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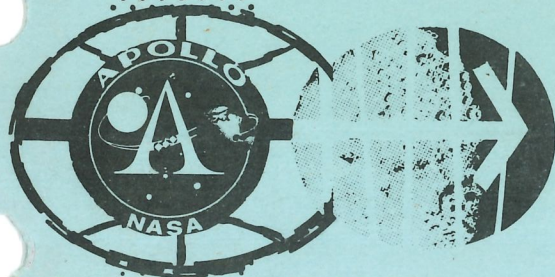
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

*LUNAR MODULE  
SYSTEMS HANDBOOK  
VEHICLE LM-1*

*AS-206  
REV A*

OCTOBER 27, 1966

PREPARED BY  
*FLIGHT CONTROL DIVISION*



MANNED SPACECRAFT CENTER  
HOUSTON, TEXAS

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## APOLLO

### LUNAR MODULE SYSTEMS HANDBOOK

VEHICLE LM-1

AS-206

REV A

#### PREFACE

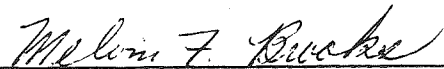
This handbook has been prepared by the Flight Control Division, Manned Spacecraft Center, Houston, Texas, with technical support by Grumman Aircraft Engineering Corporation (GAEC). Information contained within this document represents the LM-1 Systems as of October 27, 1966.

A change in AS-206 Mission requirements occurred just prior to publication, therefore, the resulting LM-1 Systems changes are not reflected in this handbook. See Section 1 for further details.

This document is intended for specialized use by Flight Controllers in real-time and near-real-time operations. Comments concerning the contents should be directed to Mr. Bernard R. Brabant, Agena/Lunar Module Systems Branch, Building 45, Room 428, Phone HU3-5104.

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SECTION 1  
INTRODUCTION

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1.1 VEHICLE CONFIGURATION

This handbook has been prepared in accordance with the former ASPO policy that LM-1 and LM-2 could be flown either unmanned or manned. Accordingly, all systems aspects required to man the vehicle were included in the handbook schematics, and the notes specified the difference in system configuration between unmanned and manned flight.

On October 12, 1966, ASPO issued a policy change which specified LM-1 would be flown unmanned and LM-2 would no longer be capable of completely unmanned flight. This policy change also included a change in LM-1 mission requirements resulting in a simplified version of the AS-206 timeline. The mission objectives are confined to full duration burns of each stage, restart of each stage, fire-in-the-hold (FITH) abort mode, and depletion burn of the ascent stage.

On October 20, 1966, Contract Change Authorization No. 398 to GAEC Contract NAS-9-1100 was issued to implement the LM-1 hardware changes based on the above policy change. This CCA deleted the requirement for all equipment not directly associated with the revised mission. Whether or not that equipment will be physically removed from LM-1, or will remain on board in a passive state is to be determined by GAEC. In addition, CCA 401 issued on October 20, 1966, specified system changes to LM-1 to eliminate critical single-point failures, primarily within the LM Mission Programmer (LMP). This CCA deleted numerous command functions and added two new command functions. Measurement Change Request 654 accounts for the telemetry changes resulting from CCA 398 and 401. The exact system configuration and associated command and measurement changes due to these CCA's are not completely defined at this time.

Rather than delay publication of Revision A until all the final changes are defined, it was considered more desirable to publish the LM-1 (AS-206) Systems Handbook as previously planned. A special updating will be distributed under separate cover at the earliest possible date, which will include all the system changes and the revised command and measurement lists.



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Table 1-1 Standard Abbreviations and Acronyms for LM Documentation

AC	ALTERNATING CURRENT
ACA	ATTITUDE CONTROLLER ASSEMBLY
ACCUM	ACCUMULATOR
ACT	ACTUAL/ACTUATOR
AEA	ABORT ELECTRONICS ASSEMBLY
AELD	ASCENT ENGINE LATCHING DEVICE
AGC	AUTOMATIC GAIN CONTROL
AGS	ABORT GUIDANCE SECTION
ALIGN	ALIGNMENT
ALM	ALARM
ALT	ALTIMETER/ALTITUDE/ALTERNATE
AM	AMMETER/AMPLITUDE MODULATION
AMP	AMPERE
AMP HR	AMPERE HOUR
ANT	ANTENNA
APS	ASCENT PROPULSION SYSTEM
ARM	ARMED
ASA	ABORT SENSOR ASSEMBLY
ASC	ASCENT
ASSY	ASSEMBLY
ATCA	ATTITUDE & TRANSLATION CONTROL ASSEMBLY
ATT	ATTITUDE
AUTO	AUTOMATIC
AUX	AUXILIARY
AVAIL	AVAILABLE
AZ	AZIMUTH
BAT	BATTERY
BIP	BIPROPELLANT
BCN	BEACON
BPS	BITS PER SECOND
BTS	BITS PER SAMPLE

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Table 1-1 Standard Abbreviations and Acronyms for LM Documentation (Cont'd)

CAB	CABIN
CAL	CALIBRATE/CALIBRATION
CALC	CALCULATE/CALCULATED
CB	CIRCUIT BREAKER
C-BND	C-BAND
CBL	CABLE
CC	CONTACT CLOSURE
CDR	COMMANDER
CDU	COUPLING DATA UNIT
CES	CONTROL ELECTRONICS SECTION
CHAR	CHARACTER
CL	CLOSE
CLSD	CLOSED
CMD	COMMAND
CMDED	COMMANDED
CNTL	CONTROL
CO <sub>2</sub>	CARBON DIOXIDE
COMM	COMMUNICATIONS
COMP	COMPARE
COND	CONDITION/CONDITIONING/CONDITIONER
CONT	CONTINUE
COOL	COOLANT
CP	COMMAND PILOT
CPS	CYCLES PER SECOND
CRT	CATHODE-RAY-TUBE
CTG	CARTRIDGE
CUR	CURRENT
D	DOWNWARD THRUSTING RCS ENGINE
DAC	DIGITAL ANALOG CONVERTER
DB	DECIBEL
DC	DIRECT CURRENT
DCA	DIGITAL COMMAND ASSEMBLY

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Table 1-1 Standard Abbreviations and Acronyms for LM Documentation (Cont'd)

DECA	DESCENT ENGINE CONTROL ASSEMBLY
DECR	DECREASE
DEDA	DATA ENTRY AND DISPLAY ASSEMBLY
DEG	DEGREE
DESC	DESCENT
DET	DETENT/DETECTOR
DFI	DEVELOPMENTAL FLIGHT INSTRUMENTATION
DIFF	DIFFERENCE/DIFFERENTIAL
DIG	DIGITAL
DIR	DIRECT
DISCH	DISCHARGE
DISP	DISPLAY
DIV	DIVERTER
DLAY	DELAY
DPLY	DEPLOY/DEPLOYED
DPS	DESCENT PROPULSION SYSTEM
DSKY	DISPLAY AND KEYBOARD
ECA	ELECTRONICS CONTROL ASSEMBLY
ECS	ENVIRONMENTAL CONTROL SYSTEM
EKG	ELECTROCARDIOGRAM
ELEC	ELECTRICAL/ELECTRICALLY
EMER	EMERGENCY
ENBL	ENABLE
ENG	ENGINE
ENGR	ENGINEER
EPS	ELECTRICAL POWER SYSTEM
EQUIP	EQUIPMENT
ERR	ERROR
EXT	EXTEND
F	FAHRENHEIT/FORWARD THRUSTING RCS ENGINE
FAIL	FAILURE
FDAI	FLIGHT DIRECTOR ATTITUDE INDICATOR
FITH	FIRE IN THE HOLD

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Table 1-1 Standard Abbreviations and Acronyms for LM Documentation (Cont'd)

FL	FLAG
FM	FREQUENCY MODULATION
FP	FLIGHT PROGRESS
FREQ	FREQUENCY
FWD	FORWARD
GASTA	GIMBAL ANGLE SEQUENCING TRANSFORMATION ASSEMBLY
GDA	GIMBAL DRIVE ACTUATOR
GLY	GLYCOL
GMBL	GIMBAL
GND	GROUND
GUID	GUIDANCE
HBR	HIGH BIT RATE
HE	HELIUM
H/H	ALTITUDE/ALTITUDE RATE
HI	HIGH
HL	HIGH LEVEL
HLD	HOLD
H <sub>2</sub> O	WATER
HSD	HIGH SPEED DATA
HV	HIGH VOLTAGE
HVR	HOVER
H/X	HEAT EXCHANGER
ID	IDENTIFICATION
IG	INNER GIMBAL
IGA	INNER GIMBAL ANGLE
IGN	IGNITION
IMU	INERTIAL MEASUREMENT UNIT
IN	INLET
INJ	INJECTOR
INCR	INCREASE
INST	INSTRUMENTATION
INVT	INVERTER



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Table 1-1 Standard Abbreviations and Acronyms for LM Documentation (Cont'd)

IRIG	INERTIAL RATE INTEGRATING GYRO
ISO	ISOLATION
ISS	INERTIAL SENSOR SYSTEM
JETT	JETTISON
JD	JET DRIVER
LAT	LATITUDE/LATERAL
LBR	LOW BIT RATE
LDG	LANDING
LGC	LEM GUIDANCE COMPUTER
LIM	LIMIT/LIMITS
LMP	LEM MISSION PROGRAMER
LO	LOW
LONG	LONGITUDE
LR	LANDING RADAR
LSB	LEAST SIGNIFICANT BIT
LV	LOW VOLTAGE
LVL	LEVEL
MAN	MANUAL/MANIFOLD
MAP	MESSAGE ACCEPTANCE PULSE
MAX	MAXIMUM
MET	MISSION ELAPSED TIME
MFC	MAIN FEEDER CONTRACTOR
MG	MIDDLE GIMBAL
MGA	MIDDLE GIMBAL ANGLE
MIN	MINIMUM
MOCR	MISSION OPERATIONS CONTROL ROOM
MPX	MULTIPLEX
MSFN	MANNED SPACEFLIGHT NETWORK
MSB	MOST SIGNIFICANT BIT
MTR	METER
(-)	NEGATIVE
NORM	NORMAL

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Table 1-1 Standard Abbreviations and Acronyms for LM Documentation (Cont'd)

O <sub>2</sub>	OXYGEN
OB	ONBOARD
OG	OUTER GIMBAL
OGA	OUTER GIMBAL ANGLE
OPN	OPEN
OPR	OPERATE
OUT	OUTLET/OUTPUT
OVR	OVER
OVRD	OVERRIDE
OX	OXIDIZER
PA	POWER AMPLIFIER
PART	PARTIAL
PCA	PROGRAM COUPLER ASSEMBLY
PCM	PULSE CODE MODULATION
PCT	PER CENT
PGNS	PRIMARY GUIDANCE AND NAVIGATION SYSTEM
PFS	PER CENT FULL SCALE
PIPA	PULSED INTEGRATING PENDULOUS ACCELEROMETER
ΔP	DIFFERENTIAL PRESSURE
PLSD	PULSED
PLSS	PORTABLE LIFE SUPPORT SYSTEM
PM	PHASE MODULATION
PNLS	PANELS
PO	POWER OUTPUT
POS	POSITION
PRA	PROGRAM READER ASSEMBLY
PRESS	PRESSURE
PRIM	PRIMARY
PROG	PROGRAM
PROP	PROPELLANT/PROPULSION
PSIA	POUNDS PER SQUARE INCH ABSOLUTE
PSID	POUNDS PER SQUARE INCH DIFFERENTIAL



Table 1-1 Standard Abbreviations and Acronyms for LM Documentation (Cont'd)

PTA	PULSE TORQUE ASSEMBLY
PVR	PRECISION VOLTAGE REFERENCE
PWR	POWER
PYRO	PYROTECHNIC
QD	QUICK DISCONNECT
QTY	QUANTITY
QUAD	QUADRANT
RC/OC	REVERSE CURRENT/OVERCURRENT
RCS	REACTION CONTROL SYSTEM
RCVR	RECEIVER
REC	RECORDER
RECD	RECEIVED
REF	REFERENCE
REG	REGULATOR
REL	RELEASE
RET	RETRACT/RETURN
REV	REVERSE
RF	RADIO FREQUENCY
RFLT	REFLECT/REFLECTED
RG	RATE GYRO ASSEMBLY
RLY	RELAY
RNG	RANGE/RANGING
RR	RENDEZVOUS RADAR
RS	REMOTE SITE
RSVR	RESOLVER
RUPT	RUPTURE
S	SIDEWARD THRUSTING RCS ENGINE
S-BND	S-BAND
S/C	SPACECRAFT
SCS	STABILIZATION AND CONTROL SYSTEM
SE	SYSTEMS ENGINEER

Table 1-1 Standard Abbreviations and Acronyms for LM Documentation (Cont'd)

SEC	SECONDARY/SECOND
SEL	SELECT
SEP	SEPARATION/SEPARATOR
SEQ	SEQUENCE
SET	SET/SETTING
SIG	SIGNAL
SLA	SPACECRAFT LAUNCH ADAPTER
S/O	SHUT OFF
SOL	SOLENOID
SOV	SHUT OFF VALVE
SP	SPARE
S/S	SAMPLES PER SECOND
SSR	STAFF SUPPORT ROOM
ST	STATIC
STGE	STAGE
STBY	STANDBY
STR	STRENGTH
STRB	STROBE
SUP	SUPPLY
SUSP	SUSPENSION
SVO	SERVO
SW	SWITCH
SYNCH	SYNCHRONIZATION
SYS	SYSTEM
TCA	THRUST CHAMBER ASSEMBLY
TCP	THRUST CHAMBER PRESSURE
TEMP	TEMPERATURE
THROT	THROTTLE
TJM	TOWER JETTISON MOTOR
TK	TANK
TLM	TELEMETRY
TOL	TOLERANCE

Table 1-1 Standard Abbreviations and Acronyms for LM Documentation (Concluded)

TRANS	TRANSLATION
TRUN	TRUNNION
T/TCA	THRUST/TRANSLATION CONTROLLER ASSEMBLY
TTY	TELETYPE/TELETYPEWRITER
U	UPWARD THRUSTING RCS ENGINE
UHF	ULTRA-HIGH FREQUENCY
V	VOLT
ΔV	CHANGE IN VELOCITY
VAC	ALTERNATING CURRENT VOLTS
VAR	VARIABLE
VDC	DIRECT CURRENT VOLTS
VEL	VELOCITY
VHF	VERY HIGH FREQUENCY
VLV(S)	VALVE/VALVES
VPI	VALVE POSITION INDICATOR
VRMS	VOLT ROOT MEAN SQUARE
W	WATT
WB	WIDEBAND
W/B	WATER BOILER
X	CROSS
XMTR	TRANSMITTER
XPNDR	TRANSPONDER
(∅)	PHASE

TABLE 1-2 DRAWING SYMBOLS STANDARDS

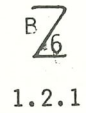


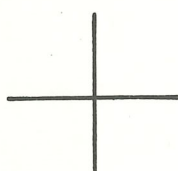
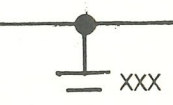
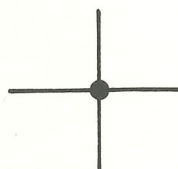
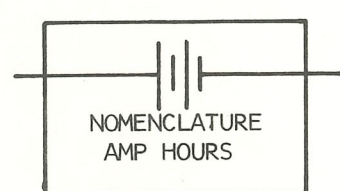
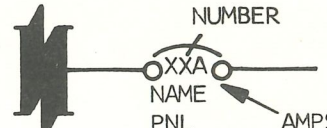
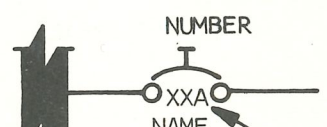
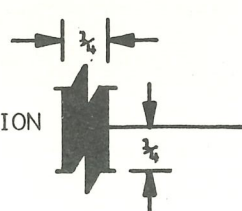


1. ZONE	5. GROUNDS
	A. SYSTEM 
2. LEADS	B. FRAME 
A. CROSSOVER 	C. CONTROLLED 
B. CONNECTED 	6. CIRCUIT BREAKERS
3. BATTERY 	A. TOGGLE 
4. BUS.	B. PUSHBUTTON 
	7. FUSES
	A. GENERAL 
	B. FUSISTOR 



TABLE 1-2 DRAWING SYMBOLS STANDARDS (Cont'd)

LM  
AS-206  
REV A

LM  
AS-206  
REV A

TABLE 1-2 DRAWING SYMBOLS STANDARDS (Cont'd)

8. DIODES

A. GENERAL



B. ZENER



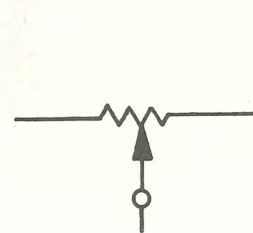
C. TUNNEL



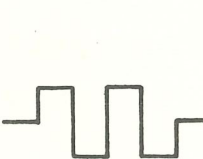
D. CONTROL RECTIFIER



9. POTENTIOMETER



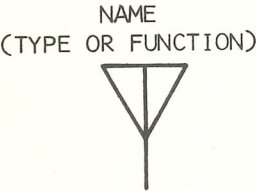
10. HEATER



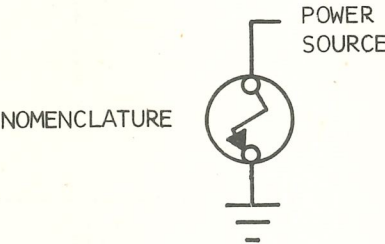
11. THERMOSTAT



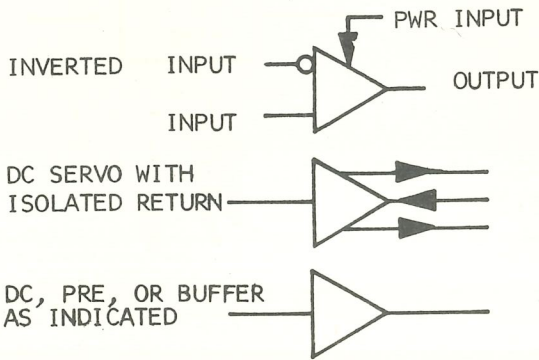
12. ANTENNA



13. EXPLOSIVE



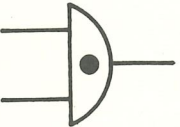
14. AMPLIFIER



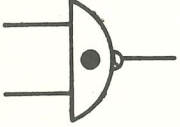
A-3  
1-12

15. GATES

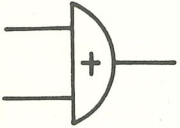
A. AND



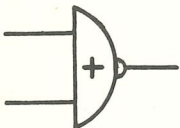
B. NAND



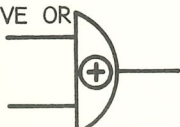
C. OR



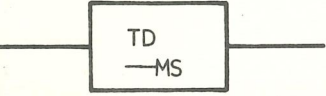
D. NOR



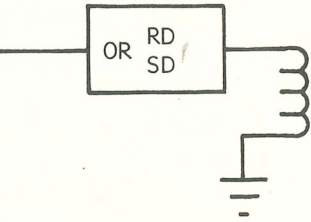
E. EXCLUSIVE OR



16. TIME DELAY



17. RELAY DRIVER OR SOLENOID DRIVER

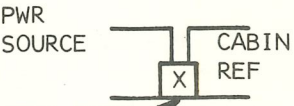


18. COMMAND



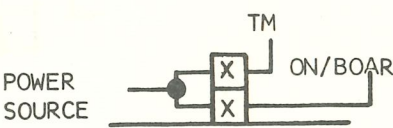
19. SENSOR

A. SINGLE SOURCE



LETTER INDICATES TYPE  
PA = PRESS PSIA W = WETNESS  
PD = PRESS PSID POS = POSITION  
T = TEMP  
Q = QUANTITY, ETC.  
Δ = DELTA

B. DOUBLE SOURCE



VG VELOCITY GENERATOR  
FEEDBACK TRANSDUCER

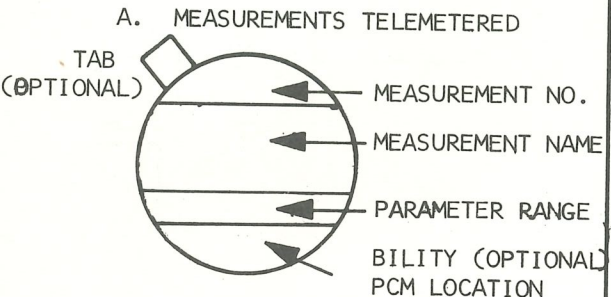
POS POSITION FEEDBACK TRANSDUCER

1-13

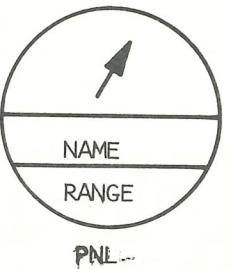
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LM  
AS-206  
REV A

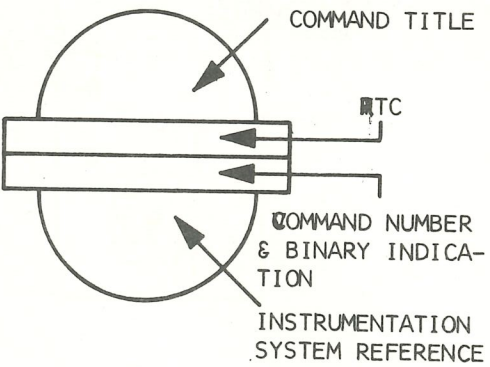
20. TELEMETRY



B. ONBOARD METERS



C. BI-LEVEL CMD



21. RELAYS

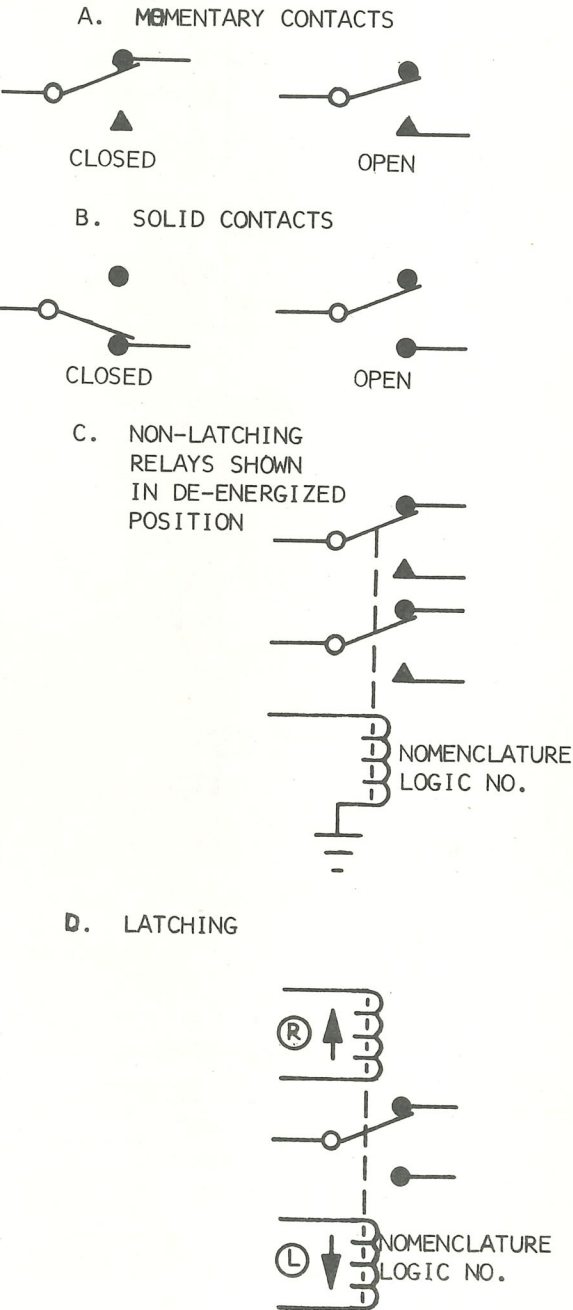
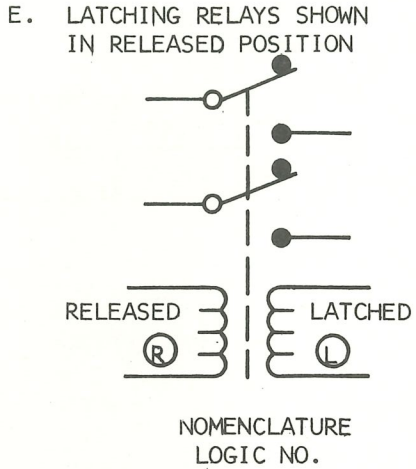


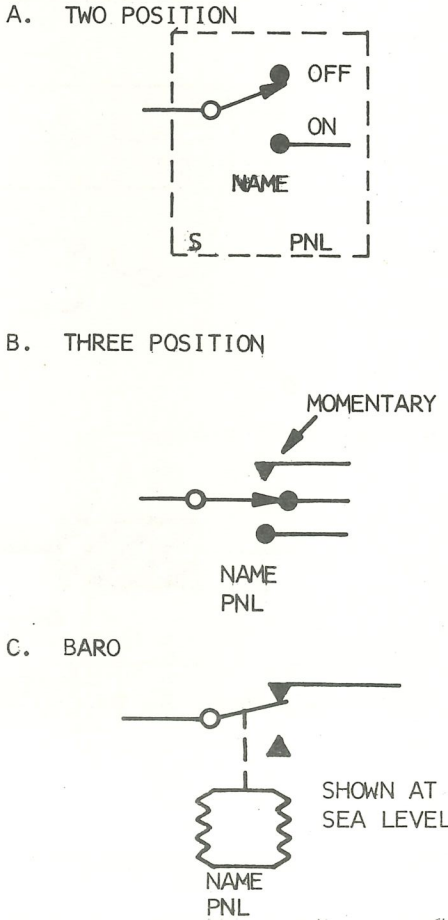
TABLE 1-2 DRAWING SYMBOLS STANDARDS (Cont'd)

LM  
AS-206  
REV A

21. RELAYS

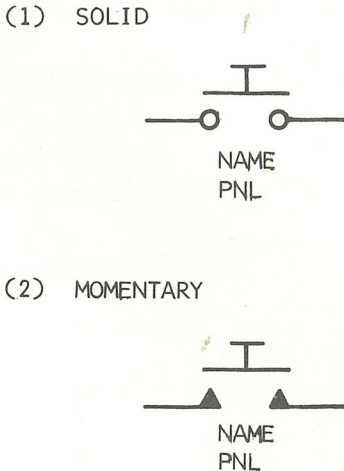


22. SWITCHES



22. SWITCHES (CONT'D)

C. PUSH BUTTON



D. COAX

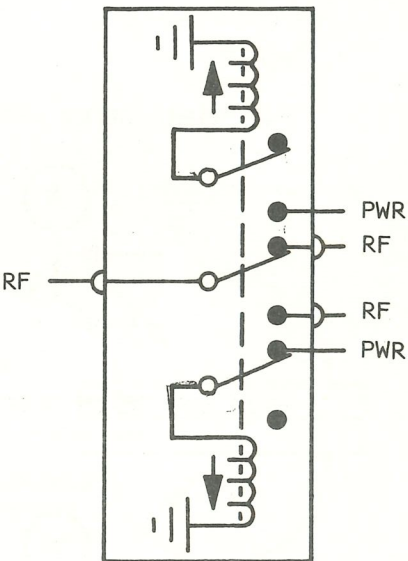


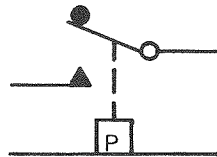
TABLE 1-2 DRAWING SYMBOLS STANDARDS (Cont'd)

LM  
AS-206  
REV A

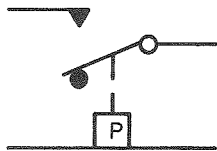
## 22. SWITCHES

### E. PRESSURE

(1) CLOSED DECREASE PRESSURE

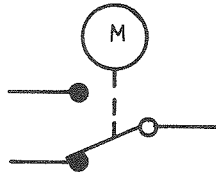


(2) CLOSED INCREASED PRESSURE

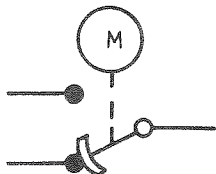


### F. MOTOR

(1) BREAK BEFORE MAKE

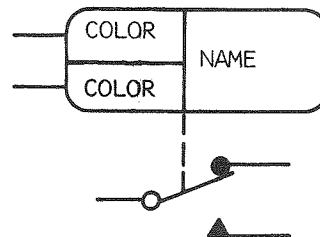
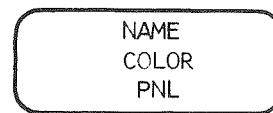
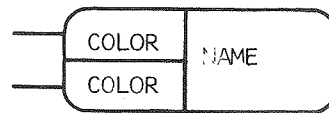


(2) MAKE BEFORE BREAK



## 23. LIGHTS

### A. TEDELIGHTS



## 24. ANNUNCIATOR FLAG





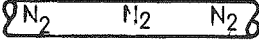
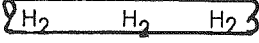
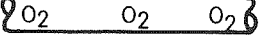
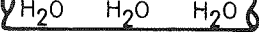

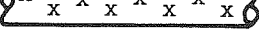





(GENERALLY, THIS IS ASSOCIATED WITH A SWITCH POSITION AND SHOULD BE LOCATED IN THE SAME BLOCK AS THE SWITCH.)



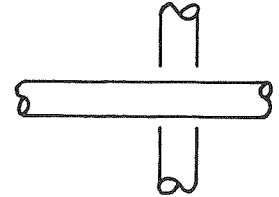
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AS-206  
REV A

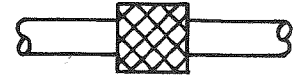
25. LINES

- 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 

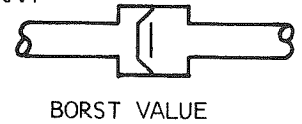
26. PIPE CROSSOVER



27. FILTER



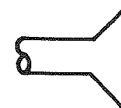
28. BURST DIAPHRAM



29. VENTURI



30. VENT



31. FILL AND DRAIN

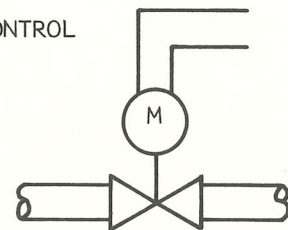


TABLE 1-2 DRAWING SYMBOLS STANDARDS (Cont'd)

LM  
AS-206  
REV A

32.

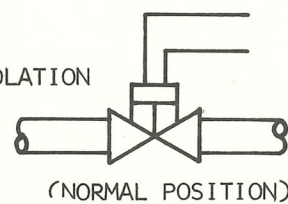
A. MOTOR CONTROL



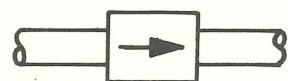
B. MANUAL CONTROL



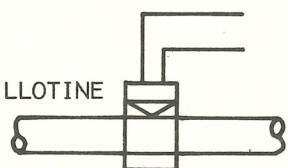
C. PYRO ISOLATION



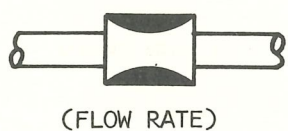
D. CHECK



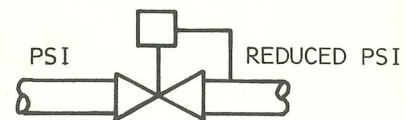
E. PYRO GUILLOTINE



F. ORIFICE



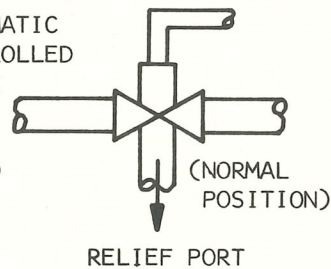
G. PRESSURE REGULATOR



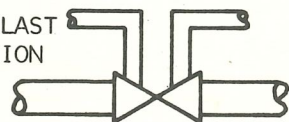
H. RELIEF VALVE



I. PNEUMATIC CONTROLLED VALVE WITH LINE BLEED (NORMAL POSITION)  
RELIEF PORT



J. FAIL LAST POSITION PNEUMATIC VALVE



K. SOLENOID VALVE

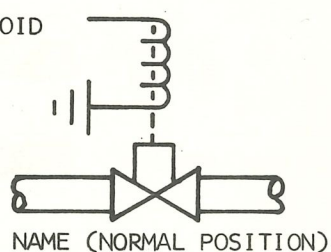
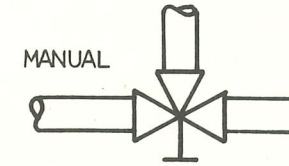


TABLE 1-2 DRAWING SYMBOLS STANDARDS (Cont'd)

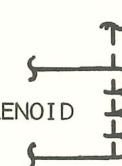
LM  
AS-206  
REV A

L. THREE-WAY VALVE

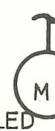
1. MANUAL



2. SOLENOID



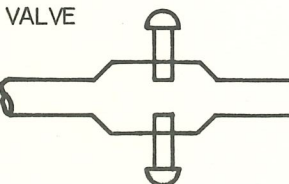
3. MOTOR CONTROLLED



M. BALL VALVE



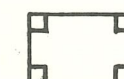
N. PU VALVE



33. DISCONNECTS



SELF-SEALING



QUICK

34. DEAD FACE CHARGE



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

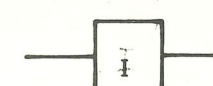
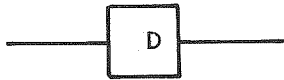
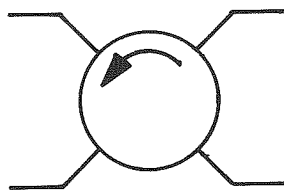


TABLE 1-2 DRAWING SYMBOLS STANDARDS (Concluded)

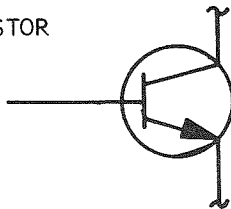
41. DEMODULATOR



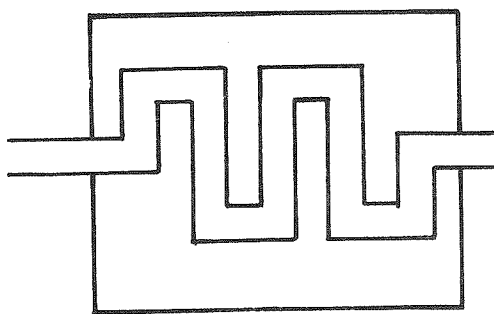
42. R.F. CIRCULATOR



43. TRANSISTOR



44. HEAT EXCHANGER







\*

SECTION 2  
PYROTECHNIC

LM  
AS-206  
REV A

2.1 SYSTEM DESCRIPTION

The LM Pyro system is composed of two fully redundant systems, "A" and "B". All switches, prime relays, and RTC relays in System A have counterparts in System B which are actuated simultaneously.

All pyrotechnic initiators used on the LM are the Single Bridge Apollo Standard Initiator (SBASI) type. These initiators have only two pins and due to several design changes are more reliable than the four pin or dual bridge type. The LM pyro electrical system is a shielded floating ground system whereas the Command Service Module (CSM) uses a grounded pyro system. The difference between the two systems is due to a compromise between EMI and static electricity effects on the pyro systems. All interstage current carrying cables and all interstage cables which would affect the ascent stage by being grounded are routed through the interstage electrical circuit interrupters. All interstage cables are routed through the interstage cable cutter. All interstage oxygen and water lines have "quick disconnect" type connectors and are not pyrotechnic in nature.

There are two differences between System A and System B. System A ignites the explosive staging bolts while System B ignites the explosive staging nuts; and System A has a telemetry point for "Landing Gear Deploy Commanded" while Systems B does not. The LM pyro system should not be confused with the spacecraft launch adapter (SLA) pyro system which performs separate functions.



2-2

TABLE 2-1 LM PYRO SYSTEM FUNCTIONS

No.	Function	Components	System A Initiators	System B Initiators	Notes
1	Deploy Landing Gear	Four uplock devices	4	4	Two opposing blades in each device, one powered by System A and one powered by System B. Either blade can sever uplock strap.
2	Staging				
	Explosive Nuts	Four nuts	0	4	One initiator per nut
	Explosive Bolts	Four bolts	4	0	One initiator per bolt
	Electrical circuit interrupters	Three interrupters	3	3	Two initiators per interrupter, one from System A and one from System B. One initiator can operate the interrupter.
	Cable Cutter	One cutter	1	1	Two opposing blades, one powered by System A and one powered by System B. Two tubes interconnect the charges behind each blade such that one initiator can fire the charge behind both blades. One blade can sever the interstage umbilical.
3	RCS He. Pressurize				
	RCS System A	Two valves in parallel	1	1	Valves are the single initiator type placed in parallel. One valve will pressurize the system.
	RCS System B	Two valves in parallel	1	1	Valves are the single initiator type placed in parallel. One valve will pressurize the system.
4	Ascent Engine Pressurize				
	He. Press. Tank 1	One valve	1	1	Valve is dual initiator type, one powered from System A and one from System B. One initiator will operate the valve.

2-3

TABLE 2-1 LM PYRO SYSTEM FUNCTIONS (CONCLUDED)

No.	Function	Components	System A Initiators	System B Initiators	Notes
	He. Press. Tank 2	One valve	1	1	Valve is dual initiator type, one powered from System A and one from System B. One initiator will operate the valve.
	Ox Comp Valves	Two valves in parallel	1	1	Valves are dual initiator type with one port plugged. With the valves in parallel one is powered from System A and the other is powered from System B. One valve will pressurize the system.
	Fuel Comp Valves	Two valves in parallel	1	1	Valves are dual initiator type with one port plugged. With the valves in parallel one is powered from System A and the other is powered from System B. One valve will pressurize the system.
5	Descent Engine Pressurize				
	He. Press.	One valve	1	1	Valve is dual initiator type, one powered from System A and one from System B. One initiator will operate the valve.
	Ox Comp Valve	One valve	1	1	Valve is dual initiator type, one powered from System A and one from System B. One initiator will operate the valve.
	Fuel Comp Valve	One valve	1	1	Valve is dual initiator type, one powered from System A and one from System B. One initiator will operate the valve.

\*

LM  
AS-206  
REV A

## 2.2 SYSTEM DATA

A. Pyro Batteries - The pyro system has two batteries, one for system A and one for System B. These batteries are 30 volt batteries rated at 0.75 amp-hours.

B. Prelaunch status of Switch/Circuit Breaker Position.

Name	Number	Position
Landing Gear Deploy	2S10 VIII	Safe
Stage	2S5 VIII	Safe
RCS Pressurize	2S2 VIII	Safe
Ascent He. Pressurize	2S4 VIII	Safe
Ascent He. Select	2S3 VIII	Both
Abort Stage	1S14 I	Safe
Master Arm	2S7 VIII	Off
Abort Stage	4CB 2	Closed
Abort Stage	4CB 3	Closed
Logic Power B	4CB75	Closed
Logic Power A	4CB76	Closed
Landing Gear Flag	4CB139	Closed



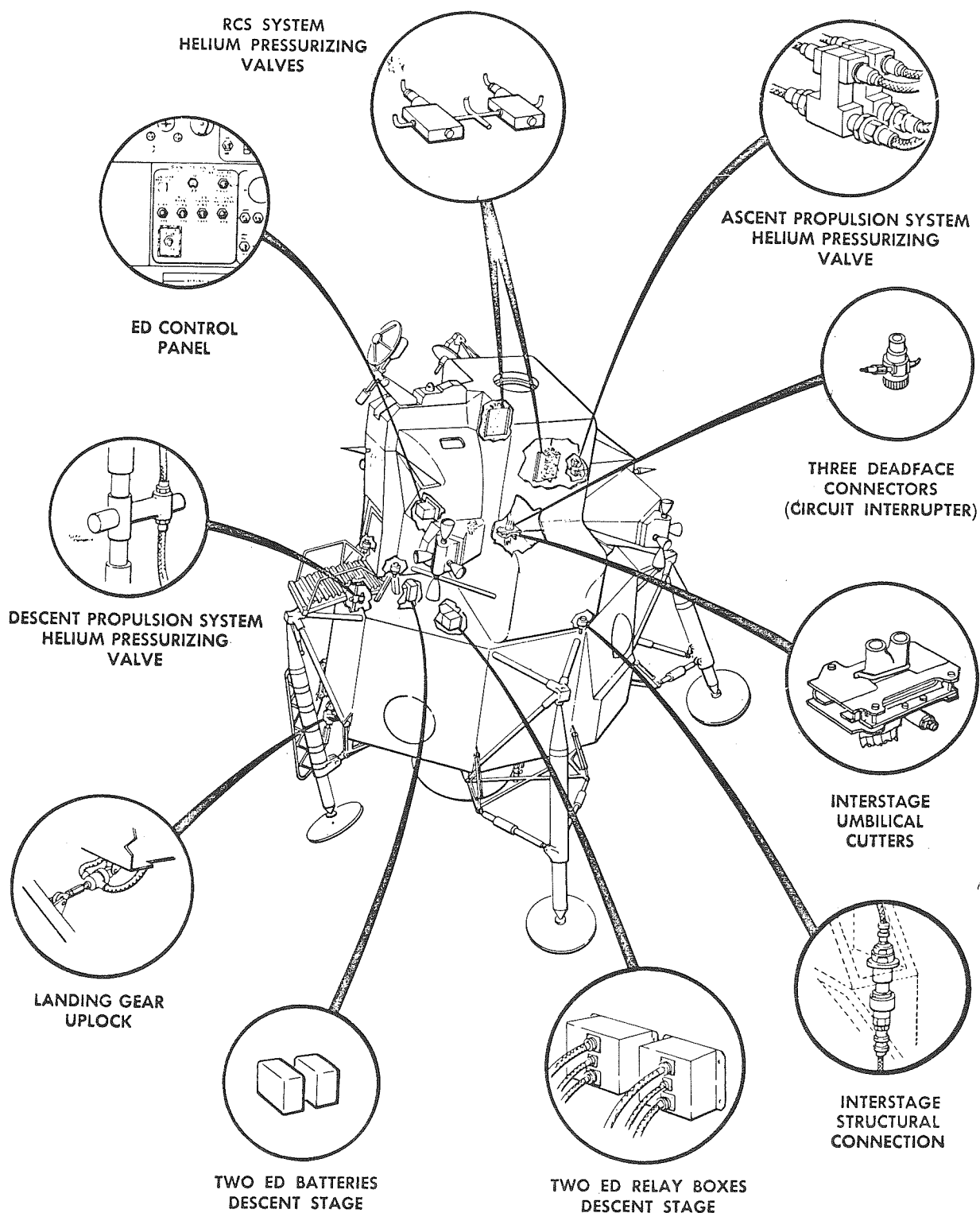
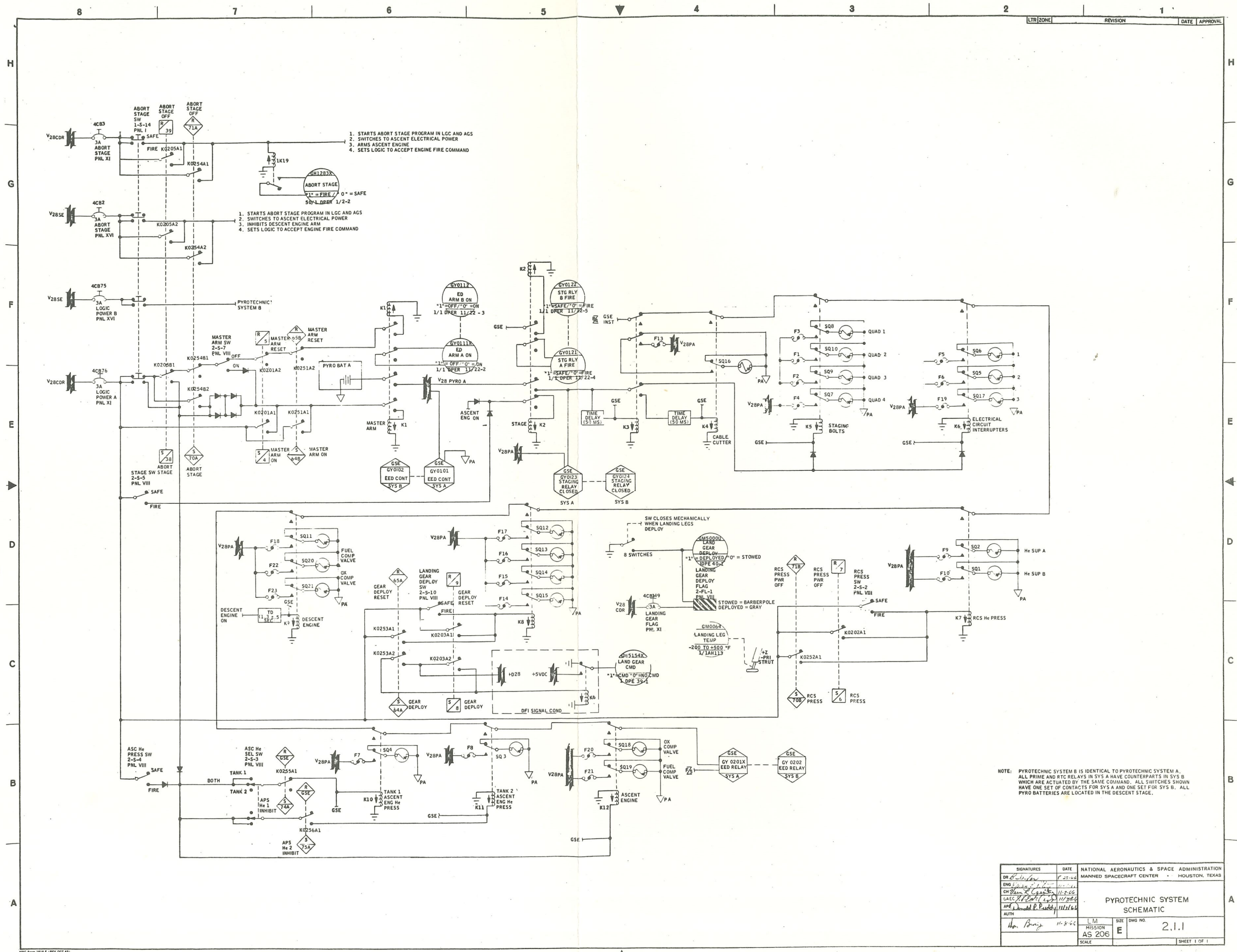


FIGURE 2-1 EXPLOSIVE DEVICES COMPONENT LOCATIONS





\*

SECTION 3  
ELECTRICAL POWER

LM  
AS-206  
REV A

3.1 SYSTEM DESCRIPTION

3.1.1 LM DC Electrical System

- A. The LM dc electrical system consists of six silver zinc primary batteries, four electrical control assemblies (ECA), and two dc buses (commander's and system engineer's).
- B. Four of the primary batteries and two ECA's are located in the descent stage. A low voltage tap is provided at the 17 cell point of the 20 cell descent battery, but will not be used on AS-206. To avoid over-voltage conditions due to using the 20 cells, the descent batteries will be predischarged before lift-off.
- C. Two of the LM primary batteries and two ECA's are located in the ascent stage. To avoid over-voltage conditions, the ascent batteries will be predischarged prior to liftoff.

3.1.2 AC Electrical System

The LM ac electrical system consists of two single phase ac inverters and one ac bus, and is located in the ascent stage. Only one of the ac inverters will supply power to the ac bus at any given time.



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### 3.2 SYSTEM DATA

#### 3.2.1 Predischarged Descent Battery

Capacity 293 amp-hrs.  
Terminal Voltage 28.0 to 32.5 VDC

#### 3.2.2 Ascent Battery

Capacity 296 amp-hrs  
Terminal Voltage 28.0 to 32.5 VDC

#### 3.2.3 AC Bus

Voltage 115  $\pm$  2.5 VAC  
Frequency 400  $\pm$  9 CPS

#### 3.2.4 Malfunction Indication

A. The limits for a malfunction indication are:

Over-temperature > 145°F  
Over-current 150 amps for more than 10 sec  
Reverse current -5 amps (indication will be reset at -4 amps.)

B. There will be no capability for a descent battery malfunction indication caused by a battery over-temperature if the battery is off.

C. There will be no capability for the respective ascent battery malfunction indication caused by a battery over-temperature or an over-current if Bat 5 is not connected to the S.E.'s or Bat 6 is not connected to the CDR's bus.

