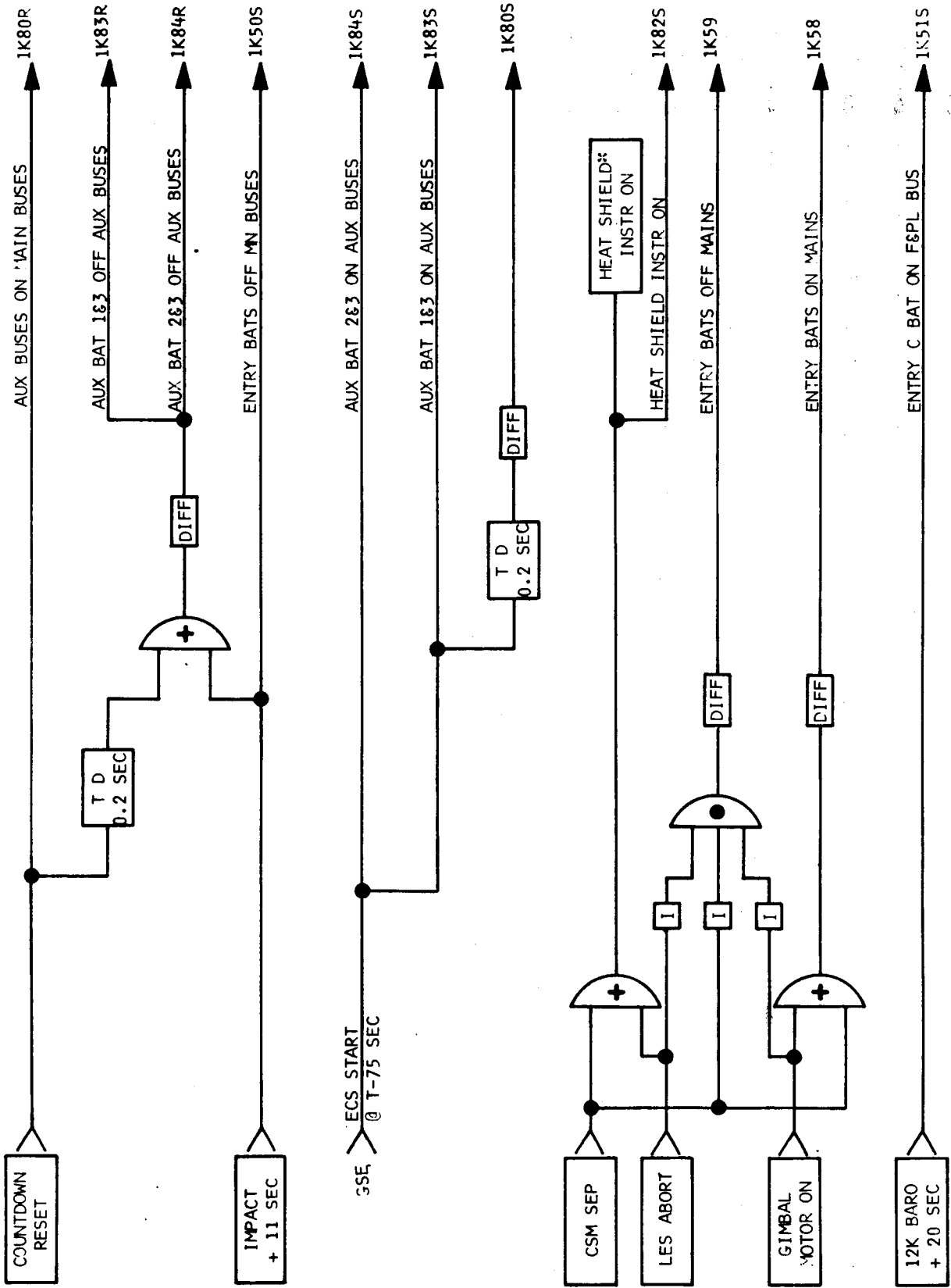


FIGURE 11.5.2A MCF7EPS LOGIC

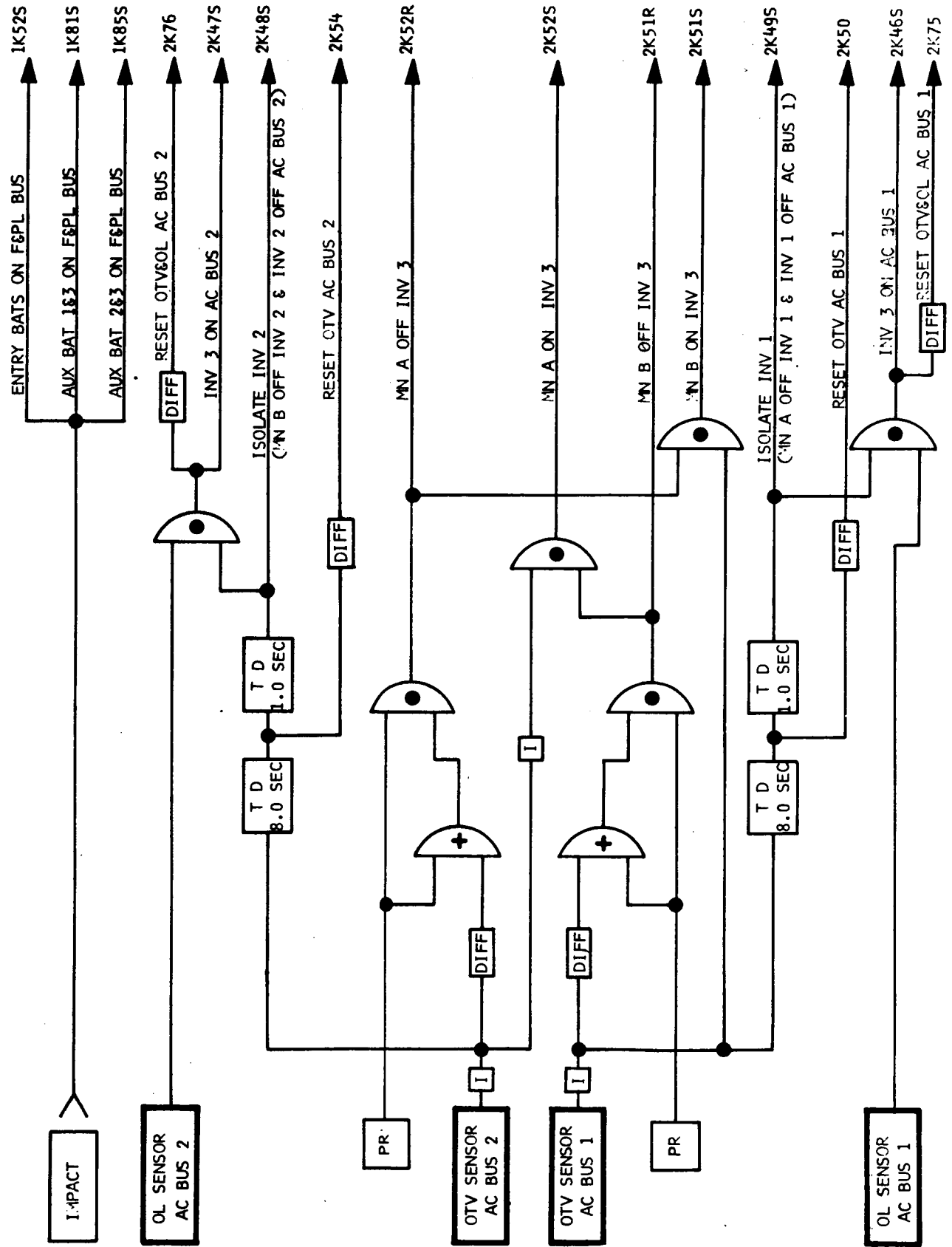


FIGURE 11.5.2B MCP/EPS LOGIC

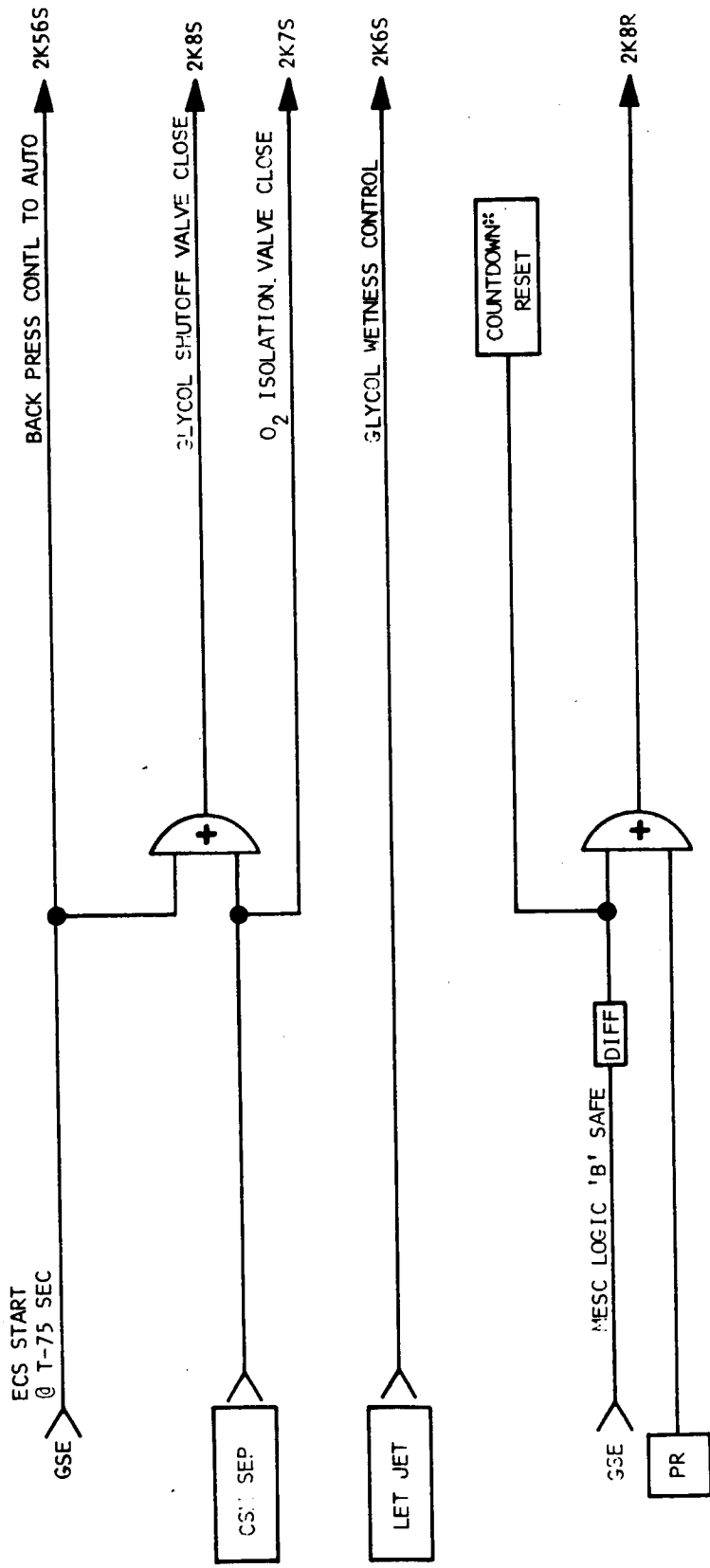


FIGURE 11.5.3 MCP/ECS LOGIC