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TABLE 3-1 COMMANDER'S BUS CIRCUIT BREAKER TABULATIONS (PANEL XI)

<u>SYSTEM</u>	<u>CIRCUIT BREAKER</u>	<u>RATING</u>	<u>NOMENCLATURE</u>
PYROTECHNICS	4CB76	3A	LOGIC PWR A
	4CB149	3A	LDG GEAR FLAG
ELECTRICAL	4CB129	3A	DOCK WINDOW (HEATER)
	4CB6	3A	ASC ECA CONT
	4CB8	3A	DES ECA CONT
	4CB10	3A	DES ECA
	4CB15	3A	ASC ECA
	4CB12	25A	INV 1
	4CB4	40A	X LUNAR BUS TIE
	4CB184	25A	BAL LOAD CROSS TIE
	4CB20	70A	BUS CROSS TIE
	4CB18	70A	BAT FEED TIE
	4CB26	70A	BAT FEED TIE
ENVIRONMENTAL	4CB107	3A	CABIN FAN 1
	4CB138	15A	SUIT FAN 1
	4CB117	3A	GLYCOL PUMP 1
	4CB141	3A	GLYCOL PUMP 2
COMMUNICATIONS	4CB137	3A	SEC S-BND XMTR/RCVR
	4CB136	3A	SEC S-BND PWR AMPL
	4CB86	3A	CDR AUDIO
	4CB87	3A	VHF A RCVR
	4CB162	3A	VHF B XMTR
INSTRUMENTATION	4CB131	3A	SIG CONDR 1
	4CB22	3A	DC BUS VOLT
	4CB181	40A	R/D INST
PROGRAMER	4CB179	40A	LMP FEED
GUIDANCE (PRIMARY)	4CB122	5A	LGC/DSKY
	4CB105	7.5A	LDG RDR
	4CB157	3A	LDG RDR (HEATER)
	4CB124	15A	IMU OPR
	4CB155	3A	RDR OPR (HEATER)
	4CB156	3A	RNDZ STBY (HEATER)
	4CB29	15A	RNDZ RDR
	4CB213	3A	AOT (HEATER)
	4CB154	3A	SIG STR DISP
	4CB161	3A	IMU STBY

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TABLE 3-1 COMMANDERS BUS CIRCUIT BREAKER TABULATIONS (PANEL XI) (CONCLUDED)

SYSTEM	CIRCUIT BREAKER	RATING	NOMENCLATURE
CONTROL	4CB3	3A	ABORT STAGE
	4CB81	3A	ATCA (PNGS)
	4CB69	15A	DECA PWR
	4CB40	5A	AELD
	4CB59	15A	ATT DIR CONT
	4CB80	3A	DES ENG CONT
	4CB106	3A	ENG FIRE OVRD
PROPULSION	4CB74	5A	DES HE. REG
	4CB67	5A	ISOL VLV
	4CB63	10A	QUAD 1 TCA-A
	4CB62	10A	QUAD 2 TCA-A
	4CB61	10A	QUAD 3 TCA-A
	4CB60	10A	QUAD 4 TCA-A
	4CB72	5A	MAIN SOV-A
	4CB164	3A	RCS QUAD (HEATER)
	4CB51	5A	ASC FEED
MISC (FLIGHT DISPLAY'S)	4CB88	3A	GASTA
	4CB168	3A	THRUST DISP
	4CB97	3A	FDAI
	4CB133	3A	X-PNTR
	4CB123	3A	RNG/RNG RT-ALT/ALT RT
	4CB159	3A	EVENT TIMER
LIGHTING	4CB146	3A	ANUN DOCK/COMPNT

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TABLE 3-2 SYSTEMS ENGINEERS BUS CIRCUIT BREAKER TABULATIONS (PANEL XVI)

SYSTEM	CIRCUIT BREAKER	RATING	NOMENCLATURE
PYROTECHNICS	4CB75	3A	LOGIC PWR B
ELECTRICAL	4CB7	3A	ASC ECA CONT
	4CB9	3A	DES ECA CONT
	4CB5	40A	X LUNAR BUS TIE
	4CB14	3A	ASC ECA
	4CB183	25A	BAL LOAD CROSS TIE
	4CB19	70A	BUS CROSS TIE
	4CB25	70A	BAT FEED TIE
	4CB17	70A	BAT FEED TIE
	4CB16	3A	DISPLAY
	4CB11	3A	DEC ECA
ENVIRONMENTAL	4CB13	25A	INV 2
	4CB108	3A	CABIN FAN 2
	4CB109	3A	CABIN FAN CONT
	4CB120	3A	SUIT FAN CONT
	4CB132	3A	SIG SENSOR
	4CB119	15A	SUIT FAN 2
	4CB112	3A	DIVERT VLV
	4CB113	3A	CABIN REPRESS
	4CB84	3A	CO2 SENSOR
COMMUNICATIONS	4CB140	3A	DISP
	4CB98	3A	PRI GLYCOL EVAP FLOW
	4CB96	3A	GLYCOL PUMP SEC
	4CB102	3A	PMP
	4CB85	3A	S.E. AUDIO
	4CB30	3A	PRIM S-BND PWR AMPL
	4CB111	3A	PRIM S-BND XMTR/RCVR
	4CB153	3A	DISPLAY
	4CB104	3A	TV
INSTRUMENTATION	4CB114	3A	VHF B RCVR
	4CB115	3A	VHF A XMTR
	4CB31	3A	S-BND ANT (HEATER)
	4CB110	3A	S-BND ANT
	4CB99	3A	CWEA
	4CB125	3A	PCMTE
	4CB1	3A	SIG CONDR 2
	4CB21	3A	DC BUS VOLT
	4CB132	3A	SIG SENSOR
GUIDANCE (ABORT)	4CB28	5A	AEA
	4CB79	15A	ASA



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TABLE 3-2 SYSTEMS ENGINEERS BUS CIRCUIT BREAKER TABULATIONS (PANEL SVI)  
(Concluded)

SYSTEM	CIRCUIT BREAKER	RATING	NOMENCLATURE
CONTROL	4CB37	3A	ENGINE ARM
	4CB41	5A	AELD
	4CB82	5A	ATCA
	4CB2	3A	ABORT STAGE
PROPULSION	4CB50	3A	TEMP/PRESS/DISP FLAGS
	4CB49	5A	ISOL VLV-B
	4CB45	10A	QUAD 1 TCA-B
	4CB44	10A	QUAD 2 TCA-B
	4CB43	10A	QUAD 3 TCA-B
	4CB42	10A	QUAD 4 TCA-B
	4CB54	5A	CROSSFEED
	4CB73	5A	MAIN SOV-B
	4CB52	5A	ASC FEED
	4CB121	3A	PQGS
	4CB68	3A	DISPLAY (HEATER)
	4CB165	5A	RCS QUAD (HEATER)
	4CB53	3A	ASC HE. REG
	4CB103	3A	TEMP/PRESS. DISPLAY
	4CB32	3A	PQGS
MISC (FLIGHT DISPLAYS)	4CB126	3A	FDAI
	4CB134	3A	X-POINTER
LIGHTING	4CB128	3A	FLOOD
	4CB147	3A	MASTER ALARM
	4CB160	20A	TRACK
	4CB148	3A	ANUN/DOCK/COMPNT
CREW PROVISIONS	4CB33	3A	CAMERA SEQUENCE

\*  
TABLE 3-3 AC BUS CIRCUIT BREAKER TABULATIONS (PANEL XI)

SYSTEM	CIRCUIT BREAKER	RATING	NOMENCLATURE
ELECTRICAL	4CB144	1A	CDR WINDOW (HEATER)
	4CB152	1A	S.E. WINDOW (HEATER)
	4CB23	5A	AC BUS FEED TIE
	4CB24	5A	AC BUS FEED TIE
COMMUNICATIONS	4CB34	1A	S-BAND ANT
INSTRUMENTATION	4CB202	3A	TAPE RCDR
	4CB27	1A	AC BUS VOLT
GUIDANCE	4CB203	3A	AGS
	4CB212	3A	AOT LAMP
	4CB206	3A	RNDZ RDR
CONTROL	4CB207	3A	DECA GIMBAL
PROPULSION	4CB169	3A	HE/PQGS DISP
	4CB163	3A	(RCS) PQGS DISPLAY
MISC (FLIGHT DISPLAY'S)	4CB201	3A	GASTA
	4CB209	1A	CDR FDAI
	4CB204	3A	RNG/RNG RT
	4CB210	1A	ALT/ALT RT
LIGHTING	4CB211	3A	INTGL
	4CB200	3A	NUM

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TABLE 3-4 LMP CIRCUIT BREAKER TABULATION

<u>CIRCUIT BREAKER</u>	<u>RATING</u>	<u>NOMENCLATURE</u>
CB1	3A	PRI H <sub>2</sub> O FEED
CB2	3A	ASC H <sub>2</sub> O FEED
CB3	25A	INV 1
CB4	25A	INV 2
CB5	3A	DCA
CB6	3A	PCA
CB7	3A	PRA
CB8	3A	EPS LOGIC
CB9	3A	LMP INTERLOCK CONTROL



\*

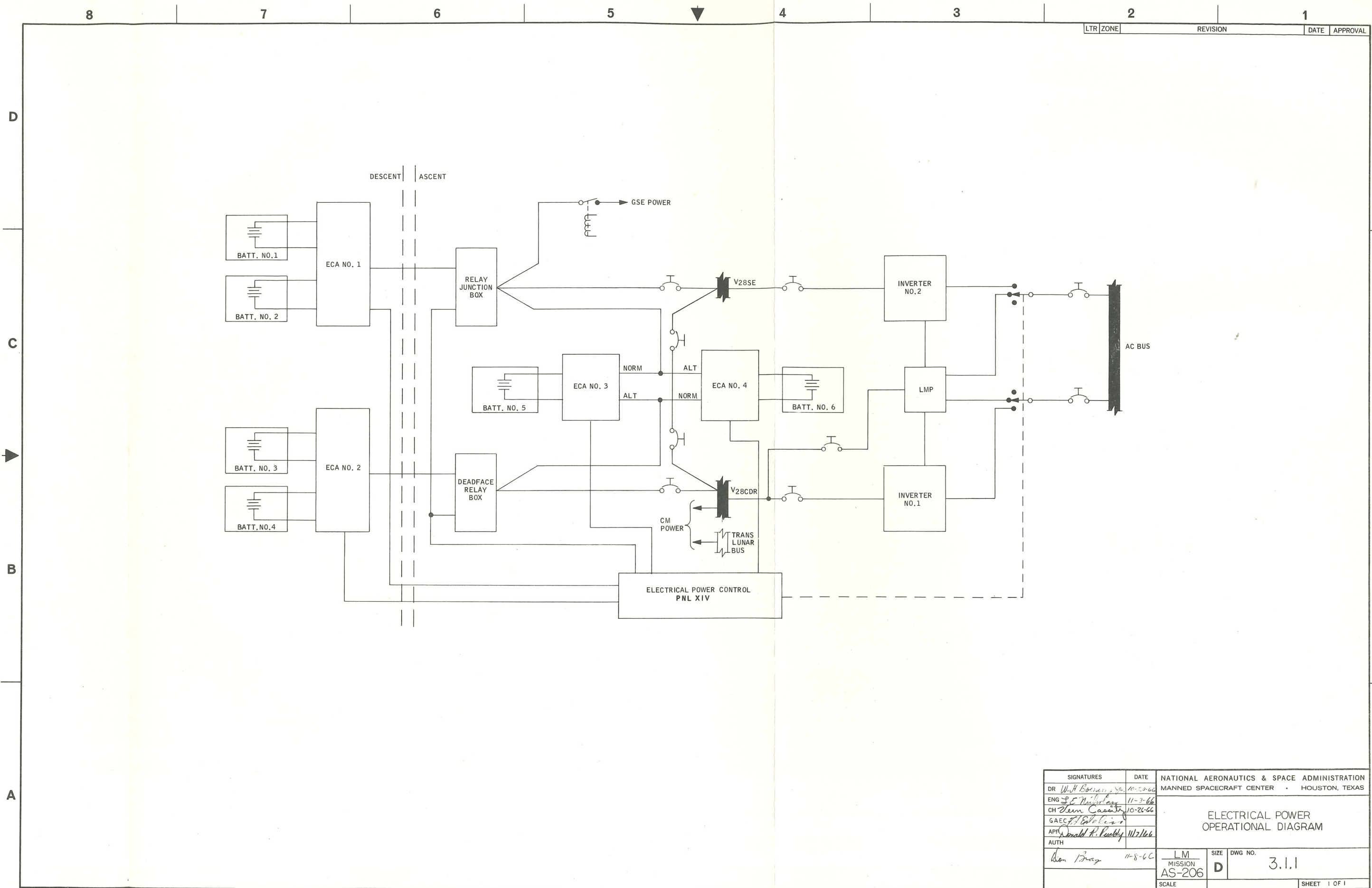
TABLE 3-5 PRELAUNCH STATUS OF SWITCH/CIRCUIT BREAKER POSITIONS

<u>NAME</u>	<u>POSITION</u>	<u>NOTES</u>
AC POWER (4-S-14)	OFF	
POWER/TEMP. MONITOR (4-S-15)	OFF	
BAT 1 HI VOLT (4-S-1)	OFF/RESET CENTER	NOTE 1
BAT 2 HI VOLT (4-S-2)	OFF/RESET CENTER	NOTE 1
BAT 3 HI VOLT (4-S-3)	OFF/RESET CENTER	NOTE 1
BAT 4 HI VOLT (4-S-4)	OFF/RESET CENTER	NOTE 1
BAT 1 LOW VOLT (4-S-5)	OFF/RESET CENTER	NOTE 1
BAT 2 LOW VOLT (4-S-6)	OFF/RESET CENTER	NOTE 1
BAT 3 LOW VOLT (4-S-7)	OFF/RESET CENTER	NOTE 1
BAT 4 LOW VOLT (4-S-8)	OFF/RESET CENTER	NOTE 1
BAT 5 NORMAL FEED (4-S-10)	OFF/RESET CENTER	NOTE 1
BAT 5 BACKUP FEED (4-S-12)	OFF/RESET CENTER	NOTE 1
BAT 6 NORMAL FEED (4-S-11)	OFF/RESET CENTER	NOTE 1
BAT 6 BACKUP FEED (4-S-13)	OFF/RESET CENTER	NOTE 1
DEADFACE SWITCH (4-S-9)	CONNECT	
ASCENT POWER TRANSFER (4-S-16)	ENABLE	THIS SWITCH IS NOT WIRED
X-LUNAR BUS TIE (4CB4)	CLOSED	
ASC ECA CONT. (4CB6)	CLOSED	
DES ECA CONT. (4CB8)	CLOSED	
DES ECA (4CB10)	CLOSED	
INV 1 (4CB12)	OPEN	
ASC ECA (4CB15)	CLOSED	
BAT 1/4/6 FEED TIE (4CB18)	CLOSED	
DC BUS TIE (4CB20)	CLOSED	
DC BUS VOLT (4CB22)	CLOSED	
AC BUS FEED TIE (INV #1) (4CB23)	CLOSED	
AC BUS FEED TIE (INV #2) (4CB24)	CLOSED	
BAT 2/3/5 FEED TIE (4CB26)	CLOSED	
AC BUS VOLT (4CB27)	CLOSED	
LMP FEED (4CB179)	CLOSED	
R/D INST. (4CB181)	CLOSED	
X-LUNAR BUS TIE (4CB5)	CLOSED	
ASC ECA CONT. (4CB7)	CLOSED	
DES ECA CONT. (4CB9)	CLOSED	
DES ECA (4CB11)	CLOSED	
INV #2 (4CB13)	OPEN	
ASC ECA (4CB14)	CLOSED	
DISP. (4CB16)	OPEN	
BAT 1/4/6 FEED TIE (4CB17)	CLOSED	
DC BUS TIE (4CB19)	CLOSED	
DC BUS-VOLT (4CB21)	CLOSED	
BAT 2/3/5 FEED TIE (4CB25)	CLOSED	

NOTE 1: THESE SWITCHES ARE MOMENTARY TYPE AND THE OFF/RESET CENTER IS THE NORMAL POSITION.

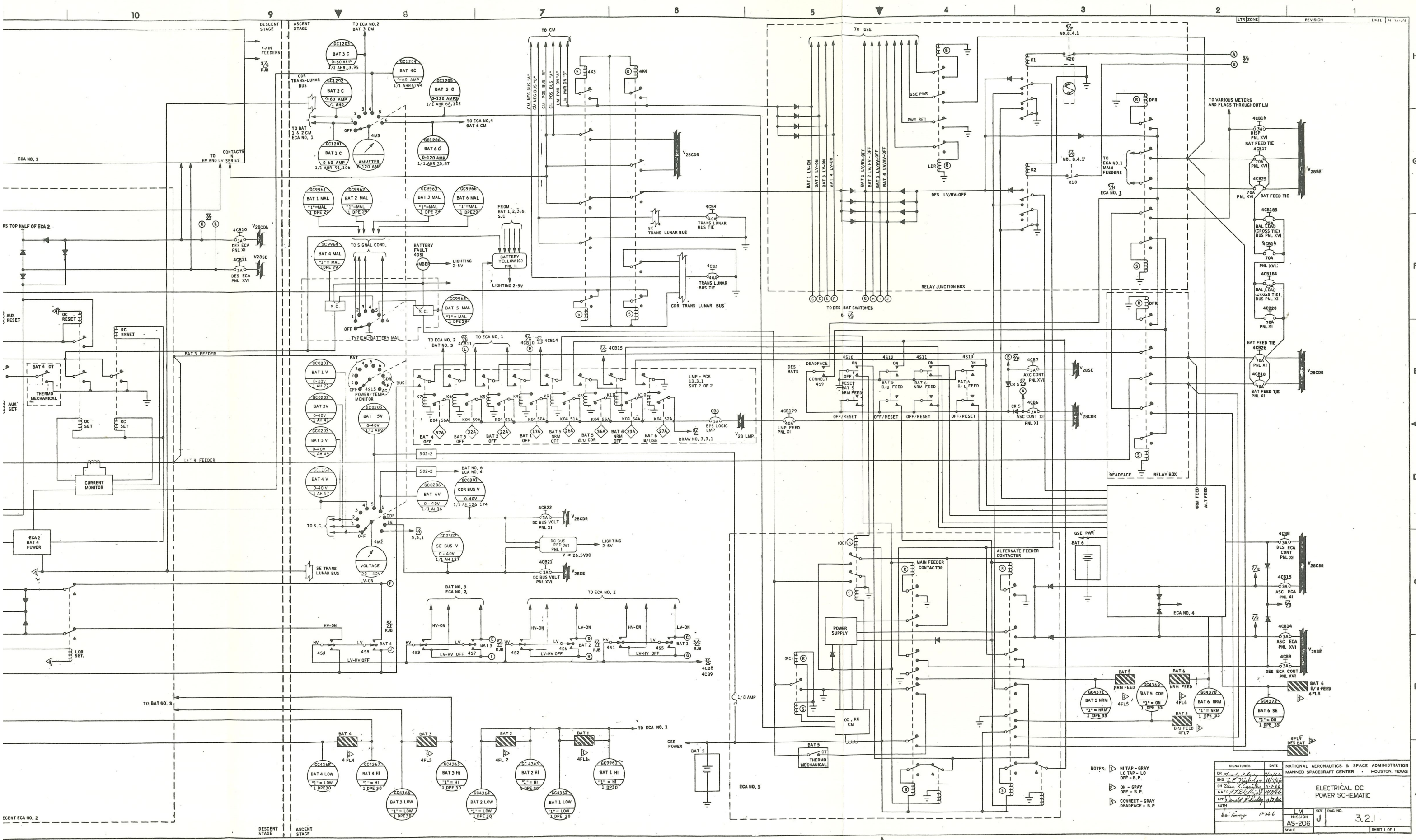
TABLE 3-7 AS-206A POWER PROFILE

MISSION PHASE	PHASE TIME	GET AT START OF PHASE	CONSTANT LOAD AMPS	CONSTANT LOAD A/H CONSUMED	INTERMITTENT LOAD A/H CONSUMED	TOTAL A/H CONSUMED PER PHASE
DESCENT						
COUNTDOWN	0:30:00	-0:30:00	53.5	26.8	0.4	27.2
ASCENT	0:10:03	0:00:00	53.5	9.0	0.3	9.3
S-IVB/LM COAST	0:43:52	0:10:03	53.5	39.1	1.1	40.2
LM SEPARATION	0:00:18	0:53:55	59.5	0.3	0.1	0.4
COAST	3:05:45	0:54:23	59.5	184	2.7	186.7
1ST DPB	0:00:39	4:00:08	59.5	0.7	0.1	0.8
COAST	0:35:48	4:00:47	59.5	35.4	1.0	36.4
2ND DPB	0:12:37	4:36:35	59.5	12.5	1.4	13.9
						314.9 TOTAL
ASCENT						
1ST APB	0:00:05	4:49:12	58.4	0.1	--	0.1
COAST	1:23:08	4:49:17	58.4	81.0	1.4	82.4
2ND APB	0:06:35	6:12:25	58.4	6.4	0.8	7.2
COAST	0:54:46	6:19:00	58.4	53.4	1.0	54.4
3RD APB	0:00:05	7:13:46	58.4	0.1	--	0.1
COAST	3:47:05	7:13:51	58.4	221.	6.9	227.9
4TH APB	0:00:05	11:00:56	58.4	0.1	--	0.1
FINAL COAST	2:24:17	11:01:01	58.4	140.	1.9	141.9
		13:25:18				514.1 TOTAL



SIGNATURES		DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION	
DR. <i>W. H. Borman</i>		10-20-66	MANNED SPACECRAFT CENTER • HOUSTON, TEXAS	
ENG. <i>J. E. McManis</i>		11-3-66	ELECTRICAL POWER OPERATIONAL DIAGRAM	
CH. <i>John Casper</i>		10-26-66		
GAECE <i>J. G. G. G.</i>				
APP. <i>Donald H. Puckley</i>		11/2/66	LM MISSION AS-206	
AUTH				
<i>Don Puckley</i>		11-8-66	SIZE D	DWG NO. 3.1.1
			SCALE	SHEET 1 OF 1





NOTES:

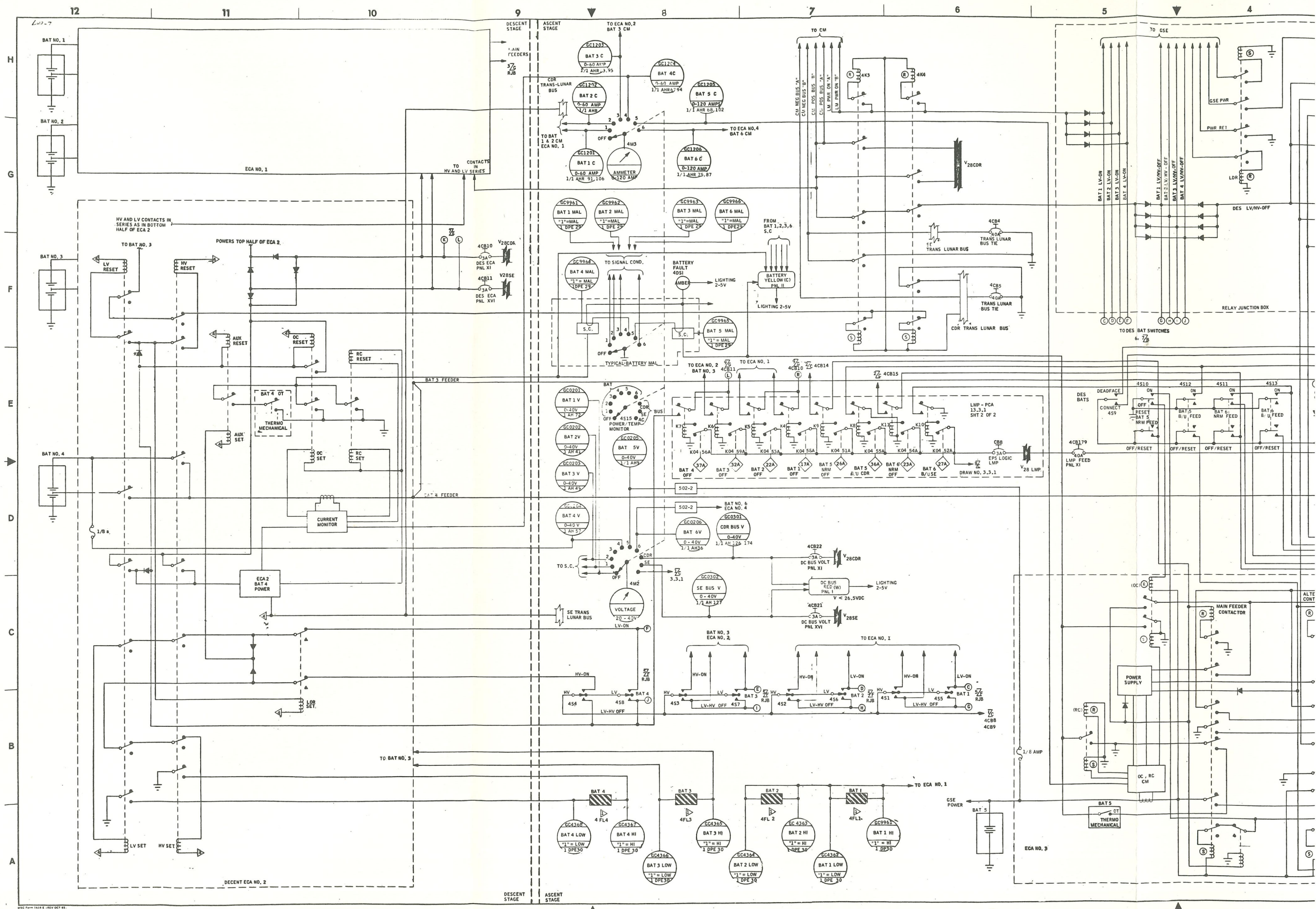
- HI TAP - GRAY
- LO TAP - LD
- OFF - B.P.
- ON - GRAY
- OFF - B.P.
- CONNECT - GRAY
- DEADFACE - B.P.

SIGNATURES	DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION
DR: <i>[Signature]</i>	11/24/66	MANNED SPACECRAFT CENTER - HOUSTON, TEXAS
ENG: <i>[Signature]</i>	11/24/66	
CHK: <i>[Signature]</i>	11/24/66	
APP: <i>[Signature]</i>	11/24/66	
AUTH: <i>[Signature]</i>	11/24/66	

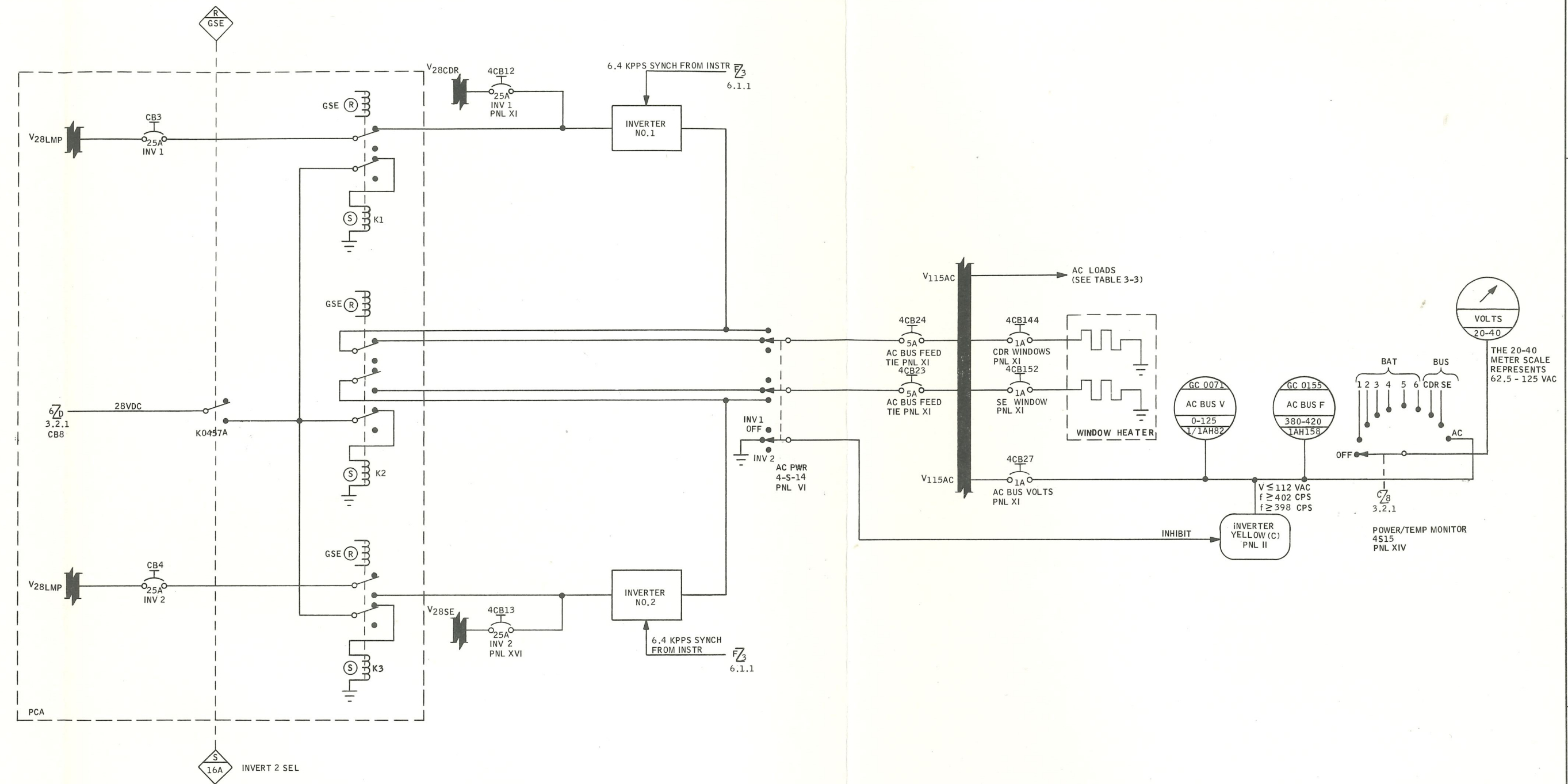
ELECTRICAL DC POWER SCHEMATIC	
MISSION	AS-206
SIZE	J
ENG. NO.	3.2.1
SCALE	

SHEET 1 OF 1









SIGNATURES		DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION MANNED SPACECRAFT CENTER • HOUSTON, TEXAS		
DR	<i>W. C. ...</i>	<i>10/1/66</i>	ELECTRICAL AC POWER SCHEMATIC		
ENG	<i>W. C. ...</i>	<i>11/3/66</i>			
CH	<i>W. C. ...</i>	<i>10-27-66</i>			
GAEC	<i>W. C. ...</i>	<i>11/3/66</i>			
APP	<i>Donald R. ...</i>	<i>11/7/66</i>			
AUTH					
<i>W. C. ...</i>		<i>11-8-66</i>	LM MISSION AS-206	SIZE D	DWG NO. 3.3.1
			SCALE	SHEET 1 OF 1	



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SECTION 4  
ENVIRONMENTAL CONTROL SYSTEM

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4.1 SYSTEMS DESCRIPTION

4.1.1 Oxygen Supply Section

A. LM-1 (AS-206)

1. Purpose - The primary operational function of the oxygen supply section on AS-206A is to supply make up oxygen to the suit loop to maintain the necessary pressure reference for water pressure regulation.
2. Tank Loading - It is planned to fill the ASC oxygen tanks completely and open the tank shutoff valves prior to launch. The descent tank will be filled and the shutoff valve will be closed. Since the oxygen tank feed configuration is fixed at launch, it will not change when the LM stages.

B. Genral LM

1. Descent Oxygen Supply and Pressure Control - The LM oxygen supply consists of three tanks, two in the ascent stage and one in the descent stage. The descent oxygen tank provides four cabin repressurizations, six PLSS refills, and a maximum lunar stay time of 35 hours. To reduce the pressure (2850 psia) under which the descent oxygen is stored, a series-redundant high pressure regulator reduces pressure to  $900 \pm 25$  psia, which is compatible with the normal operations of the oxygen control module. A bypass valve around the regulators is provided to protect against tank over pressure. A relief valve and burst disc are provided to protect against excessive pressure downstream of the regulators.
2. Ascent Oxygen Supply - The two ascent tanks each contain enough oxygen to liftoff the lunar surface and re-rendezvous with the CSM. Tank pressure is compatible with the normal operations of the oxygen control module.



\*  
4.1.2 Suit Loop

A. LM-1 (AS-206)

1. Purpose - Provide pressure reference for water supply section water pressure regulators.
2. Status - Will be operating in EGRESS mode (pressure regulators supplying  $3.8 \pm .2$  psia, and loop isolated from the cabin). The suit fans will not be turned on, so there will be no oxygen circulation.
3. Suits - Not installed. Suit flow control valves positioned to "SUIT DISCONNECT".

B. General LM

1. Oxygen Demand Regulators (2) - The regulators maintain suit and cabin pressure at  $4.8 \pm .2$  psia during normal cabin pressurized operations and maintain suit pressure at  $3.8 \pm .2$  psia during extravehicular activity (EVA) operations. The regulators serve as electrical interlocks between the cabin pressure switch and the suit diverter valve and cabin repressurization valve.
2. Suit Flow Control Valves (2) - The suit flow control valve is used in conjunction with the body flow control valve on the suit. With the body flow control valve open and the suit flow control valve in the HELMET position, half of the oxygen flows to the waist and half to the helmet. Oxygen is returned to the suit loop by ducts at the extremities. With the body flow control valve closed and the suit flow control valve in TORSO, the oxygen flows out the extremities up over the body and out the suit collar. The SUIT DISCONNECT position of the suit flow control valve allows the oxygen to bypass the suit entirely.
3. Suit Loop Diverter Valve - The control handle, positioned to the PUSH-CABIN selection, will allow suit circuit oxygen to flow into the cabin. In the event cabin pressure decays

to  $4.15 \pm .15$  psia the cabin pressure switch will provide power to a solenoid allowing the valve to reposition to the PULL-EGRESS position, isolating the suit loop from the cabin.

\*  
4.1.3 Cabin

A. LM-1 (AS-206)

1. Cabin Pressure - Will continue to decay after insertion since the ECS will be operating in the EGRESS mode (i.e., no make up oxygen from the suit loop thru the diverter or suit relief valves).
2. Cabin Temperature - Uncontrolled until cabin fan No. 1 is turned on.
3. Cabin Fans - The cabin fans will not be operated until fan No. 1 is turned on by the LMP (LGC mode) program. Cabin fan No. 2 circuit breaker will be pulled, preventing power to fan No. 2.

B. General LM

1. Cabin Repressurization Valve - The valve is used to repressurize the cabin after a deliberate decompression or in the event loss of cabin integrity. Normally, cabin pressure will be maintained by the suit relief and diverter valves. In the event cabin pressure falls to  $4.15 \pm 0.15$  psia, power is supplied to the repressurization solenoid via the cabin pressure switch. Power is removed from the solenoid when cabin pressure rises to  $4.45 \pm 0.15$  psia. The cabin repressurization valve will maintain a cabin pressure of 3.5 psia for a minimum of two minutes with a cabin puncture of one-half inch diameter.
2. Cabin Relief and Dump Valves (2) - The valves (one on each hatch) provide a cabin-to-ambient vent at 5.8 psid to protect the cabin against over pressurization. Pressure transducers within the valves will indicate oxygen losses due to cabin over pressurization (GF3591P and GF3592P).



\*  
4.1.4 Water Supply Section

A. LM-1 (AS-206)

1. Purpose - The Water Supply Section (WSS) supplies water to the primary glycol loop water boilers for heat rejection.
2. Water Supply to the Water Boilers
  - a. Descent Water Feed - Since the solenoid valve in the water supply line to the primary glycol loop W/B's cannot be actuated, a parallel path for the open position is provided via the LMP. The water tank select valve will be pre-set to DESCENT, allowing descent water to flow up to this primary water feed valve. At three minutes after liftoff, the LMP (LGC mode) will automatically command this valve open, allowing water to flow to the primary water boilers. RTC 24A, DES WATER FEED and RTC 25A, DES WATER RESET, are available to backup this onboard command.
  - b. Descent Water Feed Verification - Prior to opening the feed valve, water pressure downstream of the regulators will be 15.45 psia since the water was loaded at ambient suit reference pressure (sea level). Following liftoff, the telemetered PRI WATER REG  $\Delta P$  (GF4101P) will increase from 0.75 psid to 2.0 psid as the suit loop follows cabin pressure down to the reset pressure of the cabin relief valves (5.4 psia). Upon opening the feed valve, water pressure will decay in order to become compatible with the reduced suit loop pressure. This drop in  $\Delta P$  can be verified by PRI WATER REG  $\Delta P$  decreasing rapidly to approximately 0.75 psid.
  - c. Ascent Water Feed - Normally, the water tank select valve would be manually set to the ASCENT position to enable flow to the evaporators. In lieu of this manual

function, ascent water will flow through a section of secondary water feed line to a crossover feed line. An LMP-operated solenoid valve will automatically be commanded open prior to staging, allowing ascent water to flow into the primary water feed path. RTC 44B, ASC WATER FEED and RTC 45B, ASC WATER RESET, are available as backup to this onboard command.

- d. Ascent Water Feed Verification - Verification of ascent crossover valve opening is accomplished by monitoring GLY TEMP (GF9998U). A rise of this measurement, following the ascent water feed command is an indication that the valve did not open.

B. General LM

1. Tanks - Water is stored in positive expulsion bladder-type tanks which are prepressurized with nitrogen prior to earth launch.
2. Regulation - For proper water boiler operation, water pressure must be greater than 4 psia but less than 8 psia. In addition, water pressure must be less than suit loop static pressure plus the head pressure developed by the suit loop water separators so that water will always flow from the water separators to the water boilers. Therefore, water regulators are installed in the water feed lines and are referenced to suit loop pressure. Regulated water pressure varies from 0.5 to 1.0 psid above suit loop pressure.

4.1.5 Glycol Loops

A. LM-1 (AS-206) Primary Loop

1. Purpose - To provide thermal control of spacecraft electronic equipment.
2. Pump Switchover - Automatic primary glycol pump switchover capability from Pump 1 to Pump 2 has been incorporated.

\*

Automatic switchover occurs when pump  $\Delta P$  decreases to 4 psid and is irreversible (Pump SW/O, GW5158). The differential pressure switch will open at an increasing pump  $\Delta P$  of  $7.0 \pm 1$  psid.

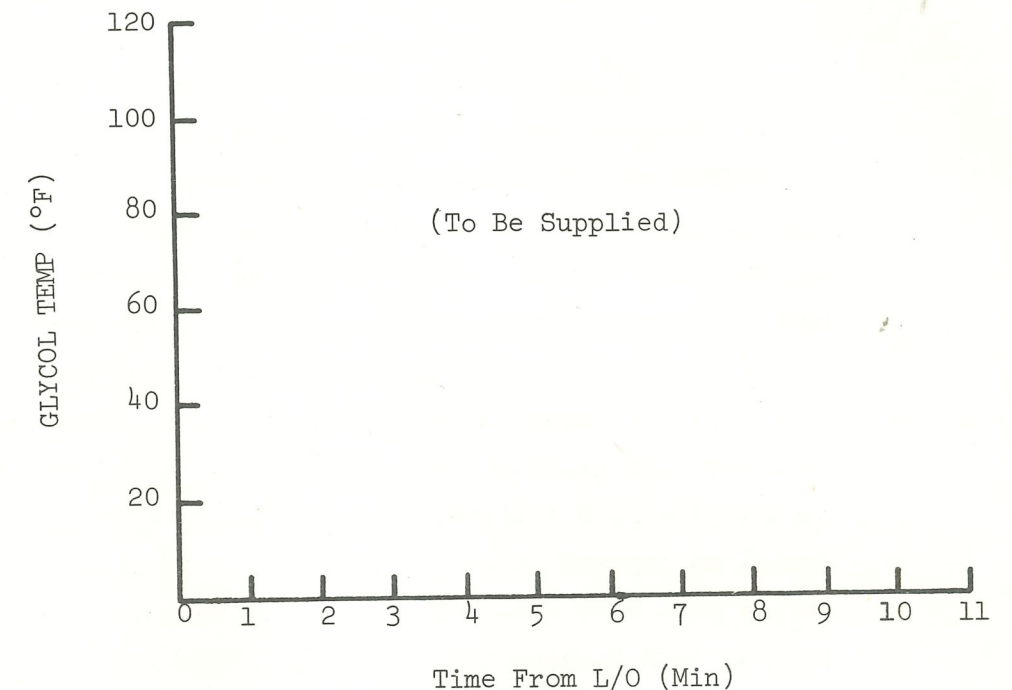
RTC 50B, PUMP 2 SEL, provides backup for automatic switchover.

RTC 51B, PUMP 1 SEL, is effective only if Pump 2 were selected by RTC 50B (i.e., automatic switchover had not occurred).

3. Cold Plates - There are additional cold plates for cooling DFI and LMP equipment.
4. Prelaunch Cooling - AS-206 is a launch of a powered up LM and spacecraft cooling must be provided up to liftoff. Since the LM ECS water boilers must be exposed to a vacuum environment to operate properly, a freon boiler is installed in the primary glycol loop. From T-5 hours to liftoff, a freon supply unit at the LUT base supplies freon to this boiler. Flyaway umbilicals terminate the freon supply at L/O. Cooling requirements prior to T-5 hours are satisfied by the Glycol Trim Control Units (GTCU) installed in parallel with the primary pumps. The GTCU pumps glycol through the onboard loop and out to a heat exchanger which rejects heat to a freon loop. This loop runs through a freon boiler at the base of the tower.

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5. Glycol Temp Behavior During Launch - Since there will be no active cooling during the first three minutes of powered flight, GLY TEMP (GF9998U) will behave as follows:



- B. LM-1 (AS-206) Secondary Loop - This hardware will be installed but cannot be activated.
- C. General LM
  1. Glycol Accumulator (Primary Loop Only) - The glycol accumulator basically consists of a cylinder and movable spring-loaded piston. The piston movement compensates for system temperature changes or any leakage which may occur. Spring compression for a full accumulator will nominally maintain 7.0 psia pressure at the inlet to the primary glycol pumps to avoid pump cavitation. Should the stored glycol fall below 10 percent of the accumulator capacity (5.5 psia pump inlet pressure), a discrete signal, glycol low (GF2041X), will be transmitted.



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2. Pump Relief Valves - A pump bypass relief valve, located downstream of each pump, will provide for relief of excessive differential pressure by routing a portion of the pump output directly to the pump inlet.
3. Water Boilers
  - a. Operation - A porous plate sublimators rejects heat to the vacuum of space by the sublimation of ice. Water from the WSS flows through the water passages, into the pores of the porous plate, and then is exposed to the space vacuum. Since the vacuum pressure is below the triple point of water, an ice layer develops within the pores and on the inside plate surface. As hot glycol flows through other passages, heat transfers from the glycol to the water and then to the ice layer. Ice then sublimates, rejecting overboard the heat load imposed on it. The ice layer thickness varies with heat load imposed on a sumblimator, resulting in a regulated output temperature for a range of input temperatures.
  - b. Freeze-Up - If the heat load entering a porous plate sublimator drops below a lower limit, the ice layer will grow so as to completely fill all the water passages. The expanding ice layer will rupture the sublimator, rendering it useless.
  - c. Break-Through - This refers to a condition where the heat load is high enough to melt the ice layer or where water pressure is high enough to break up the ice layer and force water through the plate. Heat rejection capability of the sublimator is greatly reduced because there is no ice sublimation. Water usage is high because there is no restraining ice layer.



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TABLE 4-1 ECS SYSTEMS DATA SHEET

EQUIPMENT	DATA				
OXYGEN SUPPLY SECTION					
	CRACK	OPEN	RESET	LOCKUP	FLOW RATE
BYPASS VALVES	2875	3000	2850	2800	3.0 LBS./HR. (MAX)
RELIEF VALVES	1025	1090	985	985	50.0 LBS./HR. (MAX)
BURST DISK	RUPTURE PRESS.=1350 ± 50 PSIA				600.0 LBS./HR. (MAX)
HIGH PRESS. REGULATORS	REG PRESS.=900 ± 25 PSIA				11 LBS/MIN (MAX.) 3000 PSIA AND 70°F
SUIT LOOP					
DEMAND REGULATORS	REG PRESS. =3.8 ± .2 OR 4.8 ± .2 PSIA  DIRECT (OPEN) FLOW RATE = 7.1 LBS./HR.				
REGENERATIVE H/X	____ BTU/HR. MAX. (GLYCOL TO O <sub>2</sub> ) ADJUSTABLE GLYCOL FLOW RATE: 0 TO 2 LBS./MIN. O <sub>2</sub> TEMP OUT: ____°F MAX., ____°F MIN.				
LIOH CARTRIDGES(S)	5 LBS. LIOH/CARTRIDGE CAPACITY PER CARTRIDGE: 41 MAN-HRS. AT 0/098 LBS/MAN-HR				
FAN(S)	AT 4.8 PSIA: 24 FT <sup>3</sup> /MIN. (0.7 LB./MIN.) AT 3.8 PSIA: 24 FT <sup>3</sup> /MIN. (0.5 LB./MIN) CONSTANT SPEED FANS: 25000 ± 500 RPM				
H/X	O <sub>2</sub> TEMP OUT: ____°F TO ____°F MAX CAPACITY: ____ BTU/HR.				
SUIT W/B	CAPACITY: ____ BTU/HR. MAX.				
H <sub>2</sub> O SEPARATORS	AT 4.8 PSIA: 1200 TO 3400 RPM & ____ TO 2.4 PSIA H <sub>2</sub> O AT 3.8 PSIA: 850 TO 2000 RPM & 1.1 TO ____ PSIA H <sub>2</sub> O				
CABIN					
CABIN PRESS. SWITCHES	CLOSE: 4.15 ± 0.15 PSIA (DECREASING) OPEN: 4.45 ± 0.15 PSIA (INCREASING)				
REPRESS VALVE	FLOW RATE = 480.0 LBS/HR. (MAX.)				
DUMP VALVE(S)	5.0 TO 0.08 PSID IN 180 SEC. (ONE VALVE)				

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TABLE 4-1 ECS SYSTEMS DATA SHEET (Cont'd)

EQUIPMENT	DATA									
H/X	CABIN TEMP CONTROL IN NORMAL: CABIN TEMP=75 ± 5°F									
FAN(S)	5 LBS. O <sub>2</sub> /MIN./FAN AT 13,000 ± 250 RPM									
FAN CONTROL SWITCH	CLOSE: <3.05 ± .05 PSIA OPEN: >3.15 ± .05 PSIA									
GLYCOL LOOPS										
COOLANT	65% ETHYLENE GLYCOL AND 35% H <sub>2</sub> O QUANTITY PRIME LOOP = 22 LBS. QUANTITY SEC. LOOP = 3.24 LBS. NOMINAL FLOW RATE: 222 LBS./HR. SPECIFIC HEAT = 0.866 BTU/LB. -F° SLUSH POINT = -3°F									
PUMP(S)	3.7 LBS./MIN. AT 40°F AND INLET PRESS. OF 7 PSIA AND ΔP = 20 PSID SPEED = 5200 RPM PAD DISCHARGE PRESS. = 40 PSIA									
PUMP RELIEF VALVES	CRACK = 33 PSID, OPEN = 36 PSID, RESEAT = 32 PSID									
209 W/B	ESTIMATED NOMINAL IN/OUT TEMP RANGES (°F) <table><tr><td></td><td>IN</td><td>OUT</td></tr><tr><td>HIGH</td><td>80°</td><td>43°</td></tr><tr><td>LOW</td><td>65°</td><td>36°</td></tr></table> MAXIMUM CAPACITY = 17,000 BTU/HR.  MINIMUM LOAD (TO PREVENT PREEZE-UP) = 800 BTU/HR.  BREAKTHROUGH OCCURS IF: 1. INLET TEMP > _____ °F OR 2. H <sub>2</sub> O PRESS. >APPROXIMATELY 12 TO 15 PSIA MINIMUM ALLOWABLE H <sub>2</sub> O PRESS. = 4 PSIA		IN	OUT	HIGH	80°	43°	LOW	65°	36°
	IN	OUT								
HIGH	80°	43°								
LOW	65°	36°								

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TABLE 4-1 ECS SYSTEMS DATA SHEET (Concl'd)

EQUIPMENT	DATA									
224 W/B	<p>ESTIMATED NOMINAL IN/OUT TEMP RANGES (°F)</p> <table><tr><td></td><td>IN</td><td>OUT</td></tr><tr><td>HIGH</td><td>55</td><td>45°</td></tr><tr><td>LOW</td><td>45°</td><td>40°</td></tr></table> <p>MAXIMUM CAPACITY = 9000 BTU/HR.</p> <p>MINIMUM LOAD (TO PREVENT FREEZ-UP) = 500 BTU/HR.</p> <p>BREAKTHROUGH OCCURS IF:</p> <p>1. INLET TEMP &gt; _____°F OR</p> <p>2. H<sub>2</sub>O PRESS. &gt;APPROXIMATELY 12 TO 15 PSIA</p> <p>MINIMUM ALLOWABLE H<sub>2</sub>O PRESS. = 4 PSIA</p>		IN	OUT	HIGH	55	45°	LOW	45°	40°
	IN	OUT								
HIGH	55	45°								
LOW	45°	40°								
ACCUMULATOR	<p>VOLUME = 47.5 IN<sup>3</sup></p> <p>CAPACITY = 0.83 LBS.</p> <p>FULL PRESS. (TO PUMP INLET) = 7.0 PSIA</p> <p>EMPTY PRESS. (TO PUMP INLET) = 5.5 PSIA</p>									
<u>WATER SUPPLY SECTION</u>										
H <sub>2</sub> O REGULATORS	<p>REG PRESS.= SUIT PRESS. + (0.5 TO 1.0 PSIA)</p> <p>MAX FLOW RATE (FULL TANK &amp; W/B BREAK-THROUGH) = _____LB/HR.</p>									

TABLE 4.2 ECS VALVES/CABIN FAN PRESSURE SCHEDULES

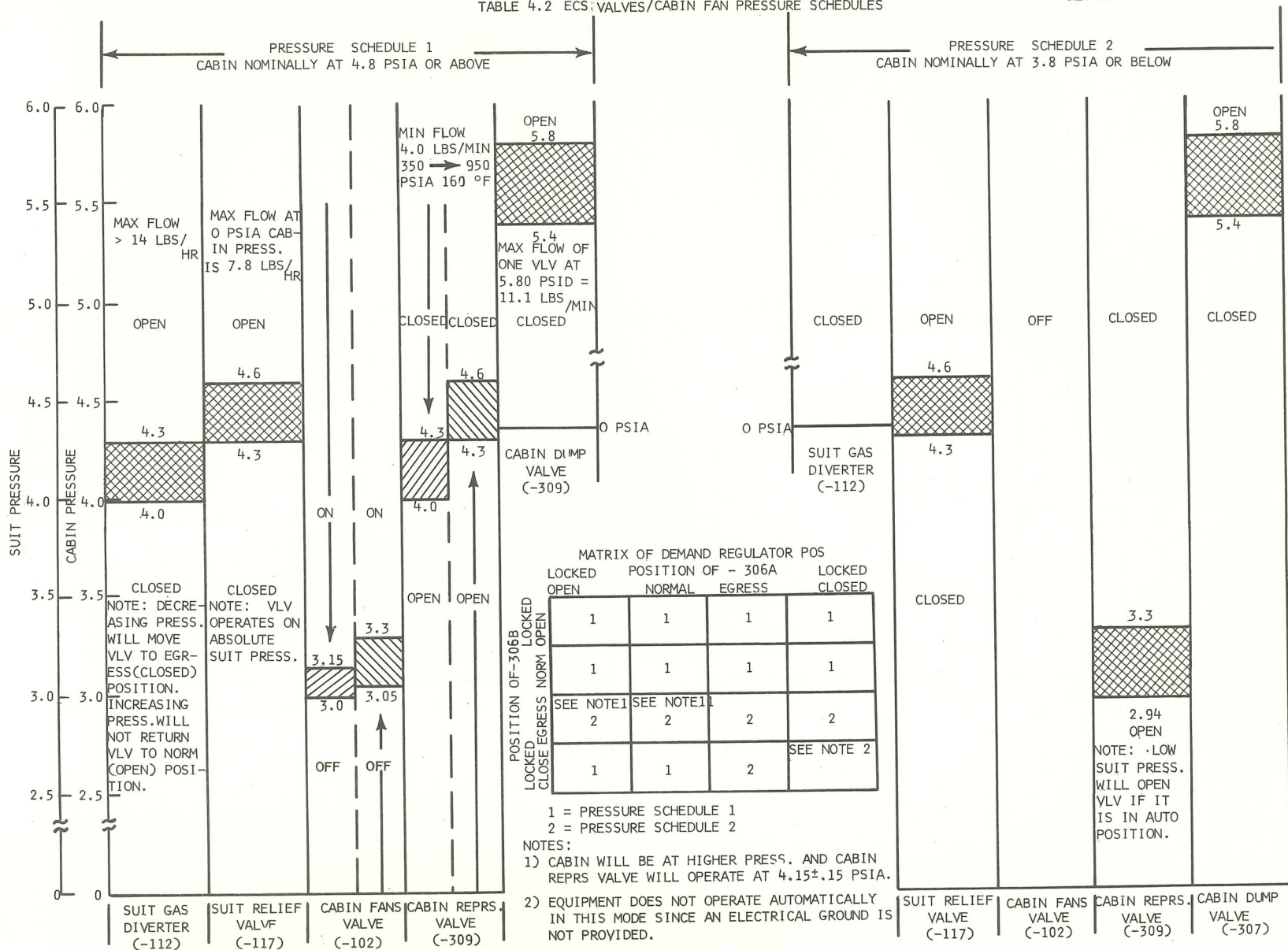


TABLE 4-3 SUIT LOOP MODES<sup>1</sup>

MODE	SWITCH/VALVE POSITION														
	DES O <sub>2</sub>	ASC 1 O <sub>2</sub>	ASC 2 O <sub>2</sub>	CABIN REPRESS	PLSS FILL	DMD REG A	DMD REG B	SUIT RELIEF	SUIT DIVERTER	CABIN RETURN	CANNISTER SEL	SUIT FAN SEL	WATER SEP SEL	CABIN DUMP	SUIT FLOW CONTROL
Cabin (DES)	OPEN	CLOSE	CLOSE	AUTO	CLOSE	CABIN	CABIN	AUTO	CABIN	AUTO	PRIM	1	SEP 1	AUTO	TORSO/HELMET
Cabin (ASC)	CLOSE	OPEN	CLOSE	AUTO	CLOSE	CABIN	CABIN	AUTO	CABIN	AUTO	PRIM	1	SEP 1	AUTO	TORSO/HELMET
EGRESS (DES)	OPEN	CLOSE	CLOSE	CLOSE	CLOSE	EGRESS	EGRESS	CLOSE	EGRESS	EGRESS	PRIM	1	SEP 1	DUMP/AUTO	SUIT DISCONNECT
EGRESS (ASC)	CLOSE	OPEN	CLOSE	CLOSE	CLOSE	EGRESS	EGRESS	CLOSE	EGRESS	EGRESS	PRIM	1	SEP 1	DUMP/AUTO	SUIT DISCONNECT

<sup>1</sup>The following C/B are closed: 4CB140 - ECS Displays; 4CB113 - Cabin Repr Valve; 4CB112 - Diverter Valve; 4CB138 - Suit Fan 1; 4CB119 - Suit Fan 2; 4CB120 - Suit Fan Control; 4CB98 - Prim H<sub>2</sub>O Feed; 4CB84 - CO<sub>2</sub> Part Pressure Sensor.



TABLE 4-4 GLYCOL LOOP MODES<sup>1</sup>

MODE	SWITCH/VALVE POSITION							
	WATER TANK SEL	PLSS/ DRINK	PRIM EVAP FLOW	SEC EVAP FLOW	SEC SUIT EVAP FLOW	GLY PUMP SEL	CABIN TEMP CONTROL	SUIT TEMP CONTROL
Normal (DES)	DES	CLOSE	OPEN	CLOSE	CLOSE	1	NORMAL	
Normal (ASC)	ASC	CLOSE	OPEN	CLOSE	CLOSE	1	NORMAL	
Secondary	SEC	CLOSE	CLOSE	OPEN	OPEN	SEC		

<sup>1</sup>The following C/B are closed: 4CB109 - Cabin Fan Control; 4CB108 - Fan 2 Pwr; 4CB107 - Fan 1 Pwr; 4CB96 - GLY Pump Sec; 4CB117 - GLY Pump 1; 4CB141 - GLY Pump 2.

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TABLE 4-5 ECS CONSUMABLES

TANK	VOLUME FT <sup>3</sup>	CAPACITY				ACTUAL LOADING				RESIDUALS			
		QUANTITY		PRESSURE PSIA	TEMPERATURE °F	QUANTITY		PRESSURE PSIA	TEMPERATURE °F	QUANTITY		PRESSURE PSIA	TEMPERATURE °F
		LBS	%			LBS	%			LBS	%		
DESC O <sub>2</sub>	2.985	48.01	100	2875	87.5					0.89	1.9	50	40
A/1 O <sub>2</sub>	0.495	2.41	100	900	104.0					0.37	1.5	75	40
A/2 O <sub>2</sub>	0.495	2.41	100	900	104.0					0.37	1.5	75	40
DESC H <sub>2</sub> O	7.120 <sup>1</sup>	332	100 <sup>3</sup>	44.5	80					21.2	6.4	7.1	
A/1 H <sub>2</sub> O	0.910 <sup>1</sup>	42.3	100 <sup>3</sup>	43.0	80					2.65	6.3	6.4	
A/2 H <sub>2</sub> O	0.910 <sup>1</sup>	42.3	100 <sup>3</sup>	43.0	80					2.65	6.3	6.4	

WATER AND OXYGEN FACTS AND FIGURES

METABOLIC LOADS<sup>2</sup>

- OXYGEN = 0.082 to 0.124  $\frac{\text{lb}}{\text{man-hr}}$
- HEAT = 500 to 760  $\frac{\text{BTU}}{\text{man-hr}}$
- CO<sub>2</sub> PRODUCTION = 0.096 to 0.146  $\frac{\text{lb}}{\text{man-hr}}$

OXYGEN USAGE (EXCEPT METABOLIC)

- CABIN LEAK RATE 0.2 lb/hr (5 psia; 75°F)
- SUIT LOOP LEAK RATE 0.01 lb/hr (3.7 psia; 70°F)
- CABIN REPRESSURIZATION (to 5.0 psia) 6.9 lb
- PLSS FILL 0.91 lb at 850 psia

HEAT CONVERSION

- 1 KWH = 3413 BTU
- 1 lb H O REJECTS  $\approx$  1025 BTU

WATER USAGE

- PLSS FILL - 6.8 lb
- AVERAGE USAGE FOR HEAT REJECTION - 6.5 to 7.5 lb/hr

<sup>1</sup>This includes gas (N<sub>2</sub>) + water volumn.

<sup>2</sup>These loads assume astronaut work in the LM while in the "cabin" mode.

<sup>3</sup>Any water quantity up to this figure may be loaded and the measuring device adjusted to indicate 100%.

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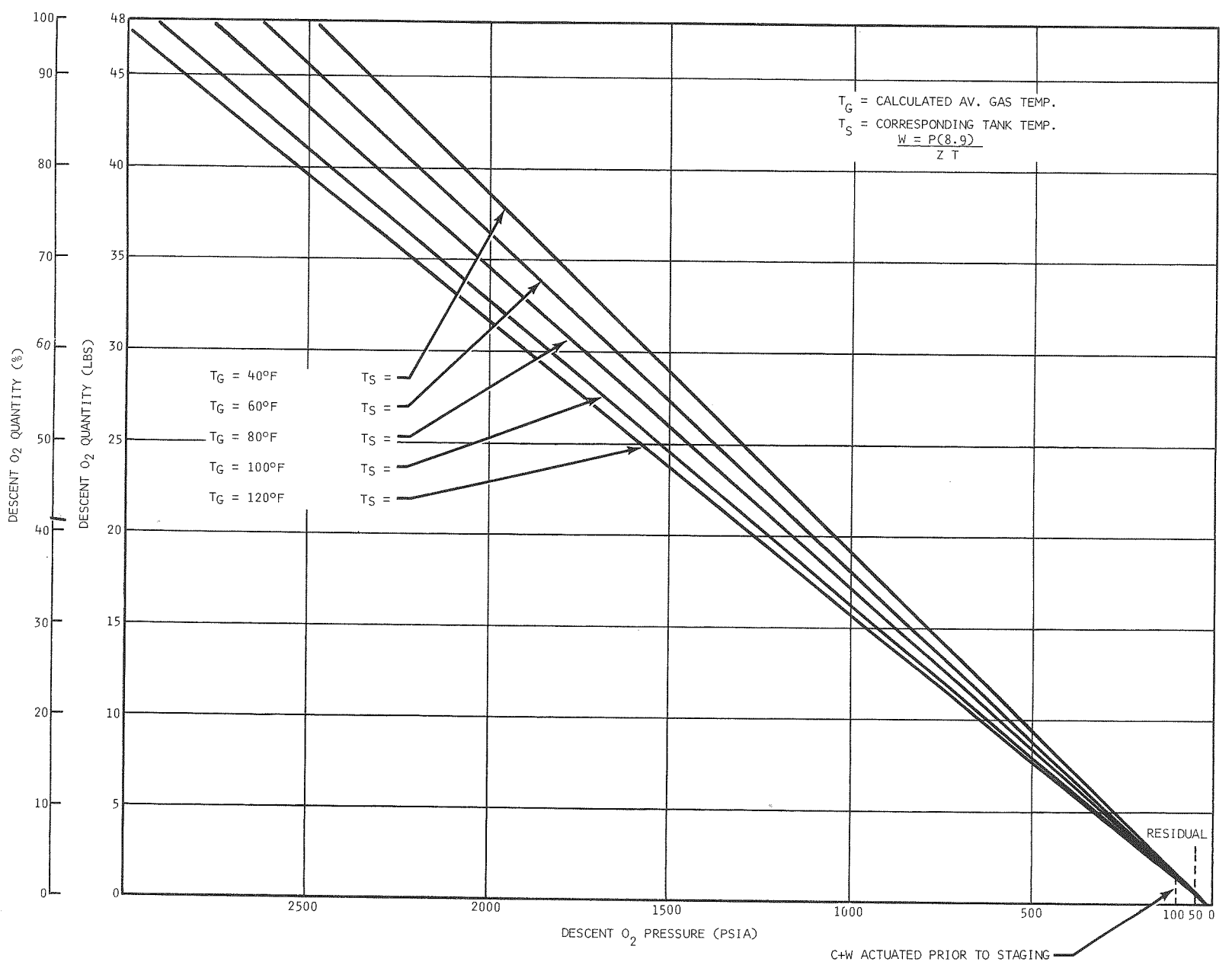


FIGURE 4-1 DESCENT O<sub>2</sub> QUANTITY VS PRESS. AND TEMP (REAL GAS)

h  
T  
-  
h

PSIA

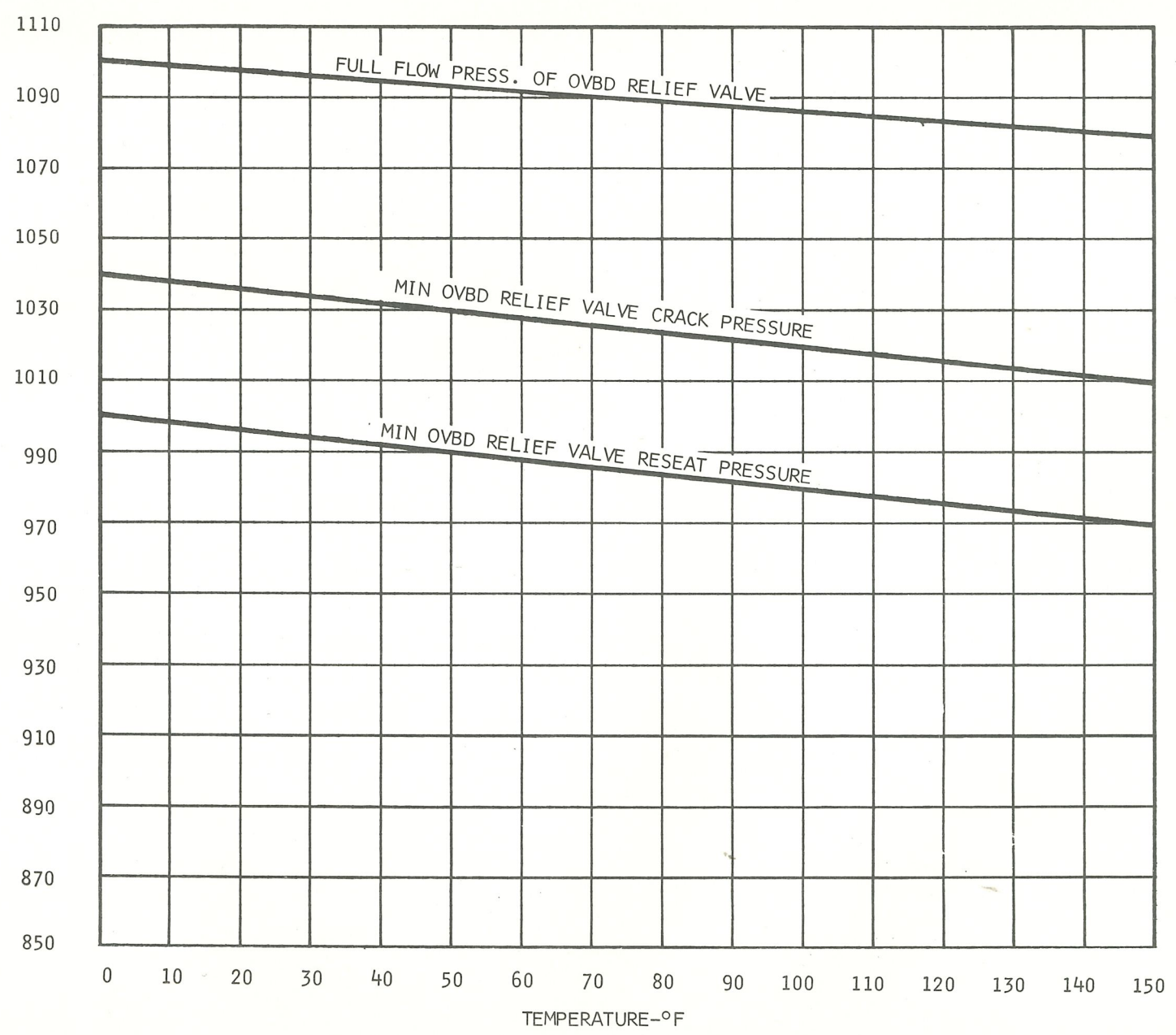


FIGURE 4-2 OPERATING CHARACTERISTICS OF HI-PRESS O<sub>2</sub> RELIEF VALVE



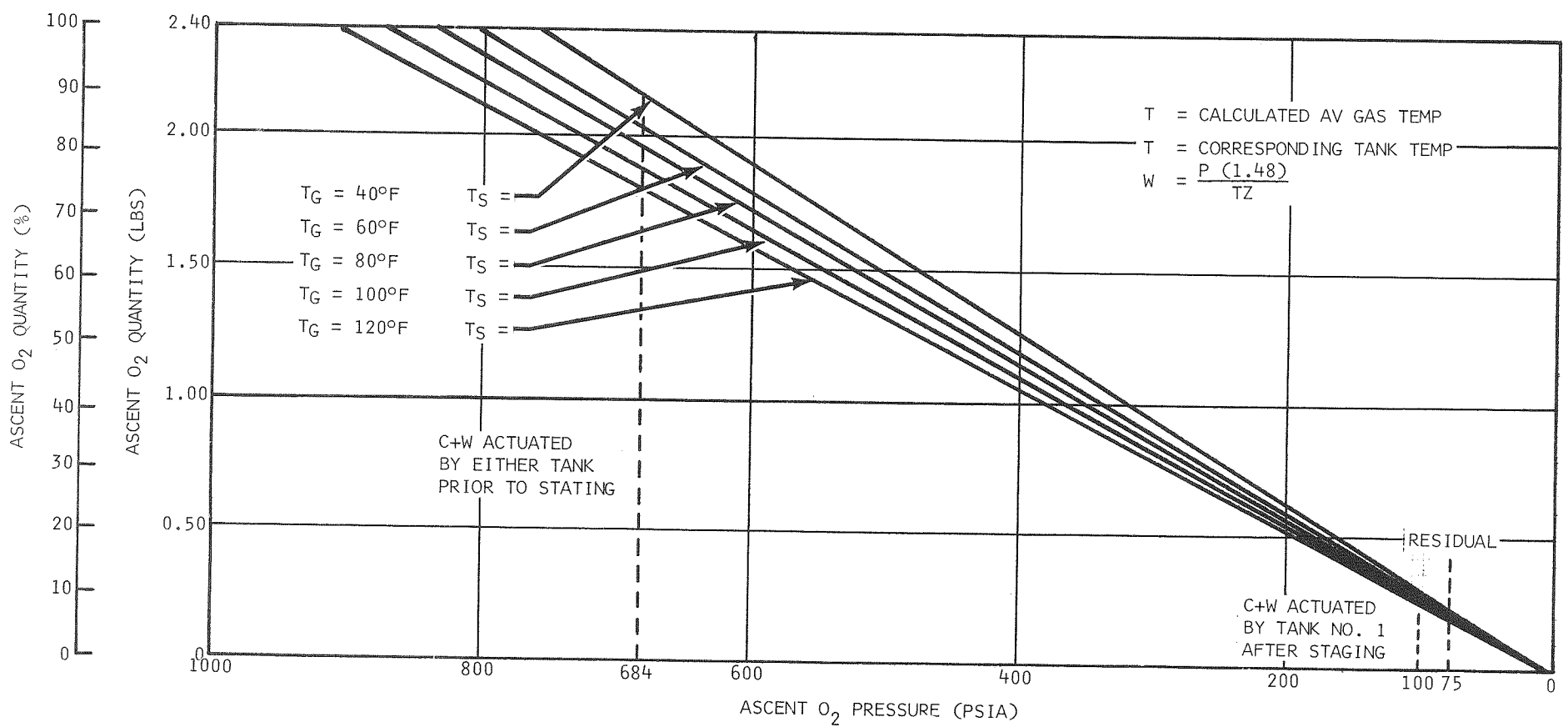


FIGURE 4-3 ASCENT O<sub>2</sub> QUANTITY VS PRESS. AND TEMP (REAL GAS)

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Figure 4-4 Estimated HTS Flow Rates - To Be Provided At a Later Date.

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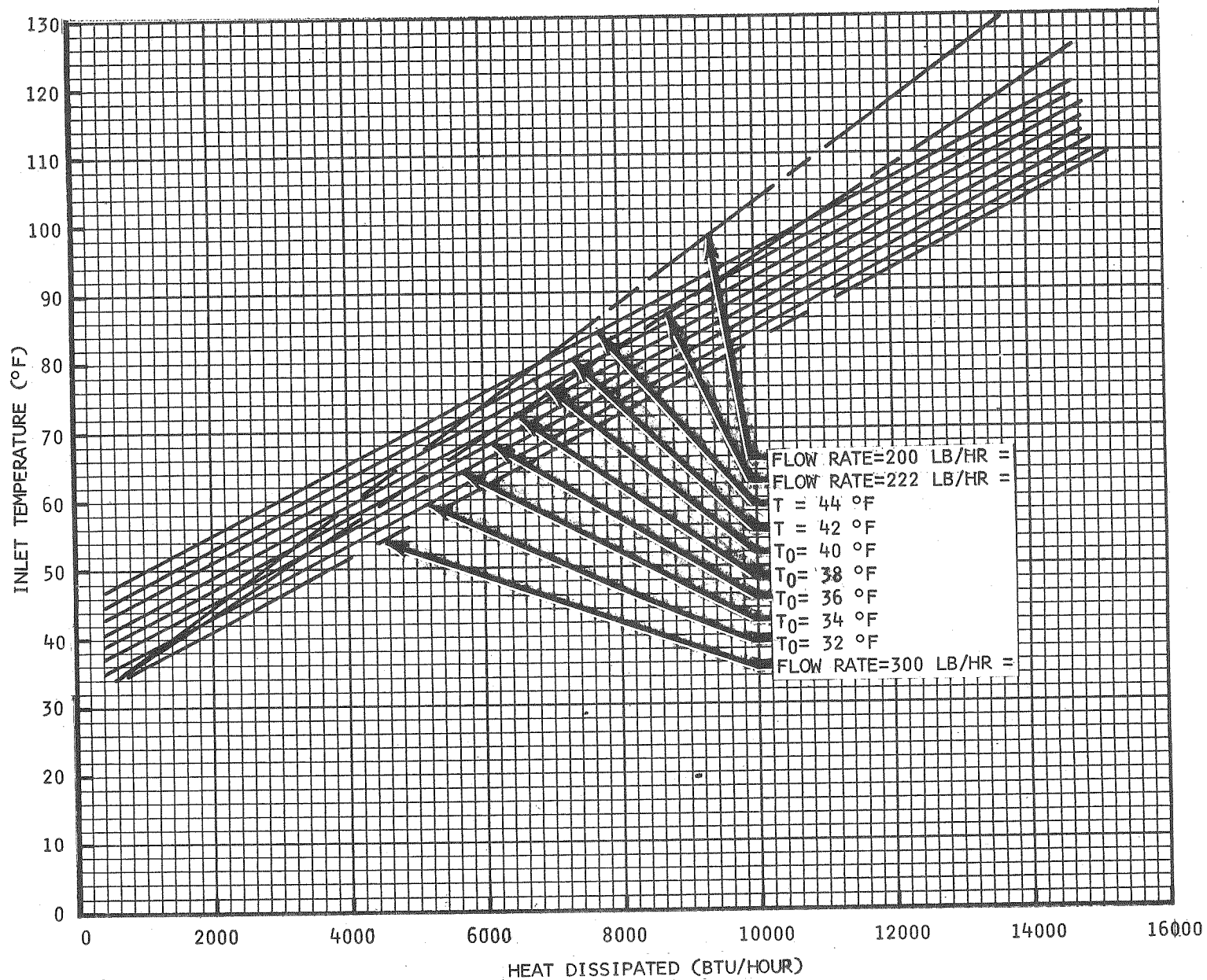


FIGURE 4-5 IM 209 WATER BOILER CHARACTERISTICS



\* TABLE 4-6 PRELAUNCH STATUS OF VALVES AND SWITCHES

<u>SWITCH/VALVE NAME</u>	<u>POSITION</u>	<u>NOTES</u>
<u>Oxygen Supply Section</u>		
DESC O <sub>2</sub> (7-H-15)	CLOSE	Prevents overboard loss of ascent O <sub>2</sub> due to tank rupture or failure of quick disconnect to seal when the S/C stages.
ASCENT O <sub>2</sub> No. 1 (7-H-21)	OPEN	Ascent O <sub>2</sub> is used from launch so that makeup O <sub>2</sub> is available following staging.
ASCENT O <sub>2</sub> No. 2 (7-H-5)	OPEN	Ascent O <sub>2</sub> is used from launch so that makeup O <sub>2</sub> is available following staging.
PLSS FILL (7-H-4)	CLOSE	Not required for AS-206A.
O <sub>2</sub> /H <sub>2</sub> O QTY MON (7-S-2)	ASC 1	Arbitrary switch position and has no effect on TM.
<u>Suit Loop</u>		
DEMAND REG A (7-H-1)	EGRESS	Required to maintain suit loop pressure at 3.8 ± 0.2 psia.
DEMAND REG B (7-H-2)	CLOSED	Required to maintain suit loop pressure at 3.8 ± 0.2 psia.
SUIT TEMP (7-H-22)	COLD	Suit loop temp control is not required due to the unmanned configuration.
CDR SUIT FLOW (7-H-6)	SUIT DIS-CONNECT	Since there are no suits on AS-206, this position is required to isolate the suit loop from the cabin.
S.E. SUIT FLOW (7-H-7)	SUIT DIS-CONNECT	Since there are no suits on AS-206, this position is required to isolate the suit loop from the cabin.
CO <sub>2</sub> SENSOR (4CB84)	OPEN	Sensor is not required on unmanned missions.
SUIT CIRCUIT RELIEF (7-H-9)	AUTO	Since the valve senses absolute suit pressure (fixed at 3 psia) and the valve automatically closes at suit pressures below 4.45 ± 0.15 psia, the valve should be closed throughout the mission.
SUIT GAS DIVERTER (7-H-8)	PULL-EGRESS	The valve is automatically in EGRESS position because selecting EGRESS on Demand Req A grounded the solenoid which closes (EGRESS position) the diverter valve.

\* TABLE 4-6 PRELAUNCH STATUS OF VALVES AND SWITCHES (Continued)

<u>SWITCH/VALVE NAME</u>	<u>POSITION</u>	<u>NOTES</u>
DIVERT VLV (4CB112)	CLOSE	
CABIN GAS RETURN (7-H-17)	CLOSE	An unmanned LM will not require purification of the cabin air. Also insures against leakage through the check valve.
CO <sub>2</sub> CANNISTER SEL (7-H-19)	PRIM	This setting is arbitrary since an unmanned LM will not require this function.
CO PRIMARY CANNISTER VENT (7-H-23)	RELEASED	This pushbutton function will not be required since pressure will not build up in the canister while the LM is unmanned.
CO <sub>2</sub> SECONDARY CANNISTER VENT (7-H-24)	RELEASED	
SUIT FAN (7-S-1)	OFF	Suit fans are not activated on AS-206A.
SUIT FAN 1 (4CB138)	OPEN	Suit fans will not be activated on AS-206A.
SUIT FAN 2 (4CB119)	OPEN	Suit fans will not be activated on AS-206A.
SUIT FAN CONT (4CB120)	OPEN	Not required. Fans not activated.
DISPLAYS (4CB140)	OPEN	Onboard lighting is not required. Pulling this breaker has no effect on TM parameters.
WATER SEP SEL (7-H-10)	PUSH: SEP 1	This setting is arbitrary since the H <sub>2</sub> O separators will not be operating.
<u>Cabin</u> CABIN REPRESS (7-H-3)	CLOSE	If the valve was positioned to auto and suit pressure fell to 3.12 ± 0.18 psia, the valve would open, dumping all remaining ASC O <sub>2</sub> into the cabin. The suit would then be open to the cabin via the open repress valve and demand regulators.
CABIN REPRESS (4CB113)	OPEN	The requirement to sustain cabin pressure does not exist on AS-206A.

\* TABLE 4-6 PRELAUNCH STATUS OF VALVES AND SWITCHES (Continued)

<u>SWITCH/VALVE NAME</u>	<u>POSITION</u>	<u>NOTES</u>
CABIN RELIEF AND DUMP VALVE (7-H-11)	AUTO	Valves are preset to this position in order to permit cabin "bleed" during launch. Also required as a protection against a failed open demand regulator.
CABIN RELIEF AND DUMP VALVE (7-H-20)	AUTO	Valves are preset to this position in order to permit cabin "bleed" during launch. Also required as a protection against a failed open demand regulator.
CABIN FAN 1 (4CB107)	CLOSE	Cabin fan will be turned on by the LMP.
CABIN FAN 2 (4CB108)	OPEN	Cabin fan No. 2 will not be operated on AS-206A.
CABIN FAN CONT (4CB109)	CLOSE	Required to operate fan No. 1 via the LMP.
CABIN TEMP (7-H-12)	COLD	Assures minimum temperature of glycol to aft equipment bay.
<u>Water Supply Section</u> WATER TANK SELECT (7-H-14)	DESCENT	This setting will permit descent H <sub>2</sub> O flow to sublimators when feed valve is opened via the LMP. Ascent feed is obtained through the use of R&D plumbing and an LMP operated crossover valve.
PRIMARY FEED (7-S-4)	NEUTRAL	Momentary toggle spring loaded to neutral. Switch is not required to initiate descent H <sub>2</sub> O flow via the LMP.
PRIM H <sub>2</sub> O FEED (4CB98)	OPEN	Power is supplied to solenoid by the LMP.
SEC GLYCOL EVAP FLOW (7-H-18)	CLOSE	The secondary glycol loop is not used on AS-206A.
SEC SUIT EVAP FLOW (7-H-16)	OPEN	Valve is required open to allow ascent H <sub>2</sub> O to sublimators. The R&D crossfeed plumbing is downstream of this valve.



\* TABLE 4-6 PRELAUNCH STATUS OF VALVES AND SWITCHES (Concluded)

<u>SWITCH/VALVE NAME</u>	<u>POSITION</u>	<u>NOTES</u>
PLSS/DRINK (7-H-13)	CLOSE	Not required on AS-206A.
<u>Glycol Loops</u>		
GLYCOL PUMP SELECT (7-S-3)	No. 1	Required for pump operation.
GLYCOL PUMP 1 (4CB117)	CLOSE	Pump 1 will be the "on-line" pump.
GLYCOL PUMP 2 (4CB141)	CLOSE	Power is required to pump 2 in order to accomplish pump switchover should pump 1 malfunction.
GLYCOL PUMP SEC (4CB96)	OPEN	The secondary glycol loop is not used on AS-206A.

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4.2 ECS CONSTRAINTS: AS-206A

4.2.1 Primary Glycol Loop

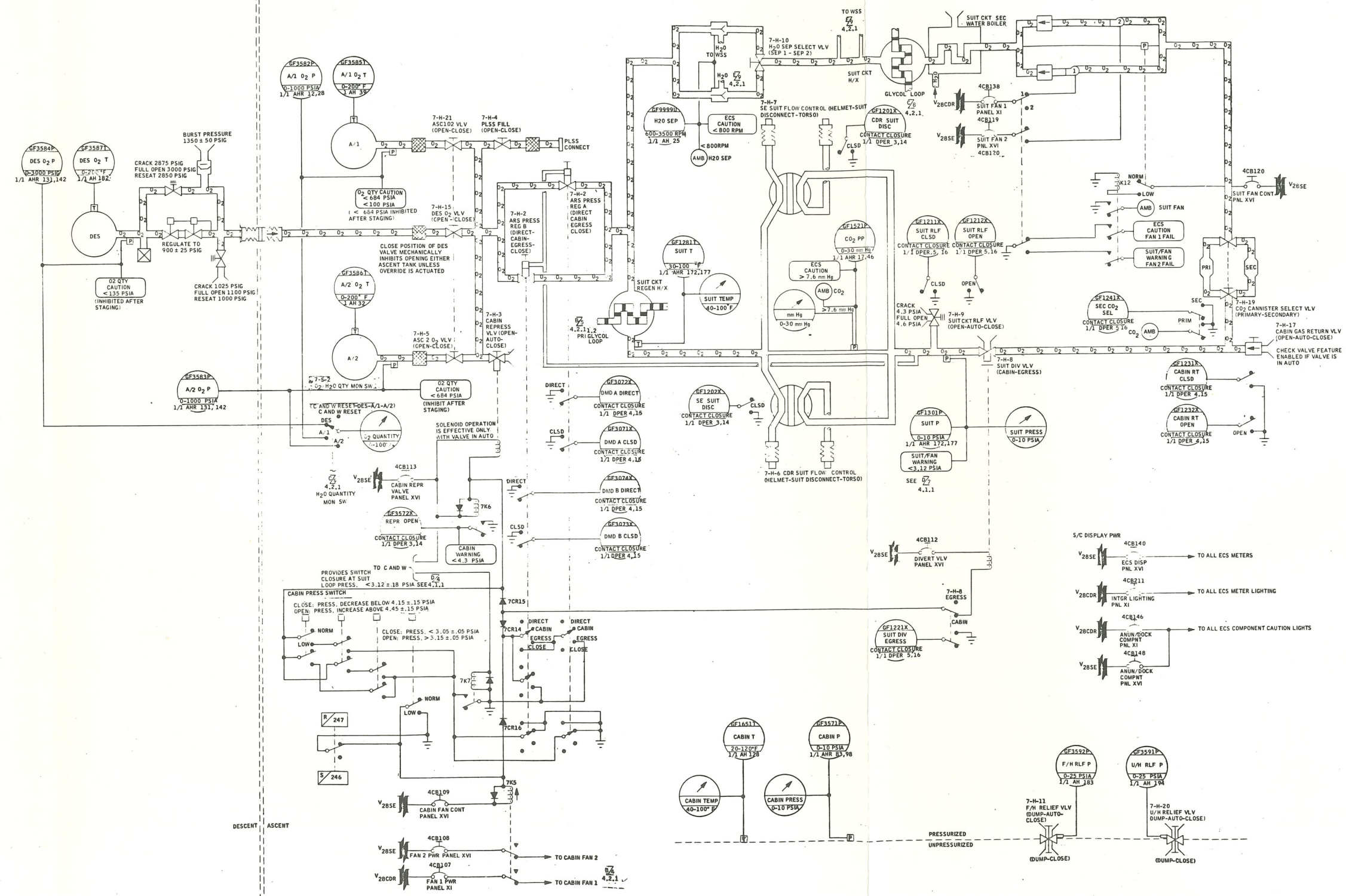
Loss of coolant recirculation (pumps fail) will result in water boiler freeze-up in \_\_ minutes and equipment overheating in \_\_ minutes.

4.2.2 Water Supply Section

- A. Failure of the PRIM FEED valve to open will result in equipment malfunction in \_\_ minutes.
- B. Failure of the ASC FEED valve to open will result in equipment malfunction in \_\_ minutes.

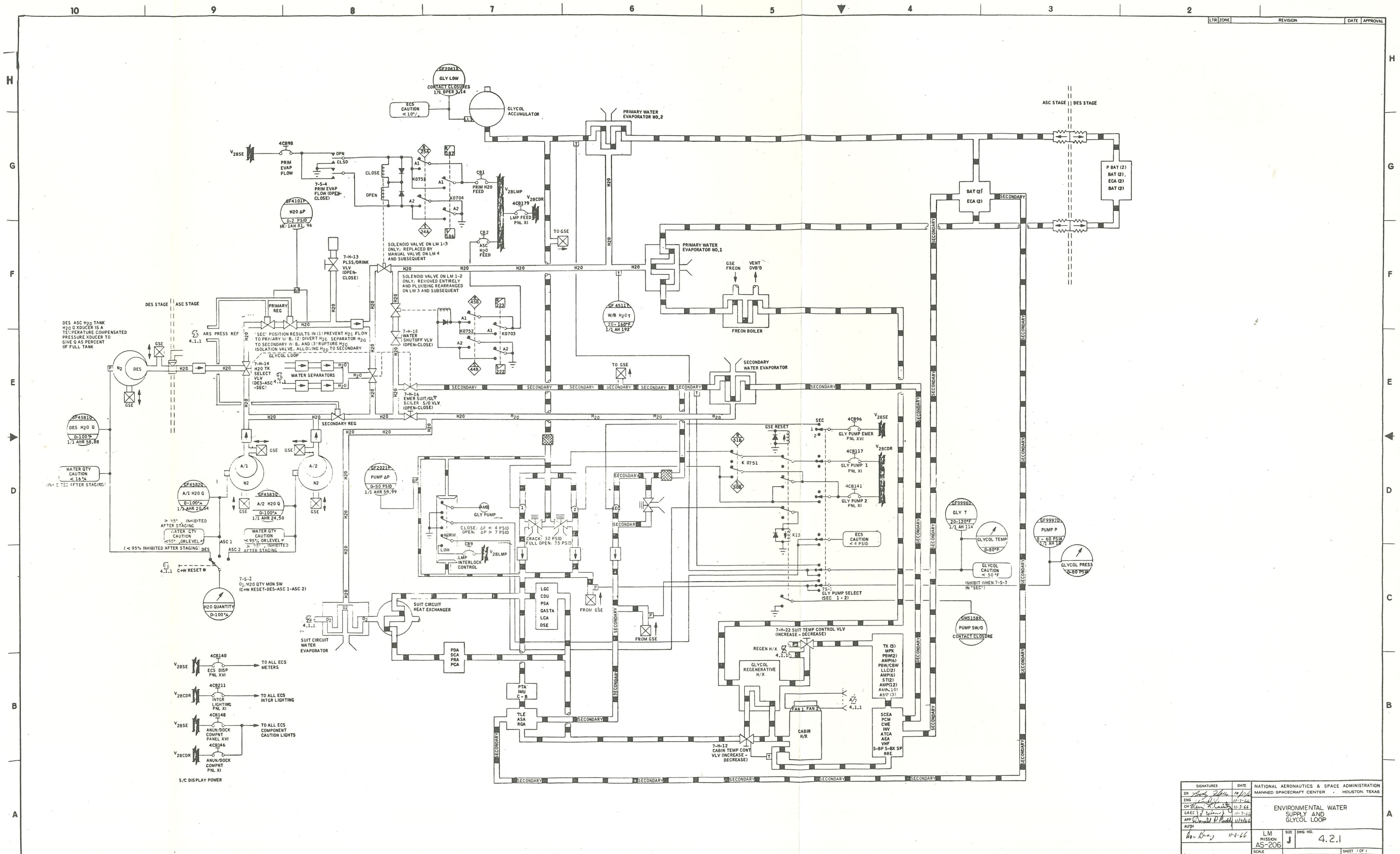




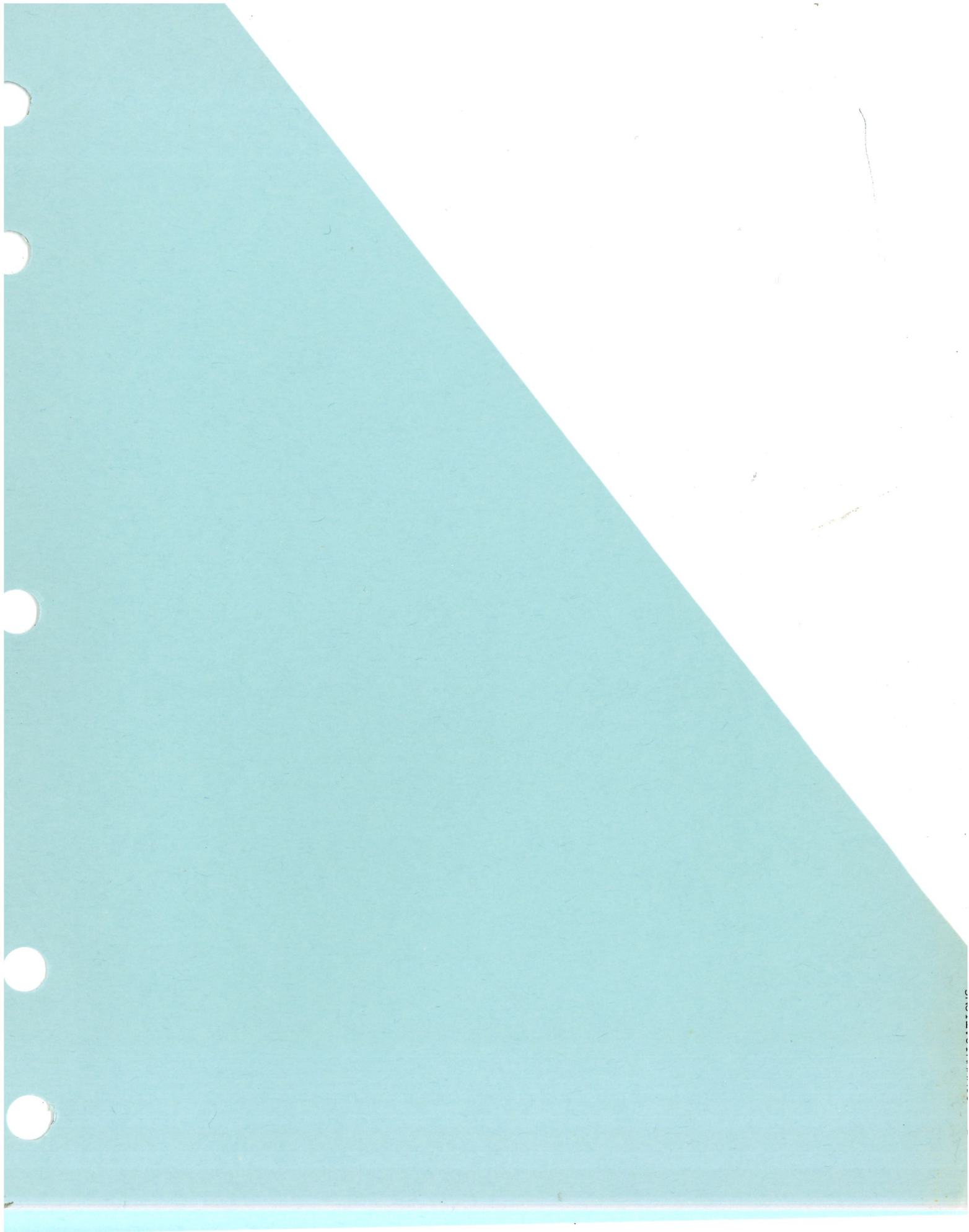


SIGNATURES		DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION	
DR		11-3-66	MANNED SPACECRAFT CENTER - HOUSTON, TEXAS	
ENG		11-2-66	ENVIRONMENTAL OXYGEN SUPPLY AND SUIT LOOP	
CHK		11-2-66		
APP		11-2-66		
AUTH		11-3-66	MISSION	
AS 206		4.1.1	SCALE	
			SHEET 1 OF 1	









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SECTION 5  
COMMUNICATIONS

LM  
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5.1 SYSTEM DESCRIPTION

5.1.1 Communications System

The communications system consists of two S-Band Transceivers and power amplifiers, two VHF/AM transceivers, two audio centers, a premodulation processor, and associated antennas. The Development Flight Instrumentation (DFI)/COMM consists of five VHF transmitters, two C-Band Beacons, a Digital Command Assembly (DCA), and associated antennas.

5.1.2 S-Band and VHF/AM Communications

For AS-206A, the S-Band will provide the capability for performing ranging and operational PCM Data Transmission using the S-Band Inflight Antenna No. 1 (-z). There is no means by which S-Band antennas can be switched during flight. The VHF/AM Transceivers and audio centers will not be used for AS-206A.

5.1.3 DFI/COMM

- A. The five DFI/COMM VHF Transmitters provide for the transmission of the following:
- |           |           |           |
|-----------|-----------|-----------|
| 1. Xmtr A | 230.9 MHZ | FM/FM     |
| 2. Xmtr B | 237.8 MHZ | PCM/FM    |
| 3. Xmtr C | 241.5 MHZ | PAM/FM/FM |
| 4. Xmtr D | 247.3 MHZ | PAM/FM/FM |
| 5. Xmtr E | 257.3 MHZ | PAM/FM/FM |
- B. There are two simultaneous paths for operational telemetry transmission. One is the DFI/COMM Transmitter B which is considered prime and the other path is S-Band.
- C. There are two C-Band Beacons used simultaneously for AS-206. Both Beacons will use the same double pulse interrogation code, i.e., two input pulses are required by the transponders to produce one output pulse.
- D. The DCA consists of a UHF Receiver, two decoders and interface circuits for the LM Guidance Computer (LGC), Program Reader

Assembly (PRA), and Program Coupler Assembly (PCA). The DCA will accept and process six each LGC commands, two PRA commands, two Real-Time Commands (RTC's) or two DCA Test Commands per second.

1. The bit configuration for each type of command is as follows:

- a. LGC (22 Bits)

<u>1 2 3</u>	<u>4 5 6</u>	<u>7</u>	<u>8 9 10 11 12 13 14 15 16 17 18 19 20 21 22</u>
Vehicle	System	Synch	Triply Redundant 5-Bit Word
Address	Address	Bit	

- b. PRA (22 Bits)

<u>1 2 3</u>	<u>4 5 6</u>	<u>7 8 9 10 11 12</u>	<u>13</u>	<u>14</u>	<u>15</u>
Vehicle	System	Time Word	Initiate	Forward	Reverse
Address	Address		Search	Search	

<u>16</u>	<u>17 18 19 20 21 22</u>
Start	Fill Bits

- c. RTC (12 Bits)

<u>1 2 3</u>	<u>4 5 6</u>	<u>7 8 9 10 11 12</u>
Vehicle	System	Command Function
Address	Address	

- d. DCA Test (22 Bits)

<u>1 2 3</u>	<u>4 5 6</u>	<u>7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22</u>
Vehicle	System	Test Word
Address	Address	

2. The DCA Test Commands are used to test the operational capability of the DCA. Test 1 processes a test command through both DCA decoders. Test 2 is a test command through Decoder B, and Test 3 processes a test command through Decoder A.

- E. The five DFI/COMM VHF Transmitters and the DCA will use the SLA VHF/UHF Antennas prior to LM/SLA separation and the LM VHF/UHF Antennas at LM/SLA separation. Antenna switchover is automatic at LM separation.

## 5.2 SYSTEM DATA

### 5.2.1 S-Band

#### A. Receiver Characteristics

1. Phase Lock Receiver
2. Frequency 2101.8 MHZ
3. Sensitivity -127 dbm
4. Power Input 6.0 Watts

#### B. Transmitter Characteristics

1. Modulation PM or FM
2. Frequency FM 2282.5 MHZ  
PM  $\frac{240}{221}$  FR MHZ
3. RF Power Output 0.75 to 1.5 Watts
4. Power Input 36 Watts

#### C. Power Amplifier Characteristics

1. Type Amplitron (QKS 1300)
2. RF Drive Level 0.72 Watts (min)
3. RF Power Output 20 Watts
4. Power Input 68.6 Watts

- D. The application of dc Power to the primary or secondary power amplifier power supply will start an automatic 20-second warmup sequence. After the warmup period, -1800 VDC is applied to the amplitron enabling the tube to lock on the input RF signal. If the amplitron fails to lock, the power supply will automatically revert to the warmup mode and the cycle will be repeated.

### 5.2.2 DFI/COMM

#### A. VHF Transmitter

1. RF Power Output 10 Watts
2. Power Input 84 Watts



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B. C-Band Beacon Characteristics

1. Receiver

- a. Frequency 5690 MHZ
- b. Sensitivity -70 dbm
- c. Interrogation Pulse Width 0.5 to 0.8 us
- d. Decoder Pulse Spacing  $3.5 \pm 0.1$  us

2. Transmitter

- a. Frequency 5795 MHZ
- b. Pulse Width  $0.75 \pm 0.1$  us
- c. Beacon Pulse Delay  $3.0 \pm 0.1$  us
- d. PRF 0-2670 PPS
- e. Peak Power Output 500 to 750 Watts

C. DCA Receiver Characteristics

- 1. Frequency 450 MHZ
- 2. Sensitivity -99 dbm

D. The following DCA Status Messages (GT0441) will be generated by the DCA:

- 1. STANDBY 1 0 1 0 0 1 0 0
- 2. OFF 0 0 0 0 0 0 0 0
- 3. MAP (LGC, PRA, or RTC) 0 1 0 1 1 0 1 1
- 4. MAP (Test) 0 1 0 0 0 1 0 0

The MAP Will be Generated for  $55 \pm 5$  ms for each command processed by the DCA.

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TABLE 5-1 PRELAUNCH STATUS OF SWITCH/CIRCUIT BREAKER POSITIONS

NAME	POSITION
S-BAND T/R (15A-S-1 and 15B-S-1)	OFF
ICS T/R (15A-S-3 and 15B-S-3)	OFF
RELAY (15A-S-4 and 15B-S-4)	RELAY OFF
S-BND RCVR VOL (15A-R-14 and 15B-R-14)	ANY POS
ICS RCVR VOL (15A-R-7 and 15B-R-7)	ANY POS
VOX ICS/XMTR (15A-S-6 and 15B-S-6)	PTT
VHF A T/R (15A-S-2 and 15B-S-2)	OFF
VHF B T/R (15A-S-9 and 15B-S-9)	OFF
VOX SENS (15A-R-8 and 15B-R-8)	CCW
VHF A VOL (15A-R-12 and 15B-R-12)	CCW
VHF B VOL (15A-R-13 and 15B-R-13)	CCW
MASTER VOL (15A-R-15 and 15B-R-15)	CCW
MODULATOR (13-S-5)	PM
S-BND XMTR/RCVR (13-S-8)	OFF
PWR AMP (13-S-2)	OFF
VOICE/BU VOICE (13-S-6)	OFF
PCM/KEY (13-S-4)	PCM
RANGE/TV (13-S-1)	OFF
VHF A XMTR (13-S-7)	OFF
VHF A RCVR (13-S-10)	OFF
VHF B XMTR (13-S-12)	OFF
VHF B RCVR (13-S-15)	OFF
BIOMED (13-S-3)	OFF
SQUELCH VHF A (13-R-10)	CCW
SQUELCH VHF B (13-R-15)	CCW
VHF RF SW (14-S-6)	1
S-BND RF SW (14-S-5)	1
CIRCUIT BREAKERS	
S-BAND ANT (4CB34)	OPEN
SEC S-BND XMTR/RCVR (4CB137)	CLOSED

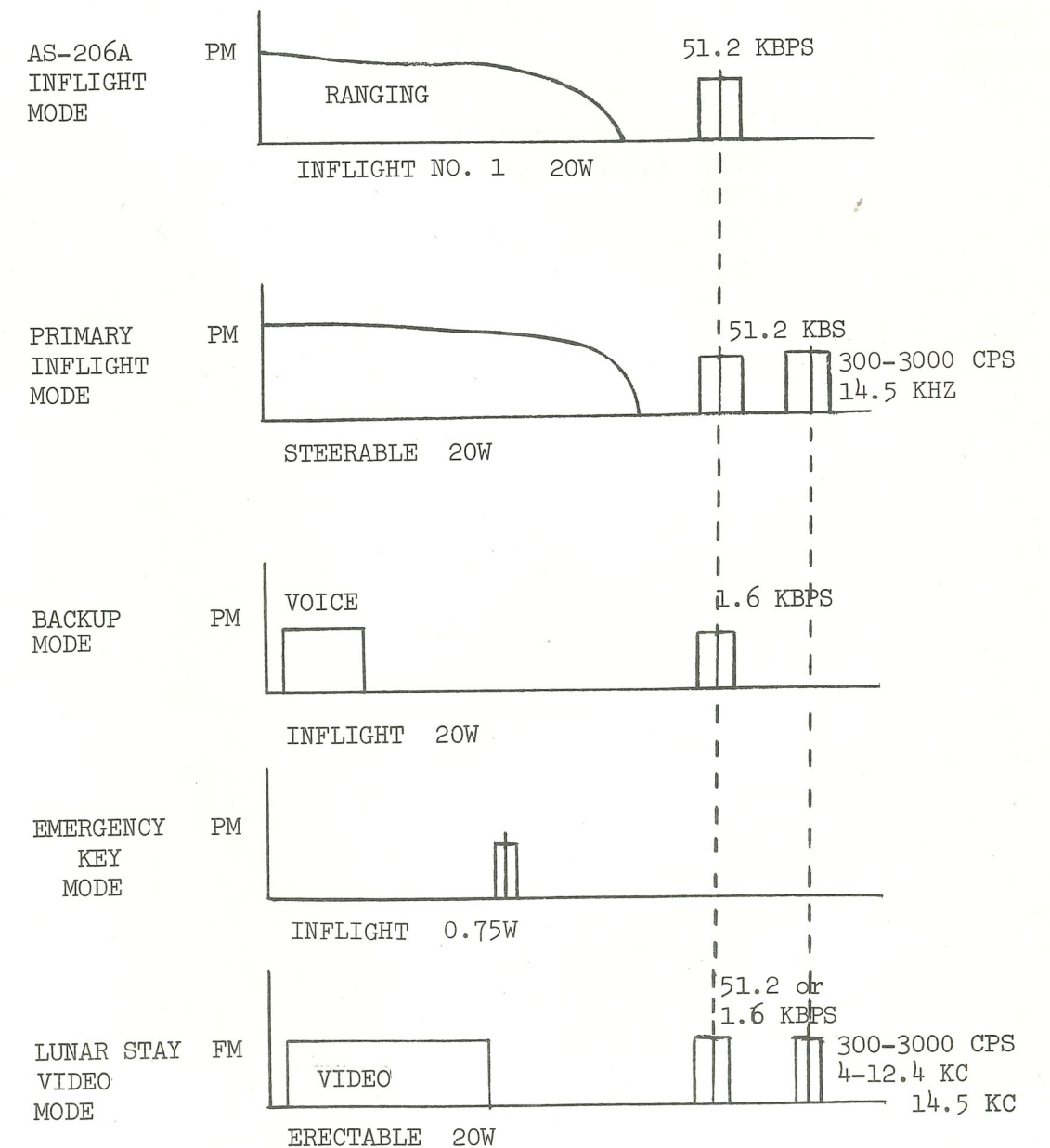
TABLE 5-1 PRELAUNCH STATUS OF SWITCH/CIRCUIT BREAKER POSITIONS (Concluded)

SEC S-BND PWR AMP (4CB136)	CLOSED
VHF A RCVR (4CB87)	OPEN
VHF B XMTR (4CB162)	OPEN
CDR AUDIO (4CB86)	OPEN
SE AUDIO (4CB85)	OPEN
VHF A XMTR (4CB115)	OPEN
VHF B RCVR (4CB114)	OPEN
PRI S-BND PWR AMP (4CB30)	CLOSED
PRI S-BND XMTR/RCVR (4CB111)	CLOSED
S-BND ANT (4CB110)	OPEN
PMP (4CB102)	CLOSED
TV (4CB104)	OPEN

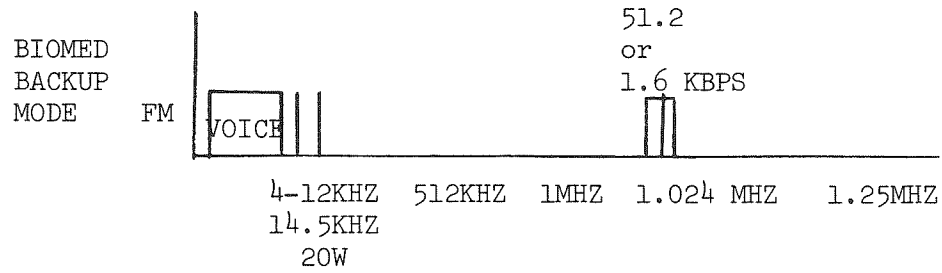
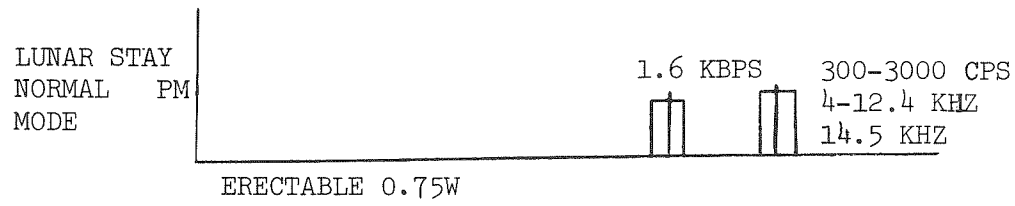
### 5.3 SYSTEM MODES

System modes are shown in the following table.