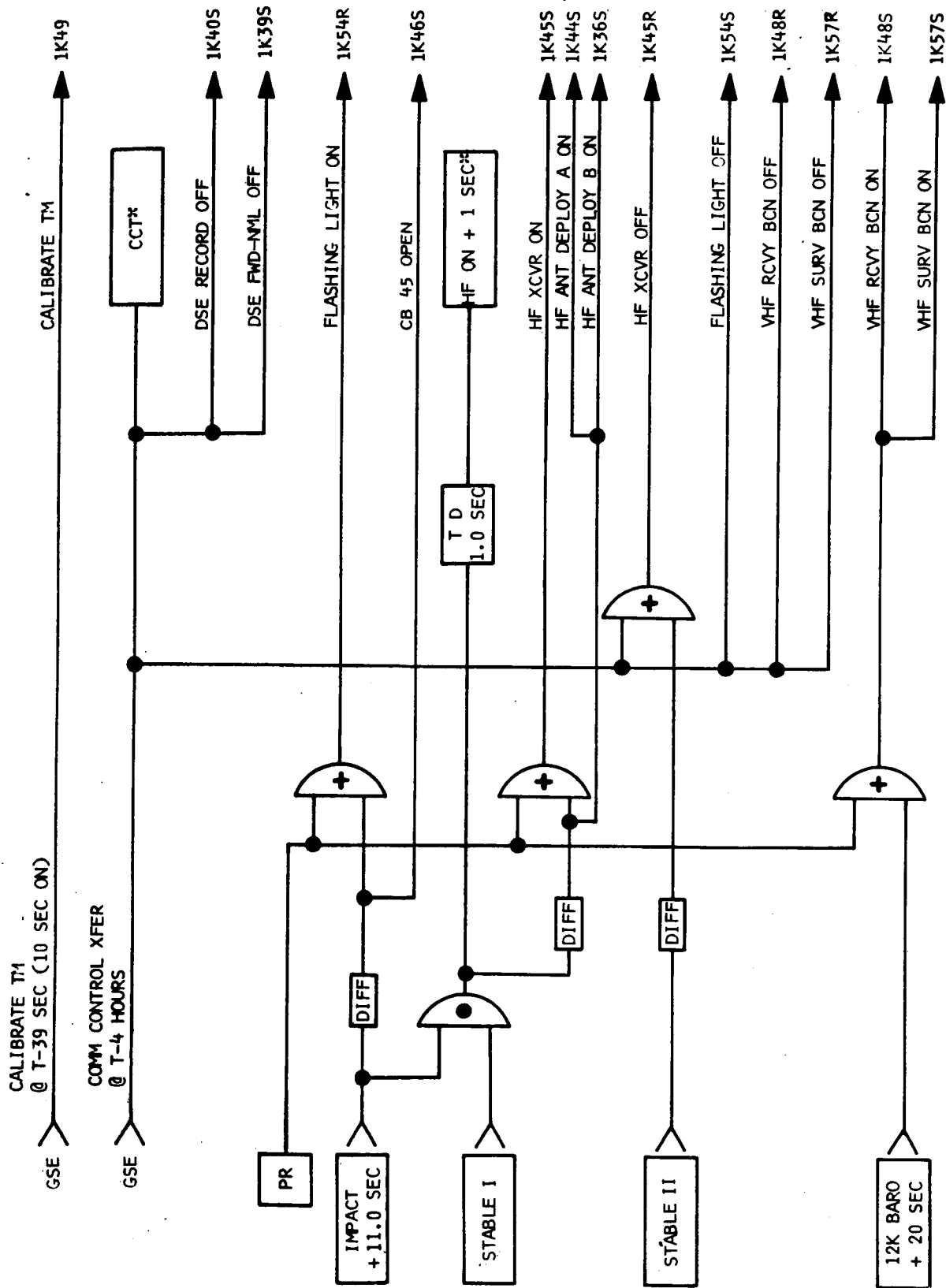


FIGURE 11.5.4A MCP/TC LOGIC

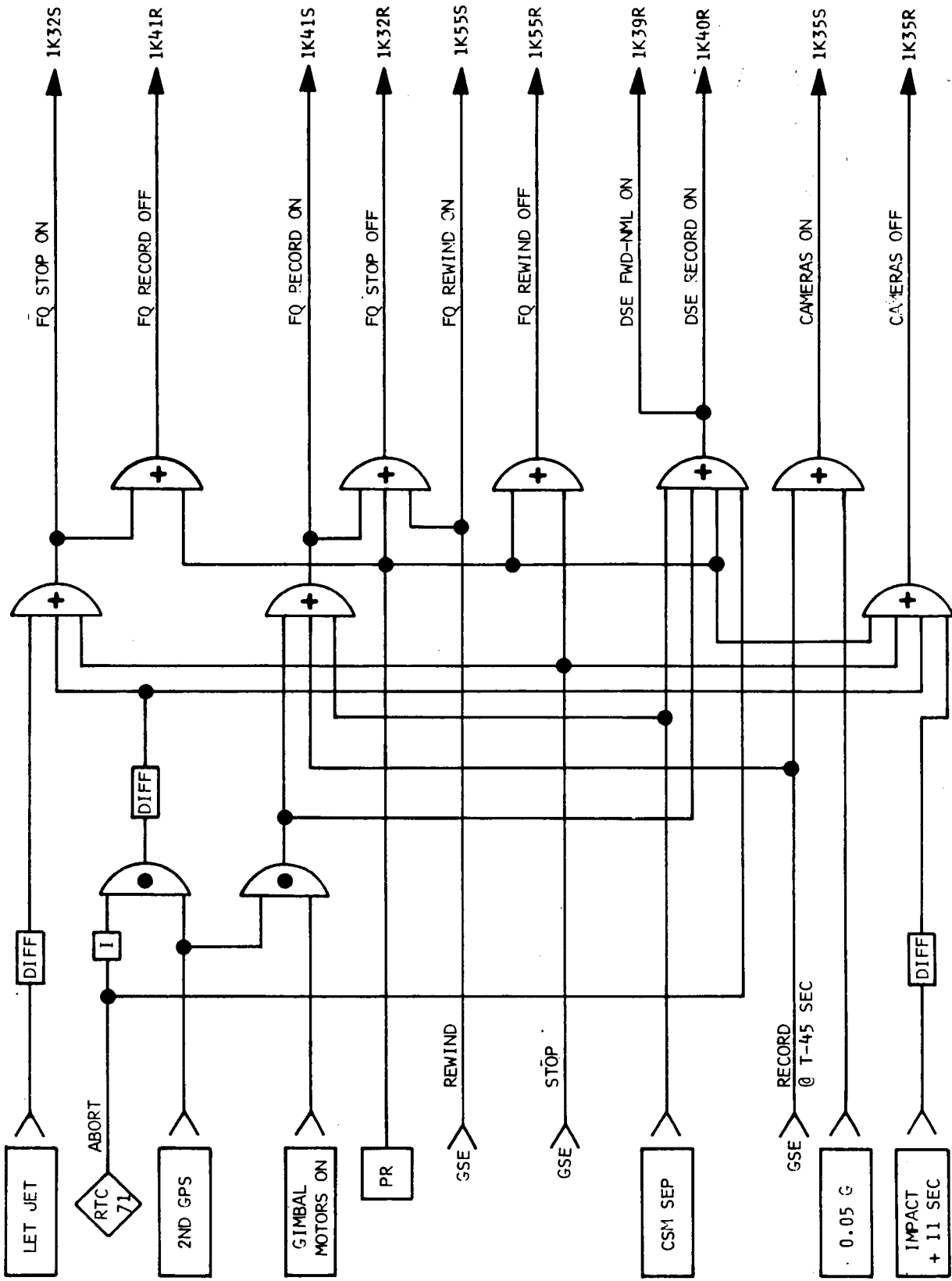


FIGURE 11.5.4B MCP/TC LOGIC

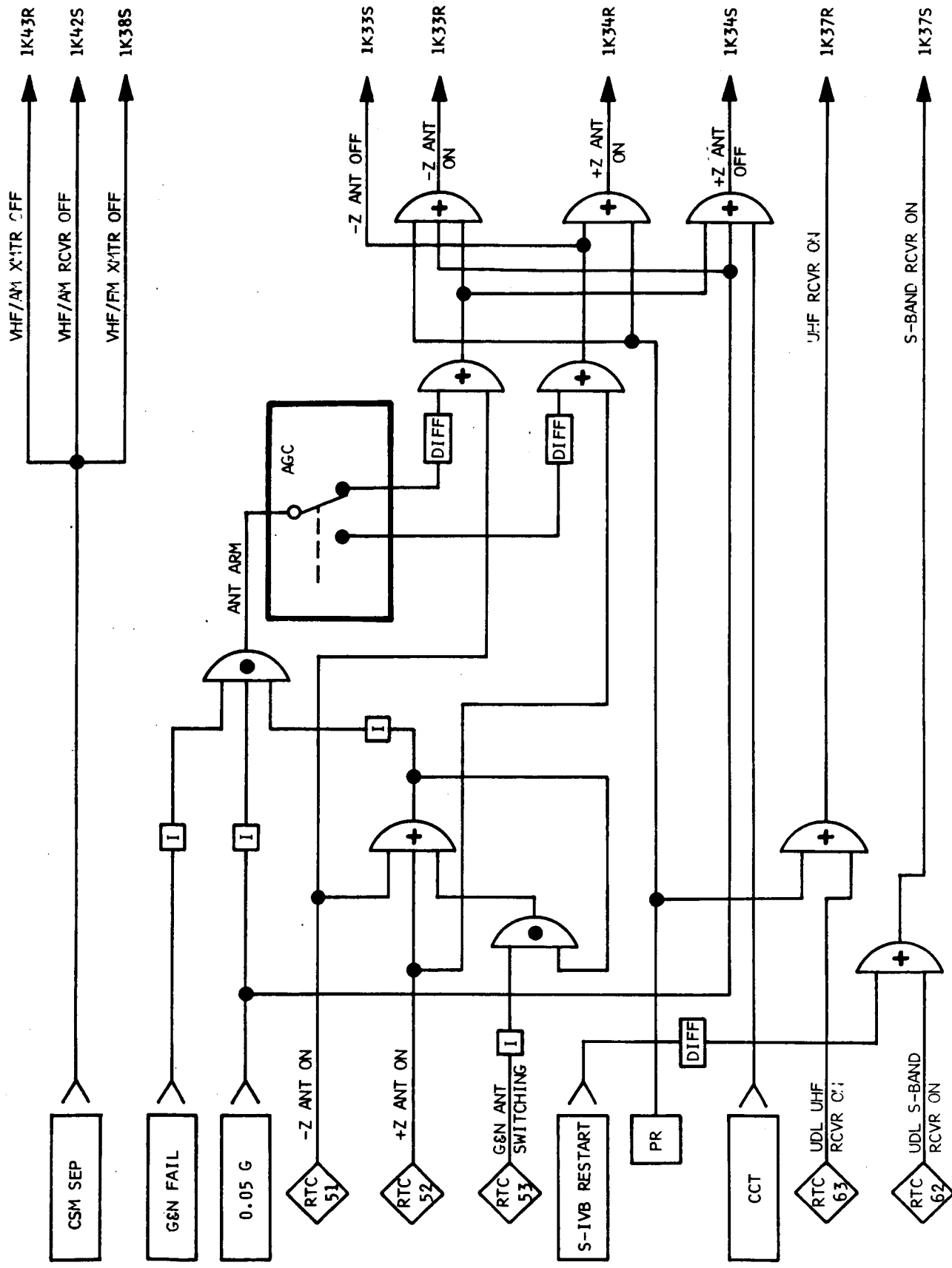


FIGURE 11.5.4C MCP/TC LOGIC

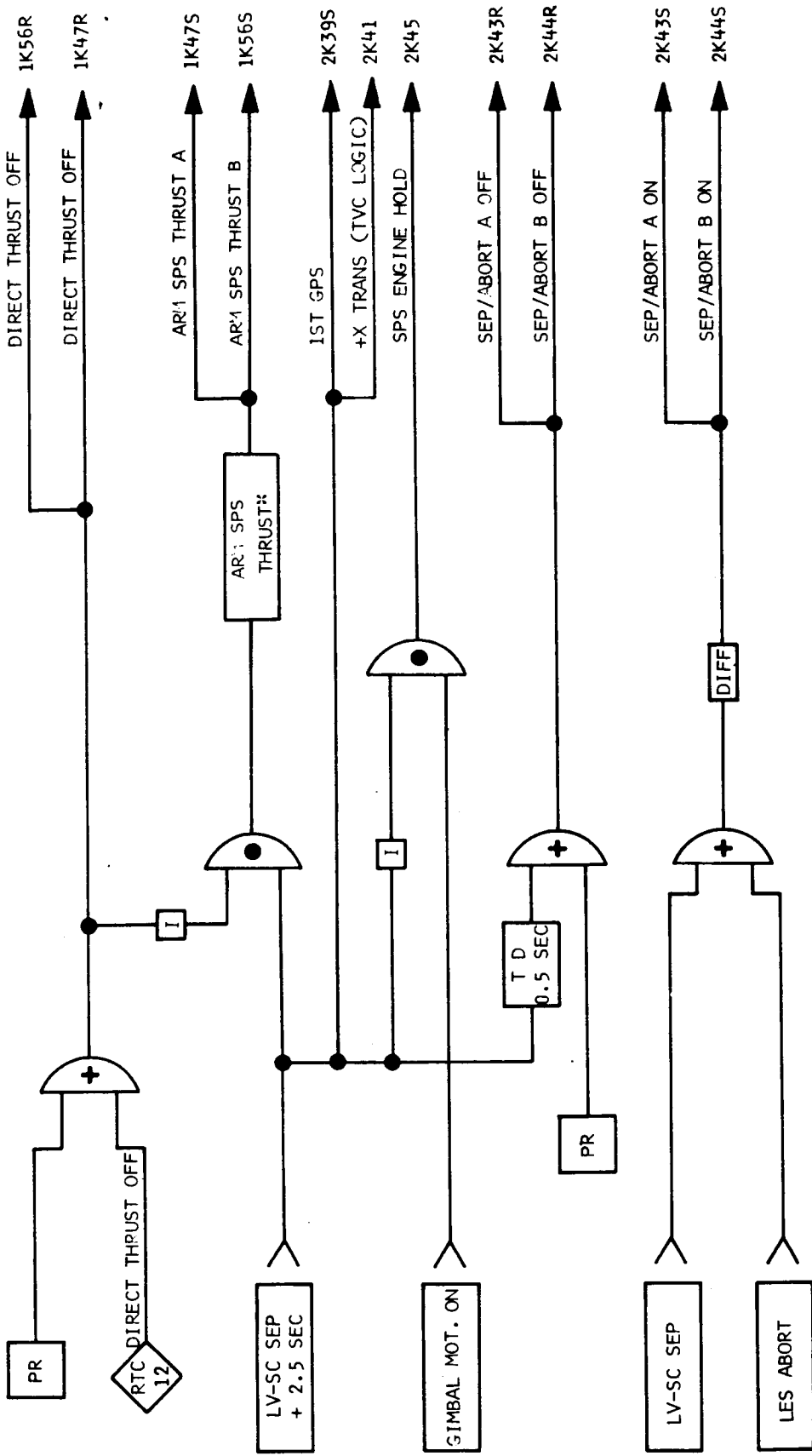


FIGURE 11.5.5A MCP/G&C LOGIC

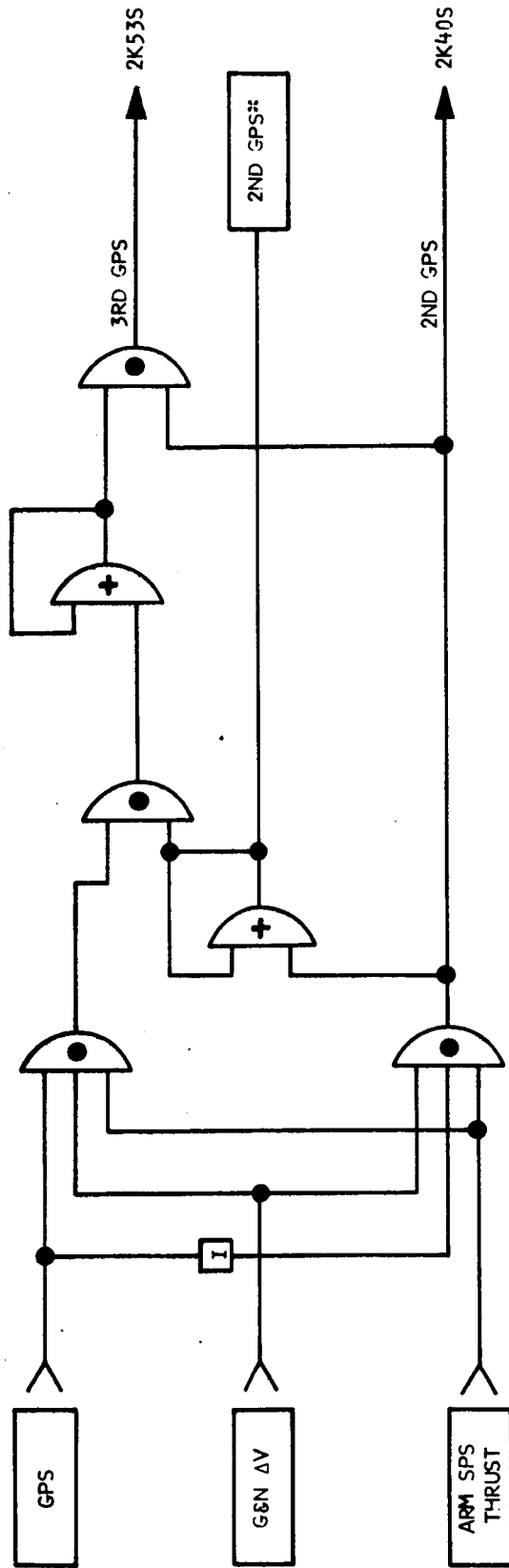


FIGURE 11.5.5B MCP/G&C LOGIC

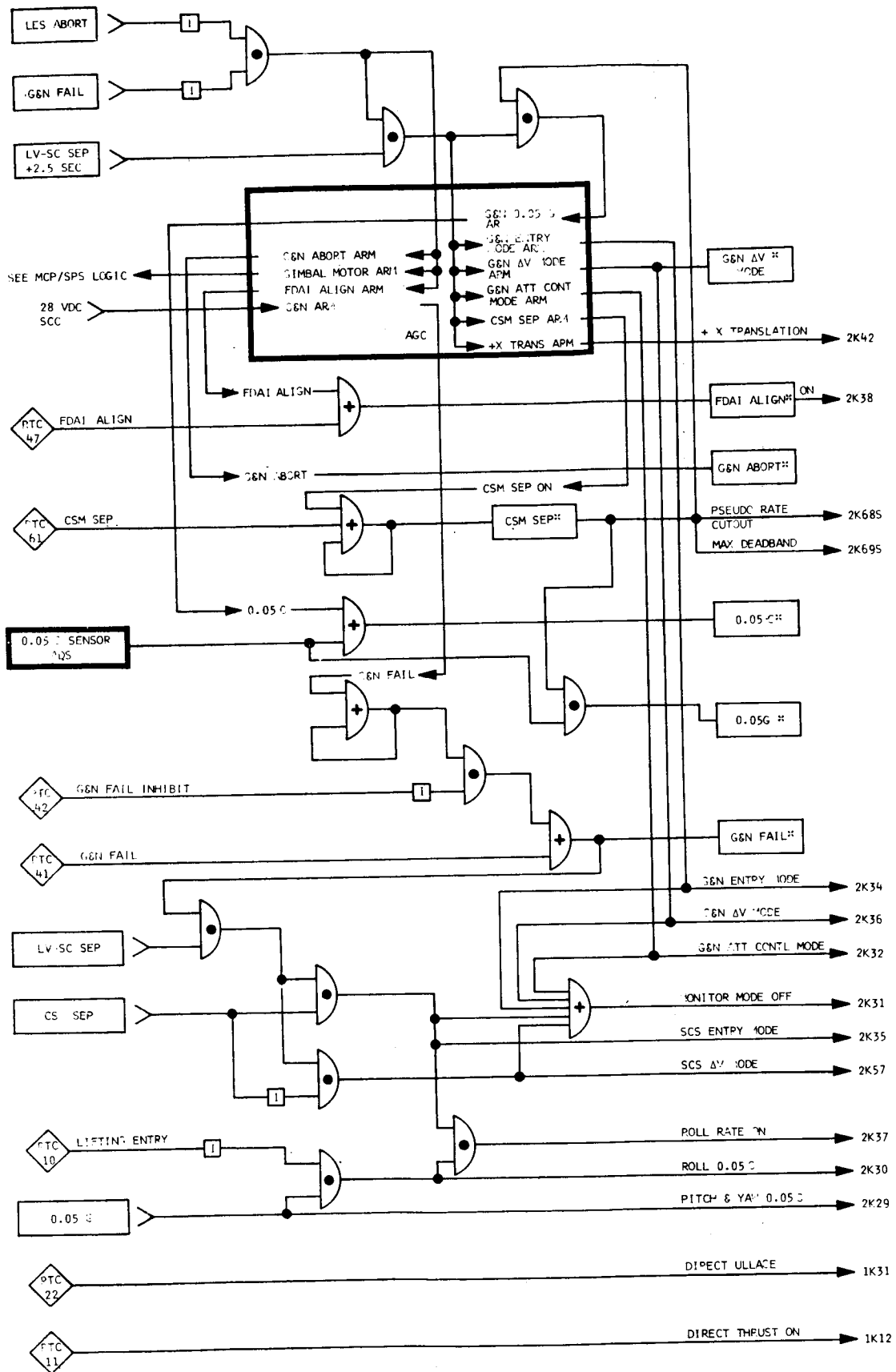


FIGURE 11.5.5C MCP/GN-SCS LOGIC

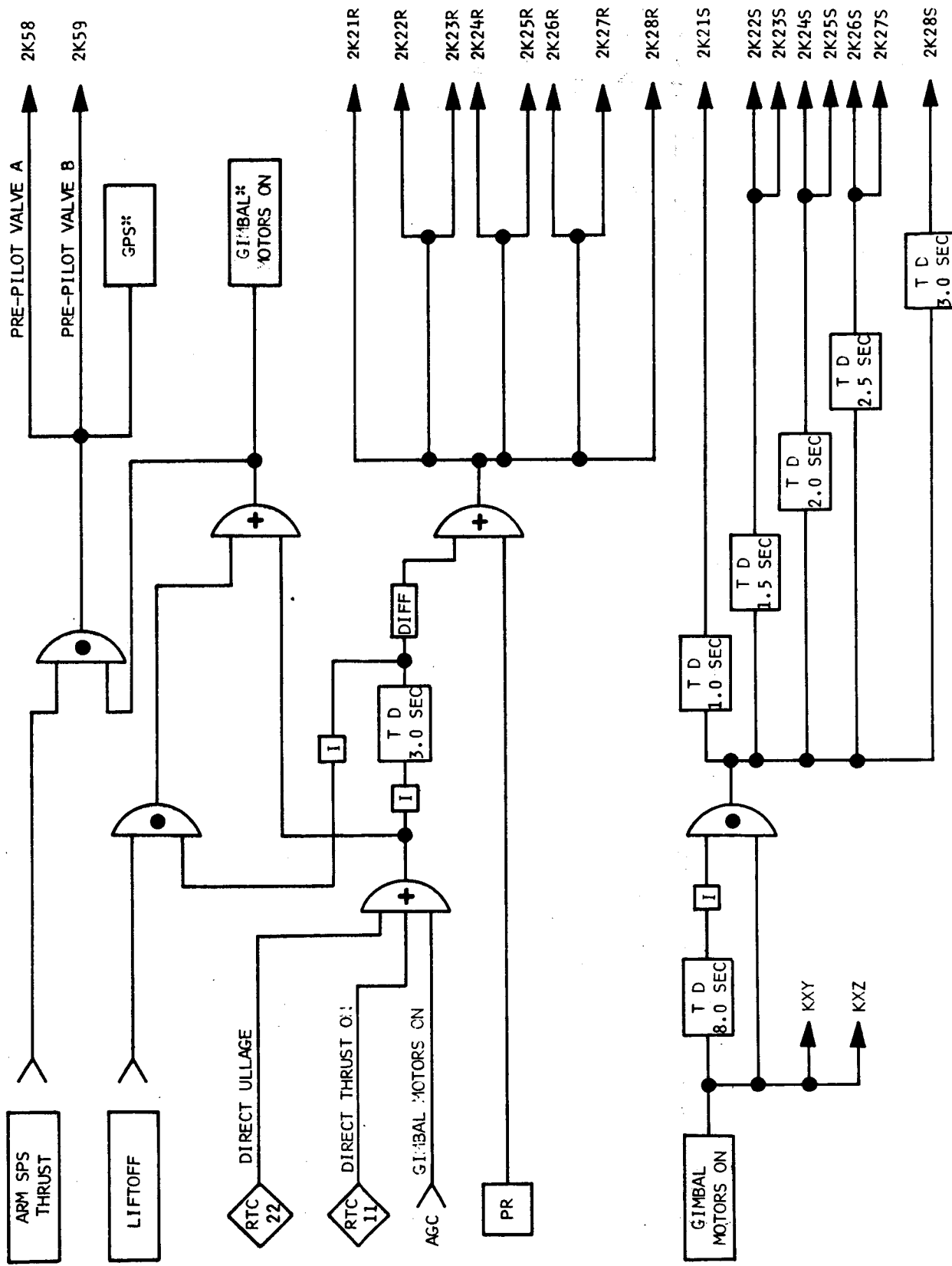


FIGURE 11.5.6 MCP/SPS LOGIC