TABLE 5-2 S-BAND COMMUNICATION MODES



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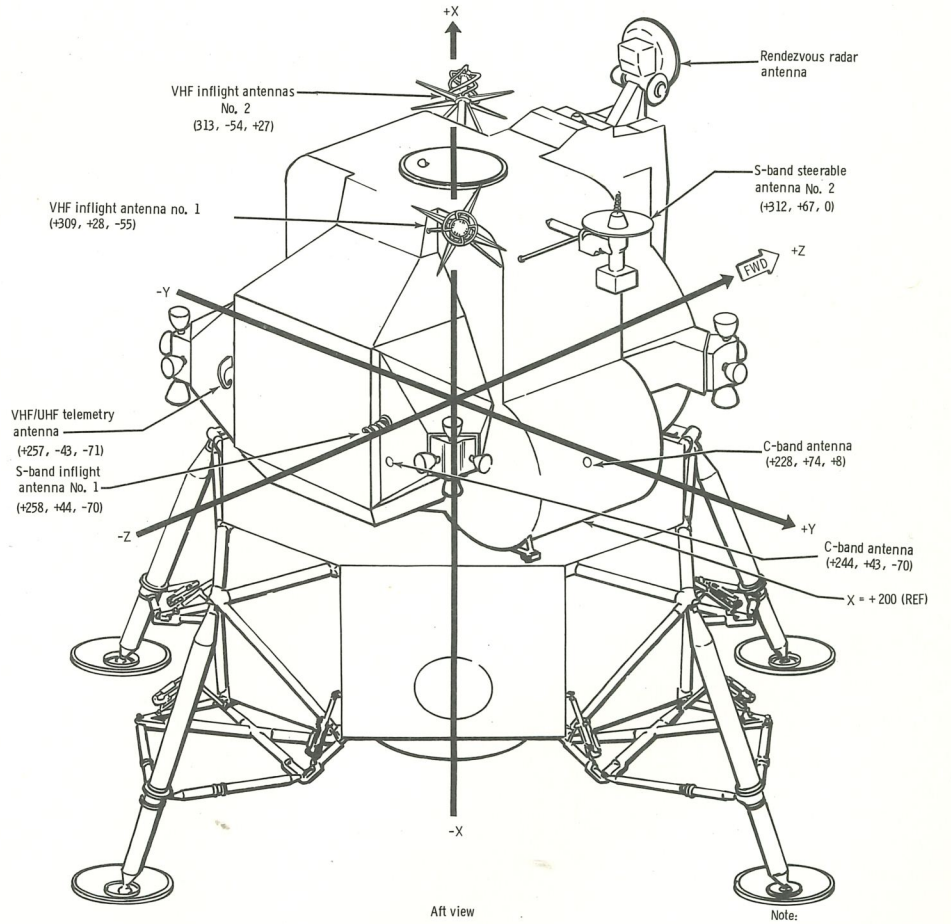
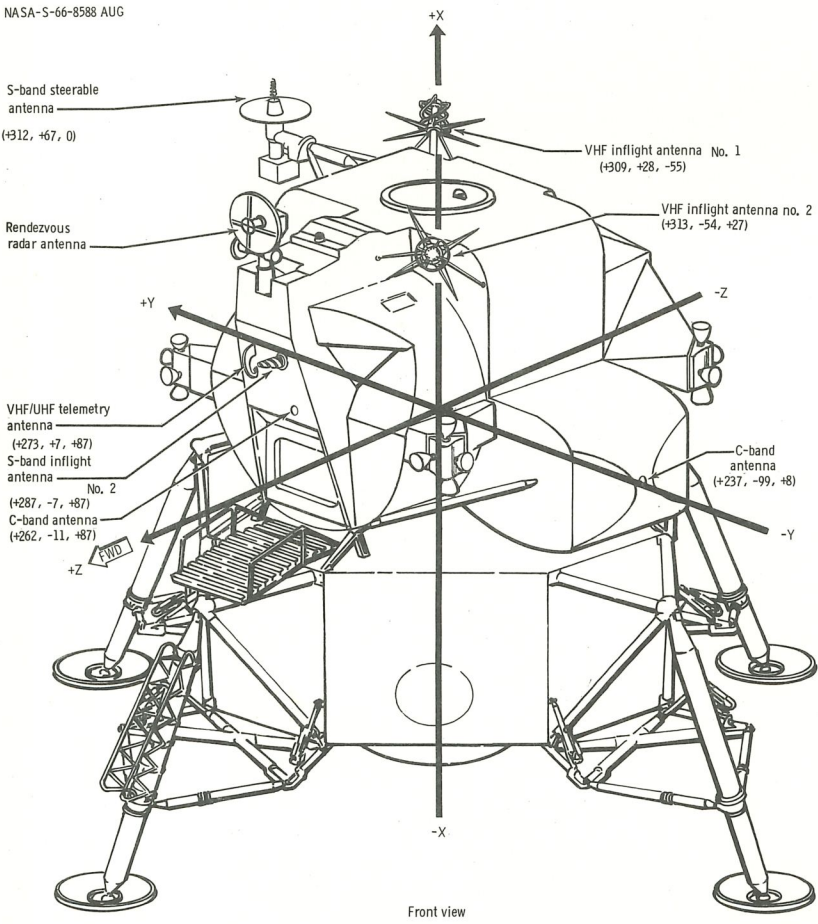
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#### 5.4 CONSTRAINTS

There is no interlock to prevent concurrent operation of both primary and secondary S-Band equipment. To prevent this damaging condition, SEC S-BND on (RTC 20A) Command should always be preceded by PRI S-BND OFF (RTC 30A).

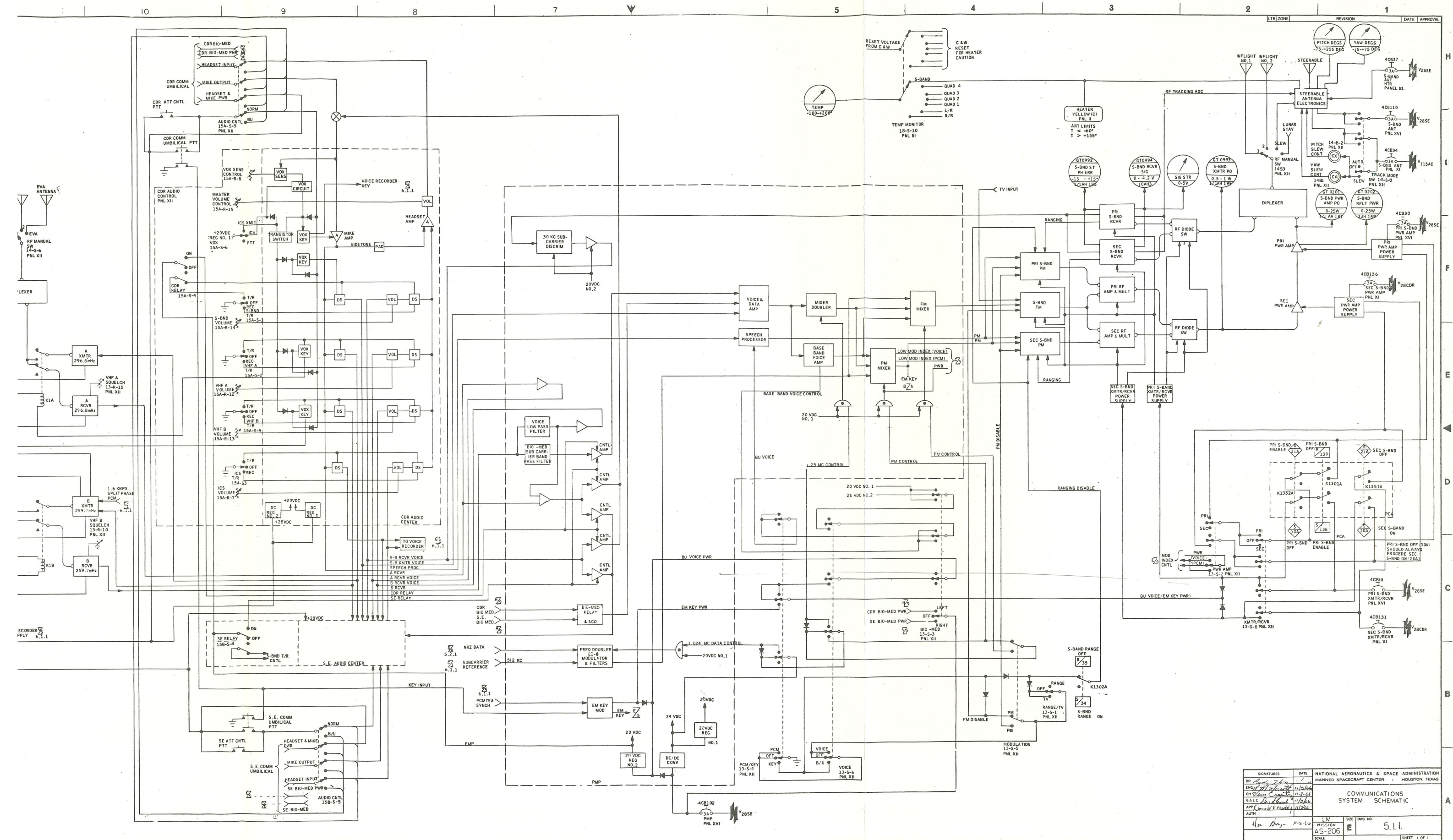
NASA-S-66-8588 AUG



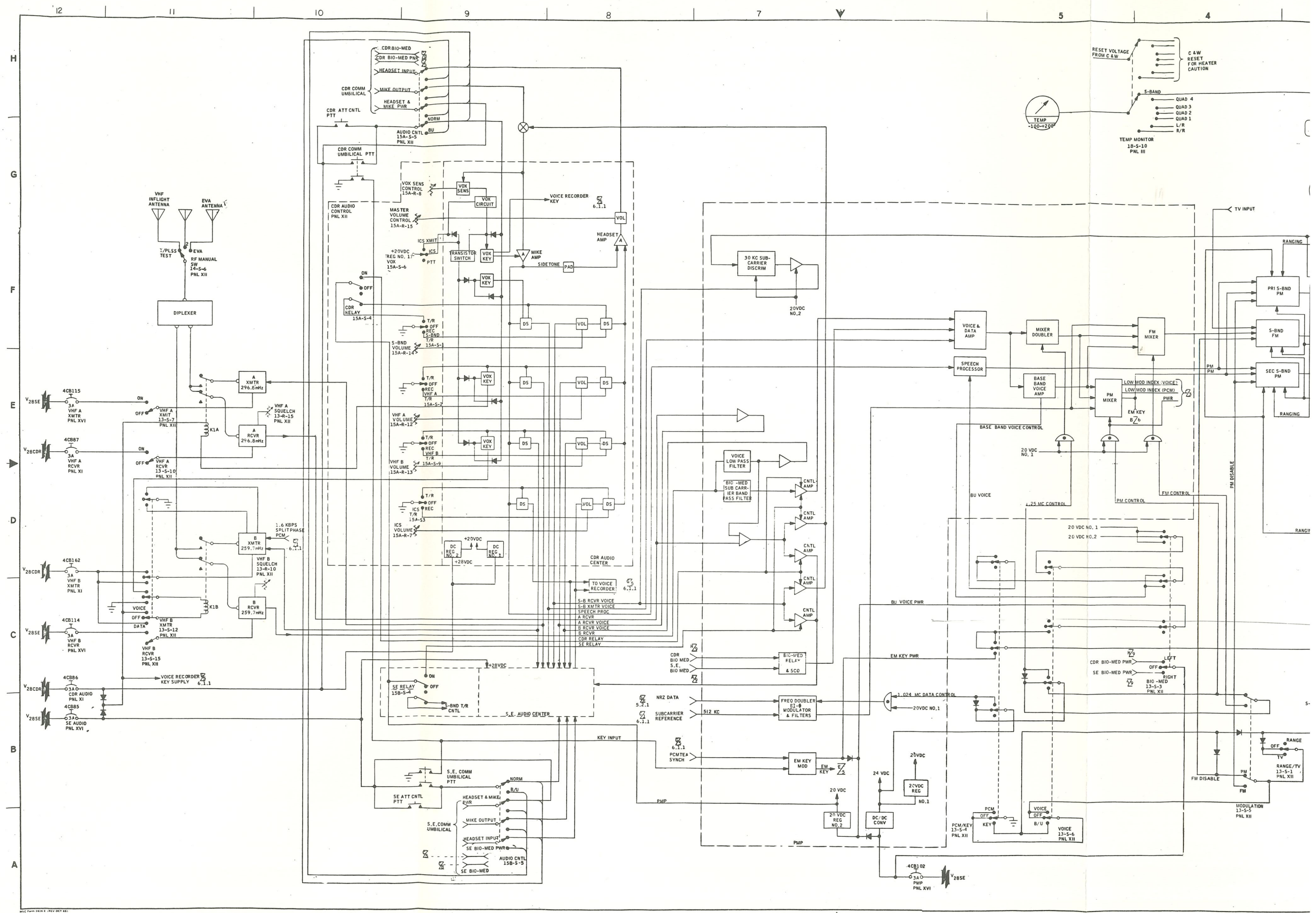
Note:  
All antenna location coordinates are given in inches, rounded off to the nearest inch, and are given in the following order: X, Y, Z.

Figure 5-1 LM 1 communications antenna locations.

















\*

## 6.1 SYSTEM DESCRIPTION

The Instrumentation Subsystem Consists of the following units:

- A. Sensors (transducers)
- B. Signal Conditioning Electronics Assembly (SCEA)
- C. Caution and Warning Electronics Assembly (C&WEA)
- D. Pulse Code Modulation and Timing Electronics Assembly (PCMTEA)
- E. Data Storage Electronics Assembly (DSEA)

### 6.1.1 Sensors (Transducers)

All sensors are permanently installed in the LM. They are utilized to sense such physical data as temperature, pressure, switch position, valve position, frequency, voltage, and current. This physical data is converted to electrical signals and sent to the SCEA, PCMTEA, C&WEA, and/or displays.

### 6.1.2 Signal Conditioning Electronics Assembly (SCEA)

The SCEA is divided into two electronic replaceable assemblies (ERA's). The ERA's are located in the ascent stage of the LM and are mounted on cold rails in the aft equipment bay (an unpressurized area).

Each ERA has the capability of mounting twenty-two plug-in replaceable subassemblies. The subassemblies are based on the following design configurations:

- |                                     |                |
|-------------------------------------|----------------|
| A. DC amplifier                     | 501-1          |
| B. Attenuator                       | 502-2          |
| C. AC to dc Converter               | 503-2          |
| D. Signal Isolating Analog Buffer   | 504-1          |
| E. Signal Isolating Discrete Buffer | 504-2, 3, 4, 5 |
| F. Frequency to dc Converter        | 505-1          |
| G. Resistance to dc Converter       | 506-2,3        |
| H. Phase Sensitive Demodulator      | 507-1          |

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Each analog subassembly consists of a common section and signal channels. The common section includes a pre-regulator, a 10kc oscillator power supply, a 1.8 kc oscillator and an isolated power supply. The signal channels include all electronics to condition data signals for PCM.

- A. DC Amplifier 501-1 - The 501-1 is a low gain dc amplifier with a gain adjust from 1 to 25, functioning with either a unipolar or bipolar floating input. When operated in the unipolar mode, the output is directly proportional to the input. It receives analog voltages of 0 to 5 volts dc and conditions them to a zero to +5 VDC full scale output. When operated in the bipolar mode the maximum negative excursions (-2.5 VDC) of the input signal corresponds to 0 VDC output and the maximum positive excursion (+2.5 VDC) corresponds to +5 VDC. Zero volts input signal produces +2.5 VDC output. The 501-1 contains four single output channels.
- B. Attenuator 502-2 - The 502-2 is capable of accepting a signal which is a unipolar or a bipolar voltage. When operated in the bipolar mode, the maximum negative excursion corresponds to 0 VDC output and the maximum positive excursion corresponds to +5 VDC output. Zero volts will produce a 2.5 VDC output. The input ranges will be between -2.5 VDC and +2.5 VDC or between -20 VDC and +20 VDC. When operated in the unipolar mode, the output will be directly proportional to the input. The input range will be 0 and +5 VDC to +40 VDC. The maximum input range corresponds to +5 VDC output. The 502-2 contains four single channel outputs.
- C. AC to DC Converter 503-2 - The 503-2 converter receives a sinusoidal ac input signal within the frequency range of

380 to 840 cycles per second and will convert this input to a dc voltage proportional to the average value of the input. The converter is adjustable to permit full scale output (+5 VDC) corresponding to any full scale input of 21, 31, 100, or 150 volts RMS. Zero output will result with zero input. The 503-2 has three single output channels.

- D. Analog Signal Isolating Buffer 504-1 - The 504-1 provides unity gain of all input signals. The range of the input signal is 0 to +5 VDC. The 504-1 has four single output channels.
- E. Discrete Signal Isolating Buffer 504-2 - The 504-2 provides ten channels with each of the channels providing two isolated step voltage outputs in response to a solid state switch closure across the channel input terminals. The buffer is turned "on" when a step voltage of between 4 and 6 VDC is sensed at the input and is turned "off" when the signal drops down to 0 + 0.5 VDC, -0 VDC.
- F. Discrete Signal Isolating Buffers 504-3, 4, 5 - The 504-3 contains twelve dual output channels. The dual output is a step voltage whose amplitude is between 4 and 6 VDC when the buffer is turned "ON" and 0V +0.5, -0.0 when the buffer is turned "OFF".

The 504-4 contains twelve dual output channels. One output is a step voltage whose amplitude is between 4 and 6 VDC when the buffer is turned "ON" and 0V + 0.5, -0.1 when the buffer is "OFF". The second output is a solid state switch closure.

The 504-5 contains twelve single output channels. The output is a step voltage with the same voltages as above resulting from turning on the buffer or turning off the buffer.

The output of 504-3, 4, and 5 will result from a switch closure at the input.

- G. Frequency to DC Converter 505-1 - The 505-1 signal input accepts variations between 380 and 420 cps with a carrier amplitude of 20 to 130V RMS. Zero volts dc will result at



the low limit of the input frequency range and the 5 VDC will result at the high limit of the input frequency range.

- H. Resistance to DC Converter 506-2, 3 - The 506-2, 3 accepts a resistance change, upsets the balance of a bridge circuit and produces bridge errors of 0-130 millivolts which will be equivalent to a 0-5 VDC output. The 506-2, 3 converter contains four dual output channels
- I. Phase Sensitive Demodulator 507-1 - The 507-1 accepts an ac voltage input, compares the input to a coherent ac reference voltage and produces an output from zero to +5 VDC full scale indicating both the magnitude of the input signal voltage and its phase relationship to the reference voltage. The 507-1 contains four single output signal channels.

#### 6.1.3 Caution and Warning Electronics Assembly (C&WEA)

The C&WEA provides the astronauts with a rapid check of LM subsystem status by continually monitoring critical subsystem parameters during the manned phases of the LM mission. The astronauts receive visual caution\*, warning\*, flag and/or indicator closures.

The C&WEA is capable of handling data in the form of analog signals, discrete voltage levels and switch closures. The C&WEA can evaluate this data and determine if the input signals are within the prescribed limits, and provide caution, warning, flag, advisory, and telemetry relay closures as required; there are three types of analog signal evaluation:

1. High limit - voltage above a specified value.
2. Low limit - voltage below a specified value
3. Bandpass - voltage above or below a specified value

#### \* Definitions:

Caution - Malfunctions not requiring immediate attention but which would affect crew safety if action is not taken. Malfunctions in subsystems which time share displays. Malfunctions in subsystems whose displays are not readily visible to the astronaut.

Warning - Malfunctions that affect crew safety and require immediate attention.

\*

The C&WEA is also capable of processing inhibits which allows the C&WEA logic to ignore out-of-tolerance conditions when it is desirable to do so.

#### 6.1.4 Pulse Code Modulation and Timing Electronics Assembly (PCMTEA)

A. The PCMTEA consists of the following components:

1. Analog multiplexer drivers
2. High level analog multiplexer
3. Calibrator
4. Analog-to-digital converter (coder)
5. Programmer
6. Digital multiplexer
7. Output register
8. Power supply
9. Timing equipment

B. Input signals for the PCM equipment are of three types:

high-level analog, parallel digital, and serial digital. Some parallel digital and high-level analog inputs are supplied directly to the PCMTEA from subsystem sensors; all other signals are first processed through the SCEA.

C. The PCM equipment accepts the high-level analog signals\* through the multiplexer. The multiplexer forms pulse-amplitude-modulated (PAM) outputs representative of the analog inputs. The high-level PAM outputs of the multiplexer are supplied to high-speed gates (see Table VII) for application to the analog-to-digital converter on command from the programmer.

D. The calibrator supplies two precision voltage outputs (4.25 and 0.75 volts dc) to the multiplexer to ensure that overall accuracy of data is maintained through the PCMTEA.



- E. The analog-to-digital converter converts the high-level PAM outputs of the high-speed gates into eight-bit binary words. For a zero-volt input, the converter generates the decimal equivalent of an eight-bit binary 1(00000001). Each additional 19.7 millivolts of input signal increases the binary output by one; therefore, with a 4.98-volt dc input, the binary output will be 254 (11111110). For an input exceeding 5 volts dc, the binary output will be all ones (11111111); for an input less than 0 VDC, the binary output will be all zeros (00000000).
- F. The programmer generates the necessary commands for analog and digital data sampling and operations and supplies the basic timing for data transfer and subcarrier frequencies required in the PCMTEA as well as other subsystems. The programmer selects the high bit rate or low bit rate data-sampling formats by actuating Switch 13S13.
- G. The output of the analog-to-digital converter is supplied to the digital multiplexer. This multiplexer gates the analog-to-digital converter outputs, along with the frame synch and format identification words from the programmer and the serial digital and parallel digital data\* from the SCEA or from the subsystem sensors, to the output register. When these data exceed eight bits per word, the most significant eight bits are gated to the output first and then followed by the next most significant eight bits. The register converts these eight-bit words (parallel by bit) to serial outputs and routes them to the Communications Subsystem. These data are sampled and routed to the Communications Subsystem in nonreturn-to-zero (NRZ), format 51,200 pulses per second (high bit rate) or split phase format at 1,600 pulses per second (low bit rate). Data generated by the LM guidance

computer (LGC) in the Primary Navigation, Guidance, and Control (PNG&C) Subsystem are supplied to the output register in a 40-bit serial word format. Data generated by the Abort Guidance Computer (AGS) are supplied to the output register in a 24-bit serial word format.

- H. The timing equipment consists of a phase lock oscillator, timing generator, time accumulator, and an output buffer. The phase lock oscillator accepts a 1024 kc sync signal from the LGC. This signal is frequency doubled, and used to control the output of a 2048 kc crystal oscillator by locking the phase of the oscillator output to the phase of the input sync signal. This phase lock output (2048 kc) is routed to the timing generator. If the LGC sync signal is lost, the crystal oscillator continues to supply the timing generator with a 2048 kc signal.

The timing generator supplies sync pulses to the Electrical Power Subsystem, the Guidance, Navigation, and Control Subsystem, and the Communications Subsystem via the output buffer. It also supplies the time accumulator with a 10 cps signal that is converted to mission-elapsed-time data. The time accumulator recycles to zero at 39 days or upon interruption of PCMTEA power. These data are routed to the DSEA for simultaneous recording with voice. The timing generator supplies all the timing signals required in the programmer for generating frame sync, frame identification, and format identification data.

\*

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\*NOTE

Some data words are wired redundantly within their respective multiplexer (analog or digital). This does not, in effect, double the sampling rate for such parameters because the redundant data word loading is spaced unevenly time-wise. (Were the time correlation evenly spaced, then sampling would be essentially doubled or supercommutated). Refer to Figure 1 for a depiction of the time correlation. An example of this type of parameter would be the battery currents GC1201-1206C. Redundant transducers, which supply duplicate data concerning a particular parameter, are wired to the PCMTTE external connector and may be treated as two separate data points. An example of this type of parameter would be GQ3018P and GQ3025 (IM-2 and sub) DPS HE REG PRESS.

6.1.5 Data Storage Electronics Assembly

The data storage electronics assembly (DSEA) is a single-speed, four-track magnetic tape recorder with electronics that records time correlated voice. A maximum of 10 hours of recording time is provided (2.5 hours on each track) by driving the tape in one direction over the record head and, on completion of a pass, switching to the next track and reversing tape direction.

The tape reel contains 450 feet of 0.25-inch wide, 0.00075-inch thick mylar instrumentation tape. Tape is driven across the record head at 0.6 inch-per-second constant to within  $\pm 0.1$  percent of driving power frequency. The DSEA will not be utilized for AS-206A.

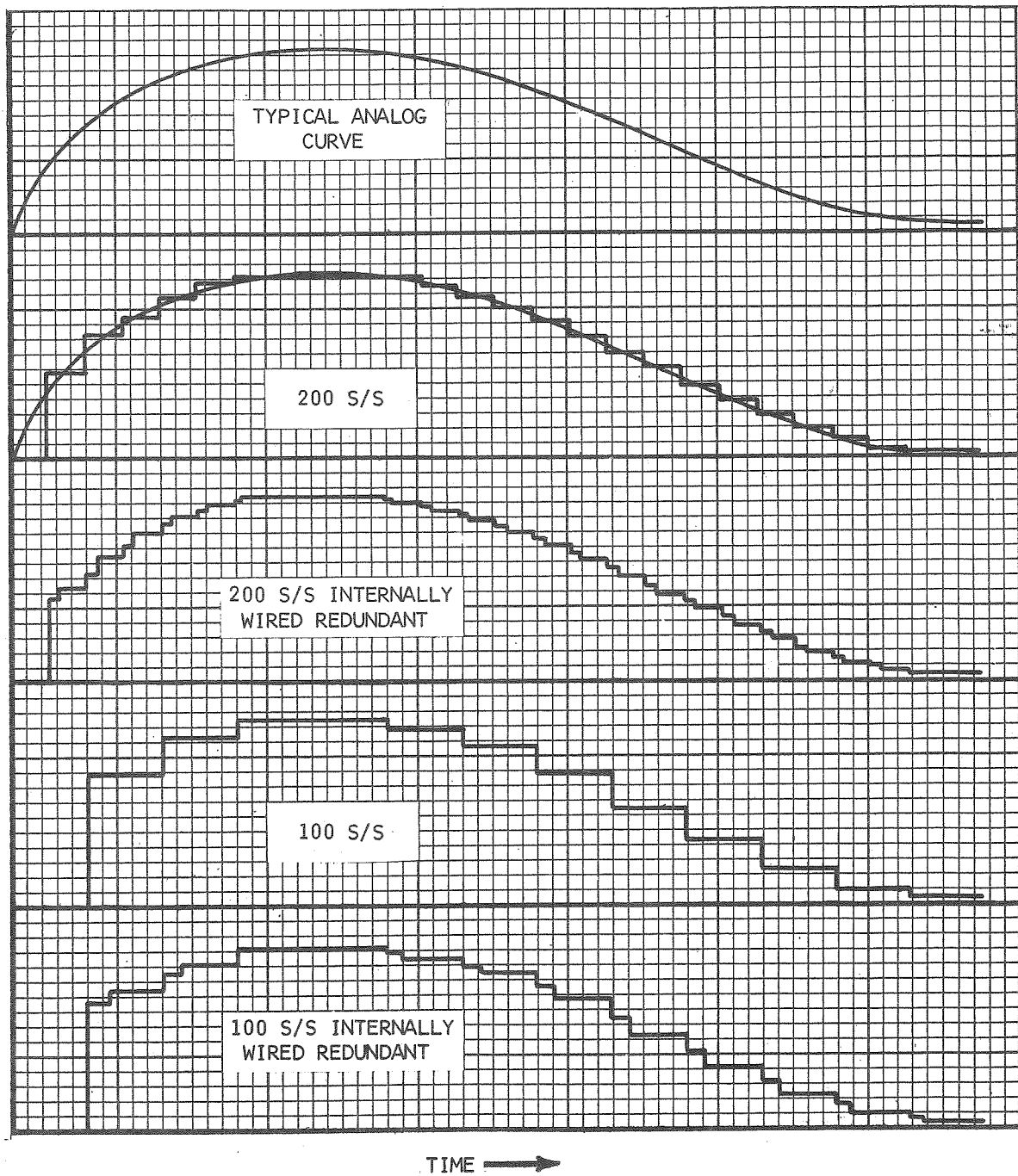


FIGURE 6-1 TIME CORRELATION - INTERNALLY REDUNDANT SAMPLING



\*

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## 6.2 SYSTEM DATA

The following tables depict the data for this system.

TABLE I PCMTEA SINGLE POINT FAILURES

FAILURE OF:	DATA LOST
Analog Multiplexer Sequencer	Up to 5 Analog Channels
Analog Multiplexer Driver	Up to 20 Analog Channels (4 Seq)
High-Speed PAM Gate	Up to 75 Analog Channels
Digital Multiplexer	(1) Loss of all Analog data; (2) Loss of all data in same bit position; (3) Loss of all data
Ouput Register	(1) Loss of all serial digital data (AGS or PGNS); (2) Loss of all data
Data Transfer Buffers	Loss of all data
Programer	
(1) Counters	Loss of all Data
(2) Matrix	(1) Loss of up to 20 Analog channels (2) Loss of Digital Data (3) Loss of all data

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TABLE II PRELAUNCH STATUS OF SWITCH AND CIRCUIT BREAKER POSITIONS

\*

NAME	POSITION
<u>Switches:</u>	
Master Alarm, CDR (6S2)	Extinguished (out)
Master Alarm, SE (6S3)	Extinguished (out)
ANUN/NUM CW Lites and Others (16R2)	DIM
PCM (13S13)	HI
Tape Recorder (13S11)	OFF
<u>CKT Breakers:</u>	
Tape Recorder (4CB202)	CLOSED
Sig Condr 1 (4CB131)	CLOSED
R/D Inst (4CB181)	CLOSED
Master Alarm (4CB147)	OPEN
PCMTEA (4CB125)	CLOSED
C&WEA (4CB94)	CLOSED
Sig Sensor (4CB132)	CLOSED
Sig Condr (4CB1)	CLOSED

TABLE III MEASUREMENTS ON UNREGULATED DC

\*

Circuit Breaker 4 CB 132 SE PNL XVI +28 VDC Fuse Assy Sensor Power

(3A Rating)

I. Block 4A9 Connector P98J98

Fuse	Meas No.	Field Title
F1	GF3582P	ASC 1 O <sub>2</sub> Press.
2	GF3583P	ASC 2 O <sub>2</sub> Press.
3	GF3584P	DESC O <sub>2</sub> Press.
4	GF2741P	(Gly Pump Press.)
5	GF2921P	(GF9997U)
6	GF4581Q	DESC H <sub>2</sub> O Qty
7	GF4582Q	ASC 1 H <sub>2</sub> O Qty
8	GF4583Q	ASC 2 H <sub>2</sub> O Qty
9		
10	GR1101P	RCS A He Press.
11	GR1102P	RCS B He Press.
12	GR1201P	RCS A Reg Press.
13	GR1202P	RCS B Reg Press.
14		
15		
16	DFI	
17		
18		
19		
20	GR3201P	A Ox Man Press.
21	GR3202P	B Ox Man Press.
22		
23	GP0001P	APS He 1 Press.
24	GP0002P	APS He 2 Press.
25	GP0025P	APS He Reg Press.
26	GP0908X	APS Fuel Low
27	GP1408X	APS Ox Low
28	GP1501P	APS Fuel Press.

TABLE III MEASUREMENTS ON UNREGULATED DC (CONCLUDED)

\*

Fuse	Meas No.	Field Title
29	GP1503P	APS Ox Press.
30	GP2010P	APS TCP
31		
32	GQ3018P	DPS He Reg Press.
33	GQ3611P	DPS Fuel Press.
34	GQ3435P	DPS He Press.
35	GQ6510P	DPS TCP
36	GQ4111P	DPS Ox Press.
37		
38		
39		Throttle instrumentation
40		Reference Power

II. Block 4A10 Connector P98AJ98

-40 None

III ECS Relay Box

3	GF3571P	Cabin Press.
4	GF3591P	U/H Rlf Press.
5	GF3592P	F/H Rlf Press.
6	GF2021P	Pri Gly Pump ΔP
7	{ GF1111F GF1112F }	{ H <sub>2</sub> O Sep Rate GF9999U }
8	GF1301P	Suit Outlet
9	GF4101P	H <sub>2</sub> O ΔP

IV Circuit breaker 4CB84 SE PNL XVI 3A rating CO<sub>2</sub> Sensor

GF1521P }  
GF1522P } CO<sub>2</sub> Part Press.



TABLE IV STATE OF DESCENT STAGE REAL-TIME ANALOG MEASUREMENTS AFTER STAGING

\*

The following measurements will indicate a minimum signal consisting of a PCM word of 00000001.

GC0201	Bat 1 Volt
GC0202	Bat 2 Volt
GC0203	Bat 3 Volt
GC0204	Bat 4 Volt
GQ3018	DPS He Reg Press.

The following measurements will indicate a maximum signal consisting of a PCM word of 11111111.

GF3487	DES O <sub>2</sub> Temp
GQ3718	DPS Fuel 1 Temp
GQ3719	DPS Fuel 2 Temp
GQ4218	DPS Ox 1 Temp
GQ4219	DPS Ox 2 Temp

The PCM word for the following signals will float. The measurement will tend to a minimum value, but may be susceptible to noise.

GC1201	Bat 1 Cur
GC1202	Bat 2 Cur
GC1203	Bat 3 Cur
GC1204	Bat 4 Cur
GF3584	DES O <sub>2</sub> Press.
GF4581	DES O <sub>2</sub> Qty
GQ3603	DPS Fuel 1 Qty
GQ3604	DPS Fuel 2 Qty.
GQ3611	DPS Fuel Press.
GQ4103	DPS Ox 1 Qty
GQ4104	DPS Ox 2 Qty
GQ4111	DPS Ox Press.
GQ6510	DPS TCP
GQ6806	Var Inj Act. Pos
GQ3435	DPS He Press.

TABLE V AS-206A (LM-1) SIGNAL CONDITIONING MEASUREMENT ASSIGNMENT

\*

Refer to Diagram 6.1.1 for ERA locations and circuits involved. The replaceable assemblies (1-22) feed signals to C&WEA, PCMTEA, or displays as indicated in this table.

ERA-1

<u>MEAS ID</u>	<u>TYPE</u>	<u>LOC</u>	<u>CKT</u>	<u>C&amp;W</u>	<u>PCM</u>	<u>DISP</u>
GC0071V	(GSE)	01		X		
GC0155F	(CK OUT)	01		(CK OUT)		
GF3582P	(CK OUT)	01		X		
GF3583P	(CK OUT)	01		X		
GF4581Q	(CK OUT)	01		X		
GF4582Q	(CK OUT)	01		X		
GF4583Q	(CK OUT)	01		X		
GH1405V	(CK OUT)	01		X		
GI3215V	(CK OUT)	01		X		
GI3233F	(CK OUT)	01		X		
GN7563T	(CK OUT)	01		X		
GN7723T	(CK OUT)	01		X		
GP0001P	(CK OUT)	01		X		
GP0002P	(CK OUT)	01		X		
GP0025P	(CK OUT)	01		X		
GP1501P	(CK OUT)	01		X		
GP1503P	(CK OUT)	01		X		
GQ3018P	(CK OUT)	01		X		
GR1101P	(CK OUT)	01		X		
GR6001T	(CK OUT)	01		X		
GR6002T	(CK OUT)	01		X		
GR6003T	(CK OUT)	01		X		
GR6004T	(CK OUT)	10		X		



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<u>MEAS ID</u>	<u>TYPE</u>	<u>LOC</u>	<u>CKT</u>	<u>C&amp;W</u>	<u>PCM</u>	<u>DISP</u>
GH1426V	504-2	02	1	X	X	
GH1427V	504-2	02	2	X	X	
GH1428V	504-2	02	3	X	X	
GH1429V	504-2	02	4	X	X	
GH1430V	504-2	02	5	X	X	
GH1431V	504-2	02	6	X	X	
GH1432V	504-2	02	8	X	X	
GH1433V	504-2	02	7	X	X	
GY0050X	504-2	02	9	X	X	
OPEN	504-2	02	10	X	X	
<hr/>						
GH1603X	504-2	3	1		X	
GH1230X	504-2	3	2		X	
OPEN	504-2	3	3-8	X	X	
GH1348X	504-2	3	9	X	X	
GH1893X	504-2	3	10		X	
<hr/>						
GI3232X	504-2	4	1	X		
OPEN	504-2	4	2	X		
GH1418V	504-2	4	3	X	X	
GH1420V	504-2	4	4	X	X	
GH1419V	504-2	4	5	X	X	
GH1421V	504-2	4	6	X	X	
GH1422V	504-2	4	7	X	X	
GH1423V	504-2	4	8	X	X	
GH1424V	504-2	4	9	X	X	
GH1425V	504-2	4	10	X	X	
<hr/>						
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<u>MEAS ID</u>	<u>TYPE</u>	<u>LOC</u>	<u>CKT</u>	<u>C&amp;W</u>	<u>PCM</u>	<u>DISP</u>
GF1301P	504-1	5	1	X	X	X
GF1521P	504-1	5	2	X	X	
GF9999U	504-1	5	3	X	X	
OPEN	504-1	5	4	X	X	
<hr/>						
GR1101P	504-1	6	1	X	X	X
GR1102P	504-1	6	2	X	X	X
GR1201P	504-1	6	3	X	X	X
GR1202P	504-1	6	4	X	X	X
<hr/>						
GF3582P	504-1	7	1	X	X	X
GF3583P	504-1	7	2	X	X	X
GF4581Q	504-1	7	3	X	X	X
OPEN	504-1	7	4	X	X	
<hr/>						
GF4582Q	504-1	8	1	X	X	X
GF4583Q	504-1	8	2	X	X	X
GP0025P	504-1	8	3	X	X	
GP0001P	504-1	8	4	X	X	X
<hr/>						
GQ3718T	506-2	9	1		X	X
GQ3719T	506-2	9	2		X	X
GP0718T	506-2	9	3		X	X
GP1218T	506-2	9	4		X	X
<hr/>						
GF9998U	506-2	10	1	X	X	X
GI3301T	506-2	10	2		X	

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MEAS ID	TYPE	LOC	CKT	C&W	PCM	DISP
GQ4218T	506-2	10	3		X	X
GQ4219T	506-2	10	4		X	X
OPEN	506-2	11	1	X	X	
OPEN	506-2	11	2	X	X	
GF1281T	506-2	11	3		X	X
GF1651T	506-2	11	4		X	X
GR9609U	504-4	12	1	X		
GR9610U	504-4	12	2	X		
OPEN	504-4	12	3		X	X
OPEN	504-4	12	4		X	X
OPEN	504-4	12	5		X	X
GP0318X	504-4	12	6		X	X
GP0320X	504-4	12	7		X	X
GR9609U	504-4	12	8		X	X
OPEN	504-4	12	9	X		X
GR9610U	504-4	12	10		X	X
OPEN	504-4	12	11		X	X
OPEN	504-4	12	12		X	X
GR9661U	504-4	13	1		X	X
GR9662U	504-4	13	2		X	X
GR9663U	504-4	13	3		X	X
GR9664U	504-4	13	4		X	X
GR9665U	504-4	13	5		X	X
GR9666U	504-4	13	6		X	X
GR9667U	504-4	13	7		X	X

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MEAS ID	TYPE	LOC	CKT	C&W	PCM	DISP
GR9668U	504-4	13	8		X	X
GM5000X	504-4	13	9		X	X
GR9611U	504-4	13	10		X	X
GR9612U	504-4	13	11		X	X
GR9613U	504-4	13	12		X	X
GR9661U	504-5	14	1	X		
GR9662U	504-5	14	2	X		
GR9663U	504-5	14	3	X		
GR9664U	504-5	14	4	X		
GR9665U	504-5	14	5	X		
GR9666U	504-5	14	6	X		
GR9667U	504-5	14	7	X		
GR9668U	504-5	14	8	X		
GY0111X	504-5	14	9		X	
GY0112X	504-5	14	10		X	
GY0121X	504-5	14	11		X	
GY0122X	504-5	14	12		X	
GH1331V	502-2	15	1		X	X
GH1311V	502-2	15	2		X	X
GC0301V	502-2	15	3	X		
GI3215V	502-2	15	4	X		
GC0155F	505-1	16	1	X		
GI3233F	505-1	16	2	X		
OPEN	505-1	16	3		X	



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MEAS ID	TYPE	LOC	CKT	C&W	PCM	DISP
GC0071V	503-2	17	1	X	X	
OPEN	503-2	17	2		X	
GH1405V	503-2	17	3	X		
GC0155F	504-1	18	1		X	
GC0071V	504-1	18	2		X	X
GC0301V	504-1	18	3		X	X
GF4101P	504-1	18	4		X	
GP0002P	504-1	19	1	X	X	X
GQ3018P	504-1	19	2	X	X	
GP1501P	504-1	19	3	X	X	X
GP1503P	504-1	19	4	X	X	X
GR6002T	506-2	20	1	X	X	X
GR6003T	506-2	20	2	X	X	X
GR6004T	506-2	20	3	X	X	X
GR6001T	506-2	20	4	X	X	X
OPEN	506-2	21	1		X	X
OPEN	506-2	21	2		X	X
GN7723T	506-2	21	3	X	X	X
GN7563T	506-2	21	4	X	X	X

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MEAS ID	TYPE	LOC	CKT	C&W	PCM	DISP
ERA-2						
GN7521X	(GSE)	01				
GN7557X	(CK OUT)	01				
GP0908X	(CK OUT)	01				
GP1408X	(CK OUT)	01				
GC9961X	(CK OUT)	01				
GC9962X	(CK OUT)	01				
GC9963X	(CK OUT)	01				
GC9964X	(CK OUT)	01				
GC9965X	(CK OUT)	01				
GC9966X	(CK OUT)	01				
GH1260X	(CK OUT)	01				
GH1283X	(CK OUT)	01				(CK OUT)
GH1401V	(CK OUT)	01				X
GH1402V	(CK OUT)	01				X
GH1403V	(CK OUT)	01				X
GF3584P	(CK OUT)	01				X
GH1408V	(CK OUT)	01				X
GH1488V	(CK OUT)	01				X
GH1489V	(CK OUT)	01				X
GI3214V	(CK OUT)	01				X
GH1406V	(CK OUT)	01				X
GH1407V	(CK OUT)	01				X
GH1493V	(CK OUT)	01				X
GH1494V	(CK OUT)	01				X
GT0454T	(CK OUT)	01				X

* LM AS-206 REV A						
<u>MEAS ID</u>	<u>TYPE</u>	<u>LOC</u>	<u>CKT</u>	<u>C&amp;W</u>	<u>PCM</u>	<u>DISP</u>
OPEN	504-3	02	1	X	X	
OPEN	504-3	02	2	X	X	
GN7521X	504-3	02	3	X	X	
GN7557X	504-3	02	4	X	X	
GN7621X	504-3	02	5	X	X	
GP0908X	504-3	02	6	X	X	
GP1408X	504-3	02	7	X	X	
OPEN	504-3	02	8	X	X	
GQ4455X	504-3	02	9	X	X	
GH1260X	504-3	02	10	X	X	
GI3305X	504-3	02	11	X	X	
OPEN	504-3	02	12	X	X	
<hr/>						
GG9003X	504-3	03	1	X	X	
GF1083X	504-3	03	2	X	X	
GF2041X	504-3	03	3	X	X	
GH1301X	504-3	03	4	X	X	
GH1621X	504-3	03	5	X	X	
GF1084X	504-3	03	6	X	X	
GF3081X	504-3	03	7	X	X	
GF3572X	504-3	03	8	X	X	
GH1323X	504-3	03	9	X	X	
GH1330X	504-3	03	10	X	X	
GG9001X	504-3	03	11	X	X	
GG9002X	504-3	03	12	X	X	
<hr/>						
GC4361X	504-4	04	1	X	X	
GC4362X	504-4	04	2	X	X	
GC4363X	504-4	04	3	X	X	
GC4364X	504-4	04	4	X	X	
GC4365X	504-4	04	5	X	X	

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<u>MEAS ID</u>	<u>TYPE</u>	<u>LOC</u>	<u>CKT</u>	<u>C&amp;W</u>	<u>PCM</u>	<u>DISP</u>
GC4366X	504-4	04	6	X	X	
GC4367X	504-4	04	7	X	X	
GC4368X	504-4	04	8	X	X	
GC4369X	504-4	04	9	X	X	
GC4370X	504-4	04	10	X	X	
GC4371X	504-4	04	11	X	X	
GC4372X	504-4	04	12	X	X	
<hr/>						
GF1241X	504-5	05	1		X	
GF1221X	504-5	05	2		X	
GF1211X	504-5	05	3		X	
GF1212X	504-5	05	4		X	
GF3071X	504-5	05	5		X	
GF3072X	504-5	05	6		X	
GF3073X	504-5	05	7		X	
GF3074X	504-5	05	8		X	
GF1231X	504-5	05	9		X	
GF1232X	504-5	05	10		X	
GF1201X	504-5	05	11		X	
GF1202X	504-5	05	12		X	
<hr/>						
GF4541T	506-2	06	1		X	
GF1291T	506-2	06	2		X	
GF1292T	506-2	06	3		X	
GF4511T	506-2	06	4		X	

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<u>MEAS ID</u>	<u>TYPE</u>	<u>LOC</u>	<u>CKT</u>	<u>C&amp;W</u>	<u>PCM</u>	<u>DISP</u>
GH1401V	503-2	07	1	X		
GH1402V	503-2	07	2	X		
GH1403V	503-2	07	3	X		
<hr/>						
GF3584P	501-1	08	1	X		
GF3584P	501-1	08	2		X	X
GH1408V	501-1	08	3	X		
GC0302V	501-1	08	4		X	X
<hr/>						
GH1313V	507-1	09	1		X	
GH1314V	507-1	09	2		X	
GH1455V	507-1	09	3		X	
GH1456V	507-1	09	4		X	
<hr/>						
GH1457V	507-1	10	1		X	
GH1461V	507-1	10	2		X	
GH1462V	507-1	10	3		X	
GH1463V	507-1	10	4		X	
<hr/>						
OPEN	LOCATION 11					
<hr/>						
OPEN	504-4	12	1	X		X
OPEN	504-4	12	2		X	X
OPEN	504-4	12	3		X	X
OPEN	504-4	12	4		X	X
OPEN	504-4	12	5		X	
OPEN	504-4	12	6		X	



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<u>MEAS ID</u>	<u>TYPE</u>	<u>LOC</u>	<u>CKT</u>	<u>C&amp;W</u>	<u>PCM</u>	<u>DISP</u>
GC9961U	504-4	12	7		X	X
GC9962U	504-4	12	8		X	X
GC9963U	504-4	12	9		X	X
GC9964U	504-4	12	10		X	X
GC9965U	504-4	12	11		X	X
GC9966U	504-4	12	12		X	X
<hr/>						
GH1628X	504-5	13	1		X	
GH1629X	504-5	13	2		X	
GF2935X	504-5	13	3	X		
OPEN	504-5	13	4		X	
GI3306X	504-5	13	5		X	
GH1630X	504-5	13	6		X	
GC9961U	504-5	13	7	X		
GC9962U	504-5	13	8	X		
GC9963U	504-5	13	9	X		
GC9964U	504-5	13	10	X		
GC9965U	504-5	13	11	X		
GC9966U	504-5	13	12	X		
<hr/>						
GH1283X	504-5	14	1		X	
GH1286X	504-5	14	2		X	
GH1608X	504-5	14	3		X	
GH1609X	504-5	14	4		X	
GH1204V	504-5	14	5		X	
GH1214X	504-5	14	6		X	
GH1217X	504-5	14	7		X	
GH1896X	504-5	14	8		X	
GQ7498X	504-5	14	9		X	
GQ7499X	504-5	14	10		X	
GP2997U	504-5	14	11		X	
GP2998U	504-5	14	12		X	

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<u>MEAS ID</u>	<u>TYPE</u>	<u>LOC</u>	<u>CKT</u>	<u>C&amp;W</u>	<u>PCM</u>	<u>DISP</u>
GH1488V	502-2	15	1	X		
GH1489V	502-2	15	2	X		
GI3214V	502-2	15	3	X		
GC0302V	502-2	15	4	X		
GC0201V	502-2	16	1		X	X
GC0202V	502-2	16	2		X	X
GC0203V	502-2	16	3		X	X
GC0204V	502-2	16	4		X	X
GC0205V	502-2	17	1		X	X
GH1240V	502-2	17	2		X	
GH1241V	502-2	17	3		X	
GH1242V	502-2	17	4		X	
GC0206V	502-2	18	1		X	X
GH1249V	502-2	18	2		X	
GH1247V	502-2	18	3		X	
GH1248V	502-2	18	4		X	
GH1406V	502-2	19	1	X		
GH1407V	502-2	19	2	X		
GH1493V	502-2	19	3	X		
GH1494V	502-2	19	4	X		
GR1121T	506-2	20	1		X	X
GR2121T	506-2	20	2		X	X
GR2122T	506-2	20	3		X	X
GR1122T	506-2	20	4		X	X

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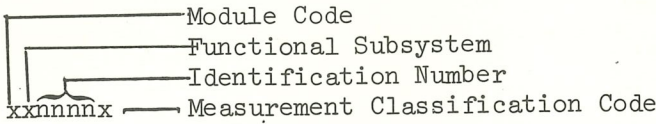
<u>MEAS ID</u>	<u>TYPE</u>	<u>LOC</u>	<u>CKT</u>	<u>C&amp;W</u>	<u>PCM</u>	<u>DISP</u>
GM0064T	506-2	21	1		X	
GT0454T	506-2	21	2	X		X
GP0201T	506-2	21	3		X	X
GP0202T	506-2	21	4		X	X

TABLE VI SPACECRAFT INSTRUMENTATION

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1. MEAS ID - Measurement identification number as delineated below:



Module Code: A = Adapter - NAA  
G = LM GAEC

Functional Subsystem Codes: A = Adapter  
C = Electrical Power  
D = Command  
F = Environmental Control  
G = Navigation and Guidance  
H = Stab and Control - CES  
I = Stab and Control - AGS  
L = Instrumentation  
M = Mechanical Design  
N = Radars  
P = Propulsion - Ascent Engine  
Q = Propulsion - Descent Engine  
R = Reaction Control  
T = Communications  
W = Programmer  
Y = Pyrotechnics

Measurement Classification Codes:

B = Phase  
C = Current  
E = Power  
F = Frequency  
H = Position  
J = Biomedical  
P = Pressure  
Q = Quantity  
R = Rate  
T = Temperature  
U = Combined meas.  
V = Voltage  
W = Time  
X = Discrete Event

2. MEAS DESCRIPTION - A brief "field title" given to each measurement.  
(Furnished BY MSC/FCD)

\*

3. SENSOR RANGE - Actual range of the transducer utilized for the measurement indicated.

Low - High: The lowest and highest analog range for each measurement.

Discretes will be delineated as follows:

- (1) Clsd - Opn: Relay or valve position
- (2) Off - ON: Status of measurement
- (3) Absnt - Presnt: Malfunction present or absent

4. TM DATA RANGE - Actual telemetered range of the data to be received by the ground stations.

1. Discretes - "0" or "1" with applicable indication
2. Analog - Lowest and highest telemetered data range for each analog measurement.

TM ACC PCT - Spacecraft telemetered data range accuracy in percent of full scale.

5. ONBOARD DISPLAY RANGE - Indicated range of the spacecraft onboard display.

ACC PCT - Onboard display accuracy in percent of full scale.

6. C&W LIMITS - The low and high value of the accuating parameter inputs to the onboard caution and warning instrumentation.

7. ADV - The spacecraft onboard advisory indication; light or flag designation number listed.

8. ESTIMATED NORMAL OPERATING LIMITS - Best engineering estimate of the low, normal, and high limits of the respective analog parameters. Discrete parameters are designated as such.