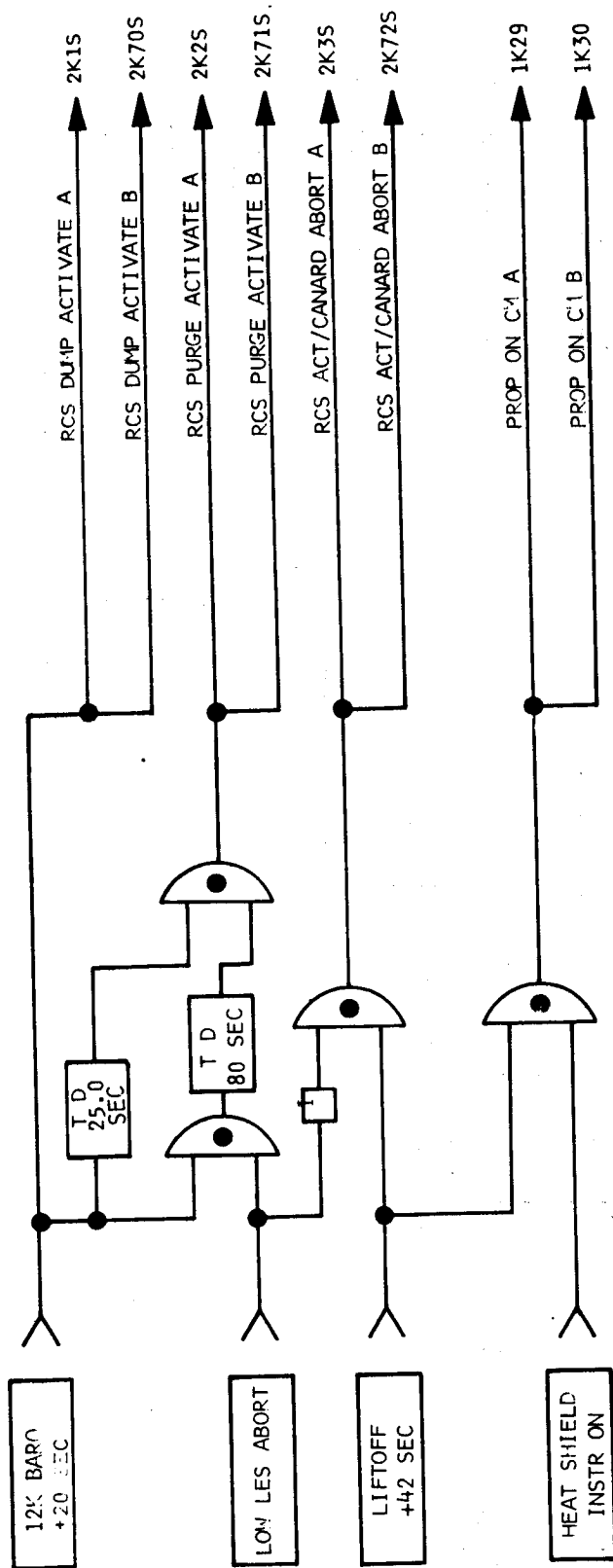


FIGURE 11.5.7 MCP/RCS LOGIC

24

23

22

21

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F

E

D

C

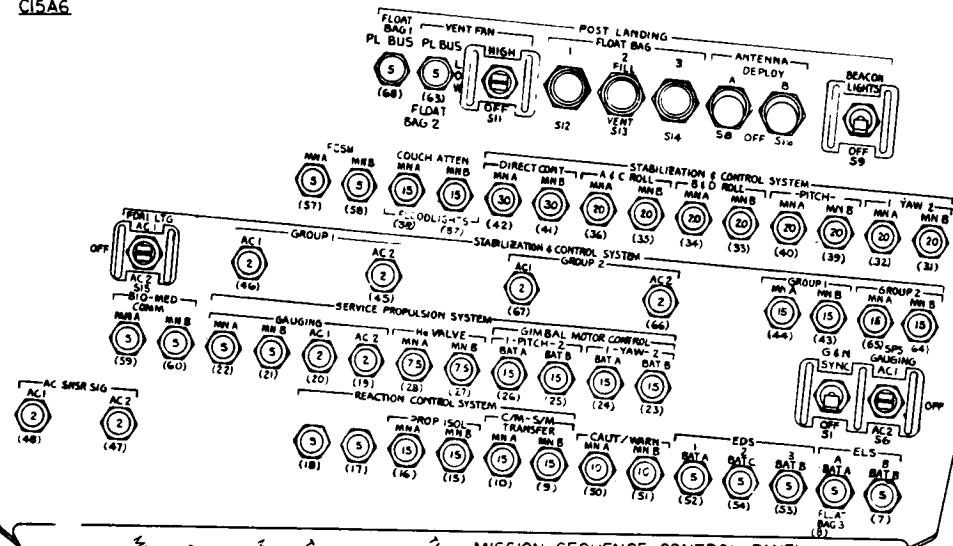
B

A

LH CIRCUIT BREAKER PANEL

C15A6

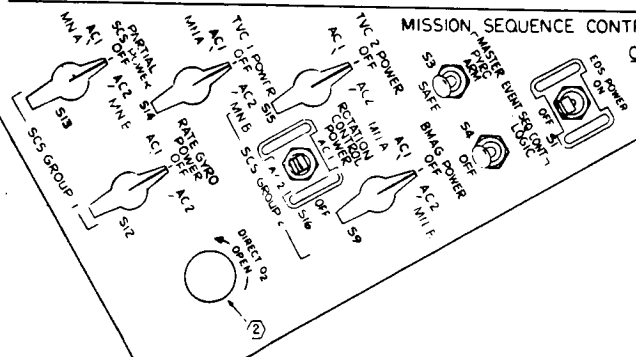
25



MISSION SEQUENCE CONTROL PANEL

C22-2A58

24



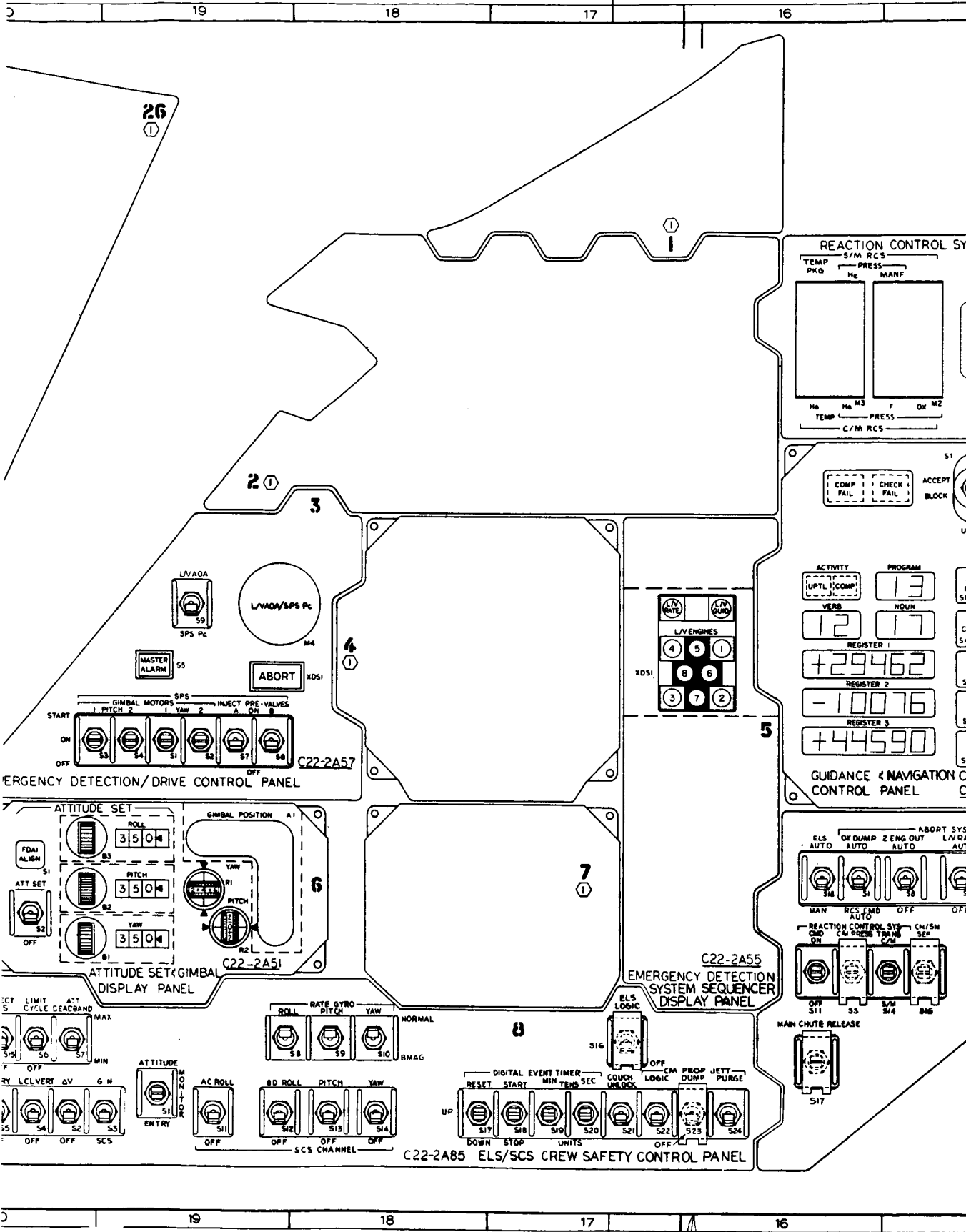
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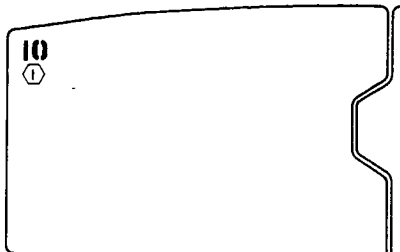
23