9. CRITICAL LIMITS - The high and/or low limits of each measurement that will cause permanent loss of equipment and/or life, or mission.

10. S/C SAMPLING - Spacecraft PCMTE data sampling rate using the following code:



EXAMPLE: 50/1DPER

Internally wired redundant on high  
and low bit rate within the PCMTE  
Event  
Parallel  
Digital  
Low bit rate samples per second  
High bit rate samples per second

NOTE

Where the redundant "R" is shown as  
1R/1..... the internal redundancy is  
wired for high bit rate only.

Alphabetic characters utilized to describe the types of input  
channels to PCM:

- AH = Analog, High Level
- D = Digital
- P = Parallel
- S = Serial
- E = Event

11. NOTES - May contain any other pertinent notation concerning each  
respective parameter.

TABLE 6.1 SPACECRAFT INSTRUMENTATION FOR SLA (S-IVB/IU)

MEAS ID	MEAS DESCRIPTION	SENSOR RANGE LOW HIGH UNITS	TM DATA RANGE LOW HIGH ACC PCT	ONBOARD DISPLAY RANGE LOW HIGH ACC PCT	C&W LIMITS LOW HIGH	ADV	ESTIMATED NORMAL OPERATING LIMITS LOW HIGH	CRITICAL LIMITS LOW HIGH	S/C SAMPLING	NOTES
AA8198X	CAP/SLA PHYS 1	OFF OR ON	0 = SEP	-	-	-	DISCRETE		120 S/S	NOT LM TM
AA8199X	CAP/SLA PHYS 2	OFF OR ON	0 = SEP	-	-	-	DISCRETE		120 S/S	NOT LM TM
AA8200U	SLA PANEL DEPLOY	0 OR 28 VDC	1 = DEPLOY	-	-	-	DISCRETE		12 S/S	NOT LM TM
AD0600X	N0SECAP RLY A	CLSD OR OPEN	1 = RLY CLSD	-	-	-	DISCRETE		12 S/S	NOT LM TM
AD0601X	N0SECAP RLY B	CLSD OR OPEN	1 = RLY CLSD	-	-	-	DISCRETE		12 S/S	NOT LM TM
AD0602X	LM/SLA SEP CMD A	CLSD OR OPEN	1 = RLY CLSD	-	-	-	DISCRETE		12 S/S	NOT LM TM
AD0603X	LM/SLA SEP CMD B	CLSD OR OPEN	1 = RLY CLSD	-	-	-	DISCRETE		12 S/S	NOT LM TM
AD0610X	SLA DEPLOY CM A	CLSD OR OPEN	1 = RLY CLSD	-	-	-	DISCRETE		12 S/S	NOT LM TM
AD0611X	SLA DEPLOY CM B	CLSD OR OPEN	1 = RLY CLSD	-	-	-	DISCRETE		12 S/S	NOT LM TM

TABLE 6.2 SPACECRAFT INSTRUMENTATION FOR ELEC/COMM

MEAS ID	MEAS DESCRIPTION	SENSOR RANGE			TM DATA RANGE			ONBOARD DISPLAY RANGE			C&W LIMITS		ADV	ESTIMATED NORMAL OPERATING LIMITS			CRITICAL LIMITS		S/C SAMPLING	NOTES
		LOW	HIGH	UNITS	LOW	HIGH	ACC PCT	LOW	HIGH	ACC PCT	LOW	HIGH		LOW	NORM	HIGH	LOW	HIGH		
GC0071V	AC BUS V	0	125	VRMS	0	125		GREEN BAND			<112		-	115		120			1/1 AH	{ GL4046 4M2
GC0155F	AC BUS F	380	420	CPS	380	420	0.5%		-				-	398		402			1 AH	GL4046
GC0201V	BAT 1 V	0	40	VDC	0	40	± 5%	20	40 VDC				-	28		32.5			1 AH	4M2
GC0202V	BAT 2 V	0	40	VDC	0	40	± 5%	20	40 VDC				-	28		32.5			1 AH	4M2
GC0203V	BAT 3 V	0	40	VDC	0	40	± 5%	20	40 VDC				-	28		32.5			1 AH	4M2
GC0204V	BAT 4 V	0	40	VDC	0	40	± 5%	20	40 VDC				-	28		32.5			1 AH	4M2
GC0205V	BAT 5 V	0	40	VDC	0	40	± 5%	20	40 VDC				-	28		32.5			1/1 AH	4M2
GC0206V	BAT 6 V	0	40	VDC	0	40	± 5%	20	40 VDC				-	28		32.5			1/1 AH	4M2
GC0301V	CDR BUS V	0	40	VDC	0	40	± 5%	20	40 VDC		<26.5		-	28		32.5			1/1 AH	4M2
GC0302V	SE BUS V	0	40	VDC	0	40	± 5%	20	40 VDC		<26.5		-	28		32.5			1/1 AH	4M2
GC1201C	BAT 1 C	0	60	AMPS	0	60	± 3.9%	0	120 AMPS		-		-		VARIES				1/1 AHR	
GC1202C	BAT 2 C	0	60	AMPS	0	60	± 3.9%	0	120 AMPS		-		-		VARIES				1/1 AHR	
GC1203C	BAT 3 C	0	60	AMPS	0	60	± 3.9%	0	120 AMPS		-		-		VARIES				1/1 AHR	
GC1204C	BAT 4 C	0	60	AMPS	0	60	± 3.9%	0	120 AMPS		-		-		VARIES				1/1 AHR	
GC1205C	BAT 5 C	0	120	AMPS	0	120	± 3.9%	0	120 AMPS		-		-		VARIES				1/1 AHR	
GC1206C	BAT 6 C	0	120	AMPS	0	120	± 3.9%	0	120 AMPS		-		-		VARIES				1/1 AHR	
GC4361X	BAT 1 HI	OFF OR	ON		1 =	HI	-		-		-		-		DISCRETE				1 DPE	
GC4362X	BAT 1 LO	OFF OR	ON		1 =	LO			-		-		-		DISCRETE				1 DPE	
GC4363X	BAT 2 HI	OFF OR	ON		1 =	HI			-		-		-		DISCRETE				1 DPE	
GC4364X	BAT 2 LO	OFF OR	ON		1 =	LO			-		-		-		DISCRETE				1 DPE	
GC4365X	BAT 3 HI	OFF OR	ON		1 =	HI			-		-		-		DISCRETE				1 DPE	
GC4366X	BAT 3 LO	OFF OR	ON		1 =	LO			-		-		-		DISCRETE				1 DPE	
GC9961X	BAT 1 MAL	OFF OR	ON		1 =	MAL			-		-		-		DISCRETE				1 DPE	{ GL9001 GL4047
GC9962X	BAT 2 MAL	OFF OR	ON		1 =	MAL			-		-		-		DISCRETE				1 DPE	{ GL9001 GL4047
GC9963X	BAT 3 MAL	OFF OR	ON		1 =	MAL			-		-		-		DISCRETE				1 DPE	{ GL9001 GL4047
GC9964X	BAT 4 MAL	OFF OR	ON		1 =	MAL			-		-		-		DISCRETE				1 DPE	{ GL9001 GL4047
GC9965X	BAT 5 MAL	OFF OR	ON		1 =	MAL			-		-		-		DISCRETE				1 DPE	{ GL9001 GL4047
GC9966X	BAT 6 MAL	OFF OR	ON		1 =	MAL			-		-		-		DISCRETE				1 DPE	{ GL9001 GL4047

TABLE 6.2 SPACECRAFT INSTRUMENTATION FOR ELEC/COMM (CONCLUDED)

MEAS ID	MEAS DESCRIPTION	SENSOR RANGE			TM DATA RANGE			ONBOARD DISPLAY RANGE			C&W LIMITS		ADV	ESTIMATED NORMAL OPERATING LIMITS			CRITICAL LIMITS		S/C SAMPLING	NOTES
		LOW	HIGH	UNITS	LOW	HIGH	ACC PCT	LOW	HIGH	ACC PCT	LOW	HIGH		LOW	NORM	HIGH	LOW	HIGH		
GL0300	FRAME SYNCH AND ID	-			-			-			-		-	-					50/1 DP	
GL0302	LBR	-			-			-			-		-	-					1/1 DP	
GL0401V	CAL 85 PCT	0	5	VDC		4.25	VDC	-			-		-	4.25	VDC				10R/1 AH	
GL0402V	CAL 15 PCT	0	5	VDC		0.75	VDC	-			-		-	0.75	VDC				10R/1 AH	
GL0501W	MET	0	39	DAYS	-			-			-		-						10/1 DP	
GL4054X	C&W PWR FAIL	PRESENT OR ABSENT			1 =	FAIL		-			-		-	DISCRETE					1/1 DPER	
GL4069X	MASTER ALARM ON	PRESENT OR ABSENT			1 =	ON		-			-		-	DISCRETE					1/1 DPER	
GL4221X	DFI CAL ON	OFF OR	ON		1 =	ON		-			-		-	DISCRETE					1 DPE	
GL4222X	LM/SLA SEP	OFF OR	ON		1 =	SEP		-			-		-	DISCRETE					1 DPE	
GM0064T	LAND LEG TEMP	-200	+500	°F				-			-		-						1/1 AH	
GM5000U	LAND GEAR DEPLOY	OFF OR	ON		1 =	DEPLOY		-			-		2FL1	DISCRETE					1 DPE	
GT0201E	S-BND PWR AMP PO	0	25	W				-			-		-						1/1 AH	
GT0202E	S-BND RFLT PWR	0	25	W				-			-		-						1 AH	
GT0441X	DCA STATUS	-			-			-			-		-						50 DP	
GT0451H	YAW DEGREES	-75° TO	+225°		-			-75° TO	+225°		-		-						-	NOT TM
GT0452H	PITCH DEGREES	-75° TO	+75°		-			-75° TO	+75°		-		-						-	NOT TM
GT0454T	S-BND ANT TEMP	-200° TO	+200°	F	-			-100°F	+200°F		<60	>155	18M1						-	NOT TM GL4053
GT0504V	S-BND RCVR AGC	0 TO	4.2	VDC	-			0 TO	5		-		14M1						-	NOT TM
GT0619	UHF SIG STR																		1 AH	
GT0992B	S-BND ST PH ERR	-15°	+15°					-			-		-						10 AH	
GT0993E	S-BND XMTR PO	0.5	1.0	W				-			-		-						1/1 AH	
GT0994V	S-BND SIG STR	0	4.2	VDC				0 TO	5V		-		-						10 AH	
GW5154X	LAND GEAR CMD	OFF OR	ON		1 =	CMD		-			-		-	DISCRETE					1 DPE	
GY0111X	ED ARM A ON	OFF OR	ON		1 =	ON		-			-		-	DISCRETE					1/1 DPER	
GY0112X	ED ARM B ON	OFF OR	ON		1 =	ON		-			-		-	DISCRETE					1/1 DPER	
GY0121X	STG RLY A FIRE	OFF OR	ON		1 =	FIRE		-			-		-	DISCRETE					1/1 DPER	
GY0122X	STG RLY B FIRE	OFF OR	ON		1 =	FIRE		-			-		-	DISCRETE					1/1 DPER	



TABLE 6.3 SPACECRAFT INSTRUMENTATION FOR ECS

MEAS ID	MEAS DESCRIPTION	SENSOR RANGE			TM DATA RANGE			ONBOARD DISPLAY RANGE			C&W LIMITS		ADV	ESTIMATED NORMAL OPERATING LIMITS			CRITICAL LIMITS		S/C SAMPLING	NOTES
		LOW	HIGH	UNITS	LOW	HIGH	ACC PCT	LOW	HIGH	ACC PCT	LOW	HIGH		LOW	NORM	HIGH	LOW	HIGH		
GF1083X	SUIT FAN 1 MAL	OFF OR	ON		1 =	MAL		-					-	DISCRETE					1/1 DPER	GL4056
GF1084X	SUIT FAN 2 MAL	OFF OR	ON		1 =	MAL		-					-	DISCRETE					1/1 DPER	GL4037
GF1087X	SEL SUIT COMP FAIL		-			-		-					7DS1	-					-	NOT TM
GF1201X	CDR SUIT DISC	OFF OR	ON		1 =	DISC		-					-	DISCRETE					1/1 DPER	
GF1202X	SE SUIT DISC	OFF OR	ON		1 =	DISC		-					-	DISCRETE					1/1 DPER	
GF1211X	SUIT RLF CLSD	OFF OR	ON		1 =	CLSD		-					-	DISCRETE					1/1 DPER	
GF1212X	SUIT RLF OPEN	OFF OR	ON		0 =	OPEN		-					-	DISCRETE					1/1 DPER	
GF1221X	SUIT DIV EGRESS	OFF OR	ON		1 =	EGRESS		-					-	DISCRETE					1/1 DPER	
GF1231X	CABIN RET CLSD	OFF OR	ON		1 =	OPEN		-					-	DISCRETE					1/1 DPER	
GF1232X	CABIN RET OPEN	OFF OR	ON		0 =	OPEN		-					-	DISCRETE					1/1 DPER	
GF1241X	SEC CO <sub>2</sub> SEL	OFF OR	ON		1 =	SEL		-					-	DISCRETE					1/1 DPER	
GF1281T	SUIT TEMP	20	120	°F				40	100				-	50		70 °F			1/1 AHR	7M3B
GF1291T	SUIT 1 OUT TEMP	20	120	°F					-				-	55		80 °F			1/1 AH	
GF1292T	SUIT 2 OUT TEMP	20	120	°F					-				-	55		80 °F			1/1 AH	
GF1301P	SUIT PRESS.	0	10	PSIA				0	10		<3.12		-	3.6		5.0 PSIA			1/1 AHR	GL4037
GF1521P	CO <sub>2</sub> PART PRESS.	0	30	MMHG					-			>7.6	-	0		1.5 MMHG			1/1 AHR	GL4056
GF1522P	CO <sub>2</sub> PART PRESS.	0	30	MMHG				0	30				-						-	7M1 NOT TM
GF1651T	CABIN TEMP	20	120	°F				40	100				-	75		90 °F			1/1 AH	
GF2021P	PRI GLY PUMP ΔP	0	50	PSID					-				-	20		28 PSID			1/1 AHR	
GF2041X	GLY LEVEL LOW	OFF OR	ON		1 =	LOW			-				-	DISCRETE					1/1 DPER	GL4058
GF2935X	SEL GLY PUMP FAIL		-			-			-				-	-					-	GL4056 NOT TM
GF2936X	SEL GLY PUMP FAIL		-			-			-				7DS3	-					-	NOT TM
GF3071X	DEMAND REG A CLSD	OFF OR	ON		1 =	CLSD			-				-	DISCRETE					1/1 DPER	
GF3072X	DEMAND REG A DIR	OFF OR	ON		1 =	DIR			-				-	DISCRETE					1/1 DPER	
GF3073X	DEMAND REG B CLSD	OFF OR	ON		1 =	CLSD			-				-	DISCRETE					1/1 DPER	
GF3074X	DEMAND REG B DIR	OFF OR	ON		1 =	DIR			-				-	DISCRETE					1/1 DPER	
GF3571P	CABIN PRESS.	0	10	PSIA	0 TO	10 PSIA		0	10				-	0		50 PSIA			1/1 AHR	7M2A
GF3572X	REPR ELEC OPEN	OFF OR	ON		1 =	OPEN			-				-	DISCRETE					1/1 DPER	
GF3582P	ASC 1 O <sub>2</sub> PRESS.	0	1000	PSIA				0	100%		<100	>684	-						1/1 AHR	GL4057 7M4A

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TABLE 6.3 SPACECRAFT INSTRUMENTATION FOR ECS (CONCLUDED)

MEAS ID	MEAS DESCRIPTION	SENSOR RANGE			TM DATA RANGE			ONBOARD DISPLAY RANGE			C&W LIMITS		ADV	ESTIMATED NORMAL OPERATING LIMITS			CRITICAL LIMITS		S/C SAMPLING	NOTES
		LOW	HIGH	UNITS	LOW	HIGH	ACC PCT	LOW	HIGH	ACC PCT	LOW	HIGH		LOW	NORM	HIGH	LOW	HIGH		
GF3583P	ASC 2 O <sub>2</sub> PRESS.	0	1000	PSIA				0	100%		<684	>684	-						1/1 AHR	GL4057 7M4A
GF3584P	DES O <sub>2</sub> PRESS.	0	3000	PSIA				0	100%		<135		-						1/1 AHR	GL4057 7M4A
GF3585T	ASC 1 O <sub>2</sub> TEMP	0	200	°F					-				-						1 AH	GL4057 7M4A
GF3586T	ASC 2 O <sub>2</sub> TEMP	0	200	°F					-				-						1 AH	7M4A
GF3587T	DES O <sub>2</sub> TEMP	0	200	°F					-				-						1/1 AH	
GF3591P	U/H RLF PRESS.	0	25	PSIA					-				-	0		5.8 PSIA			1/1 AH	
GF3592P	F/H RLF PRESS.	0	25	PSIA					-				-	0		5.8 PSIA			1/1 AH	
GF4101P	PRI H <sub>2</sub> O REG ΔP	0	2	PSID					-				-	0.5		1.0 PSID			1/1 AHR	
GF4511T	PRI W/B H <sub>2</sub> O TEMP	20	160	°F					-				-	40		60 °F			1/1 AH	
GF4541T	SUIT W/B IN TEMP	20	160	°F					-				-	40		60 °F			1/1 AH	
GF4581Q	DES H <sub>2</sub> O QTY	0	100	PCT				0	200%		<16%		-						1/1 AHR	
GF4582Q	ASC 1 H <sub>2</sub> O QTY	0	100	PCT				0	100%		<95%		-						1/1 AHR	GL4059 7M4B
GF4583Q	ASC 2 H <sub>2</sub> O QTY	0	100	PCT				0	100%		<95%		-						1/1 AHR	
GF9993U	LI0H SEL/HIGH CO <sub>2</sub>		-			-			-				7DS6						-	NOT TM
GF9997U	GLY PUMP PRESS.	0	60	PSIA				0	80				-	25		33 PSIA			1/1 AH	
GF9998U	GLY TEMP	20	120	°F				0	80		<50		-	35		50 °F			1/1 AH	7MSA
GF9999U	H <sub>2</sub> O SEP RATE	500	3600	RPM							<800		7DS7	900		1500 RPM			1/1 AH	GL4058 7MSB
GW5158X	GLY PUMP 2 SEL	OFF OR	ON		1 =	SEL			-				-	DISCRETE					1 DPE	GL4056

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TABLE 6.4 SPACECRAFT INSTRUMENTATION FOR GNC

MEAS ID	MEAS DESCRIPTION	SENSOR RANGE			TM DATA RANGE			ONBOARD DISPLAY RANGE			C&W LIMITS		ADV	ESTIMATED NORMAL OPERATING LIMITS			CRITICAL LIMITS		S/C SAMPLING	NOTES
		LOW	HIGH	UNITS	LOW	HIGH	ACC PCT	LOW	HIGH	ACC PCT	LOW	HIGH		LOW	NORM	HIGH	LOW	HIGH		
GG0001X	PGNS CMTR WORD	-			-			-			-		-	-					50 DS	-
GG0117H	POS ALT (LGC)	-			-			0	60.5 KFT		-		-	VARIES					-	NOT TM
GG0118L	VEL ALT RATE (LGC)	-			-				± 700 F/S		-		-	VARIES					-	NOT TM
GG0119L	VEL FWD (LGC)	-			-				± 200 F/S		-		-	VARIES					-	NOT TM
GG0120L	VEL LAT (LGC)	-			-				± 200 F/S		-		-	VARIES					-	NOT TM
GG1040V	PLS TORQ REF	85	135	VDC				-			-		-	120					1AHR	-
GG1110V	2.5 VDC TM BIAS	0	5	VDC				-			-		-	2.5					1R/1AH	-
GG1201V	IMU 28 VAC 800	0	31.1	VRMS				-			-		-	28					1/1 AH	-
GG1331V	IRIG SUSP 3.2 KC	0	31.1	VRMS				-			-		-	28					1/1 AH	-
GG1513X	IMU STBY	OFF OR ON			1 = STBY			-			-		-	DISCRETE					1/1 DPER	-
GG1523X	LGC OPR	OFF OR ON			1 = OPR			-			-		-	DISCRETE					1/1 DPER	-
GG2001V	X PIPA OUT IN φ		± 2.5	VRMS				-			-		-	VARIES					50 AHR	-
GG2021V	Y PIPA OUT IN φ		± 2.5	VRMS				-			-		-	VARIES					50 AH	-
GG2041V	Z PIPA OUT IN φ		± 2.5	VRMS				-			-		-	VARIES					50 AHR	-
GG2107V	IG SVD ERR IN φ		± 3	VRMS				-			-		-	VARIES					100 AHR	-
GG2110C	IG TORQ MTR CUR		± 0.5	AMPS				-			-		-	VARIES					100 AH	-
GG2112V	IG RSVR OUT SIN		±20.25	VRMS				-			-		-	VARIES					100 AH	-
GG2113V	IG RSVR OUT COS		± 5	VRMS				-			-		-	VARIES					10/1 AH	-
GG2121V	IG RSVR SIN (EXP)		± 5	VRMS				-			-		-	VARIES					10/1 AH	-
GG2122V	IG RSVR OUT SIN	-			-			0	28 VRMS		-		-	VARIES					100 AH	-
GG2123V	IG RSVR OUT COS	-			-			0	28 VRMS		-		-	VARIES					-	NOT TM
GG2137V	MG SVO ERR IN φ		± 3	VRMS				-			-		-	VARIES					-	NOT TM
GG2140C	MG TORQ MTR CUR		± 0.5	AMPS				-			-		-	VARIES					100 AHR	-
GG2142V	MG RSVR OUT SIN		± 20.25	VRMS				-			-		-	VARIES					100 AH	-
GG2143V	MG RSVR OUT COS		± 20.25	VRMS				-			-		-	VARIES					100 AH	-
GG2151V	MG RSVR SIN (EXP)		± 5	VRMS				-			-		-	VARIES					10R/1 AH	-
GG2152V	MG RSVR OUT SIN	-			-			0	28 VRMS		-		-	VARIES					1/1 AH	-
GG2153V	MG RSVR OUT COS	-			-			0	28 VRMS		-		-	VARIES					10 AH	-
GG2167V	OG SVO ERR IN φ		± 3	VRMS				-			-		-	VARIES					100 AH	-

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TABLE 6.4 SPACECRAFT INSTRUMENTATION FOR GNC (CONT'D)

MEAS ID	MEAS DESCRIPTION	SENSOR RANGE			TM DATA RANGE			ONBOARD DISPLAY RANGE			C&W LIMITS		ADV	ESTIMATED NORMAL OPERATING LIMITS			CRITICAL LIMITS		S/C SAMPLING	NOTES
		LOW	HIGH	UNITS	LOW	HIGH	ACC PCT	LOW	HIGH	ACC PCT	LOW	HIGH		LOW	NORM	HIGH	LOW	HIGH		
GG2170C	OG TORQ MTR CUR		± 0.9	AMP				-			-		-	VARIES					100 AH	-
GG2172V	OG RSVR OUT SIN		± 20.25	VRMS				-			-		-	VARIES					10/1 AH	-
GG2173V	OG RSVR OUT COS		± 20.25	VRMS				-			-		-	VARIES					1/1 AH	-
GG2181V	OG RSVR SIN (EXP)		± 5	VRMS				-			-		-	VARIES					10 AH	-
GG2182V	OG RSVR OUT SIN	-			-			0	28 VRMS		-		-	VARIES					100 AH	-
GG2183V	OG RSVR OUT COS	-			-			0	28 VRMS		-		-	VARIES					-	NOT TM
GG2217V	PITCH ATT ERR (PGNS)	-			-			0	10 VRMS		-		-	VARIES					-	NOT TM
GG2219V	PITCH ATT ERR		± 5	VRMS				-			-		-	VARIES					-	NOT TM
GG2247V	ROLL ATT ERR (PGNS)	-			-			0	10 VRMS		-		-	VARIES					10 AH	-
GG2249V	YAW ATT ERR		± 5	VRMS				-			-		-	VARIES					-	NOT TM
GG2277V	YAW ATT ERR (PGNS)	-			-			0	10 VRMS		-		-	VARIES					10 AH	-
GG2279V	ROLL ATT ERR		± 5	VRMS				-			-		-	VARIES					-	NOT TM
GG2300T	PIPA TEMP	120	140	°F				-			-		-	120	130	140			10 AH	-
GG2301T	IRIG TEMP	123	143	°F				-			-		-	123	133	143			1/1 AHR	-
GG3304V	RR SHFT SIN		±21.5	VRMS				-			-		-	VARIES					1 AH	-
GG3305V	RR SHFT COS		± 21.5	VRMS				-			-		-	VARIES					10 AH	-
GG3324V	RR TRUN SIN		± 21.5	VRMS				-			-		-	VARIES					10 AH	-
GG3325V	RR TRUN COS		± 21.5	VRMS				-			-		-	VARIES					10 AH	-
GG6020T	PIPA CAL TEMP	0	150	°F				-			-		-	82					10 AH	-
GG9001X	LGC WARNING	OFF OR ON			1 = WARNING			-			-		-	DISCRETE					1 AH	-
GG9002X	ISS WARNING	OFF OR ON			1 = WARNING			-			-		-	DISCRETE					1/1 DPE	GL4029
GG9003X	PGNS CAUTION	OFF OR ON			1 = CAUTION			-			-		-	DISCRETE					1/1 DPE	GL4030
GH1204X	OUT DET	OFF OR ON			1 = OUT			-			-		-	DISCRETE					1/1 DPE	GL4045
GH1214X	AUTO ON	OFF OR ON			1 = ON			-			-		-	DISCRETE					1 DPE	-
GH1217X	AUTO OFF	OFF OR ON			1 = OFF			-			-		-	DISCRETE					1/1 DPE	-
GH1230X	APS ARM	0 OR 28	VDC		1 = ARM			-			-		-	DISCRETE					1 DPE	-
GG1240V	X-TRANS CMD	-10 TO +10	VDC		-10 TO +10			-			-		-	DISCRETE					10 AH	-
GH1241V	Y-TRANS CMD	-10 TO +10	VDC		-10 TO +10			-			-		-	DISCRETE					10 AH	-
GH1242V	Z-TRANS CMD	-10 TO +10	VDC		-10 TO +10			-			-		-	DISCRETE					10 AH	-

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TABLE 6.4 SPACECRAFT INSTRUMENTATION FOR GNC (CONT'D)

MEAS ID	MEAS DESCRIPTION	SENSOR RANGE			TM DATA RANGE			ONBOARD DISPLAY RANGE			C&W LIMITS		ADV	ESTIMATED NORMAL OPERATING LIMITS			CRITICAL LIMITS		S/C SAMPLING	NOTES
		LOW	HIGH	UNITS	LOW	HIGH	ACC PCT	LOW	HIGH	ACC PCT	LOW	HIGH		LOW	NORM	HIGH	LOW	HIGH		
GH1247V	YAW ERR CMD	-13 TO	+13	VDC	-13 TO	+13			-		-		-	0.5					10 AH 1/1 AH	9M7R
GH1248V	PITCH ERR CMD	-13 TO	+13	VDC	-13 TO	+13			-		-		-	0.5					10 AH 1/1 AH	
GH1249V	ROLL ERR CMD	-13 TO	+13	VDC	-13 TO	+13			-		-		-	0.5					10 AH 1/1 AH	
GH1260X	APS ON	OFF OR	ON		1 =	ON			-		-		-	DISCRETE					50/1 DPER	
GH1283X	ABORT STAGE	OFF OR	ON		1 =	STAGE			-		-		-	DISCRETE					50/1 DPER	GL4043
GH1286X	ENG FIRE OVERRIDE	OFF OR	ON		1 =	ON			-		-		-	DISCRETE					1 DPE	
GH1301X	DPS ON	OFF OR	ON		1 =	ON			-		-		-	DISCRETE					1/1 DPE	
GH1311V	MAN THRUST CMD	0 TO	14.6	VDC	0 TO	14.6		0	100%		-		-	VARIES					1/1 AH	
GH1313V	PITCH GDA POS	-15 TO	+15	VRMS	-15 TO	+15			-		-		-	VARIES					10 AH 1/1 AH	GL4043
GH1314V	ROLL GDA POS	-15 TO	+15	VRMS	-15 TO	+15			-		-		-	VARIES					10 AH 1/1 AH	
GH1323X	P TRM FAIL	OFF OR	ON		1 =	FAIL			-		-		-	DISCRETE					1/1 DPE	
GH1330X	R TRM FAIL	OFF OR	ON		1 =	FAIL			-		-		-	DISCRETE					1/1 DPE	
GH1331V	AUTO THRUST CMD	0 TO	12	VDC	0 TO	12		0	100%		-		-	.015					10 AH 1/1 AH	9M7B
GH1348X	DPS ARM	0 OR	28	VDC	1 =	ARM			-		-		-	DISCRETE					1 DPE	
GH1401V	RGA SP MTR A-B	23	29	VRMS	-				-		<23	>29	-						-	
GH1402V	RGA SP MTR B-C	23	29	VRMS	-				-		<23	>29	-						-	
GH1403V	RGA SP MTR C-A	23	29	VRMS	-				-		<23	>29	-						-	GL4026
GH1405V	RGA PICKOFF EXCIT	26	30	VRMS	-				-		<26	>30	-						-	GL4026
GH1406V	+15 VDC SUP	14	16	VDC	-				-		<14	>16	-						-	GL4027
GH1407V	-15 VDC SUP	-16	-14	VDC	-				-		<-16	>-14	-						-	GL4027
GH1408V	4.3 VDC SUP	3.8	4.8	VDC	-				-		<3.8	>4.8	-						-	GL4027
CH1418V	JD 4U OUTPUT	OFF OR	ON		1 =	ON			-		-		-	DISCRETE					200 DPE	GL4031
CH1419V	JD 4D OUTPUT	OFF OR	ON		1 =	ON			-		-		-	DISCRETE					200 DPE	GL4031
CH1420V	JD 4F OUTPUT	OFF OR	ON		1 =	ON			-		-		-	DISCRETE					200 DPE	GL4031
CH1421V	JD 4S OUTPUT	OFF OR	ON		1 =	ON			-		-		-	DISCRETE					200 DPE	GL4031
CH1422V	JD 3U OUTPUT	OFF OR	ON		1 =	ON			-		-		-	DISCRETE					200 DPE	GL4031
CH1423V	JD 3D OUTPUT	OFF OR	ON		1 =	ON			-		-		-	DISCRETE					200 DPE	GL4031
CH1424V	JD 3F OUTPUT	OFF OR	ON		1 =	ON			-		-		-	DISCRETE					200 DPE	GL4031
CH1425V	JD 3S OUTPUT	OFF OR	ON		1 =	ON			-		-		-	DISCRETE					200 DPE	GL4031

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TABLE 6.4 SPACECRAFT INSTRUMENTATION FOR GNC (CONT'D)

MEAS ID	MEAS DESCRIPTION	SENSOR RANGE			TM DATA RANGE			ONBOARD DISPLAY RANGE			C&W LIMITS		ADV	ESTIMATED NORMAL OPERATING LIMITS			CRITICAL LIMITS		S/C SAMPLING	NOTES
		LOW	HIGH	UNITS	LOW	HIGH	ACC PCT	LOW	HIGH	ACC PCT	LOW	HIGH		LOW	NORM	HIGH	LOW	HIGH		
GH1426V	JD 2U OUTPUT	OFF OR	ON		1 =	ON			-		-		-	DISCRETE					200 DPE	GL4031
GH1427V	JD 2D OUTPUT	OFF OR	ON		1 =	ON			-		-		-	DISCRETE					200 DPE	GL4031
CH1428V	JD 2F OUTPUT	OFF OR	ON		1 =	ON			-		-		-	DISCRETE					200 DPE	GL4031
CH1429V	JD 2S OUTPUT	OFF OR	ON		1 =	ON			-		-		-	DISCRETE					200 DPE	GL4031
CH1430V	JD 1U OUTPUT	OFF OR	ON		1 =	ON			-		-		-	DISCRETE					200 DPE	GL4031
GH1431V	JD 1D OUTPUT	OFF OR	ON		1 =	ON			-		-		-	DISCRETE					200 DPE	GL4031
CH1432V	JD 1F OUTPUT	OFF OR	ON		1 =	ON			-		-		-	DISCRETE					200 DPE	GL4031
CH1433V	JD 1S OUTPUT	OFF OR	ON		1 =	ON			-		-		-	DISCRETE					200 DPE	GL4031
CH1455V	YAW ATT ERR	-5 TO	+5	VRMS					-		-		-						10 AHR 1/1 AH	GL4050
CH1456V	PITCH ATT ERR	-5 TO	+5	VRMS					-		-		-						10 AHR 1/1 AH	
CH1457V	ROLL ATT ERR	-5 TO	+5	VRMS					-		-		-						10 AHR 1/1 AH	
CH1461V	RGA YAW RATE	-3.5 TO	+3.5	VRMS					-		-		-						10/1 AHR	
CH1462V	RGA PITCH RATE	-3.5 TO	+3.5	VRMS					-		-		-						10/1 AHR	GL4050
CH1463V	RGA ROLL RATE	-3.5 TO	+3.5	VRMS					-		-		-						10/1 AHR	
CH1488V	PRI -4.7 VDC	-5.2 TO	-4.2	VDC		-			-		<-5.2	>-4.2	-						-	
CH1489V	SEC -4.7 VDC	-5.2 TO	-4.2	VDC		-			-		<-5.2	>-4.2	-						-	
CH1493V	+ 6 VDC SUP	5.4	6.6	VDC		-			-		<5.4	>6.6	-						-	GL4027
CH1494V	- 6 VDC SUP	-6.6	-5.4	VDC		-			-		<-6.6	>-5.4	-						-	GL4027
CH1497V	YAW RGA SIG	-3.5	+3.5	VRMS		-			-		-		-						-	9M1/6
CH1498V	PITCH RGA SIG	-3.5	+3.5	VRMS		-			-		-		-						-	9M1/6
CH1499V	ROLL RGA SIG	-3.5	+3.5	VRMS		-			-		-		-						-	9M1/6
CH1603X	MIN D-BND (INVRS LOGIC)	0 OR	28	VDC	1 =	0 VDC			-		-		-	DISCRETE					1 DPE	INVERSE GRND DIS
CH1608X	AUTO MODE	OFF OR	ON		1 =	ON			-		-		-	DISCRETE					1 DPE	
CH1609X	ATT HOLD	OFF OR	ON		1 =	HOLD			-		-		-	DISCRETE					1 DPE	
CH1621X	AGS SEL	OFF OR	ON		1 =	SEL			-		-		-	DISCRETE					1/1 DPE	
CH1628X	ROLL PLSD/DIR	OFF OR	ON		1 =	ON			-		-		-	DISCRETE					1 DPE	GL4027
CH1629X	PITCH PLSD/DIR	OFF OR	ON		1 =	ON			-		-		-	DISCRETE					1 DPE	
CH1630X	YAW PLSD/DIR	OFF OR	ON		1 =	ON			-		-		-	DISCRETE					1 DPE	
CH1893X	X-TRANS OVERRIDE	0 OR	28	VDC	1 =	ON			-		-		-	DISCRETE					1 DPE	

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TABLE 6.4 SPACECRAFT INSTRUMENTATION FOR GNC (CONT'D)

MEAS ID	MEAS DESCRIPTION	SENSOR RANGE			TM DATA RANGE			ONBOARD DISPLAY RANGE			C&W LIMITS		ADV	ESTIMATED NORMAL OPERATING LIMITS			CRITICAL LIMITS		S/C SAMPLING	NOTES
		LOW	HIGH	UNITS	LOW	HIGH	ACC PCT	LOW	HIGH	ACC PCT	LOW	HIGH		LOW	NORM	HIGH	LOW	HIGH		
GH1896X	UNBAL CPLS	OFF OR	ON		1 =	ON		-			-		-	DISCRETE					1 DPE	
GI0001X	AGS DOWNLINK		-			-		-			-		-	DISCRETE					50 DS	
GI3151V	SIN ALP TOT ATT		± 15	VRMS		-					-		-	VARIES					-	9M1/6
GI3152V	COS ALP TOT ATT		± 15	VRMS		-					-		-	VARIES					-	9M1/6
GI3153V	SIN BET TOT ATT		± 15	VRMS		-					-		-	VARIES					-	9M1/6
GI3154V	COS BET TOT ATT		± 15	VRMS		-					-		-	VARIES					-	9M1/6
GI3155V	SIN GAM TOT ATT		± 15	VRMS		-					-		-	VARIES					-	9M1/6
GI3156V	COS GAM TOT ATT		± 15	VRMS		-					-		-	VARIES					-	9M1/6
GI3166V	E X YAW ATT ER		± 4.5	VRMS		-					-		-	VARIES					-	9M1/6
GI3167V	E Y PITCH ATT ER		± 4.5	VRMS		-					-		-	VARIES					-	9M1/6
GI3168V	E Z ROLL ATT ER		± 4.5	VRMS		-					-		-	VARIES					-	9M1/6
GI3203H	ALT TO DSPLY	0 TO	70	K FT		-					-		-	VARIES					-	9M9A
GI3204L	ALT RATE DSPLY		± 8200	FPS		-					-		-	VARIES					-	9M9B
GI3205L	VY LAT VEL	-200 TO	+200	FPS		-		-200 TO	+200		-		-	VARIES					-	9M2/3
GI3214V	+ 28 VDC ASA	25.2 TO	30.8	VDC		-			-		<25.2	>30.8	-	VARIES					-	GL4028
GI3215V	+ 12 VDC	10.8 TO	13.2	VDC		-			-		<10.8	>13.2	-	VARIES					-	GL4028
GI3232	AEA MODE FAIL		-			-			-		OFF OR	ON	-	DISCRETE					-	GL4028
GI3233F	FREQ ASA 28V/40DC	380 TO	420	CPS		-			-		<385	>415	-	395 TO		405			-	GL4028
GI3301T	ASA TEMP	0 TO	250	°F	0 TO	250			-		-		-						1/1 AHR	
GI3305X	AGS WARMUP	OFF OR	ON		1 =	WARMUP			-		-		-	DISCRETE					1 DPE	
GI3306X	AGS STANDBY	OFF OR	ON		1 =	STANDBY			-		-		-	DISCRETE					1 DPE	
GL4026X	CES AC PWR FAIL	OFF OR	ON		1 =	FAIL			-				6DS6	DISCRETE					1/1 DPER	GH1401-3V1
GL4027X	CES DC PWR FAIL	OFF OR	ON		1 =	FAIL			-				6DS7	DISCRETE					1/1 DPER	GH1405V
GL4028X	AGS PWR FAIL	OFF OR	ON		1 =	FAIL			-				6DS8	DISCRETE					1/1 DPER	GH1406-8V
GN7521X	LR RANGE BAD	PRESENT OR ABSENT			1 =	BAD			-				-	DISCRETE					1/1 DPER	GH1492, 4
GN7523L	LR V <sup>1</sup> XA VEL	-700 TO	+700	FT/S		-		-700 TO	+700		-		-						-	NOT TM
GL7524L	LR V <sup>1</sup> YA VEL	-200 TO	+200	FT/S		-		-200 TO	+200		-		-						-	9M9B
GN7525L	LR V <sup>1</sup> ZA VEL	-200 TO	+200	FT/S		-		-200 TO	+200		-		-						-	NOT TM
GN7527H	LR RNG DATA	0 TO	60.5	K FT		-		0 TO	60.5		-		-						-	9M2/3
																			-	NOT TM
																			-	9M9A

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TABLE 6.4 SPACECRAFT INSTRUMENTATION FOR GNC (CONCLUDED)

MEAS ID	MEAS DESCRIPTION	SENSOR RANGE			TM DATA RANGE			ONBOARD DISPLAY RANGE			C&W LIMITS		ADV	ESTIMATED NORMAL OPERATING LIMITS			CRITICAL LIMITS		S/C SAMPLING	NOTES
		LOW	HIGH	UNITS	LOW	HIGH	ACC PCT	LOW	HIGH	ACC PCT	LOW	HIGH		LOW	NORM	HIGH	LOW	HIGH		
GN7545E	LR VEL XMTR RF	0 TO	5	MW	-			0 TO	5		-		-						-	NOT TM 17M1
GN7546E	LR ALT XMTR RF	0 TO	5	MW	-			0 TO	5		-		-						-	NOT TM 17M1
GN7557X	LR VEL BAD	PRESENT OR ABSENT			1 =	BAD			-				-	DISCRETE					1/1 DPER	GL4049
GN7563T	LR ANT TEMP	-200 TO	+200	°F	-200 TO	+200					-15	+150	-			~ +75°F			1R/1 AH	GL4053 18M1
GN7609H	RR SHFT ANGLE				-						-		-						-	9M1/6
GN7610R	RR SHFT RATE				-						-		-						-	9M2/3
GN7611H	RR TRUN ANGLE				-						-		-						-	9M1/6
GN7612R	RR TRUN RATE				-						-		-						-	9M2/3
GN7613H	RR RANGE				-						-		-						-	9M9A
GN7614L	RR RANGE RATE	-700 TO	+700	FT/S	-			-700 TO	+700		-		-						-	9M9B
GN7616H	RR RANGE PRF				-						-		-						-	9M9A
GN7621X	RR NO TRACK	PRESENT OR ABSENT			1 =	NO TRACK							-						1/1 DPER	GL4048 17DS1
GN7642E	RR RF PWR	0 TO	5	MW	-			0 TO	5		-		-						-	NOT TM 17M1
GN7644V	RR ATM OUT TRUN	-150 TO	+150	MVDC	-						-		-						-	NOT TM
GN7646V	RR ATM OUT SHFT	-3 TO	+3	VDC	-						-		-						-	NOT TM
GN7648V	RR ATM OUT AGC	0 TO	5	VDC	-			0 TO	5		-		-						-	NOT TM 17M1
GN7723T	RR ANT TEMP	-200 TO	+200	°F	-200 TO	+200		-100 TO	+200		-50	+150	-						1 AHR	GL4053 18M1
GW5151V	PRA COMPARE	0 TO	+4.4	VDC	1 =	COMPARE			-		-		-	DISCRETE					50 DPE	
GW5153V	PRA CLOCK ON	0 TO	+4.4	DC	1 =	ON			-		-		-	DISCRETE					10 DPE	
GY0050X	ABORT CMD	OFF OR	ON		1 =	CMD			-		-		-	DISCRETE					1/1 DPER	

TABLE 6.5 SPACECRAFT INSTRUMENTATION FOR PROPULSION (CONT'D)

MEAS ID	MEAS DESCRIPTION	SENSOR RANGE			TM DATA RANGE			ONBOARD DISPLAY RANGE			C&W LIMITS		ADV	ESTIMATED NORMAL OPERATING LIMITS			CRITICAL LIMITS		S/C SAMPLING	NOTES
		LOW	HIGH	UNITS	LOW	HIGH	ACC PCT	LOW	HIGH	ACC PCT	LOW	HIGH		LOW	NORM	HIGH	LOW	HIGH		
GQ4111P	DPS OX PRESS.	0 TO	300	PSIA	0 TO	300	± 5%	0 TO	300		-		-					1/1 AHR	10M3B	
GQ4218T	DPS OX 1 TEMP	0 TO	250	°F	0 TO	250	±1/2°F	40 TO	100		-		-					1 AHR	10M4B	
GQ4219T	DPS FUEL 2 TEMP	0 TO	250	°F	0 TO	250	±1/2°F	40 TO	100		-		-					1 AHR	10M4B	
GQ4455X	DPS PROP LO	OFF OR	ON		1 =	LO		-			-		-	DISCRETE				1 DPE	GL4024	
GQ6510P	DPS TCP	0 TO	200	PSIA	0 TO	200		0 TO	100%		-		-					1/1 AHR	9M7A	
GQ6806H	VAR INJ ACT POS	0 TO		1 INCH	0 TO	.755	1 INCH	-			-		-					50 AH		
GQ7498U	DPS PROP VLVS ΔPOS	0 TO	100%		0 TO	75.5%	± 5%	-			-		-					1/1 AH		
GQ7499U		OFF OR	ON		1 =	ON		-			-		-	DISCRETE				100 DPE	1 DPE	
GR1085Q	PROP QTY A (PVT)	0 TO	99%		0 TO	99%		-			-		-					1R/1 AH	MAY BF GR1121 GR1122	
GR1095Q	PROP QTY B (PVT)	0 TO	99%		0 TO	99%		-			-		-					1R/1 AH		
GR1101P	RCS A HE PRESS.	0 TO	3500	PSIA	0 TO	3500		0 TO	4000		<1700		-					1/1 AHR		
GR1102P	RCS B HE PRESS.	0 TO	3500	PSIA	0 TO	3500		0 TO	4000		<1700		-					1/1 AHR	GL4052 8M1A	
GR1201P	RCS A REG PRESS.	0 TO	350	PSIA	0 TO	350		0 TO	400		<165	>205	-	165 TO		205		1 AH	GL4052 8M1B	
GR1202P	RCS B REG PRESS.	0 TO	350	PSIA	0 TO	350		0 TO	400		<165	>205	-					1/1 AH	GL4032 8M1A	
GR2121T	RCS A FUEL TEMP	20 TO	120	°F				20 TO	120		-		-					1/1 AH	GL4033 8M1B	
GR2122T	RCS B FUEL TEMP	20 TO	120	°F				20 TO	120		-		-					1/1 AH	8M2A	
GR2201P	A FUEL MFLD PRESS.	0 TO	350	PSIA	0 TO	350		0 TO	400		-		-					200 AHR	8M2B	
GR2202P	B FUEL MFLD PRESS.	0 TO	350	PSIA	0 TO	350		0 TO	400		-		-					1R/1 AH	8M1A	
GR3201P	A OX MFLD PRESS.	0 TO	350	PSIA	0 TO	350		0 TO	400		-		-					200 AHR	8M1B	
GR3202P	B OX MFLD PRESS.	0 TO	350	PSIA	0 TO	350		0 TO	400		-		-					1R/1AH	8M1A	
GR5031P	TCP 4U	OFF OR	ON		-			-			0 OR	1		DISCRETE				200 AHR	8M1B	
GR5032P	TCP 4D	OFF OR	ON		-			-			0 OR	1		DISCRETE				1R/1AH		
GR5033P	TCP 4F	OFF OR	ON		-			-			0 OR	1		DISCRETE				-	GL4031	
GR5034P	TCP 4S	OFF OR	ON		-			-			0 OR	1		DISCRETE				-	GL4031	
GR5035P	TCP 3U	OFF OR	ON		-			-			0 OR	1		DISCRETE				-	GL4031	
GR5036P	TCP 3D	OFF OR	ON		-			-			0 OR	1		DISCRETE				-	GL4031	
GR5037P	TCP 3F	OFF OR	ON		-			-			0 OR	1		DISCRETE				-	GL4031	
GR5038P	TCP 3S	OFF OR	ON		-			-			0 OR	1		DISCRETE				-	GL4031	
GR5039P	TCP 2U	OFF OR	ON		-			-			0 OR	1		DISCRETE				-	GL4031	



TABLE 6.5 SPACECRAFT INSTRUMENTATION FOR PROPULSION

MEAS ID	MEAS DESCRIPTION	SENSOR RANGE			TM DATA RANGE			ONBOARD DISPLAY RANGE			C&W LIMITS			ADV	ESTIMATED NORMAL OPERATING LIMITS			CRITICAL LIMITS		S/C SAMPLING	NOTES
		LOW	HIGH	UNITS	LOW	HIGH	ACC PCT	LOW	HIGH	ACC PCT	LOW	HIGH			LOW	NORM	HIGH	LOW	HIGH		
GP0001P	APS HE 1 PRESS.	0 TO	4000	PSIA	0 TO	4000		0 TO	4000		<3000			-						1/1 AHR	GL4022 10M1
GP0002P	APS HE 2 PRESS.	0 TO	4000	PSIA	0 TO	4000		0 TO	4000		<3000			-						1/1 AHR	GL4022 10M1
GP0025P	APS HE REG PRESS.	0 TO	300	PSIA	0 TO	300		-			<220			-						1/1 AHR	GL4041
GP0201T	APS HE 1 TEMP	-200 TO	+200	°F	-200	+200		-200 TO	+200		-			-						1/1 AHR	10M1
GP0202T	APS HE 2 TEMP	-200 TO	+200	°F	-200	+200		-200 TO	+200		-			-						1/1 AHR	10M1
GP0318X	APS HE 1 CLSD	OFF OR	ON		1 =	CLSD		-			-		10FL1							1 DPE	
GP0320X	APS HE 2 CLSD	OFF OR	ON		1 =	CLSD		-			-		10FL2							1 DPE	
GP0718T	APS FUEL TEMP	20 TO	120	°F				40 TO	100		-			-						1/1 AHR	10M4A
GP0908X	APS FUEL LO	OFF OR	ON		1 =	LO		-			-			-						1/1 DPE	GL4042
GP1218T	APS OX TEMP	20 TO	120	°F				40 TO	100		-			-						1/1 AHR	10M4B
GP1408X	APS OX LO	OFF OR	ON		1 =	LO		-			-			-						1/1 DPE	GL4042
GP1501P	APS FUEL PRESS.	0 TO	250	PSIA	0 TO	250	± 5%	0 TO	250		<120			-						1/1 AHR	GL4022 10M3A
GP1503P	APS OX PRESS.	0 TO	250	PSIA				0 TO	300		<120			-						1/1 AHR	GL4022 10M3B
GP2010P	APS TCP	0 TO	150	PSIA				-			-			-						1/1 AHR	
GP2997U	APS PROP VLVS ΔPOS	OFF OR	ON		1 =	MISMATCH		-			-			-						1 DPE	
GP2998U																				100 DPE	
GQ3018P	DPS HE REG PRESS.	0 TO	300	PSIA	0 TO	250	± 3%	-			-			-						1/1 AH	GL4023
GQ3309X	DPS HE 1 CLSD	OFF OR	ON		1 =	CLSD	± 5%	-			-		10FL3		DISCRETE					1 DPE	
GQ3310X	DPS HE 2 OPN	OFF OR	ON		1 =	OPN	± 5%	-			-		10FL4		DISCRETE					1 DPE	
GQ3435P	DPS HE PRESS.	0 TO	1750	PSIA	0 TO	1750		0 TO	1750		-			-						1/1 AHR	10M1
GQ3603Q	DPS FUEL 1 QTY	0 TO	100%		0 TO	95%	± 1%	SELECTED			-			-		VARIES				1R/1 AH	10M5B
GQ3604Q	DPS FUEL 2 QTY	0 TO	100%		0 TO	95%	± 1%	SELECTED			-			-		VARIES				1R/1 AH	10M5B
GQ3605Q	DPS FUEL QTY SEL	0 TO	95%		-			(SELECTED)			-			-						-	10M5B
GQ3611P	DPS FUEL PRESS.	0 TO	300	PSIA	0 TO	300	± 5%	0 TO 300 (GQ3603, 3604)			-			-						1/1 AHR	10M3A
GQ3718T	DPS FUEL 1 TEMP	0 TO	250	°F	0 TO	250	±1/2°F	40 TO	100		-			-						1 AHR	10M4A
GQ3719T	DPS FUEL 2 TEMP	0 TO	250	°F	0 TO	250	±1/2°F	40 TO	100		-			-						1 AHR	10M4A
GQ4103Q	DPS OX 1 QTY	0 TO	100%		0 TO	95	± 1%	SELECTED			-			-						1R/1 AH	10M5A
GQ4104Q	DPS OX 2 QTY	0 TO	100%		0 TO	95	± 1%	SELECTED			-			-						1R/1AH	10M5A
GQ4105Q	DPS OX QTY SEL	0 TO	95%		-			(SELECTED GQ4103, 4104)			-			-						-	10M5A

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TABLE 6.5 SPACECRAFT INSTRUMENTATION FOR PROPULSION (CONT'D)