22

21

20





STEM & GMT PANEL
C22-2A63

PROPELLANT QUANTITY
106 4

OXIDIZER
53 2

FUEL
MI

RCS INDICATORS



TEL BRIGHTNESS

R1

INC

DM

REACTION CONTROL SYSTEM PANEL
C22-2A64

QTY GAUGING S/M RCS

POWER ON TEST A B HELIUM C D

S1 S2 S3 S4 S5 S6

DS1 DS2 -OFF- DS3 DS4

HELIUM 2

S9 S10 S11 S12

DS7 DS8 -OFF- DS9 DS10

C/M RCS PRPLNT A B PROPELLANT - ON -

S13 S14 S15 S16 S17 S18

DS11 DS12 DS13 DS14 DS15 DS16

KEY LSE

ERROR RESET S17

EAR	VERB S1	NOUN S2	ENTER S3
+	7 S14	8 S15	9 S16
-	4 S11	5 S12	6 S13
0	1 S8	2 S9	3 S10

COMPUTER
27-2A60

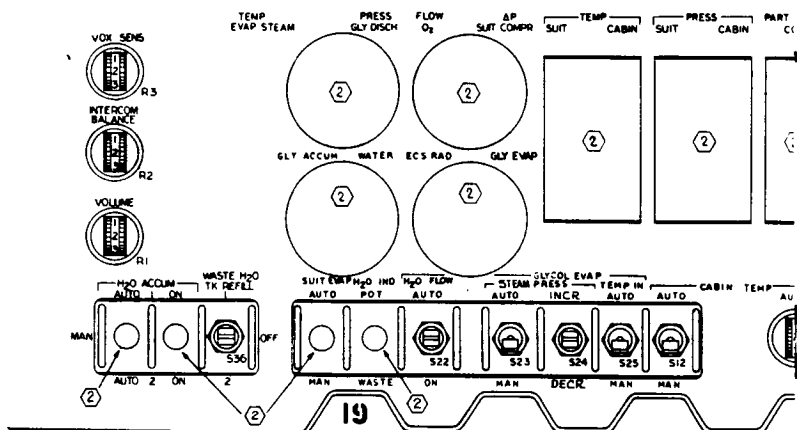
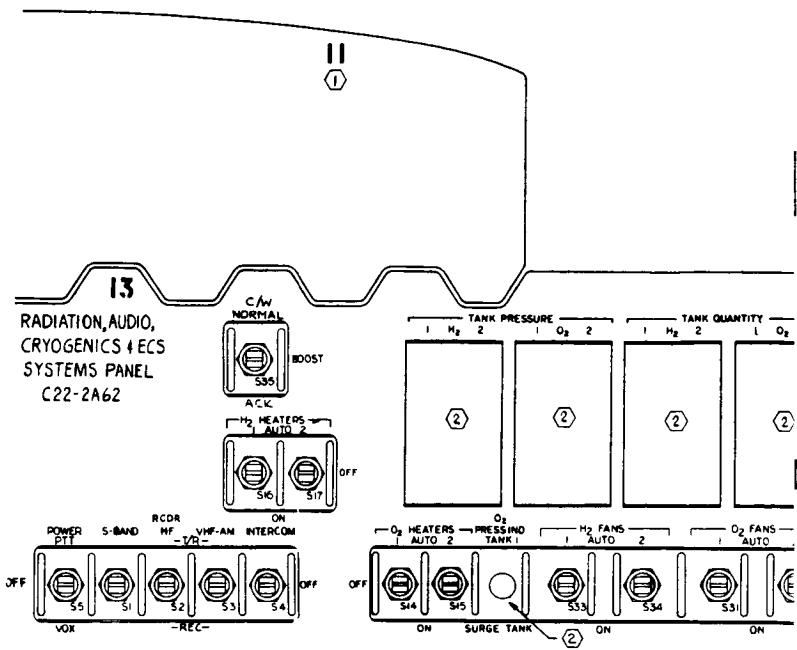
CREW SAFETY CONTROL PANEL
C22-2A61

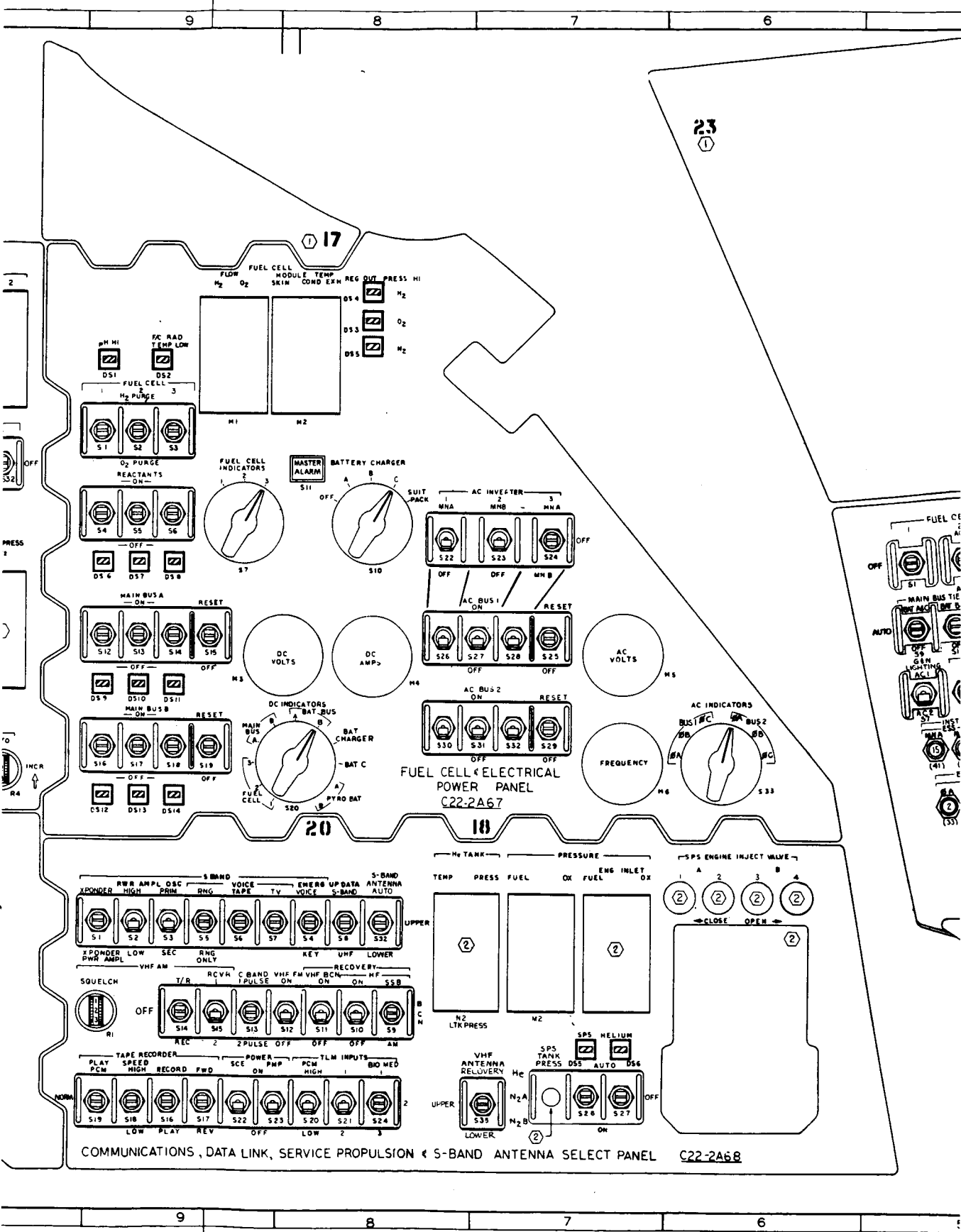
TEM TES

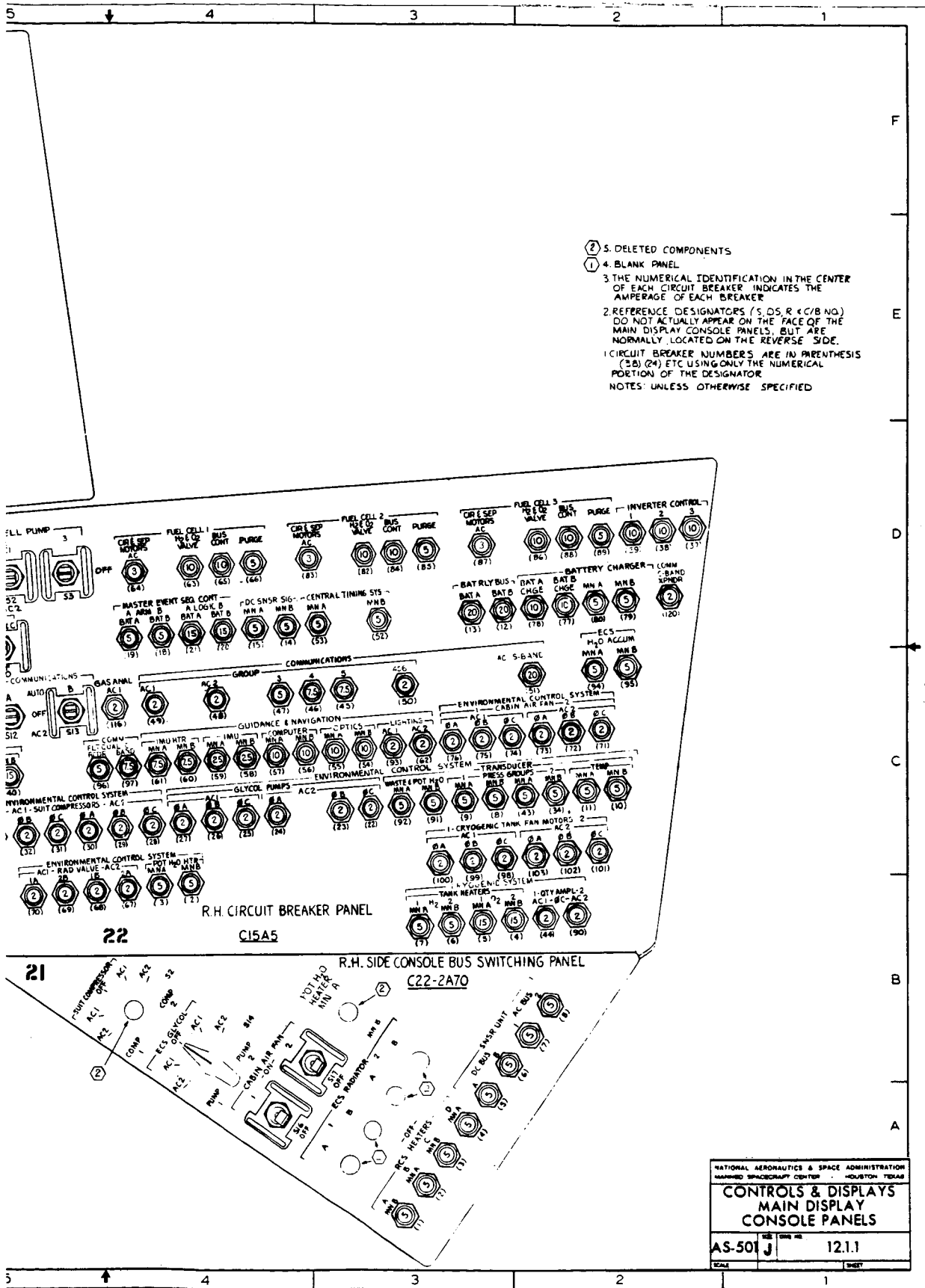
LES MODE AUTO E.D.S

TWR JETT SPS MODE

S15 S16







- ⑤ 5. DELETED COMPONENTS
 - ④ 4. BLANK PANEL
 - ③ 3. THE NUMERICAL IDENTIFICATION IN THE CENTER OF EACH CIRCUIT BREAKER INDICATES THE AMPERAGE OF EACH BREAKER
 - ② 2. REFERENCE DESIGNATORS (S, DS, R, C/B NO.) DO NOT ACTUALLY APPEAR ON THE FACE OF THE MAIN DISPLAY CONSOLE PANELS, BUT ARE NORMALLY LOCATED ON THE REVERSE SIDE.
 - ① 1. CIRCUIT BREAKER NUMBERS ARE IN PARENTHESES (23) (24) ETC USING ONLY THE NUMERICAL PORTION OF THE DESIGNATOR
- NOTES: UNLESS OTHERWISE SPECIFIED

R.H. CIRCUIT BREAKER PANEL
22 C15A5

R.H. SIDE CONSOLE BUS SWITCHING PANEL
21 C22-2A70

24

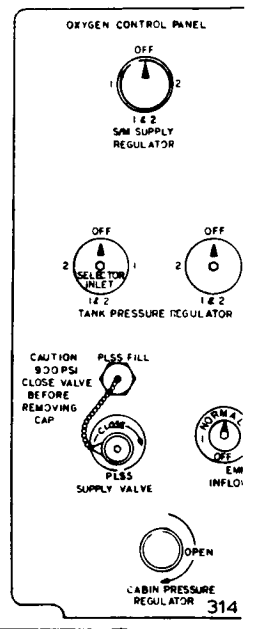
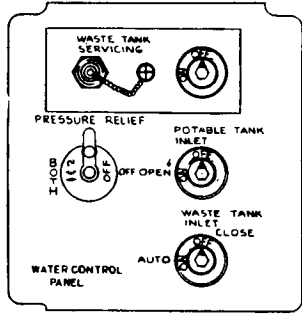
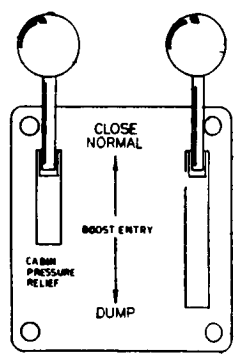
23

22

21

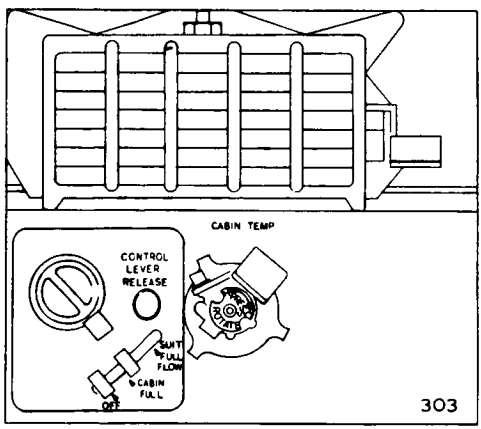
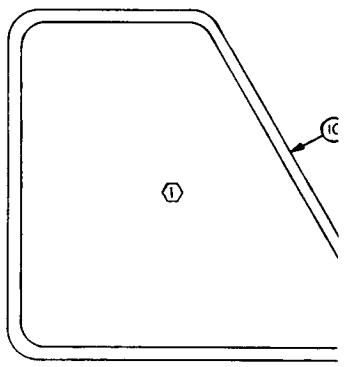
20