MEAS ID	MEAS DESCRIPTION	SENSOR RANGE			TM DATA RANGE			ONBOARD DISPLAY RANGE			C&W LIMITS			ADV	ESTIMATED NORMAL OPERATING LIMITS			CRITICAL LIMITS		S/C SAMPLING	NOTES
		LOW	HIGH	UNITS	LOW	HIGH	ACC PCT	LOW	HIGH	ACC PCT	LOW	HIGH			LOW	NORM	HIGH	LOW	HIGH		
GQ4111P	DPS OX PRESS.	0 TO	300	PSIA	0 TO	300	± 5%	0 TO	300		-			-						1/1 AHR	10M3B
GQ4218T	DPS OX 1 TEMP	0 TO	250	°F	0 TO	250	±1/2°F	40 TO	100		-			-						1 AHR	10M4B
GQ4219T	DPS FUEL 2 TEMP	0 TO	250	°F	0 TO	250	±1/2°F	40 TO	100		-			-						1 AHR	10M4B
GQ4455X	DPS PROP LO	OFF OR	ON		1 =	LO		-			-			-						1 DPE	GL4024
GQ6510P	DPS TCP	0 TO	200	PSIA	0 TO	200		0 TO	100%		-			-						1/1 AHR	9M7A
GQ6806H	VAR INJ ACT POS	0 TO	100%	1 INCH	0 TO	75.5%	1 INCH ± 5%	-			-			-						50 AH	
GQ7498U	DPS PROP VLVS ΔPOS	OFF OR	ON		1 =	ON		-			-			-						1/1 AH	
GQ7499U																				100 DPE	
GR1085Q	PROP QTY A (PVT)	0 TO	99%		0 TO	99%		-			-			-						1R/1 AH	MAY BF GR1121 GR1122
GR1095Q	PROP QTY B (PVT)	0 TO	99%		0 TO	99%		-			-			-						1R/1 AH	
GR1101P	RCS A HE PRESS.	0 TO	3500	PSIA	0 TO	3500		0 TO	4000		<1700			-						1/1 AHR	GL4052 8M1A
GR1102P	RCS B HE PRESS.	0 TO	3500	PSIA	0 TO	3500		0 TO	4000		<1700			-						1/1 AHR	GL4052 8M1B
GR1201P	RCS A REG PRESS.	0 TO	350	PSIA	0 TO	350		0 TO	400		<165	>205	-	165 TO		205				1 AH	GL4032 8M1A
GR1202P	RCS B REG PRESS.	0 TO	350	PSIA	0 TO	350		0 TO	400		<165	>205	-							1/1 AH	GL4033 8M1B
GR2121T	RCS A FUEL TEMP	20 TO	120	°F				20 TO	120		-			-						1/1 AH	8M2A
GR2122T	RCS B FUEL TEMP	20 TO	120	°F				20 TO	120		-			-						1/1 AH	8M2B
GR2201P	A FUEL MFLD PRESS.	0 TO	350	PSIA	0 TO	350		0 TO	400		-			-						200 AHR	8M1A
GR2202P	B FUEL MFLD PRESS.	0 TO	350	PSIA	0 TO	350		0 TO	400		-			-						1R/1 AH	8M1B
GR3201P	A OX MFLD PRESS.	0 TO	350	PSIA	0 TO	350		0 TO	400		-			-						1R/1AH	8M1A
GR3202P	B OX MFLD PRESS.	0 TO	350	PSIA	0 TO	350		0 TO	400		-			-						200 AHR	8M1B
GR5031P	TCP 4U	OFF OR	ON		-			-			0 OR	1			DISCRETE					-	GL4031
GR5032P	TCP 4D	OFF OR	ON		-			-			0 OR	1			DISCRETE					-	GL4031
GR5033P	TCP 4F	OFF OR	ON		-			-			0 OR	1			DISCRETE					-	GL4031
GR5034P	TCP 4S	OFF OR	ON		-			-			0 OR	1			DISCRETE					-	GL4031
GR5035P	TCP 3U	OFF OR	ON		-			-			0 OR	1			DISCRETE					-	GL4031
GR5036P	TCP 3D	OFF OR	ON		-			-			0 OR	1			DISCRETE					-	GL4031
GR5037P	TCP 3F	OFF OR	ON		-			-			0 OR	1			DISCRETE					-	GL4031
GR5038P	TCP 3S	OFF OR	ON		-			-			0 OR	1			DISCRETE					-	GL4031
GR5039P	TCP 2U	OFF OR	ON		-			-			0 OR	1			DISCRETE					-	GL4031

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TABLE 6.5 SPACECRAFT INSTRUMENTATION FOR PROPULSION (CONCLUDED)

MEAS ID	MEAS DESCRIPTION	SENSOR RANGE			TM DATA RANGE			ONBOARD DISPLAY RANGE			C&W LIMITS		ADV	ESTIMATED NORMAL OPERATING LIMITS			CRITICAL LIMITS		S/C SAMPLING	NOTES
		LOW	HIGH	UNITS	LOW	HIGH	ACC PCT	LOW	HIGH	ACC PCT	LOW	HIGH		LOW	NORM	HIGH	LOW	HIGH		
GR5040P	TCP 2D	OFF	OR	ON		-			-		0	OR	1		DISCRETE				-	GL4031
GR5041P	TCP 2F	OFF	OR	ON		-			-		0	OR	1		DISCRETE				-	GL4031
GR5042P	TCP 2S	OFF	OR	ON		-			-		0	OR	1		DISCRETE				-	GL4031
GR5043P	TCP 1U	OFF	OR	ON		-			-		0	OR	1		DISCRETE				-	GL4031
GR5044P	TCP 1D	OFF	OR	ON		-			-		0	OR	1		DISCRETE				-	GL4031
GR5045P	TCP 1F	OFF	OR	ON		-			-		0	OR	1		DISCRETE				-	GL4031
GR5046P	TCP 1S	OFF	OR	ON		-			-		0	OR	1		DISCRETE				-	GL4031
GR6001T	QUAD 4 TEMP	20	TO	200	°F			0	TO	200	<40	>180							1/1 AH	GL4053
GR6002T	QUAD 3 TEMP	20	TO	200	°F			0	TO	200	<40	>180							1/1 AH	GL4053
GR6003T	QUAD 2 TEMP	20	TO	200	°F			0	TO	200	<40	>180							1/1 AH	GL4053
GR6004T	QUAD 1 TEMP	20	TO	200	°F			0	TO	200	<40	>180							1/1 AH	GL4053
GR9609U	RCS MAIN A CLSD	CLSD	OR	OPEN		1 = CLSD			-		0	OR	1	8FL5	DISCRETE				1/1 DPER	GL4053
GR9610U	RCS MAIN B CLSD	CLSD	OR	OPEN		1 = CLSD			-		0	OR	1	8FL7	DISCRETE				1/1 DPER	GL4053
GR9611U	ASC FEED A OPN	CLSD	OR	OPEN		1 = OPEN			-		0	OR	1	8FL6	DISCRETE				1/1 DPER	GL4053
GR9612U	ASC FEED B OPN	CLSD	OR	OPEN		1 = OPEN			-		0	OR	1	8FL8	DISCRETE				1/1 DPER	GL4053
GR9613U	A/B X-FEED OPN	CLSD	OR	OPEN		1 = OPEN			-		0	OR	1	8FL17	DISCRETE				1/1 DPER	GL4053
GR9661U	4A ISO CLSD	CLSD	OR	OPEN		1 = CLSD			-		0	OR	1	8FL14	DISCRETE				1 DPE	GL4053
GR9662U	4B ISO CLSD	CLSD	OR	OPEN		1 = CLSD			-		0	OR	1	8FL16	DISCRETE				1 DPE	GL4053
GR9663U	3A ISO CLSD	CLSD	OR	OPEN		1 = CLSD			-		0	OR	1	8FL13	DISCRETE				1 DPE	GL4053
GR9664U	3B ISO CLSD	CLSD	OR	OPEN		1 = CLSD			-		0	OR	1	8FL15	DISCRETE				1 DPE	GL4053
GR9665U	2A ISO CLSD	CLSD	OR	OPEN		1 = CLSD			-		0	OR	1	8FL10	DISCRETE				1 DPE	GL4053
GR9666U	2B ISO CLSD	CLSD	OR	OPEN		1 = CLSD			-		0	OR	1	8FL12	DISCRETE				1 DPE	GL4053
GF9667U	1A ISO CLSD	CLSD	OR	OPEN		1 = CLSD			-		0	OR	1	8FL9	DISCRETE				1 DPE	GL4053
GR9668U	1B ISO CLSD	CLSD	OR	OPEN		1 = CLSD			-		0	OR	1	8FL11	DISCRETE				1 DPE	GL4053

TABLE 6.6 TELEMETRY VERSUS PAN STATES

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AS-206  
REV A

PAN 1						PAN 2						PAN 3						PAN 4					
SEQ	CHANNEL(S)	ELEC/COMM	ECS	GNC	PROP	SEQ	CHANNEL(S)	ELEC/COMM	ECS	GNC	PROP	SEQ	CHANNEL(S)	ELEC/COMM	ECS	GNC	PROP	SEQ	CHANNEL(S)	ELEC/COMM	ECS	GNC	PROP
1	200AH1 (200AH4)				R2201	1	200AH2 (200AH5)				R3202	1	200AH3 (200AH16)			G2137	R2202	1	200AH4 (200AH1)				R2201
	100AH1 (100AH9)			G2107			100AH2			G2151			100AH10 (100AH18)	--	--	--	--		100AH4 (100AH12)	--	--	--	--
	100AH8			H1466			100AH9 (100AH1)			G2107			100AH17			G2137			100AH11			H1465	--
	100AH15			G2107			100AH16 (100AH3)			G2137			50AH5 (50AH6)			G2041			100AH18 (100AH10)	--	--	--	--
	50AH1			G2021			50AH2 (50AH5)			G2001									50AH4			--	Q6806
2	200AH5 (200AH2)				R3202	2	200AH6				R3201	2	200AH7			H1464		2	100AH22	--	--	--	--
	100AH5			G2167			100AH6			G2121			100AH7			G2170			50AH8	--	--	--	Q6806
	100AH12 (100AH3)	--	--	G2167			100AH13 (100AH19)			G2167			100AH14			G2140							
	100AH19 (100AH13)			G2167			100AH20			G2181			100AH21			G2110							
	50AH5 (50AH2)			G2001			50AH6 (50AH3)			G2041			50AH7			--	--						
3	10AH1			H1240		3	10AH2			T0992		3	10AH3			T0994		3	10AH4	--	--	--	--
	10AH8			H1241			10AH9 (10AH40)***			HG2142			10AH10			G3305			10AH11			G3324	--
	10AH18			H1242			10AH19 (10AH43)			H1461			10AH20			G3325			10AH21			H1331	--
	10AH28			G2173			10AH29 (10AH45)			H1462			10AH30			H1313			10AH31			H1314	--
	10AH17 (10AH13)			H1457			10AH38 (10AH34)			H1463			10AH39 (10AH15)			H1455			10AH40 (10AH0)***			G2142	--
4	10AH12			G2143		4	10AH5			H1249		4	10AH6 (10AH44)	--	--	--	--	4	10AH7 (10AH42)			H1456	--
	10AH22			--	--		10AH13 (10AH37)			H1457			10AH14			HG2113			10AH15 (10AH39)			H1455	--
	10AH32			G3304			10AH23			G2279			10AH24			HG2172			10AH25			H1247	--
	10AH41			H1457			10AH33			H1248			10AH34 (10AH38)			H1465			10AH35			G2219	--
							10AH42 (10AH7)			H1456			10AH43 (10AH19)			H1461			10AH35			--	--
5	1AH3 (1AH48)			Q4218		5	1AH1			T0619		5	10AH16			HG2112		5	10AH17			G2249	--
	1AH7			HG2143			1AH5			HG1331			10AH36 (10AH41)***	L0401					10AH27 (10AH36)***	H1402			--
	1AH11			H1314			1AH9			HG1521			10AH37 (10AH27)***	L0402									--
	1AH15 (1AH44)***			H2202			1AH13 (1AH27)			H2202			10AH45 (10AH29)			H1462							--
	1AH19 (1AH29)			HQ4111			1AH17 (1AH46)			H2202													--
6	1AH22			H1313		6	1AH20 (1AH54)			H2202		6	1AH2 (1AH49)			G1040		6	1AH4 (1AH47)				Q3718
	1AH26			H1455			1AH24 (1AH50)			H2202			1AH6 (1AH50)			H2202			1AH8			H2202	--
	1AH30 (1AH6)			H2202			1AH25 (1AH52)			H2202			1AH10			H2202			1AH12 (1AH28)			H2202	--
	1AH34 (1AH56)			H2202			1AH32			H2202			1AH14 (1AH45)***			H2202			1AH16 (1AH43)***			H2202	--
	1AH38 (1AH52)			H2202			1AH36			H2202			1AH18			H2202							--
7	1AH41			C0202		7	1AH39			F3585		7	1AH21 (1AH53)***			H2202		7	1AH23 (1AH52)***			H2202	--
	1AH45 (1AH14)***			C0204			1AH43 (1AH16)***			F3585			1AH25			H2202			1AH27 (1AH13)			H2202	--
	1AH49 (1AH42)			G1040			1AH47 (1AH4)			H2202			1AH29 (1AH19)			H2202			1AH31 (1AH55)			H2202	--
	1AH53 (1AH21)***			H2202			1AH51 (1AH23)***			H2202			1AH33			H2202			1AH35			H2202	--
	1AH57			C0204			1AH55 (1AH31)			H2202			1AH37			H2202							--
8	1AH60			H1456		8	1AH58 (1AH88)			H2202		8	1AH40			--	--	8	1AH42			H2202	--
	1AH64			H2202			1AH62 (1AH92)			H2202			1AH44 (1AH15)***			H2202			1AH46 (1AH17)			H2202	--
	1AH68 (1AH102)			H2202			1AH66			H2202			1AH48 (1AH5)			H2202			1AH50 (1AH24)			H2202	--
	1AH72			H2202			1AH70			H2202			1AH52 (1AH38)***			H2202			1AH54 (1AH20)			H2202	--
	1AH76 (1AH66)			H2202			1AH74			H2202			1AH56 (1AH34)			H2202							--
9	1AH79			C0203		9	1AH77 (1AH104)***			H2202		9	1AH59 (1AH99)			H2202		9	1AH61 (1AH105)			H2202	--
	1AH83 (1AH98)			H2202			1AH81 (1AH96)***			H2202			1AH63 (1AH95)			H2202			1AH65 (1AH89)			H2202	--
	1AH87 (1AH75)			H2202			1AH85			H2202			1AH67 (1AH94)			H2202			1AH68 (1AH101)***			H2202	--
	1AH91 (1AH106)			H2202			1AH89 (1AH65)			H2202			1AH71			H2202			1AH73 (1AH97)			H2202	--
	1AH95 (1AH63)			H2202			1AH93 (1AH100)			H2202			1AH75 (1AH87)			H2202							--
10	1AH99 (1AH59)			H2202		10	1AH97 (1AH73)			H2202		10	1AH78			--	--	10	1AH80			H2202	--
	1AH103 (1AH90)			H2202			1AH101 (1AH69)***			H2202			1AH82			H2202			1AH84			H2202	--
	1AH107			G6020			1AH105 (1AH61)			H2202			1AH86 (1AH75)			H2202			1AH88 (1AH58)			H2202	--
	1AH111			H1457			1AH109			H2202			1AH90 (1AH103)			H2202			1AH92 (1AH62)			H2202	--
	1AH115			H1457			1AH113			H2202			1AH94 (1AH67)			H2202							--
11	1AH119 (1AH146)***			--	--	11	1AH117 (1AH148)			H2202		11	1AH98 (1AH83)			H2202		11	1AH96 (1AH81)***			--	--
	1AH123 (1AH166)			--	--		1AH121			H2202			1AH102 (1AH68)			H2202			1AH100 (1AH93)			--	--
	1AH127			H2202			1AH125 (1AH160)			H2202			1AH106 (1AH91)			H2202			1AH104 (1AH77)***			--	--
	1AH131 (1AH142)			H2202			1AH129 (1AH144)			H2202			1AH110			H2202			1AH106 (1AH77)***			--	--
	1AH135 (1AH170)			H2202			1AH133 (1AH176)***			H2202			1AH114			H2202			1AH108			--	--
12	1AH139			H1247		12	1AH137			H2202		12	1AH118			G2701		12	1AH116 (1AH163)***			H2202	--
	1AH143 (1AH134)			--	--		1AH141 (1AH168)			H2202			1AH122 (1AH167)			H2202			1AH120 (1AH169)			H2202	--
	1AH147 (1AH130)			--	--		1AH145 (1AH124)			H2202			1AH126			H2202			1AH124 (1AH145)			H2202	--
	1AH151 (1AH162)			--	--		1AH149 (1AH164)***			H2202			1AH130 (1AH147)			H2202			1AH128			H2202	--
	1AH155			H1248			1AH153 (1AH179)			H2202			1AH134 (1AH143)			H2202			1AH132			H2202	--
13	1AH159			T0202		13	1AH157			H2202		13	1AH138			H2202		13	1AH136			--	--
	1AH163 (1AH154)			--	--		1AH161 (1AH152)			H2202			1AH142 (1AH131)			H2202			1AH140			--	--
	1AH167 (1AH172)			--	--		1AH165 (1AH116)***			H2202			1AH146 (1AH119)***			H2202			1AH144 (1AH129)			--	--
	1AH171			--	--		1AH169 (1AH120)			H2202			1AH150			H2202			1AH148 (1AH117)			--	--
	1AH175			H1249			1AH173 (1AH178)			H2202			1AH154 (1AH163)			H2202			1AH152 (1AH161)			--	--
14	1AH179 (1AH153)			P0001		14	1AH177 (1AH172)			H2202		14	1AH158			C0155		14	1AH156			--	--
	1AH183			--	--		1AH181			H2202			1AH162 (1AH151)***			H2202			1AH160 (1AH125)			--	--
	1AH187			--	--		1AH185			H2202			1AH166 (1AH123)			H2202			1AH164 (1AH143)***			--	--
	1AH191			--	--		1AH189			H2202			1AH170 (1AH135)			H2202			1AH168 (1AH141)			--	--
	1AH195			H2202			1AH193			H2202			1AH174			H2202			1AH172 (1AH177)			--	--
15						15						15	1AH178 (1AH173)			--	--	15	1AH176 (1AH133)***			H2202	--
							1AH182			H2202			1AH180			H2202			1AH184			H2202	--
							1AH186			H2202			1AH190			H2202			1AH192			H2202	--
							1AH194			H2202						H2202						--	--
																							--



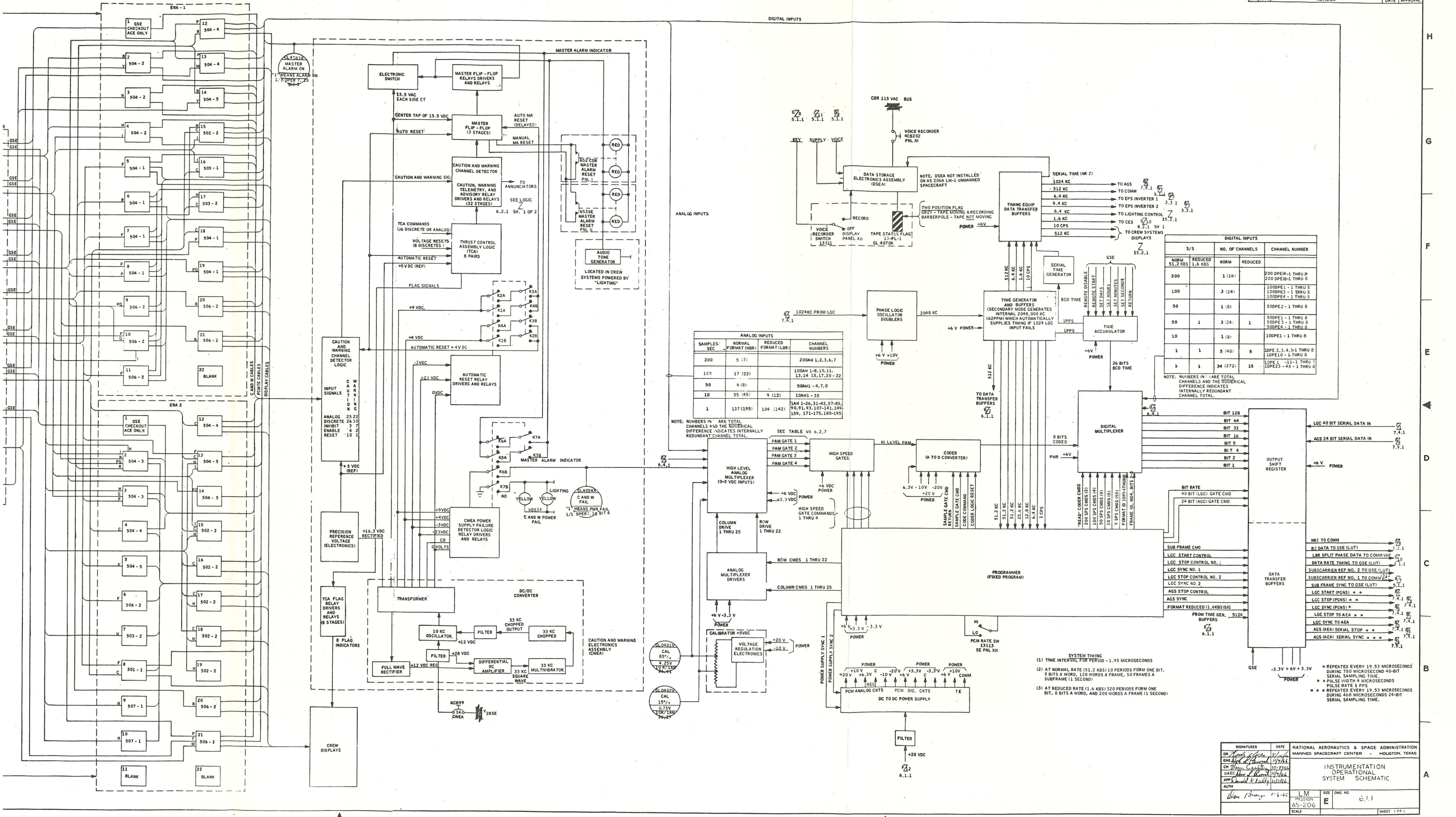
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### 6.3 SYSTEM MODES

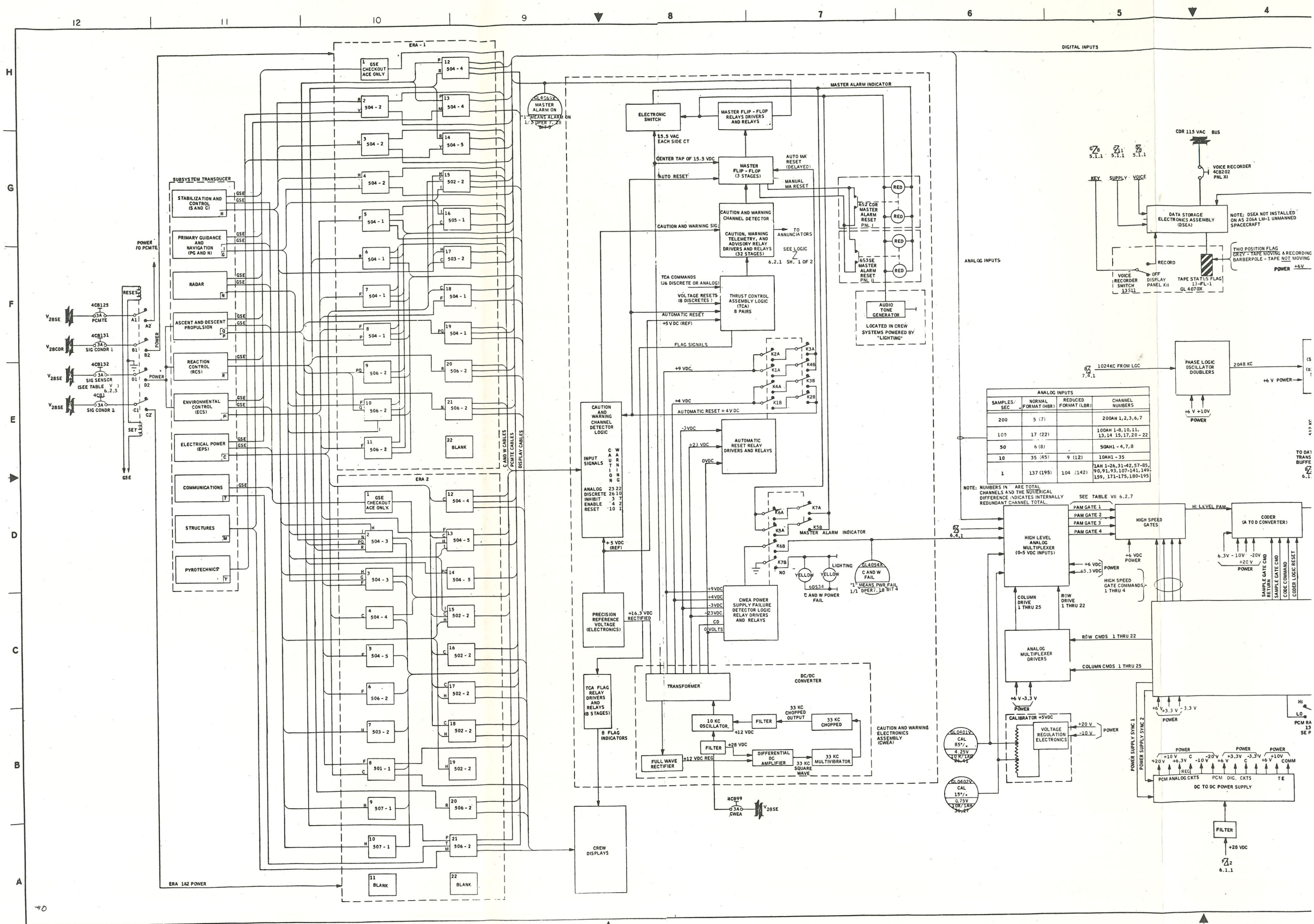
High bit rate (Normal mode at 51.2 Kbs) and low bit rate (Reduced mode at 1.6 Kbs) are available from the PCMTEA. However, the low bit rate mode must be manually switched by an onboard astronaut, and therefore, will not be available on AS-206A.

### 6.4 CONSTRAINTS

None.



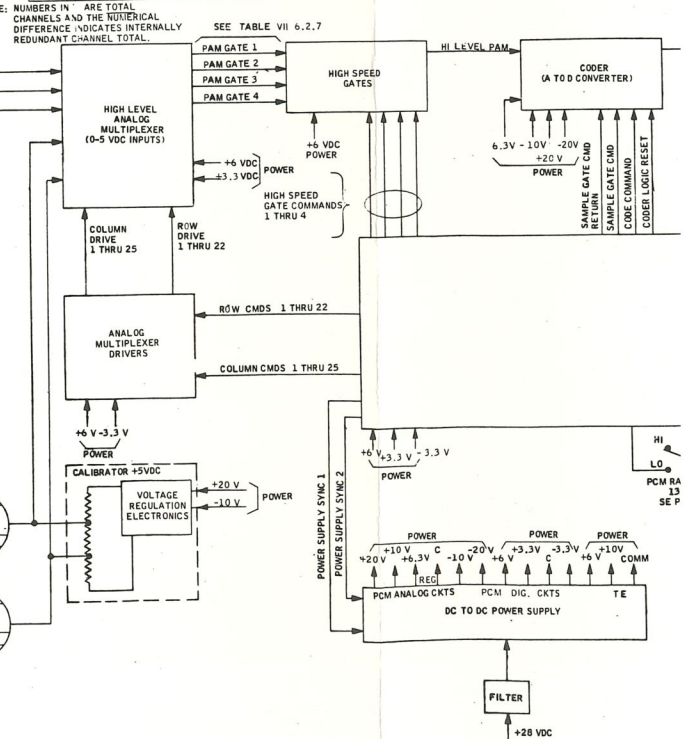




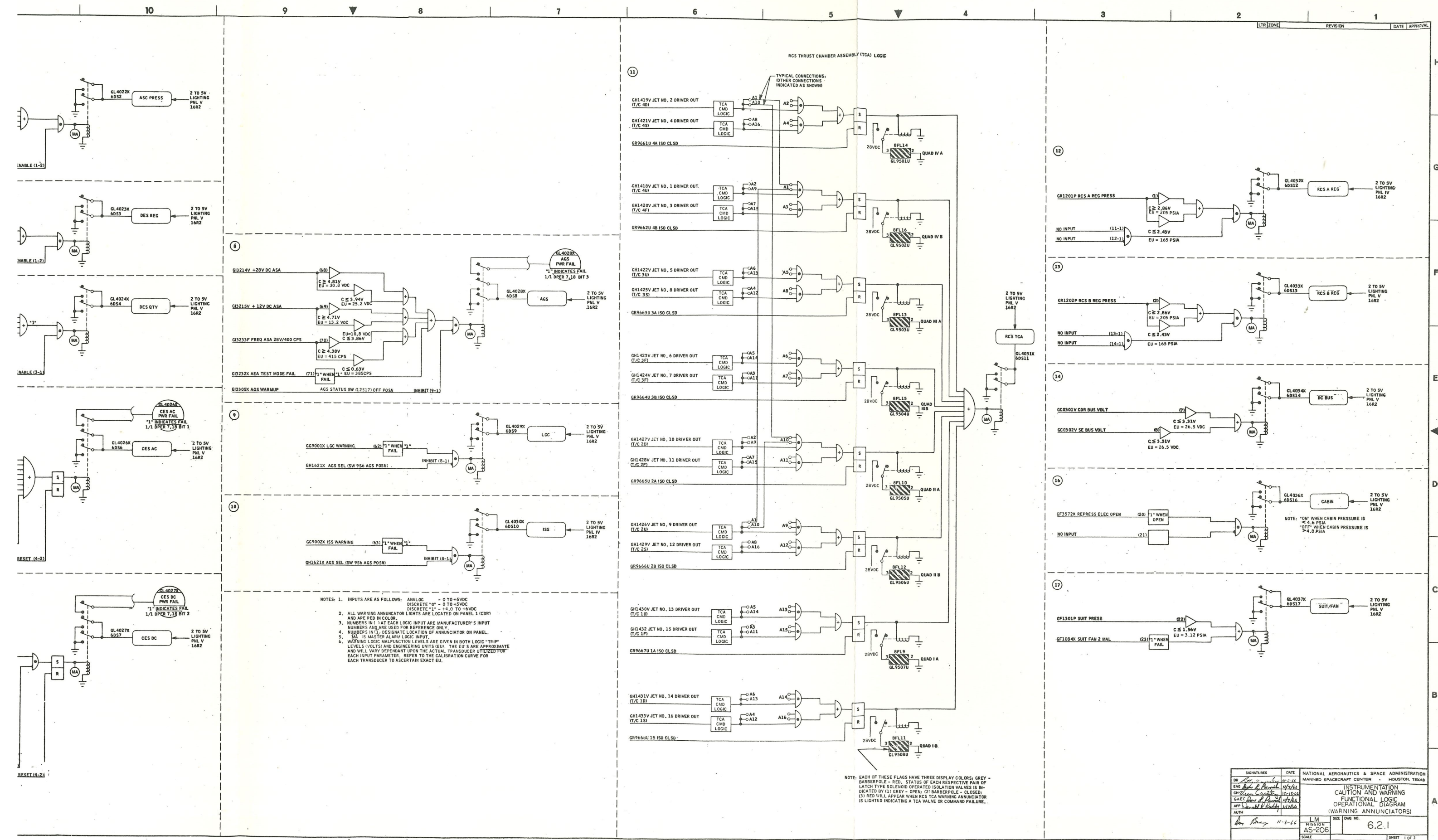
ANALOG INPUTS

SAMPLES/ SEC	NORMAL FORMAT (HBR)	REDUCED FORMAT (LBR)	CHANNEL NUMBERS
200	5 (7)		200AH 1,2,3,6,7
100	17 (22)		100AH 1-8,10,11, 13,14 15,17,20-22
50	6 (8)		50AH1-4,7,8
10	35 (45)	9 (12)	10AH1-35
1	137 (195)	104 (142)	1AH 1-26,31-42,57-85, 90,91,93,107-141,149, 159, 171-175,180-195

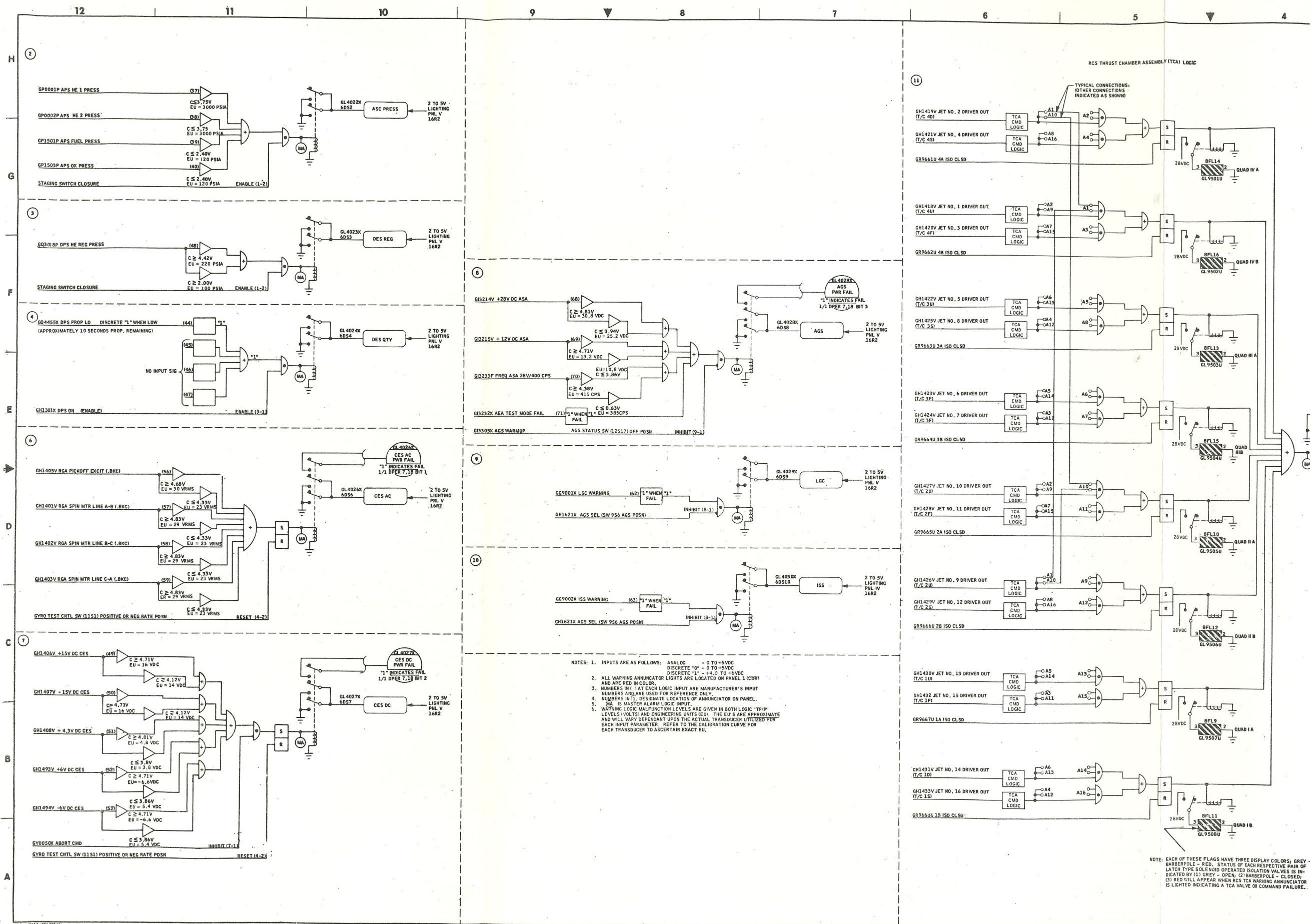
NOTE: NUMBERS IN " " ARE TOTAL CHANNELS AND THE NUMERICAL DIFFERENCE INDICATES INTERNALLY REDUNDANT CHANNEL TOTAL.







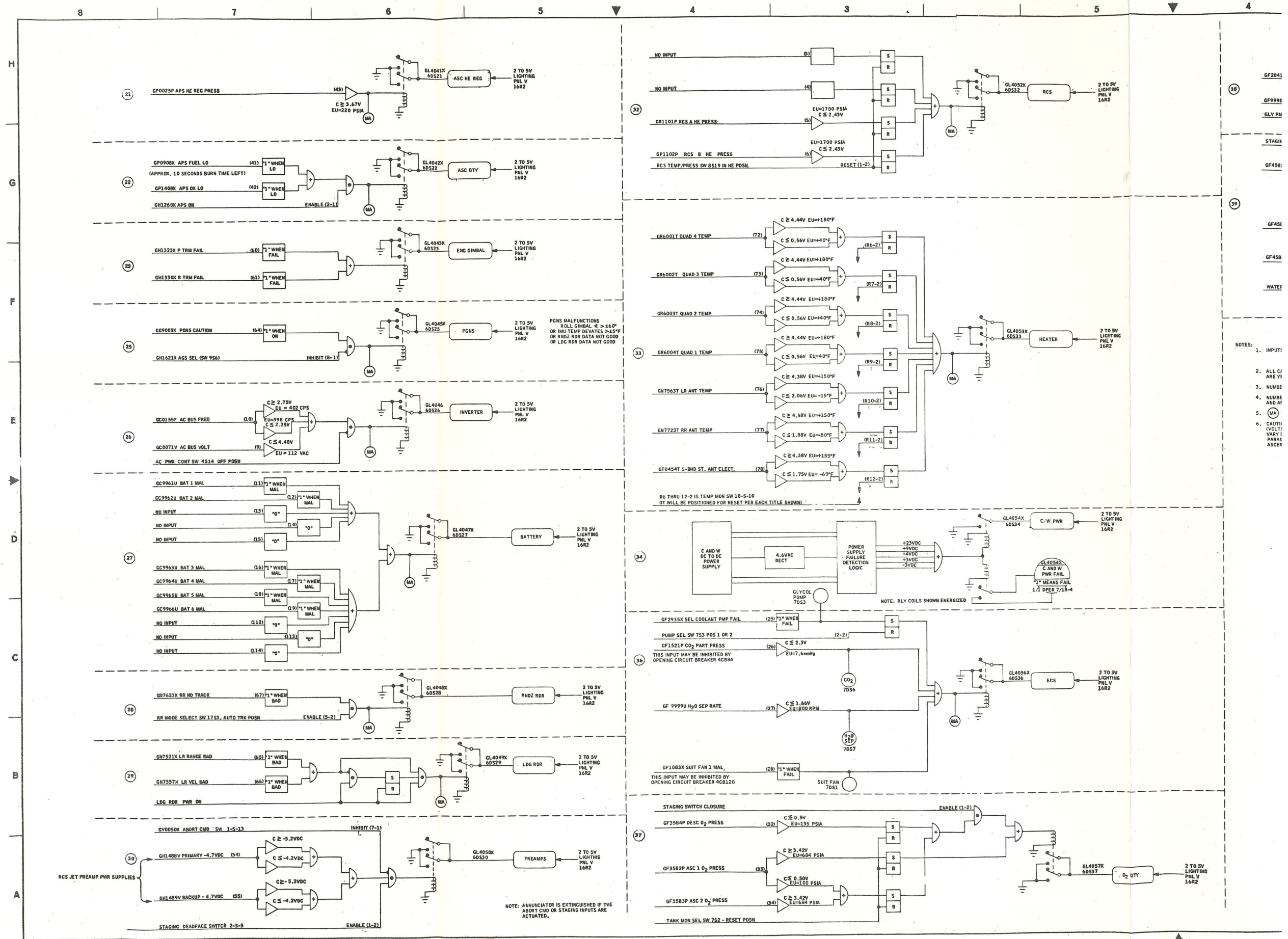


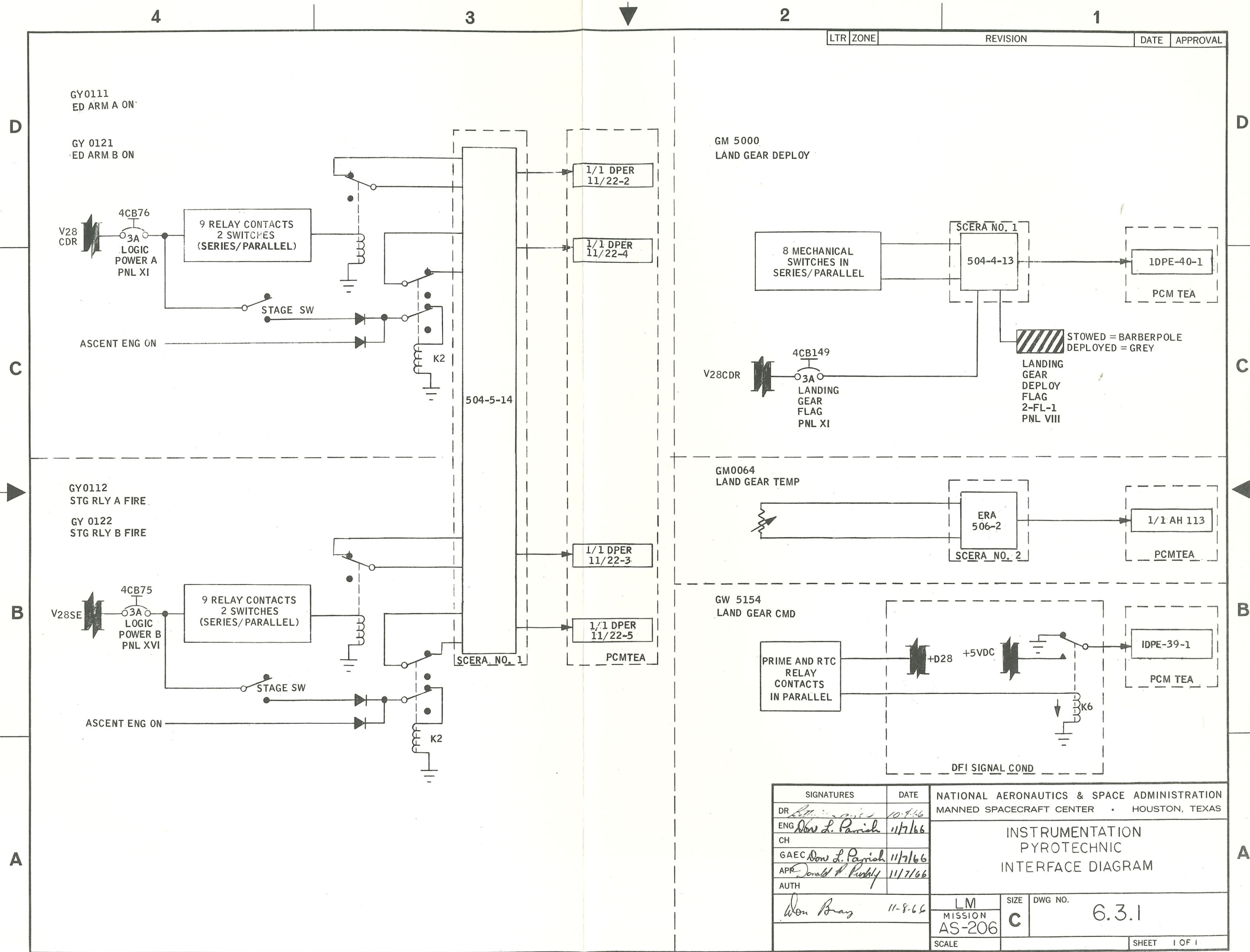




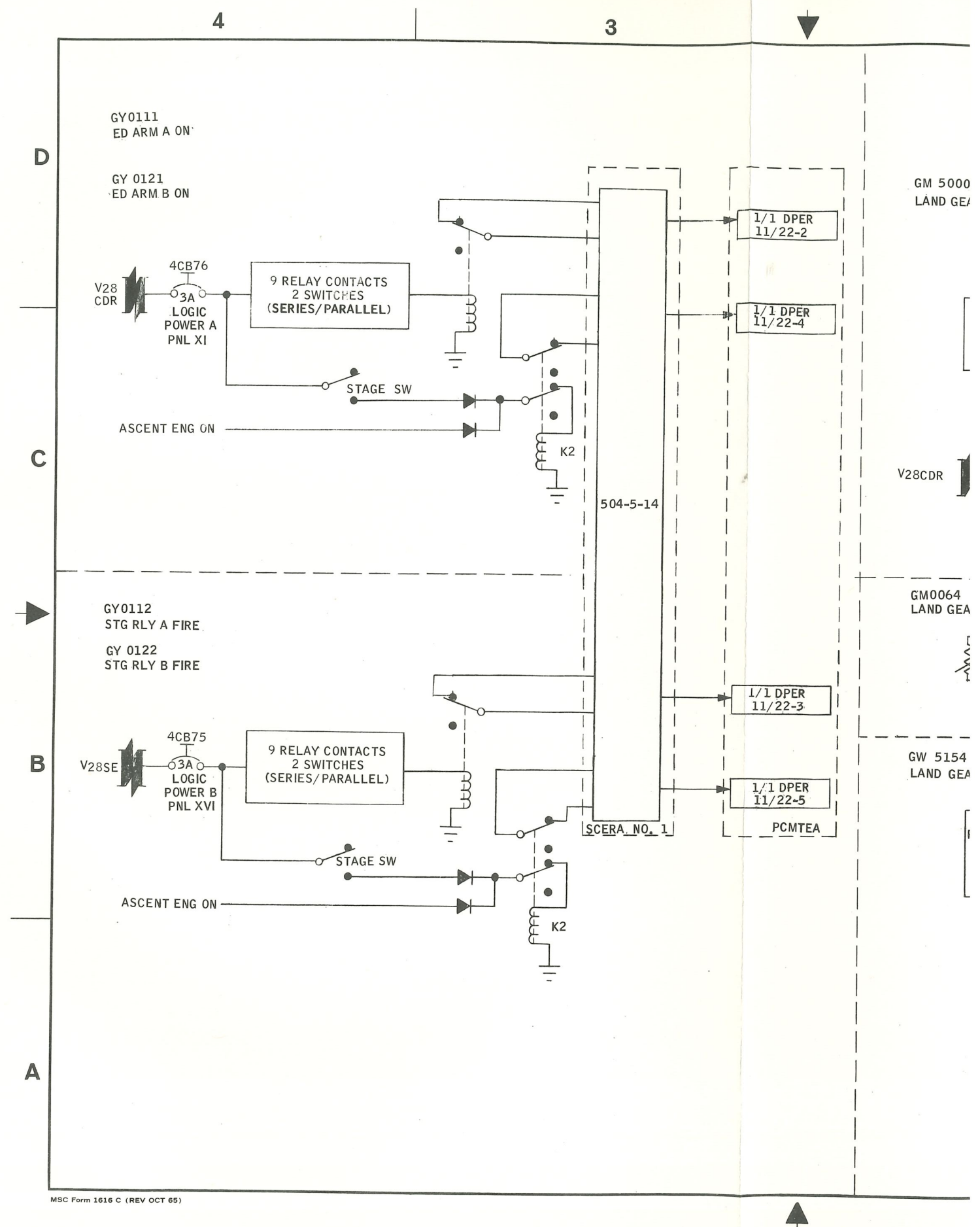




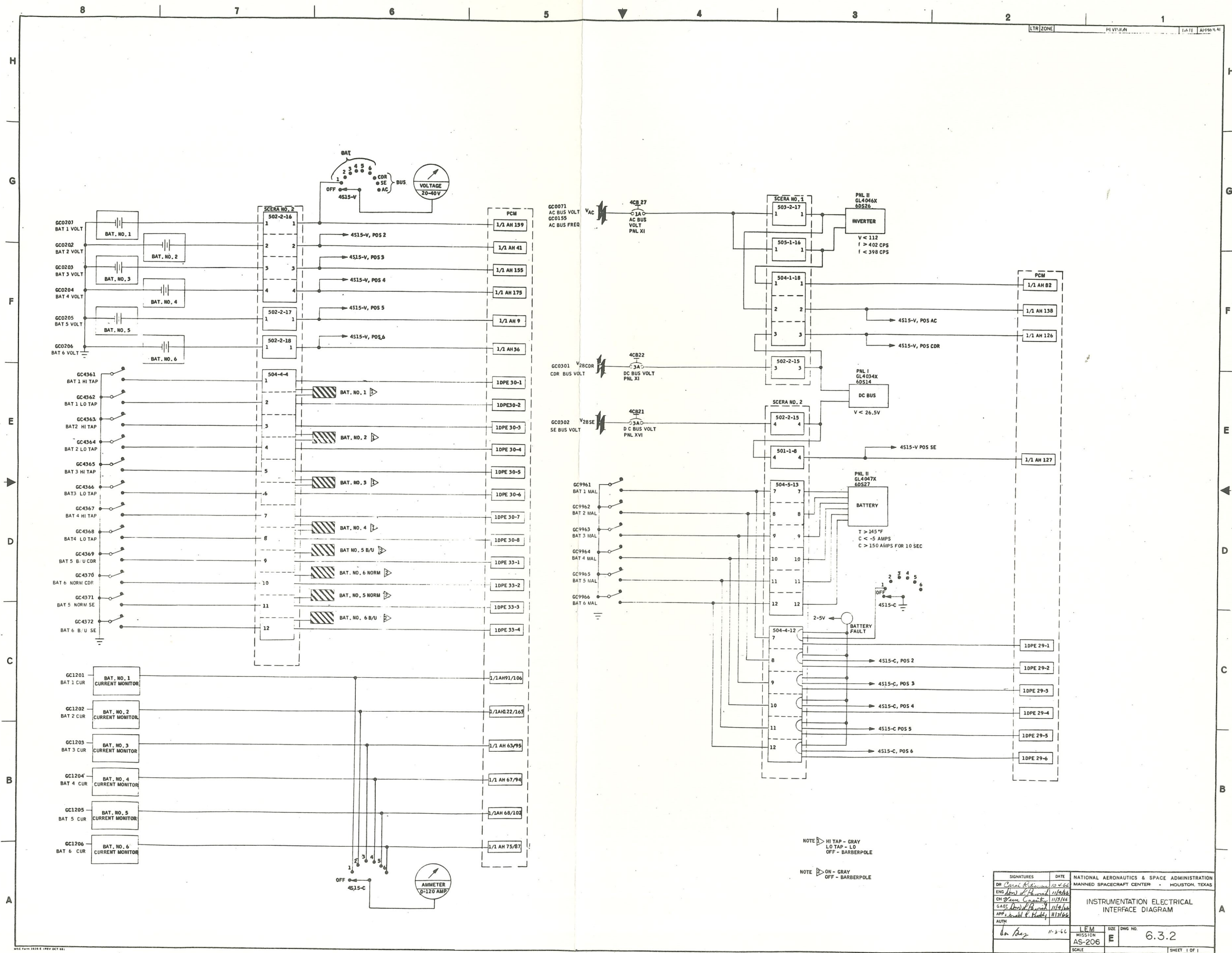




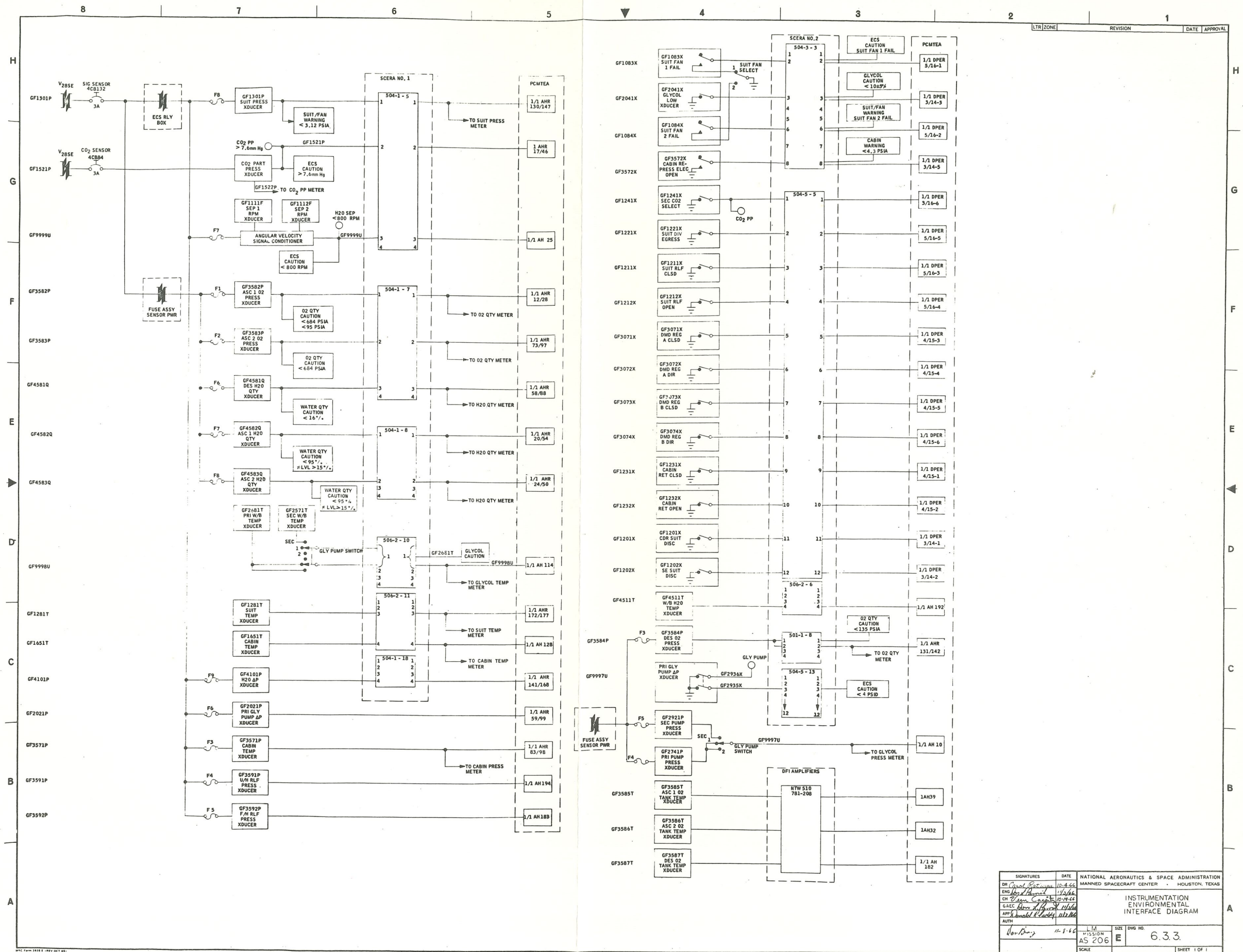




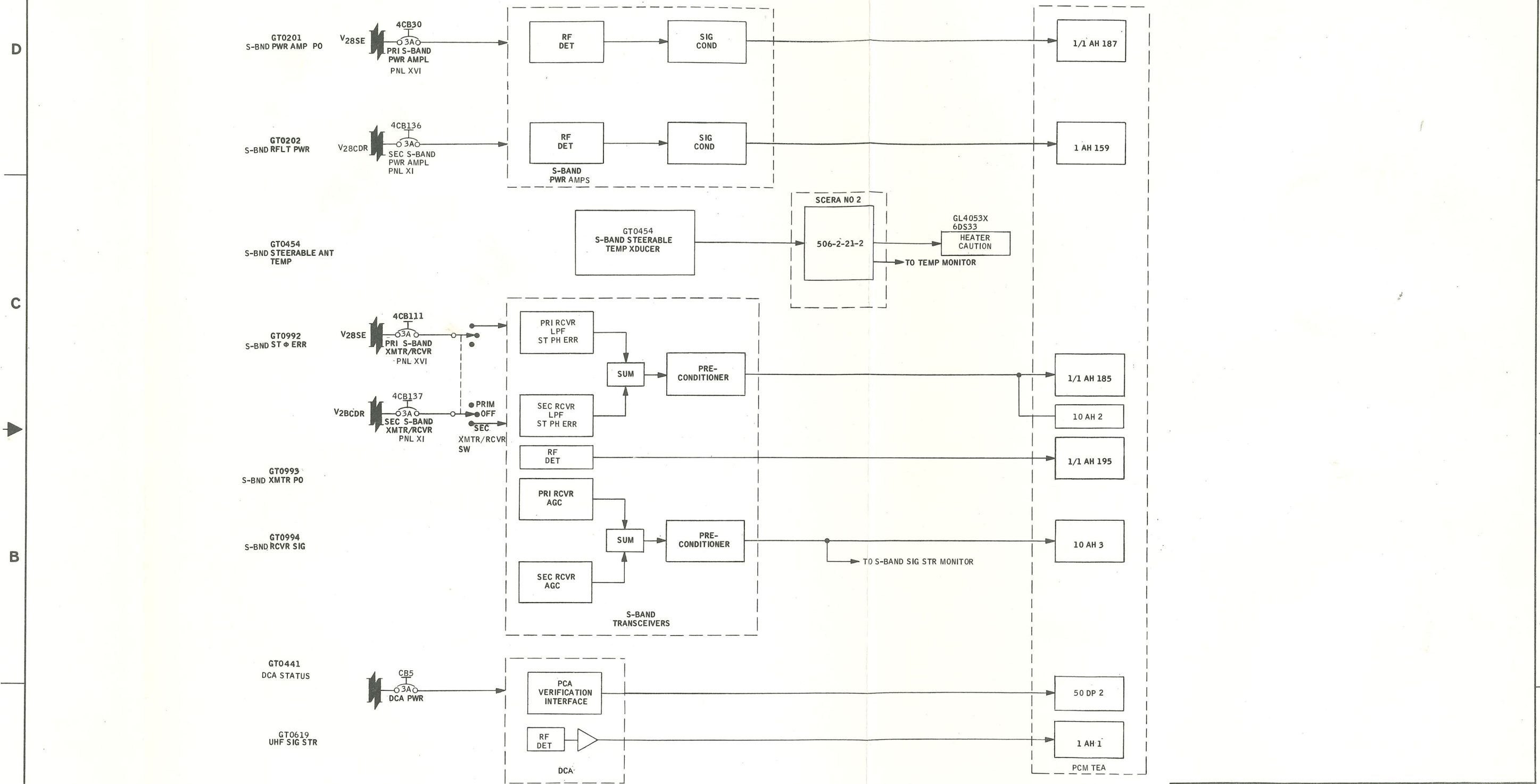




SIGNATURES	DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION
DR <i>[Signature]</i> 10/1/66	10/1/66	MANNE SPACECRAFT CENTER - HOUSTON, TEXAS
ENR <i>[Signature]</i> 11/15/66	11/15/66	
CH <i>[Signature]</i> 11/15/66	11/15/66	
SAEC <i>[Signature]</i> 11/15/66	11/15/66	
APP <i>[Signature]</i> 11/15/66	11/15/66	
AUTH	LEM	SIZE
<i>[Signature]</i>	AS-206	E
	MISSION	DWG NO.
		6.3.2
	SCALE	SHEET 1 OF 1