LH EQUIPMENT BAY



314

LH FWD EQUIPMENT BAY



303

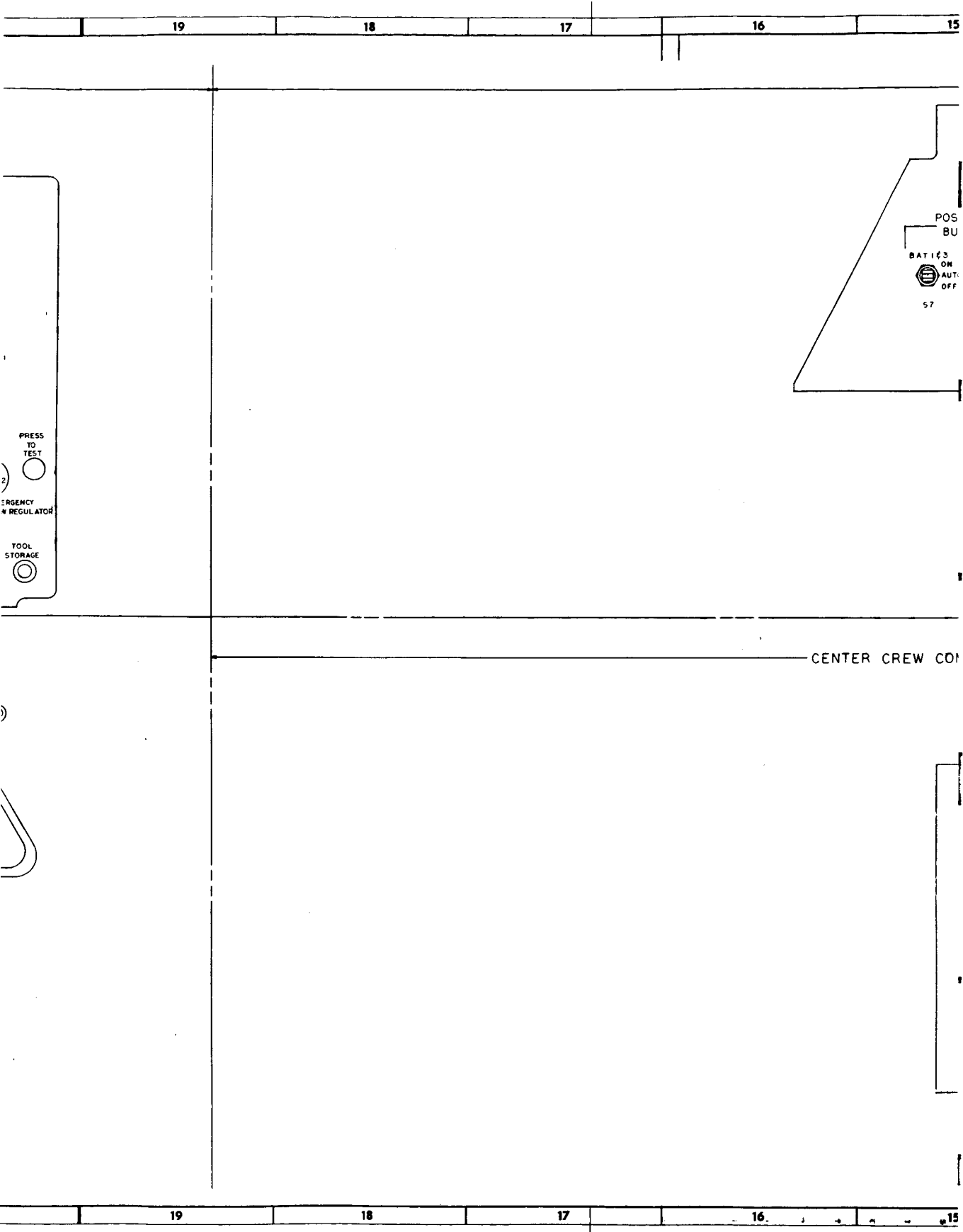
24

23

22

21

20



19 18 17 16 15

PRESS TO TEST
EMERGENCY # REGULATOR

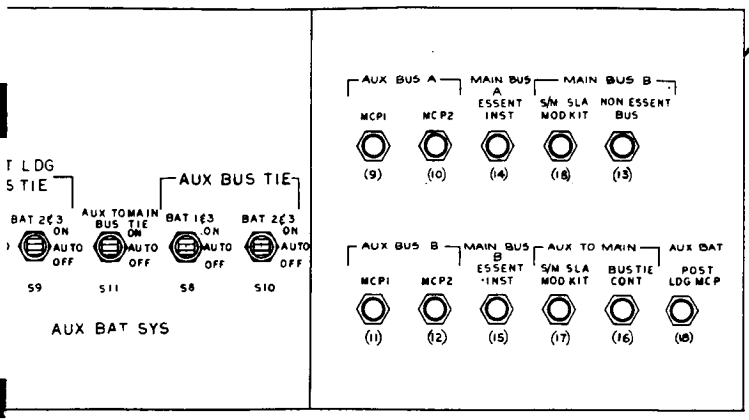
TOOL STORAGE

POS BU
BATTERY ON/AUT. OFF
57

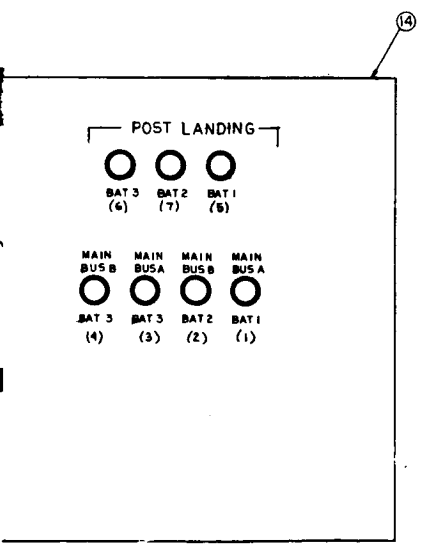
CENTER CREW CO

19 18 17 16 15

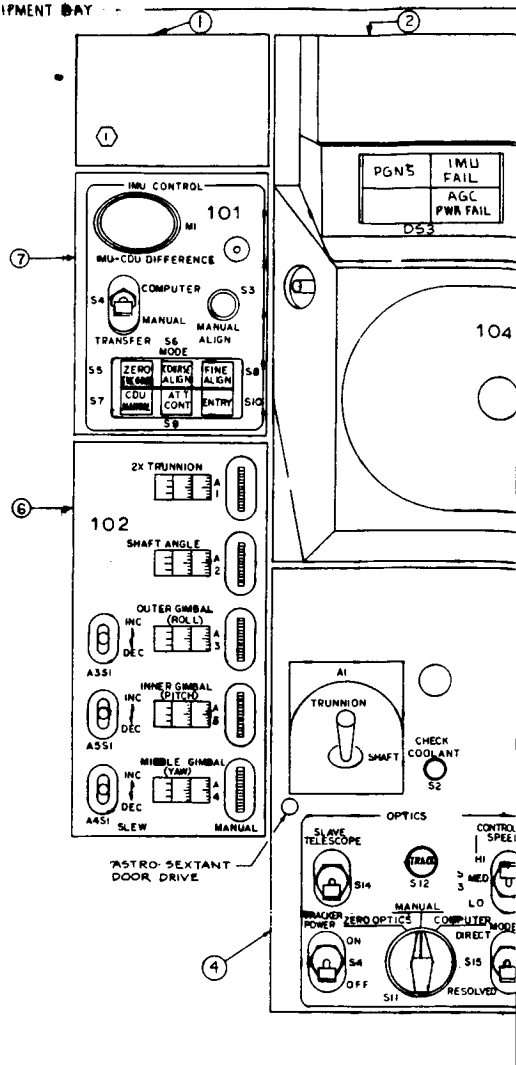
LOWER

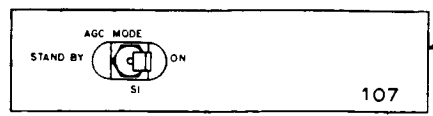
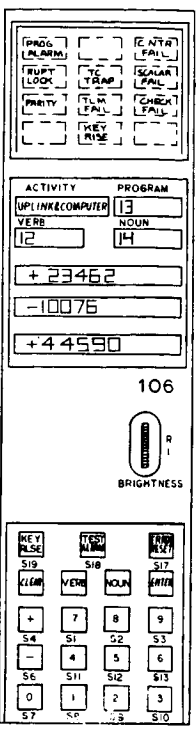
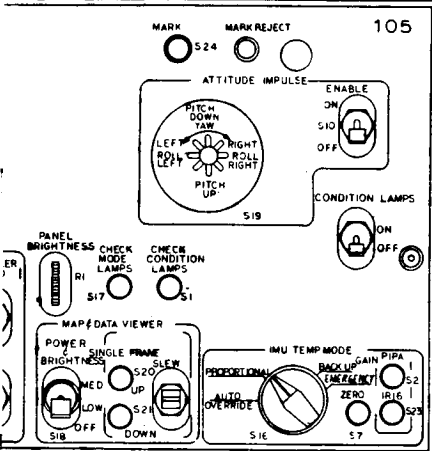
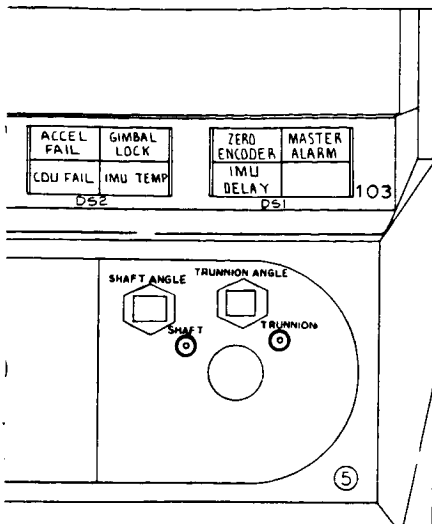


APARTMENT PLATFORM



EQUIPMENT BAY





ITEM NO	PANEL REFERENCE DESIGNATOR	PANEL NOMENCLATURE
①	C22-1A34	CONTROL LOWER EQUIPMENT BAY PANEL 88
②	C27-1A29	CONDITION LIGHT ASSY PANEL 103
③	C27-1A32	AGC COMPUTER DISPLAY AND KEYBOARD PANEL 106
④	C27-1A31	G&N OPTICS CONTROL PANEL 105
⑤	C27-1A30	G&N OPTICS PANEL 104
⑥	C27-1A28	CDU CONTROL PANEL 102
⑦	C27-1A27	IMU CONTROL PANEL 101
⑧	C14A7	ELECTRICAL POWER CIRCUIT BREAKER PANEL
⑨	C14A16	BATTERY CIRCUIT BREAKER PANEL
⑩	C22-1A38	CLOCK AND TIMER PANEL 99
⑪	C26-4A44	AUXILIARY DISPLAY PANEL 97
⑫		AGC PANEL 107
⑬	C14A14	AUXILIARY POWER CONTROL BOX ASSY
⑭	C14A15	AUXILIARY POWER SYSTEM CIRCUIT BREAKER BOX ASSY
⑮	C14A13	UP-RIGHTING CONTROL ASSY
⑯	C23	EC5 STEAM DUCT HRT BREAKERS
⑰	C28A25	DC POWER CONTROL MOD.