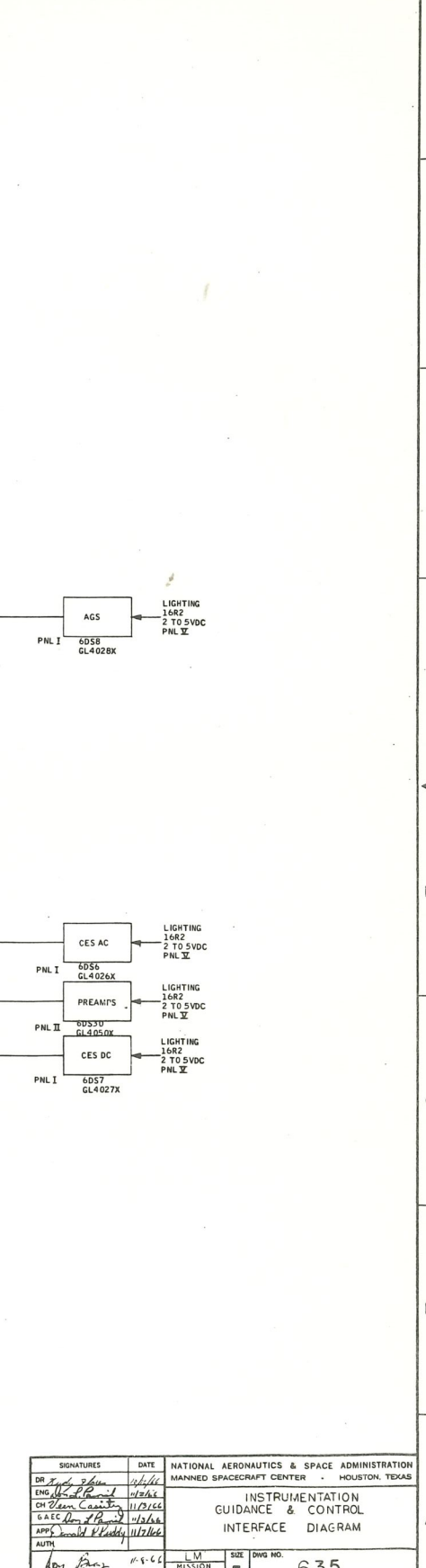
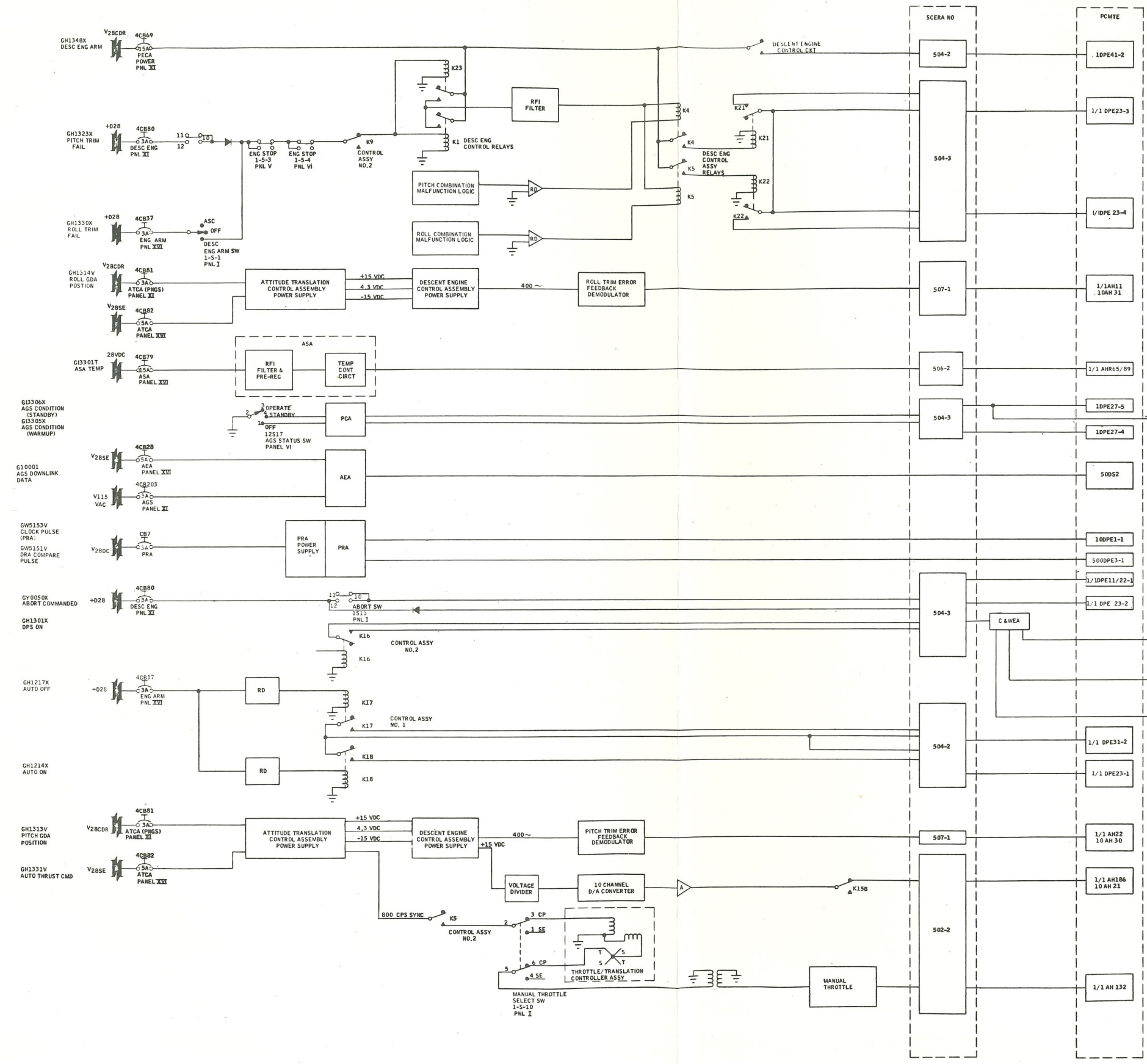
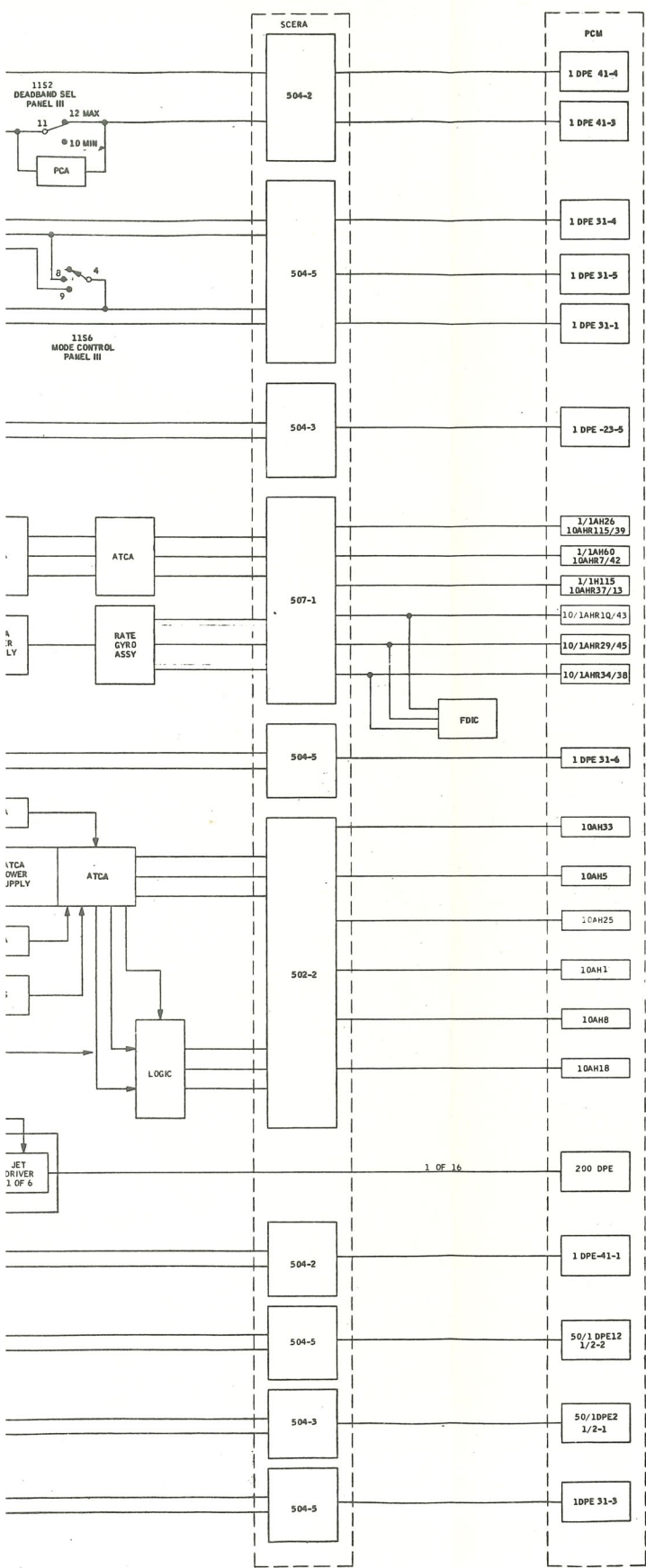




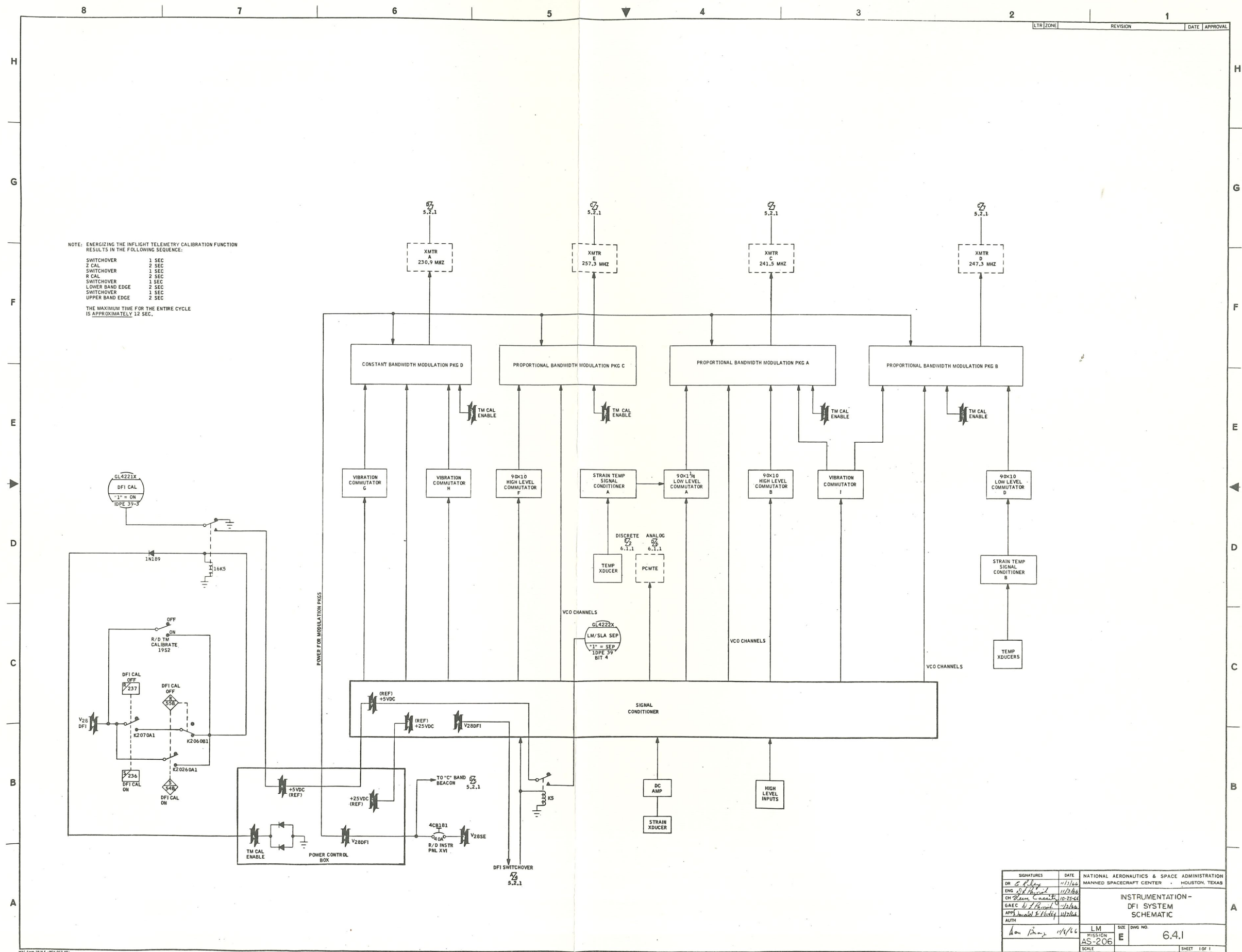


SIGNATURES		DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION	
DR	<i>[Signature]</i>	11-7-66	MANNED SPACECRAFT CENTER • HOUSTON, TEXAS	
ENG	<i>[Signature]</i>	11/4/66	INSTRUMENTATION COMMUNICATIONS INTERFACE DIAGRAM	
CH	<i>[Signature]</i>	11-7-66		
GAEC	<i>[Signature]</i>	11/4/66		
APP	<i>[Signature]</i>	11/7/66		
AUTH	<i>[Signature]</i>	11-8-66	LM MISSION AS-206	SIZE D
			SCALE	DWG NO. 634
			SHEET 1 OF 1	





SIGNATURES	DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION
DR. J. R. ...	...	MANNED SPACECRAFT CENTER - HOUSTON, TEXAS
ENG. ...	...	
CH. ...	...	
SEC. ...	...	
APP. ...	...	
AUTH.	...	
		INSTRUMENTATION GUIDANCE & CONTROL INTERFACE DIAGRAM
		SCALE
		SHEET 1 OF 1









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SECTION 7  
GUIDANCE

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7.1 GENERAL

7.1.1 General Information

The LM Guidance, Navigation and Control Subsystem controls the attitude and the flight path of this spacecraft. Primary guidance and control is provided by the main digital Primary Guidance and Navigation Section (PGNS). Abort guidance and control is provided by digital/analog mechanization contained in the Control Electronics Section (CES) and Abort Guidance Section (AGS).

7.1.2 Primary Guidance and Navigation Section (PGNS)

- A. The LM Guidance and Navigation Section provides guidance functions to accomplish the following LM mission-related requirements:
1. Separation of the LM from the Command and Service Module (CSM) while in lunar orbit, and orientation of the LM for subsequent phases.
  2. Insertion into the necessary descent transfer orbit so that the LM arrives at a 50,000 foot pericyynthion altitude at the required lunar central angle from the preselected lunar landing site.
  3. Powered descent maneuver to a specified landing site within the required constraints including the capability for manual inputs and overrides.
  4. Determine, while on the lunar surface, the nominal launch window for direct ascent trajectory, and latest launch time for insertion into a parking orbit having a clear pericynthion altitude.
  5. Powered ascent guidance with the  $\Delta V$  budget constraints to achieve burnout conditions resulting in a LM trajectory that nominally intercepts the CSM at the predetermined aimpoint.

6. Midcourse corrections within the  $\Delta V$  constraints to reduce dispersions about the nominal aimpoint.
  7. Terminal rendezvous guidance within the mission constraints including manual override to allow manual takeover for docking.
- B. The PGNS provides guidance to accomplish the following abort-related requirements:
1. Inject the Apollo space vehicle (CSM with LM attached) into a trans-earth trajectory that will achieve a safe atmospheric entry corridor in the event of a Service Module Propulsion Subsystem failure prior to LM - CSM separation.
  2. To insert the LM (during ascent) into a nominal intercept trajectory with the CSM for a short time of flight with the  $\Delta V$ , propulsion, vehicle dynamics, and crew limitations.
  3. To inject the LM into an approximately circular orbit at an altitude of about 50,000 feet.
  4. Midcourse corrections within  $\Delta V$  budget constraints to reduce dispersions about the nominal aimpoint.
  5. Terminal rendezvous guidance within the mission constraints including manual takeover for docking.

The PGNS has the capability of accomplishing the powered ascent portion of the above aborts with the descent and/or the ascent engine as determined by the quantity of fuel remaining in the descent stage. It also has the capability of accomplishing the midcourse corrections and terminal rendezvous portions of these aborts with the RCS thrusters, the descent engine, the ascent engine, or appropriate combinations of these.

The PGNS is an aggregate of sections. These sections create display drive signals, data processing, measurements, and control functions required to navigate and to guide the LM for a successful bi-directional mission. The navigation function deals with the position and velocity of the LM along various sets of axes. Error signals are generated to be used for trajectory corrections in order to achieve safe lunar landing, lunar stay, ascent, and docking with the CSM in orbit. The guidance function deals with RCS and main engine (descent or ascent engine) thrust, vehicle attitude, and the generation of signals to control the LM RCS and Propulsion Subsystem.

The PGNS uses optical, inertial, and radar sensors, a general purpose digital computer, associated displays, control panels, and support equipment.

The LM PGNS consists of:

1. Alignment Optical Telescope (AOT)
2. Inertial Measuring Unit (IMU)
3. Radars
  - a. Landing Radar (LR)
  - b. Rendezvous Radar/Transponder (RR/T)
4. LM Guidance Computer (LGC)
5. Electronic Coupling Data Units (ECDU's)
6. Pulse Torque Assembly (PTA)
7. Power and Servo Assembly (PSA)
8. Display and Keyboard (DSKY)
9. Landing Point Designator (LPD)
10. Signal Conditioning Assembly (SCA)

The pieces of the above equipment which are Government Furnished Equipment (GFE) include:



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1. Inertial Measuring Unit (IMU)
2. Power and Servo Assembly (PSA)
3. Signal Conditioning Assembly (SCA)
4. Pulse Torquing Assembly (PTA)
5. Electronic Coupling Data Units (ECDU's)
6. LM Guidance Computer (LGC)
7. Display and Keyboard (DSKY)
8. Alignment Optical Telescope (AOT)

The jets of the Reaction Control Subsystem (RCS), the descent engine, and the ascent engine are used to control the rate of rotation, rate of translation, attitude, and position of the LM. Signals from the PGNS are routed to the jet drivers and engine control assemblies in the Control Electronics Section (CES) of the Stabilization and Control Subsystem (SCS).

An astronaut maneuvers the AOT to obtain angles between the Lines-of-Sight (LOS) to stars and the LM body axes. The astronaut provides the LGC with this information through the DSKY. The LGC is thus enabled to send alignment signals (some through ECDU's) to the IMU. The IMU is sensitive to changes in the LM attitude and to changes in LM translatory thrust velocities. CDU's send this information to the LGC for processing, corrective action, if required, and display.

The LR functions as a radar altimeter and as doppler velocity sensors. It furnishes:

1. Range along an altitude radar beam.
2. Velocity data in antenna coordinates.
3. Velocity data in a coordinate system convenient for displays.

Much of this information is required by, and hence is routed to, the LGC.

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The RR/T uses an amplitude comparison, monopulse scheme in conjunction with a Cassegrainian antenna for tracking the transponder on the CSM by virtue of its triggered transmission.

This system furnishes:

1. Range
2. Range Rate
3. Direction angles to tracked object.

The Transponder section of the RR/T is mounted on the CSM and is capable of being coherently tracked by the RR in the LM. Its transmission is triggered by the signal received from the RR in the LM.

The LGC accepts inputs from the LR, RR, IMU, and DSKY; it processes the information to obtain LM position, velocity, acceleration, attitude, and timing information for:

1. Guidance and Control computation
2. Displays to the flight crew
3. Alignment of the Abort Guidance Section (AGS)
4. Telemetry to Earth

A Display and Keyboard (DSKY) accepts navigational data inserted by the flight crew, and displays other information obtained by processing sensor output data in the LGC for guidance monitoring.

The PGNS has two primary modes of operation (Automatic and Manual), and three secondary modes of operation (Alignment, IMU Temperature control, and LGC control).

In the Automatic mode, the PGNS generates and exports the commands required to effect thrust vector control and/or LM stabilization control. In the Manual mode, the PGNS generates and exports the commands as directed by the crew via the hand controllers.



In the alignment mode the stable element of the IMU is aligned by using the flight crew inputs to the DSKY to initiate each of the three phases of this mode. In the zero mode phase the gimbal angle registers in certain ECDU's, and in the LGC are set to zero. This initiating signal is also sent to the AGS. The Coarse Align Mode is used for the initial coarse alignment of the IMU stable element by torquing the gimbals with ECDU error signals derived from LGC specified gimbal angles. The Fine Align Mode Phase is used for the fine adjustment of the IMU stable element to the preferred space axes.

Three integrated circuits comprise the system used for the IMU Temperature Control Mode (Temperature Control Circuit, Alarm Circuit, and Blower Control Circuit). This control, which is completely automatic, remains in operation once power is applied by closing an IMU standby switch. Control of the IMU temperature is continuous during shipping, transportation, and shelf time.

The operating modes for the LGC are:

1. Power off
2. Standby (LGC clock on)
3. Power on

Once the LGC is initialized, the power is not turned off; the standby mode is used for retention of data.

### 7.1.3 Interfaces

The PGNS interfaces with the Control Electronics Section (CES) to perform the following functions:

- A. Out of Detent-Signals from the attitude controller stick advises LGC when; and that the attitude controller stick is not in the neutral position.

- B. X, Y, or Z translation - LGC commands translation by ON/OFF firing of the necessary RCS jets.
- C. Engine ON Command - Initiates engine start sequence.
- D. Engine OFF Command - Initiates engine stop sequence.
- E. Increase Throttle - LGC commands the DE thrust to increase.
- F. Decrease Throttle - LGC commands the DE thrust to decrease.
- G.  $\pm$  Pitch Gimbal Trim Commands - LGC signals CES to position the DE gimbal.
- H.  $\pm$  Roll Gimbal Trim Commands - LGC signals CES to position the DE gimbal.
- I. 16 RCS Jet ON Commands - LGC signals to the jet driver pre-amplifiers.
- J. Pitch, Roll, and Yaw Proportional Rate Commands - Attitude signals from Attitude Controller.
- K. Pitch Gimbal or Roll Gimbal - Signals to advise LGC of DE pitch gimbal or DE roll gimbal failure.

The PGNS interfaces with the Abort Guidance Section (AGS) to perform the following functions:

- A.  $\pm$ Aig - Increments of inner gimbal angle used in transfer of alignment to the AGS.
- B.  $\pm$  A mg - Increments of middle gimbal angle used in transfer of alignment to the AGS.
- C.  $\pm$  A og - Increments of outer gimbal angle used in transfer of alignment to the AGS.
- D. CDU Zero (Initial Clear) - Signal to advise AGS that PGNS is zeroing the CDU's.
- E. Serial Digital Data - LGC downlink data.

The PGNS interfaces with the Instrumentation Subsystem (IS) to perform the following functions:

- A. Synch (1024 KPPS) - Synchronize LM master timing equipment with the LGC.

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- B. Serial Digital Data - Digital data from LGC for downlink.
  - C. Start Pulse - Signal to indicate start of LGC downlink word transmission.
  - D. Stop Pulse - Signal to indicate end of LGC downlink transmission.
  - E. Bit Synch Pulses - Synchronized serial bits transmitted through downlink between start and stop pulses.
  - F. PGNS Status Data Discretes - PGNS Caution and Warning signals to Instrumentation for Control Panel Display and Telemetry.
  - G. PGNS Status Analog Data - Analog data to the IS for telemetry.
- The PGNS interfaces with the Explosive Devices Subsystem (EDS)

for performance of the following functions:

- A. To receive:
  - a. Abort command signals
  - b. Staging information
- B. Staged Status - Removes stage status signal from LGC at stage operation.

The PGNS also interfaces with the:

- A. Ascent Stage Structure - Provision is made for the required physical bonding and alignment for the RR antenna, AOT, IMU, and PTA.
- B. Descent Stage Structure - Provision is made for the required bonding and alignment for the LR antenna.
- C. Electrical power subsystem - The PGNS accepts the required electrical power for the particular loads incorporated in the PGNS.
- D. Ground Support Equipment (GSE) - The PGNS and the GSE exchange intelligence required for ground (Prelaunch) testing.
- E. Command and Service Module (CSM) - The RR of the LM PGNS tracks the CSM Transponder.

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#### 7.1.4 Abort Guidance Section (AGS)

The Abort Guidance Control path, consisting of the AGS and the CES, is provided to increase crew safety. The AGS performs guidance computations and steering required to place the LM in a direct intercept trajectory with the CSM or in an elliptical lunar parking orbit with minimum pericynthion of 30,000 feet upon abort from descent, powered ascent, or from the lunar surface. During coasting phases of flight, the AGS supplies an inertial attitude reference and measures transfer and midcourse  $\Delta V$ . The AGS midcourse correction  $\Delta V$  and rendezvous maneuvers are manually controlled.

The AGS uses a strap-down inertial technique instead of an inertial platform as used in the IMU. Where the inertial platform relies on a stabilized gimbal system to maintain fixed accelerometer orientation, the strap-down system measures the accelerometer rotation from a fixed reference frame and resolves the acceleration into the fixed reference frame. The AGS employs three gyros and three accelerometers. Angular velocity data from the gyros is processed to update vehicle attitude and resolve acceleration data. From this information the remainder of the computations may be made (navigation, guidance, steering, display information, etc.). The AGS is initially aligned to the PGNS for attitude, velocity, and position data. Guidance and steering are initiated only if the PGNS has malfunctioned.

The AGS consists of three assemblies; the Abort Sensor Assembly (ASA), the Abort Electronics Assembly (AEA), and the Data Entry and Display Assembly (DEDA).

##### A. Abort Sensor Assembly (ASA)

The ASA is a strap-down inertial sensor package containing three pulse rebalanced rate integrating gyros and three pulse rebalanced accelerometers with their associated electronics and power supply. The ASA outputs are incremental angle changes about the LM axes and



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incremental velocity changes along the LM axes. These data are sent to the Abort Electronics Assembly for guidance and navigation computations.

B. Abort Electronics Assembly (AEA)

The AEA is a 1.024 mc, 18-bit serial-parallel general purpose digital computer. The computer contains a 4096 word ferrite-core memory divided into a non-eraseable fixed program and an eraseable scratch pad. All arithmetic operations are performed by addition, transfer, and complement operations. The AEA performs the computations necessary for abort guidance, navigation, steering, and required displays. It contains all input/output circuitry required to interface with the ASA, CES, controls and displays, and PGNS. Incremental body rotations and velocity changes are received from the ASA. The interface with the PGNS is for initial conditions insertion of attitude, position, and velocity. Steering signals and propulsion commands are sent to the CES.

C. Data Entry and Display Assembly (DEDA)

The DEDA is a keyboard and display for astronaut communication with the AEA. The crew manually uses the DEDA to control the AGS modes of operation, insert data into the AEA, and command the contents of a desired AEA memory word location to be displayed on the DEDA.

7.1.5 AGS Modes of Operation

The AGS operates in three modes: OFF, STANDBY, and OPERATE.

These modes are selected by the crew by means of the AGS STATUS switch on the control panel.

- A. OFF MODE - During the OFF MODE the only function performed by the AGS is to apply excitation to the fast warm-up heaters of the ASA.
- B. STANDBY MODE - During the STANDBY MODE the AGS performs the following:

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- 1. Provides excitation and power for all subassemblies within the ASA.
  - 2. Provides "degraded" operation after a 10 minute period.
  - 3. Provides the capability of entering the alignment mode after a 35 minute period.
  - 4. Provides the capability of accepting PGNS alignment information twenty seconds after entering this mode.
- C. OPERATE MODE - The OPERATE MODE incorporates the alignment and inertial reference submodes. Selection of the desired submode is controlled by manually inserting the proper command into the DEDA.
- 1. Alignment - One of three alignment submodes, IMU, LUNAR, and ORBITAL can be selected via the DEDA. When the AGS is aligned via the PGNS the IMU alignment submode is used. In this submode the AGS aligns to the inertial reference frame of the IMU. If the AGS is aligned on the lunar surface and the PGNS is inoperative the LUNAR alignment submode is used. In this submode the AGS uses the local vertical and the orbital plane of the Command and Service Module as reference. The local vertical is sensed by the ASA accelerometers. The value of the outer gimbal angle or equivalent angle will be determined at lunar touchdown from the PGNS or AGS, and will be updated prior to lunar alignment for launch by voice link information defining CSM orbital inclination and LM landing site lunar latitude. When the AGS is aligned in orbit and no external information is available the ORBITAL alignment submode is used. In this submode the AGS aligns itself to the body axes, i.e., the AGS Euler angles are equal to zero.



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2. Inertial Reference - When the AGS is operating in the inertial reference mode, it provides signals to the CES for vehicle stabilization and/or for directing vehicle abort. The three submodes available are Automatic, attitude Hold, and Followup. When operating in the Automatic submode, the AGS generates signals necessary to guide the LM to a safe parking orbit or to a direct rendezvous with the CSM. In the Attitude Hold sub-mode the AGS generates attitude error signals which will maintain the vehicle attitude which existed upon entering this submode. In the Followup submode, the attitude error is reduced to zero during any change in vehicle attitude.

#### 7.1.6 AGS Interfaces

- A. CES - The AGS receives Engine On, Abort Stage, and Mode signals from the CES. The AGS provides the CES with steering signals and engine commands during abort.
- B. Instrumentation Subsystem - The AGS receives its basic clock signal and Telemetry Control signals from the IS. The AGS supplies a Digital Telemetry signal and required outputs for test instrumentation.
- C. PGNS - The AGS receives IMU gimbal angle increments and downlink information on position and velocity from the PGNS.
- D. Explosive Devices Subsystem - The Abort button provides the closure to inform the AGS of an abort condition.
- E. Displays - The AGS provides the displays with:
  - a. Total vehicle attitude
  - b. Attitude error
  - c. Lateral Velocity
  - d. Altitude
  - e. Altitude rate

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#### 7.1.7 Landing Radar

The Landing Radar (LR) senses LM velocity and altitude with respect to the lunar surface when the LM is moving in a tangential approach to the lunar surface and when it rotates to a vertical attitude to complete its final descent. Velocity and altitude information is applied to the LM guidance computer (LGC), where it is used to check or update inertially derived data, and is also displayed during descent from an altitude of 40,000 feet to touchdown. The LR is composed of an antenna assembly, electronics assembly, and a control assembly; it is functionally divided into a three-beam, continuous wave, doppler velocity sensor and a narrowbeam, linear radar altimeter. The antenna assembly consists of a space-duplexed array of Transmit and Receive antennas on which the solid-state transmitters, modulator, detectors, preamplifiers, test modulators, and waveguides are mounted. The Transmit array generates four beams, three of which are arranged in a lambda configuration and used by the doppler velocity sensor: the fourth beam is used by the Radar Altimeter. The Receiving antennas consist of four individual broadside arrays. The Receiving array beam-widths are wider than those of the Transmit array; therefore, antenna boresighting is not critical. The electronics assembly contains the frequency trackers, coordinate converters, high-speed counter, and the power supply. It provides binary word outputs (to the LGC) that correspond to the range along the altitude beam. Prf outputs to the controls and displays permit display of the LM velocity components ( $V_x$ ,  $V_y$ , and  $V_z$ ), and range along the altitude beam. The LR supplies accurate data from 25,000 feet to touchdown without altitude holes and has provisions for hovering and negative speeds. Self-test devices within the LR enable operational checks of the entire LR without radar returns from the lunar surface; the astronauts can evaluate the operational status of the LR at any time during the LM mission.



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#### 7.1.8 Doppler Velocity Sensor

The Doppler Velocity Sensor consists of a solid-state transmitter, frequency trackers, and beam-to-orthogonal velocity converters: it provides the desired doppler frequencies and LM component velocity outputs. The received energy from each beam is detected with the direct-to-audio detection technique. The received signals are detected in quadrature to retain sign sense and applied to dual preamplifiers. Unwanted transmitter leakage is heterodyned to zero and rejected because the detectors are ac coupled to the preamplifiers. The amplified quadrature doppler signals for each beam are then applied to velocity sensor frequency trackers, which search the band of expected doppler frequencies with a narrow bandwidth filter. When the doppler signal appears in the tracker band, the tracker locks on and continuously tracks and filters the doppler spectrum. The outputs of the velocity sensor frequency trackers are converted to  $V_x$ ,  $V_y$ ,  $V_z$  and applied to prf form to the high-speed counter and then to the LGC. The converter generates output signals representing three orthogonal velocities and range rate along the altitude beam, supplied in prf form to displays.

#### 7.1.9 Radar Altimeter

The Radar Altimeter is of the narrow beam linear, FM/CW type; it consists of a solid-state transmitter, frequency tracker, and an altitude converter and provides outputs that represent range along the altitude beam. The received energy is detected in a manner almost identical with that of the doppler velocity sensor. The detected quadrature signals are amplified in a dual preamplifier and applied to the altimeter frequency tracker. The frequency along the range beam is the sum of the range frequency and the doppler frequency ( $f_r + f_d$ ). The doppler component is removed in the altitude converter by mixing operations; the range frequency signal is applied to the altitude frequency converter, where the range signals are derived.

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#### 7.1.10 Rendezvous Radar/Transponder

The primary function of the Rendezvous Radar/Transponder (RR/T) is to provide range, range rate, and angle data to the LGC to enable computation of a trajectory from the moon to a point in space where the final docking of the LM to the CSM can begin. Outputs from the RR are displayed on the commander's center panel.

When the LM is on the lunar surface, the RR tracks the associated transponder in the CSM. During the LM ascent coasting phases, RR is used for monitoring or midcourse correction maneuvers.

When automatic operation of the RR is selected, the RR is controlled by inputs from the LGC. During manual operation, the astronauts control the RR with controls and indicators on the radar panel of the commander's lower console.

The RR antenna assembly includes a gyro-stabilized monopulse antenna; sum and difference hybrid networks; a duplexer; a high level, solid-state varactor-multiplier-transmitter; three mixers, and three i-f preamplifiers. The shaft-error receiver, sum channel receiver, and trunion-error receiver are identical i-f assemblies that convert the reference and error signals to an intermediate frequency of 1.7 mc. The sum-channel receiver output is used as a reference signal for the two phase-sensitive detectors within the angle track module. These detectors convert the output of the shaft and trunion-error receivers into two bipolar video angle-error signals.

The frequency synthesizer generates the basic stable frequencies required for operation of the frequency tracker, range tracker, modulator, and RR logic circuits. The range tracker provides range information in digital form to the LGC via the RR logic circuits and to the displays. During operation, a multitone ranging system is used; RR transmission is phase modulated with three sinewave tones. By comparing the phase of the received low frequency tone with the phase of transmitted tone, unambiguous range measurements can be made from 80 feet to 400 n.m. Similar phase comparisons made with the other two tones provide



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successive refinement of ranging accuracy. The lower frequency tone is used for coarse range data extraction while the upper frequency tone provides fine range data. The range rate data is extracted by the RR doppler frequency tracker, which nulls through the band of expected received doppler frequencies. The output of the doppler frequency tracker represents the range rate data.

The angle track module converts the shaft- and trunnion-error signals to dc error signals which are used to position the RR antenna. In addition, the angle tracker generates the AGC signal that is displayed on the radar panel and regulates the gain of the i-f amplifiers.

The RR logic circuits provide the interfaces between the RR and the LGC. Radar output signals are processed into the format required by the LGC and selected sequentially for transfer by coded strobe signals generated by the LGC.

#### 7.1.11 Alignment Optical Telescope

The Alignment Optical Telescope (AOT) is a nonarticulating, unit power, 60° field-of-view telescope for aligning the Inertial Measurement Unit. The AOT provides the astronauts with data obtained by measuring angles between lines of sight to celestial bodies to establish the inertial reference. The telescope optics mechanism has three viewing positions and a stowage position. Data obtained with the AOT is manually entered into the LGC.

#### 7.1.12 Inertial Measurement Unit

The Inertial Measurement Unit (IMU) is the primary inertial sensing device of the LM. Three integrating gyroscopes and three pendulous accelerometers are mounted on the innermost gimbal of a three-degree-of-freedom gimbal system. The innermost gimbal is held nonrotating with respect to inertial space by the three gimbal servos, which derive their input error signals from the three gyroscopes. The orthogonal input axes of the three accelerometers represent the LM X, Y, and Z axes. Velocity changes along these axes are sensed by the accelerometers, which produce signals that represent incremental changes in velocity

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and apply them to the LGC for the calculation of total velocity. Signals proportional to the attitude of the LM are generated by the inner, middle, and outer gimbal angle resolvers. These signals are applied to the LGC and to the displays. The LGC calculates gimbal angles that would result from bringing the LM to a desired attitude and compares these with the actual gimbal angles supplied by the gimbal angle resolvers. Any difference between the actual and calculated gimbal angles results in generation of steering-error signals, which are applied to the descent engine trim gimbal system during descent and to the Reaction Control Subsystem (RCS) jet driver during all mission phases, to correct the attitude of the LM.

#### 7.1.13 Coupling Data Units

The Coupling Data Units (CDU's) convert and transfer angular information between major elements of the G&N Subsystem and the Stabilization and Control Subsystem (SCS). The PG&N subsystem uses five CDU's: one for the shaft axis, one for the trunnion axis of the RR antenna, and one for each of the three gimbals of the IMU.

The two CDU's used with the RR antenna provide interfaces between the antenna and the LGC. The LGC calculates digital antenna position cammands before acquisition of the CSM transponder. These signals are converted into analog form by the CDU's and applied to the antenna drive mechanism to aim the antenna toward the CSM. Following transponder acquisition, tracking information is digitized by the CDU's and applied to the LGC.

The three CDU's used with the IMU provide interfaces between the IMU and the LGC, and between the LGC and the SCS. Each IMU gimbal angle resolver provides its CDU with analog gimbal angle signals that represent the attitude of the LM. The CDU converts these signals to digital form and applies them to the LGC. The LGC uses these signals to calculate necessary attitude or translation commands and routes the commands through the SCS to the proper RCS jets. The CDU converts

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the steering-error signals to 800 cps analog signals and applies them to the flight director attitude indicator. IMU coarse and fine align commands, generated by the LGC are coupled to the IMU.

The digital CDU principle is based upon the use of ac analog computing techniques to derive error voltages from analog resolver angle signals. Digital circuitry continuously alters the analog computational scaling factor to null the error voltages. When this null occurs, the state of the digital memory drive circuit exactly corresponds to the resolver position.

#### 7.1.14 LM Guidance Computer

The LM Guidance Computer (LGC) is the central data-processing device of the PG&N subsystem. It is a parallel, fixed-point, one's-complement, general-purpose digital computer with a fixed rope core memory, an erasable ferrite core memory, and a limited self-check capability. Inputs to the LGC are received from the landing and rendezvous radars, from the IMU through the coupling data units, and from an astronaut via the data entry keyboard on the primary guidance and navigation panel. The LGC performs four major functions: (1) calculates steering signals and generates engine and RCS jet commands to keep the LM on a required trajectory, (2) aligns the stable member (innermost gimbal) of the IMU to a coordinate system defined by precise optical measurements, (3) conducts limited malfunction isolation of the PG&N subsystem, and (4) computes pertinent navigation information for display to the astronauts. Using information from navigation fixes, the LGC determines the amount of deviation from the required trajectory and calculates the necessary attitude and thrust corrective commands. Velocity corrections are measured by the IMU and controlled by the LGC. During coasting phases of the mission, velocity corrections are not made continuously, but are initiated at predetermined checkpoints.

The LGC memory consists of an erasable and a fixed magnetic core memory with an approximate combined capacity of 35,000 16-bit words.

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The erasable memory is a coincident-current, ferrite core array with a total capacity of 2,048 words, and is characterized by destructive readout. Fixed memory consists of eight magnetic core rope modules, each with a capacity of 4,096 words.

Readout from fixed memory is nondestructive. The operating logic of the LGC is mechanized with micrologic elements where the necessary resistors and transistors are diffused into single silicon wafers. Flip-flops, registers, counters, etc., are composed of standard NOR elements in different wiring configurations. The LGC performs all necessary arithmetic operations by addition, adding two complete words and preparing for the next operation in approximately 24 microseconds. To subtract, the LGC adds the complement of the subtrahend. Multiplication is performed by successive additions and shifting; division, by successive addition of complements and shifting.

#### 7.1.15 Power and Servo Assembly

The Power and Servo Assembly (PSA) provides a central mounting place for most of the PG&N subsystem amplifiers, modular electronic components, and power supplies. The PSA consists of the following subassemblies: gimbal, servo, align, and power amplifiers, CDU electronics, power diodes and signal conditioners, and power supplies. A coldplate through which water-glycol coolant from the ECS flows, is mounted under the PSA subassemblies to dissipate heat.

#### 7.1.16 PIPA and IRIG Electronics

The Pulsed Integrating Pendulous Accelerometer (PIPA) and Inertial Rate Integrating Gyro (IRIG) consists of the gyro and accelerometer amplifiers and electronics.

#### 7.1.17 Thrust Control (Ascent - Descent Engine)

The propulsion system contains two engines; a throttleable, restartable, gimballed descent engine of 10,500 pounds thrust and fixed non-throttleable, restartable ascent engine of about 3,500 pounds thrust.



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Automatic On/Off control of each engine is provided by commands from the PGNS or AGS with manual override capability. Both automatic (PGNS) and manual throttle control are provided for the descent engine over 10 to 100 percent thrust range (1050 pounds to 10,500 pounds thrust). Gimbal actuation signals, derived from the PGNS or CES Y and Z-axis attitude error channels are used for automatic thrust vector trim control of the descent engine.

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## 7.2 PRIMARY GUIDANCE SYSTEM GENERAL NOTES

- A. For the AS-206A Mission, the LGC will function as a completely automatic programmer that will control all onboard functions for the unmanned vehicle. The PGNS will automatically accomplish all guidance, navigation, and control of the LM. An uplink command capability exists for the LM to provide a limited amount of program change, in real time, by ground control. Table 7-1 is a list of uplink words and keycodes that will be used to update the PGNS Program. A major failure with either the LGC or IMU will automatically remove PGNS from control of the vehicle. This will force the LM into a PRA or ground RTC backup control. A major failure to PGNS would prevent any long APS or DPS test on the unmanned LM.
- B. The LGC will perform all functions that are normally accomplished by the astronaut to control the unmanned LM. A 12-bit parallel word is sent from the LGC to the PCA for controlling relay functions in the LMP. This parallel word consists of eight bits for a command and a four-bit enable code to enable the PCA decoder. Should the four-bit enable code show an error, the LGC command is inhibited and will not be accepted by the LMP. All other commands and inputs to and from the LM will be executed in normal methods such as auto throttle, engine ON/OFF, descent gimbal drive, etc.
- C. The Rendezvous Radar (RR) and Alignment Optical Telescope (AOT) will not be used on the unmanned flight.
- D. The Inertial Measurement Unit (IMU) is aligned at prelaunch to a Cape Kennedy inertial reference coordinate system and will remain unchanged throughout the flight. There is no update of the inertial reference after liftoff, and the system will be in the inertial reference mode continuously. A guidance reference release signal will be executed just prior to

liftoff to place the IMU in the inertial reference mode.  
The PGNS system will be completely operative from approximately T-12 hours to end of flight.

E. The following RTC capability is provided by the PCA:

1. Landing Radar ON (04B, K1751)  
Supplies power to the landing radar.
2. Landing Radar OFF (05B, K1752)  
Turns off landing radar.
3. AGS SEL (40B, K2059)  
Enables AGS guidance control mode and PRA control to the Program Coupler Assembly, commands PRA to stop, enables auto engine stop for a PGNS controlled engine, selects manual throttle, and disables auto throttle.

NOTE

AGS will be selected automatically in the event that an ISS fail or LGC fail discrete is generated by the PGNS.

4. PGNS SEL (41B, K2059, preset)  
Enables PGNS guidance control mode and LGC control to Program Coupler Assembly, removes auto engine stop inhibit and enables auto throttle control.

TABLE 7-1 UPLINK FORMAT

<u>Keycodes</u>	<u>Uplink Word (Octal)</u>
+	1 6 4 2 7 2
-	1 6 6 2 3 3
0	1 4 0 7 6 0
1	1 0 3 7 0 1
2	1 0 5 6 4 2
3	1 0 7 6 0 3
4	1 1 1 5 4 4
5	1 1 3 5 0 5
6	1 1 5 4 4 6
7	1 1 7 4 0 7
8	1 2 1 3 5 0
9	1 2 3 3 1 1
Verb	1 4 2 7 2 1
Noun	1 7 6 0 3 7
Enter	1 7 0 1 7 4
Error Reset	1 4 4 6 6 2
Clear	1 7 4 0 7 6
Key Release	1 6 2 3 3 1
Clear LGC	1 0 0 0 0 0

<u>Literal Definition</u>	<u>Verb</u> <u>Keycode (Octal)</u>
Modify Counter	70
Modify Counter Register	71
Modify Counter/Counter Register	72
Enable/Disable Major Programs (21, 22, 23, 24)	73
Halt	74
Execute Prime Relay	67
Message Accept	33

\*

TABLE 7-1 UPLINK FORMAT (Cont'd)

LM  
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REV A

<u>Verb (Cont'd)</u>	
<u>Literal Definition</u>	<u>Keycode (Octal)</u>
Message Terminate	34
Target Update	75
Guidance Reference Release	65
State Vector Update	76
LGC Clock Align	21
LGC Clock Increment	55
DPI T/M Calibrate	66

<u>Noun</u>	
<u>Literal Definition</u>	<u>Keycode (octal)</u>
Counter I	
Counter II	
Counter III	④ ①
Counter IV	
LGC Clock	16
Burn Phase Register I	01
Burn Phase Register II	02
Burn Phase Register III	03
Burn Phase Register IV	04
Burn Phase Register V	05

<u>Target and State Parameters</u>		
<u>Parameter</u>	<u>Octal Identifier</u>	
	<u>Most Significant Part</u>	<u>Least Significant Part</u>
R <sub>p</sub>	1	2
R <sub>I<sub>x</sub></sub>	1	2
R <sub>I<sub>y</sub></sub>	3	4
R <sub>I<sub>z</sub></sub>	5	6



\*

TABLE 7-1 UPLINK FORMAT (Cont'd)

LM  
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REV A

Target and State Parameters (Cont'd)

<u>Parameter</u>	<u>Octal Identifier</u>	
	<u>Most Significant Part</u>	<u>Least Significant Part</u>
$V_{Ix}$	7	10
$V_{Iy}$	11	12
$V_{Iz}$	13	14
$A_{Ix}$	15	16
$A_{Iy}$	17	20
$A_{Iz}$	21	22
$T_I$	23	--
$R_{IIx}$	24	25
$R_{IIy}$	26	27
$R_{IIz}$	30	31
$V_{IIx}$	32	33
$V_{IIy}$	34	35
$V_{IIz}$	36	37
$A_{IIx}$	40	41
$A_{IIy}$	42	43
$A_{IIz}$	44	45
$T_{II}$	46	--
$T_{III}$	47	--
$T_A$	1	--
$R_{CSMx} (T_A)$	2	3
$R_{CSMy} (T_A)$	4	5
$R_{CSMz} (T_A)$	6	7
$R_D$	10	11

TABLE 7-1 UPLINK FORMAT (Concl'd)

\*

Major Programs

<u>Literal Definition</u>	<u>Keycode (Octal)</u>
Prelaunch Initialization	01
Prelaunch Gyro Compassing	02
Prelaunch Inertial	07
Pre LET Jettison Boost Monitor	11
Post LET Jettison Boost Monitor	12
Coast S-IVB Attached	13
S-IVB/LM Separation	14
Manual Translation	21
Manual Rotation	22
Coast DPS Cold Soak	23
Coast RCS Cold Soak	24
Auto Translation	26
LGC Update	27
Pre DPS 1	31
Pre DPS 2	32
Pre APS 2	34
Pre APS 3	35
DPS Burn 1	41
DPS Burn 2 Phase I	42
DPS Burn 2 Phase II	43
DPS Burn 2 Phase III	44
APS Burn 2	46
APS Burn 3	47
Pre DPS 3	71
DPS Burn 3	72
APS Burn 1	73

\*

7.3 INERTIAL MEASUREMENT UNIT SCHEMATIC NOTES (Drawing 7.2.1

Notes:

1. All latching relays are shown in the reset position and all un-latching relays are shown in the de-energized position.

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LM  
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#### 7.4 COUPLING DATA UNIT SCHEMATIC NOTES (Drawing 7.3.1)

A. The following abbreviations are applicable to the CDU schematic:

1. Aig = Inner gimbal angle (actual)
2. Amg = Middle gimbal angle (actual)
3. Aog = Outer gimbal angle (actual)
4.  $\Delta A_{ic}$  = Increment of command angle (inner gimbal)
5.  $\Delta A_{mc}$  = Increment of command angle (middle gimbal)
6. Aoc = Increment of command angle (outer gimbal)
7. AGS = Abort Guidance System
8. CDU = Coupling Data Unit
9. CS = Crew Systems
10. EX = Attitude Error signal about X-axis
11. EY = Attitude Error signal about Y-axis
12. EZ = Attitude Error signal about Z-axis
13. IMU = Inertial Measurement Unit
14. ISS = Inertial Subsystem
15. LGC = LM Guidance Computer
16. PC = Percent
17. RR = Rendezvous Radar

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#### 7.5 COMPUTER SCHEMATIC NOTES (Drawing 7.4.1)

(To be supplied at a later date)



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LM  
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## 7.6 LANDING RADAR SCHEMATIC NOTES (Drawing 7.5.1)

A. The following abbreviations are applicable to the LR schematic:

1. F1 = Velocity transmitter frequency
2. F2 = Altimeter transmitter frequency
3.  $D1/0^\circ$  = Beam 1 doppler frequency spectrum
4.  $D1/90^\circ$  = Beam 1 doppler frequency spectrum shifted  $90^\circ$
5.  $D2/0^\circ$  = Beam 2 doppler frequency spectrum
6.  $D2/90^\circ$  = Beam 2 doppler frequency spectrum shifted  $90^\circ$
7.  $D3/0^\circ$  = Beam 3 doppler frequency spectrum
8.  $D3/90^\circ$  = Beam 3 doppler frequency spectrum shifted  $90^\circ$
9. FR = Transmitted/Received altimeter frequency spectrum difference
10.  $D4/0^\circ$  = Beam 4 doppler frequency spectrum
11.  $D4/90^\circ$  = Beam 4 doppler frequency spectrum shifted  $90^\circ$
12. Quadrature = Two signals differing in phase by  $90^\circ$
13. FC = 600 KCS
14. FR = Discrete frequency difference between altimeter transmitted and received frequencies.
15. D1 = Discrete center frequency of Beam 1 doppler spectrum
16. D2 = Discrete center frequency of Beam 2 doppler spectrum
17. D3 = Discrete center frequency of Beam 3 doppler spectrum
18. D4 = Discrete center frequency of Beam 4 doppler spectrum
19. VYA = Velocity component parallel to LM Y-axis
20. VXA = Velocity component along the antenna beam group center line.
21. VZA = Velocity component orthogonal to VXA and VYA and lying in a plane parallel to the LM XZ plane.
22. Range = Along the altimeter beam
23. VXA = Velocity along the altimeter beam

\*

LM  
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REV A

24.  $VYA$  = Velocity parallel to the LM Y-axis
25.  $VZA$  = Velocity orthonogonal to  $VXA$  and  $VYA$  lying in a plane parallel to the LM XZ plane.

\*

LM  
AS-206  
REV A

#### 7.7 RENDEZVOUS RADAR SCHEMATIC NOTES (Drawing 7.6.1)

- A. A complete Rendezvous Radar (RR) system will be onboard LM-1 (AS-206A). However, the system will be inoperative during the mission.

\*

7.8 ALIGNMENT OPTICAL TELESCOPE SCHEMATIC NOTES (Drawing 7.7.1)

- A. The Alignment Optical Telescope (AOT) will be onboard LM-1 (AS-206A). However, the system will be inoperative during the mission.



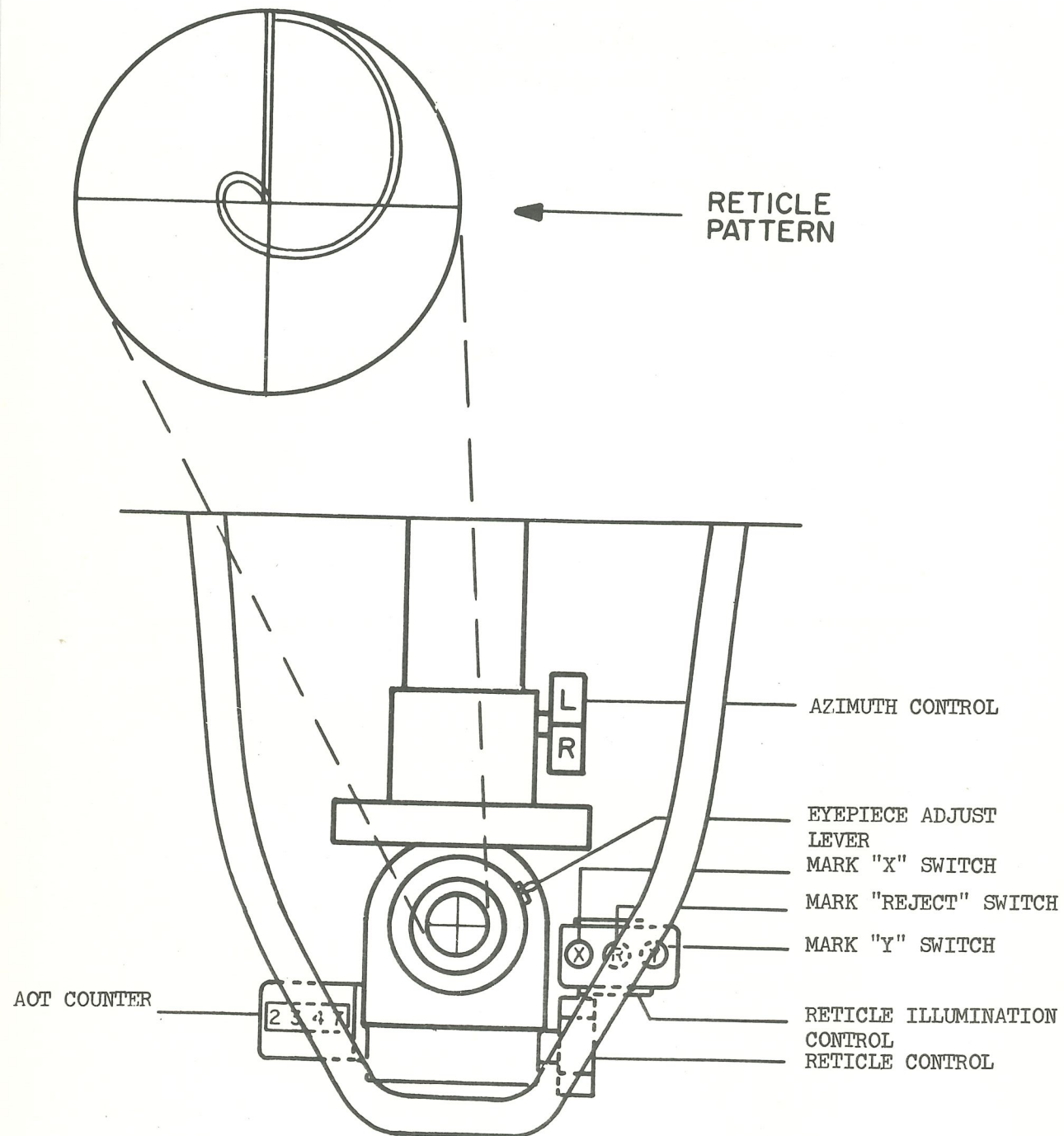


FIGURE 7-1 ALIGNMENT OPTICAL TELESCOPE

## 7.9 ABORT GUIDANCE SYSTEM GENERAL NOTES

- A. The Abort Guidance System for AS-206A will perform a backup attitude control function for the AS-206A, unmanned vehicle. The system is in "warmup" status at launch and will not be powered until after insertion. The LGC will place the system in "standby" status (for 25 minutes minimum) after insertion. The LGC will place the AGS in "operate" status at some undefined time during the flight. Throughout the PGNS control of the LM, the AGS will remain in the "followup" mode, and at AGS mode select it will control the attitude of the unmanned LM. No control capabilities of the AGS other than attitude control is presently planned.
- B. There will be no special earth orbit software or hardware change made to the AGS program. The ground can select one of two modes for AGS control, either attitude hold or the automatic attitude control. The AGS will normally be in the automatic control mode until changed by real-time command or PCA prime relays.
- C. If the lunar program is available for AS-206A, it will be installed and operated without modification. If the lunar program is not available, an interim modified lunar program for attitude control only will be installed for the unmanned flight.
- D. No position and velocity vectors are planned for the AGS program. The inertial reference for the AGS will not be updated during the AS-206A Mission; therefore, no known inertial reference will exist in the AGS during the mission. The lack of an inertial reference will normally preclude any major DPS or APS test and in the AGS mode, the minimum alternate propulsion test will be performed.
- E. The following RTC capability is provided by the PCA:
  1. AGS Standby (66A, K1154)

\*

LM  
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Places AGS in "standby" status providing that AGS was in warmup. Overrides Prime Relay (K1103) which has the same function.

2. AGS Standby Release (67A, K1154, Preset)  
Releases AGS standby function to Prime Relay (K1103) control, remaining in standby or going to warmup depending on the onboard program.
3. AGS Operate (72A, K1155)  
Places the AGS in operate status providing that the AGS was in standby status. Overrides Prime Relay (K1104) which has the same function.
4. AGS Operate Release (73A, K1155, Preset)  
Releases AGS operate function to Prime Relay (K1104) control, remains in "operate" (K1104 set) or goes to "standby" (K1104 Reset) on Prime Relay (K1104) condition.

\*

LM  
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REV A

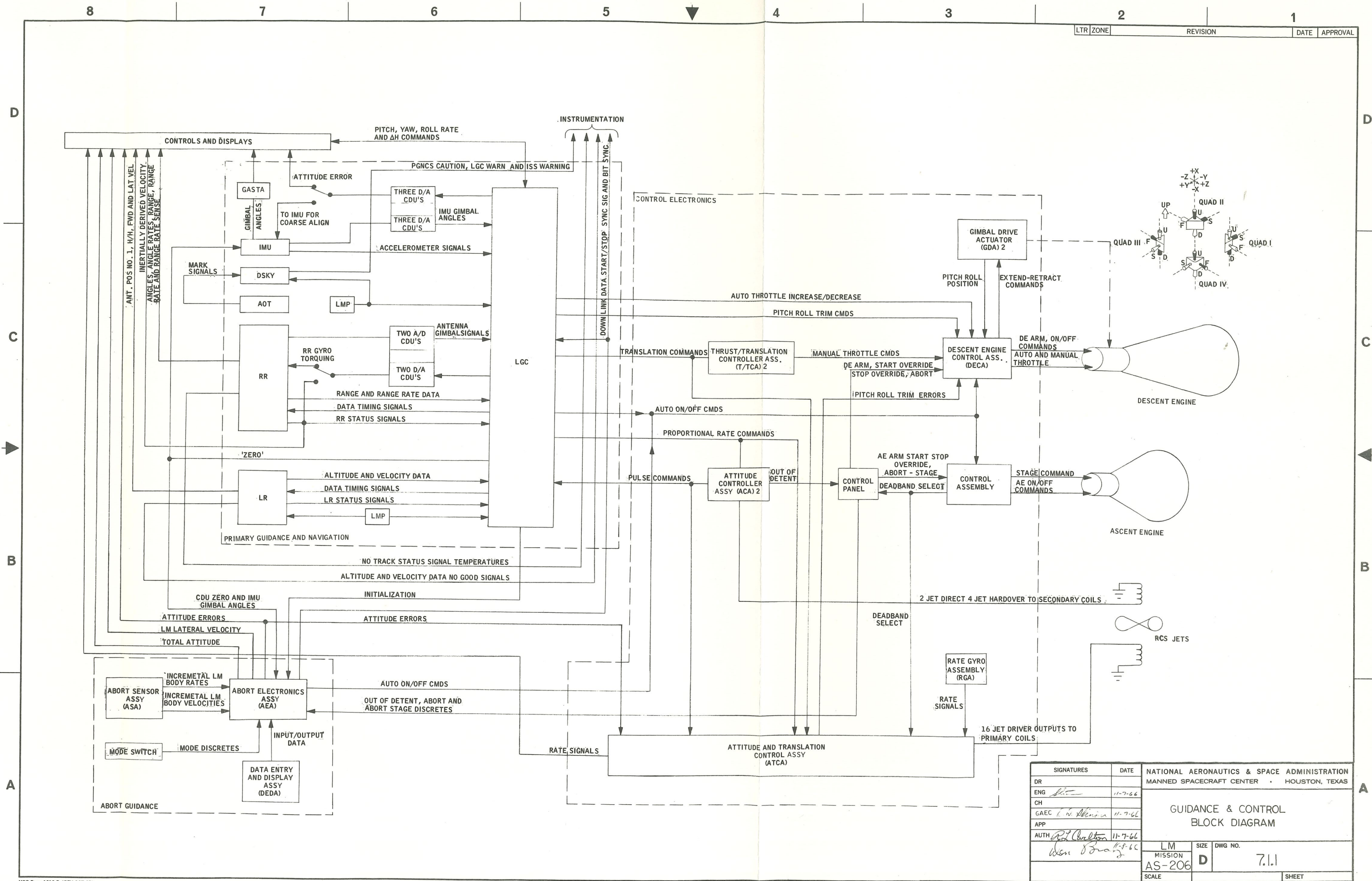
#### 7.10 ABORT SYSTEM SCHEMATIC NOTES (Drawing 7.9.1)

##### Notes:

- A. The existing LMP circuitry is such that the Prime Relay Master Reset will turn the AGS off. To prevent this from happening the PCA ground matrix relays K1154 (A11K16) and K1155 (A11K24) must be activated prior to activating the prime matrix master reset. Activating these relays will maintain the AGS operational and independent of the prime matrix master reset.
- B. AGS power supply fail warning light will operate with AGS warmup fail plus any one of the following;  
ASA 28 VDC fail, ASA 12 VDC fail, ASA test condition

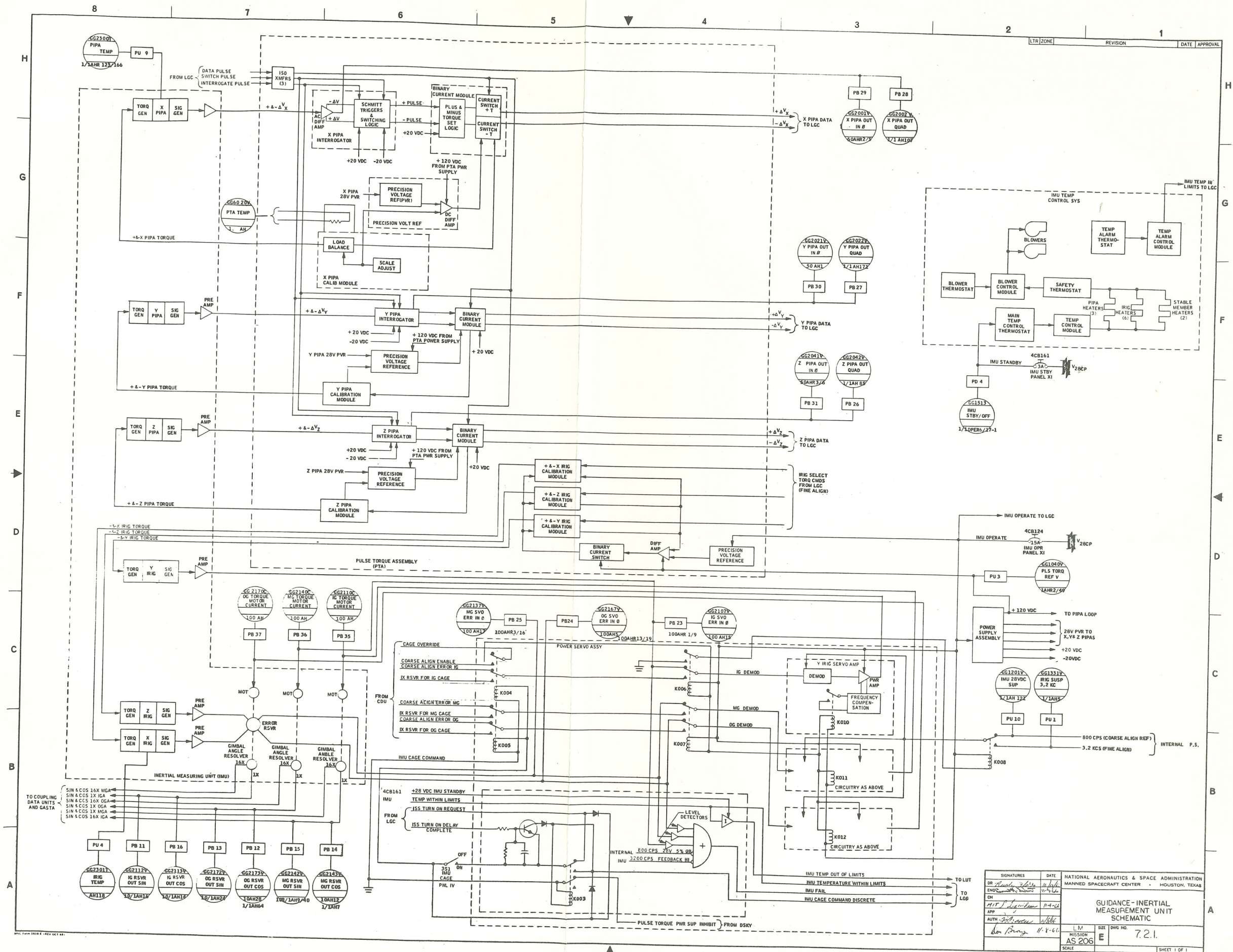
AGS warmup fail



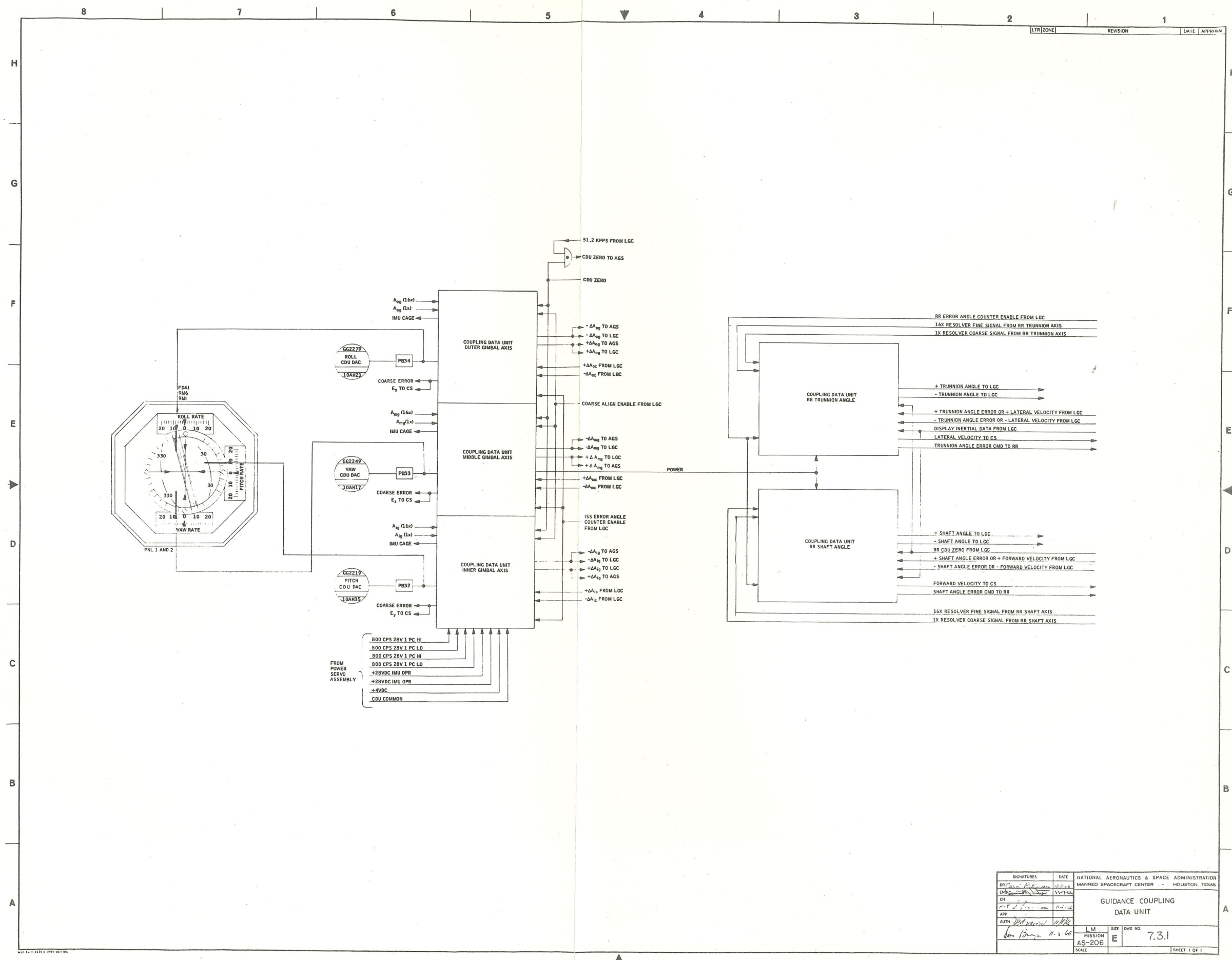


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GAEC	<i>[Signature]</i>	11-7-66		
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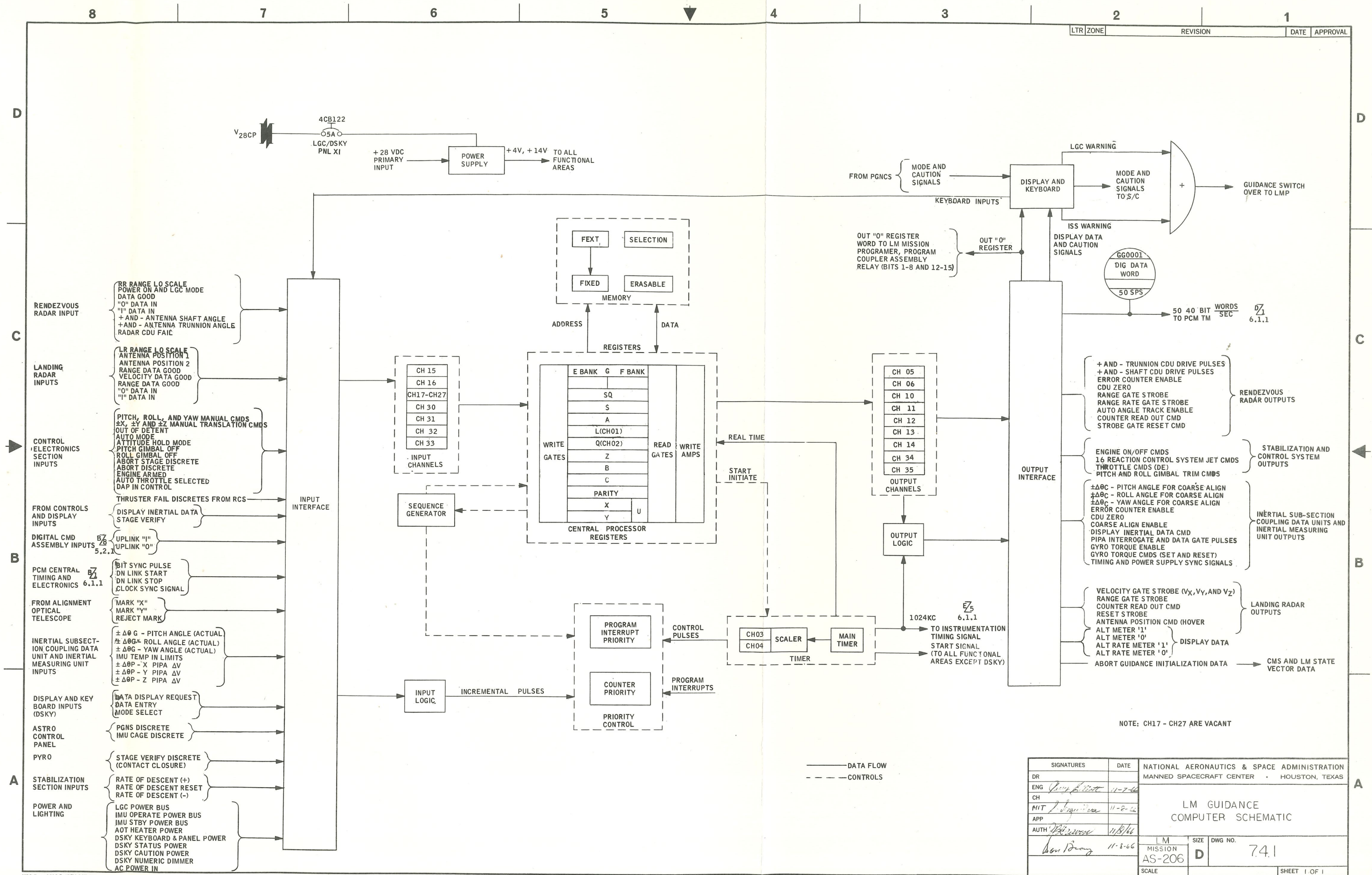


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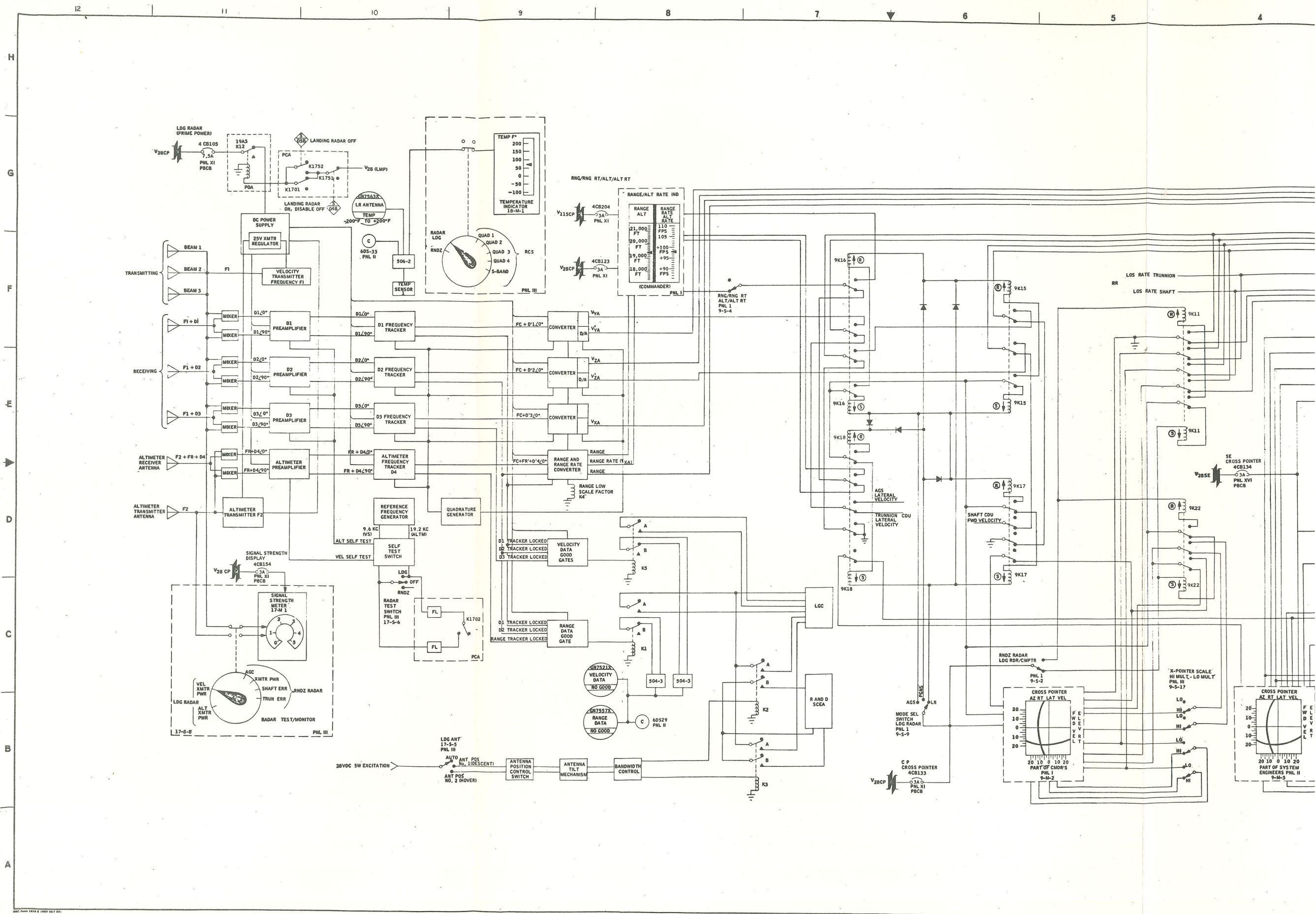


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CH			
MIT	11-8-66		
APP			
AUTH	11/8/66	MISSION AS-206	SIZE D
		SCALE	DWG NO. 7.4.1
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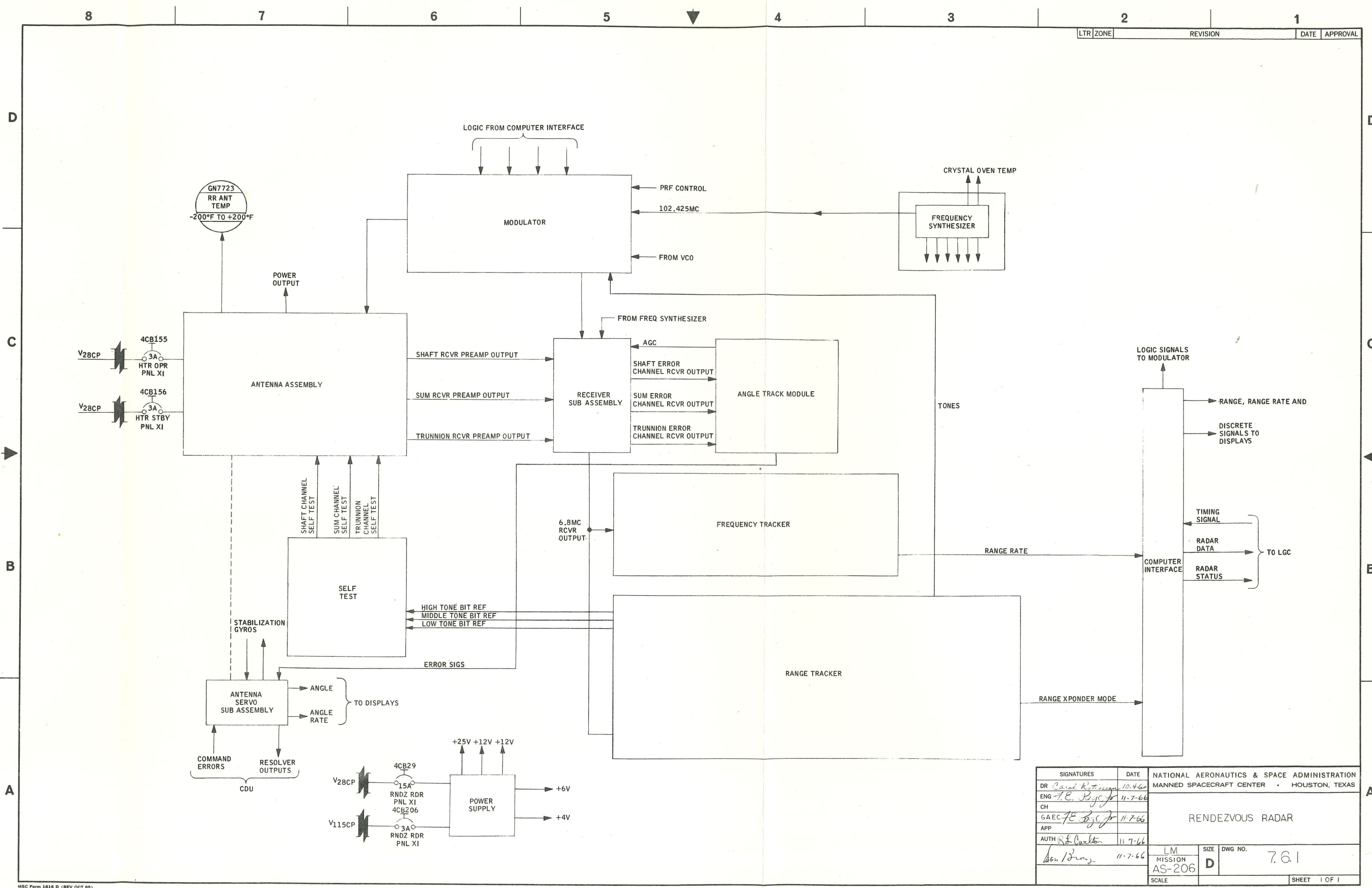




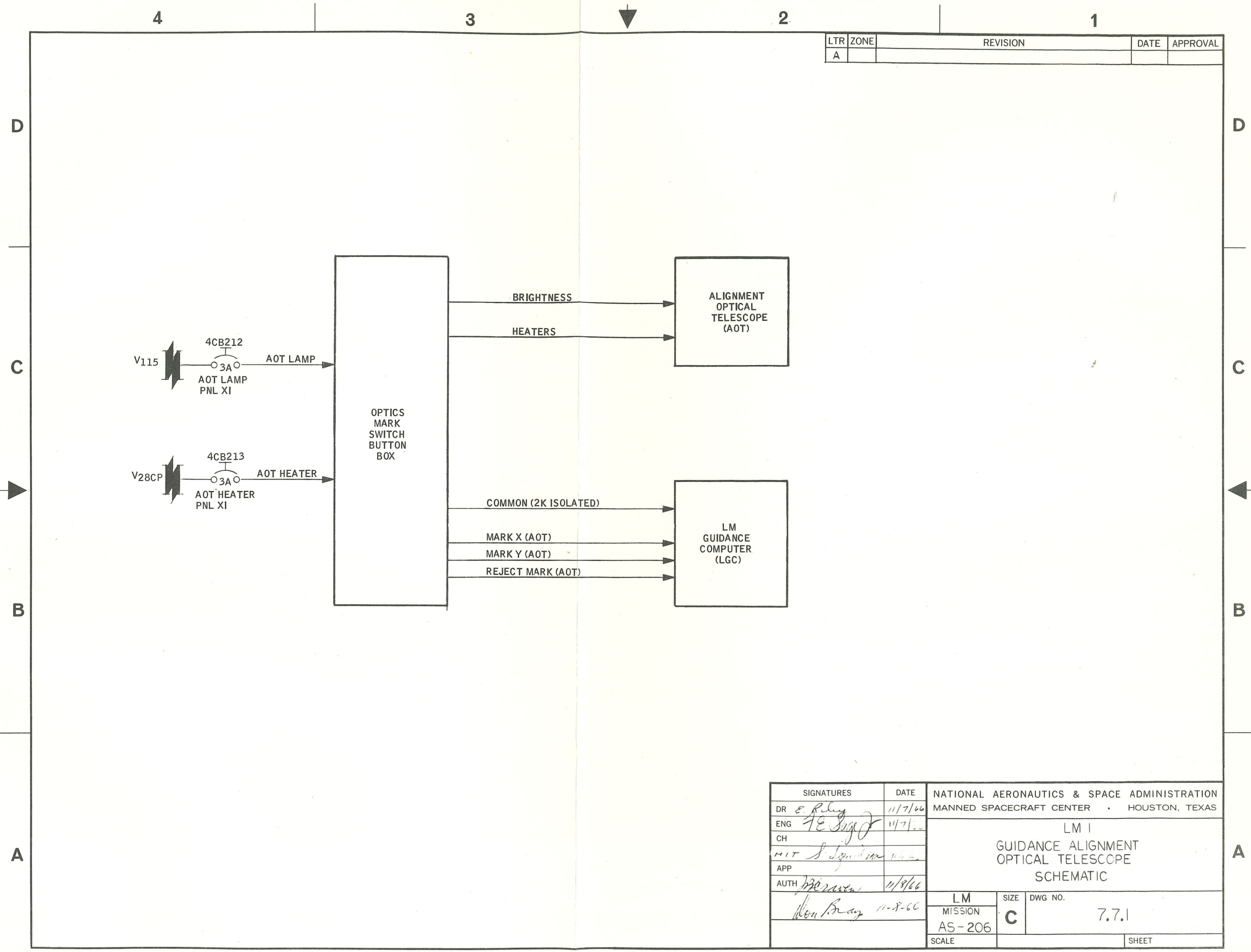


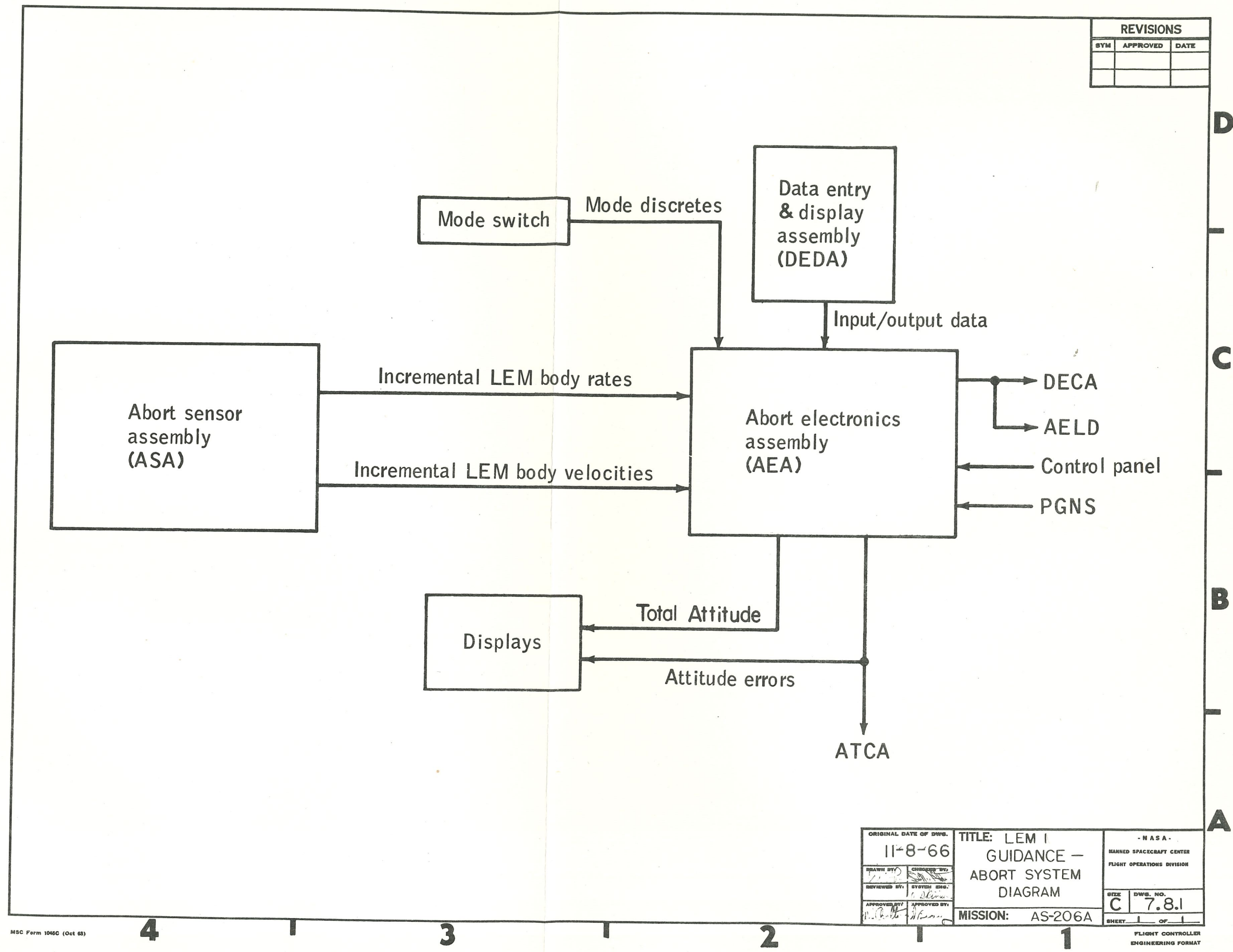






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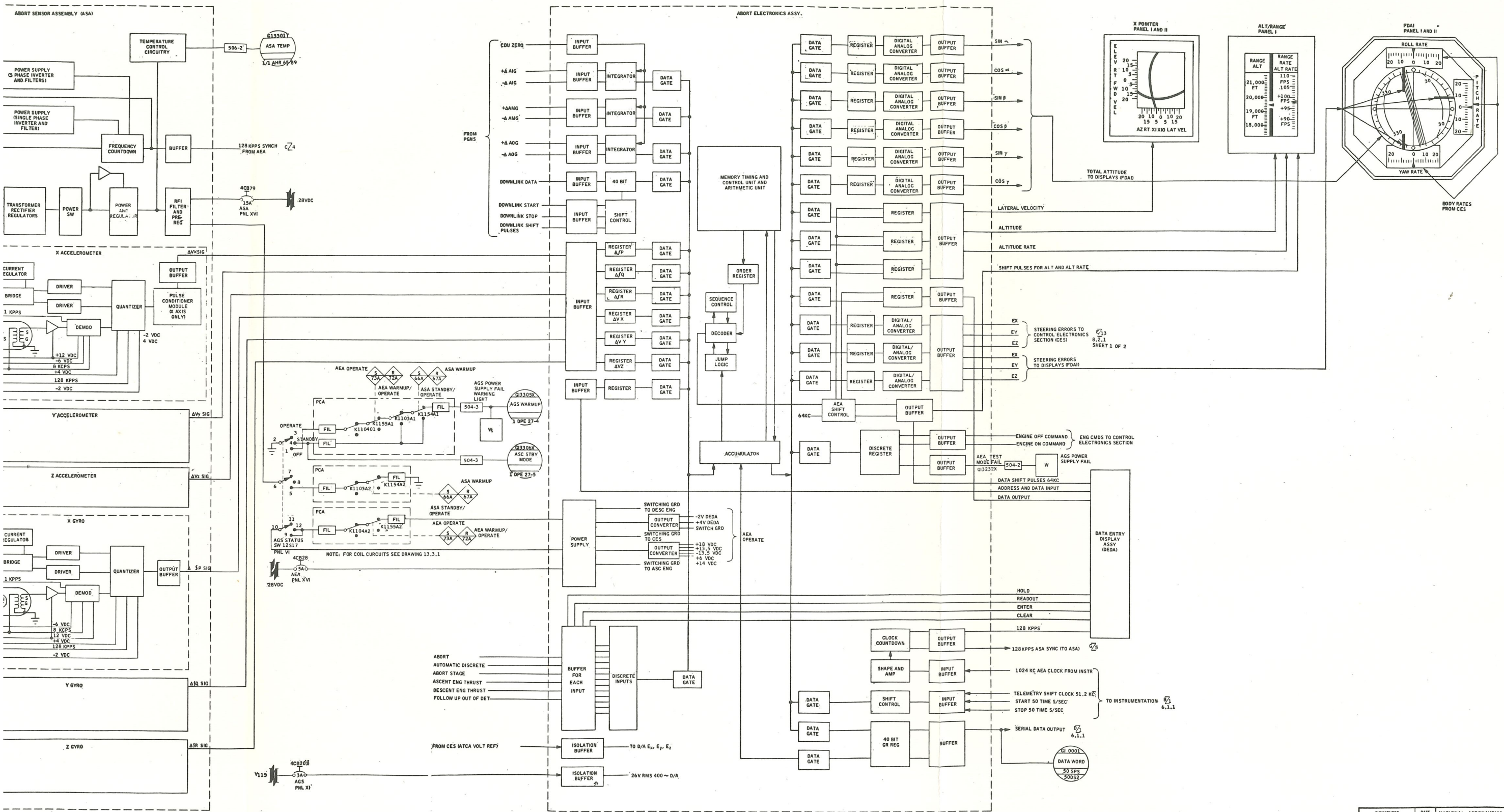




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SYM	APPROVED	DATE

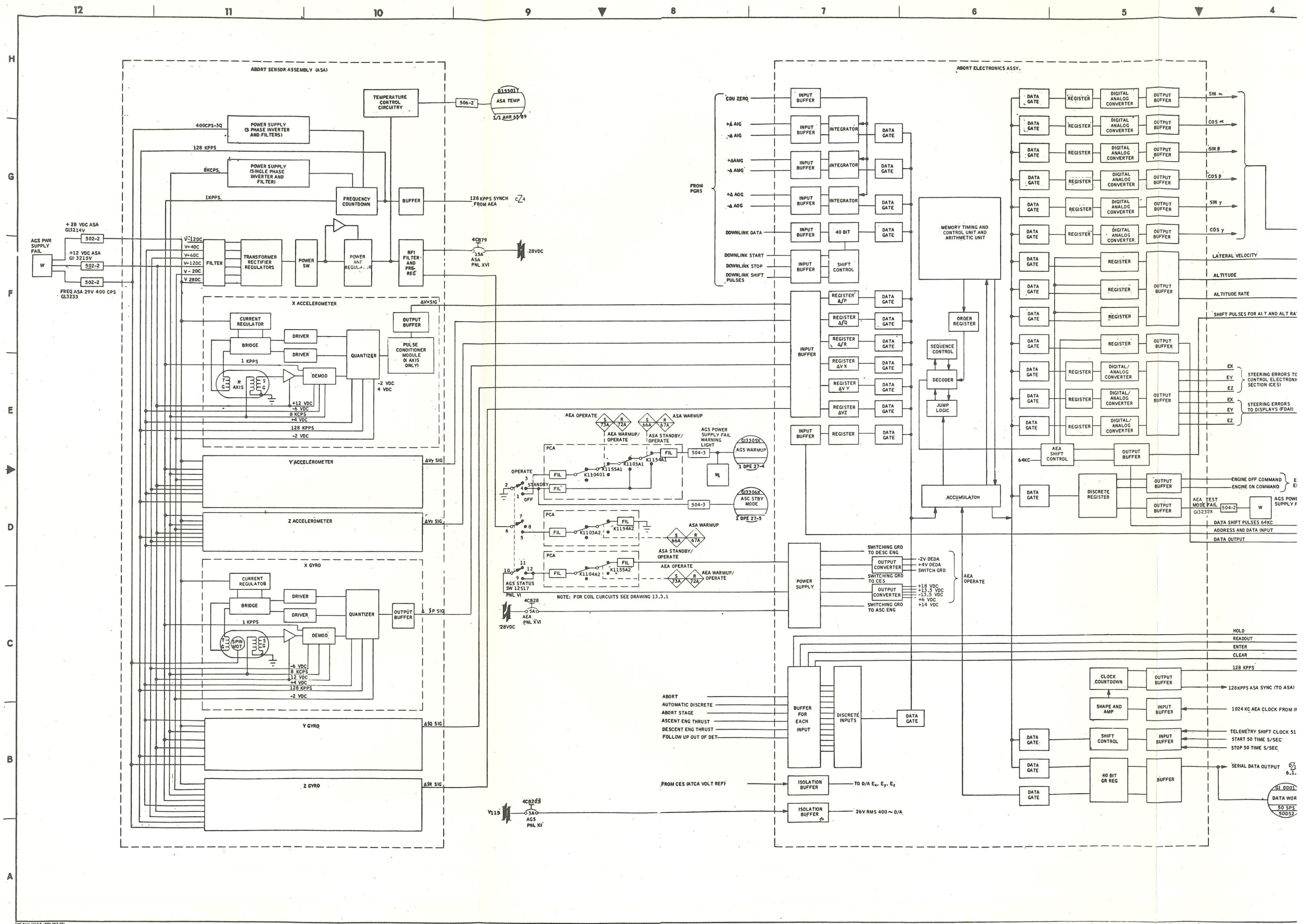
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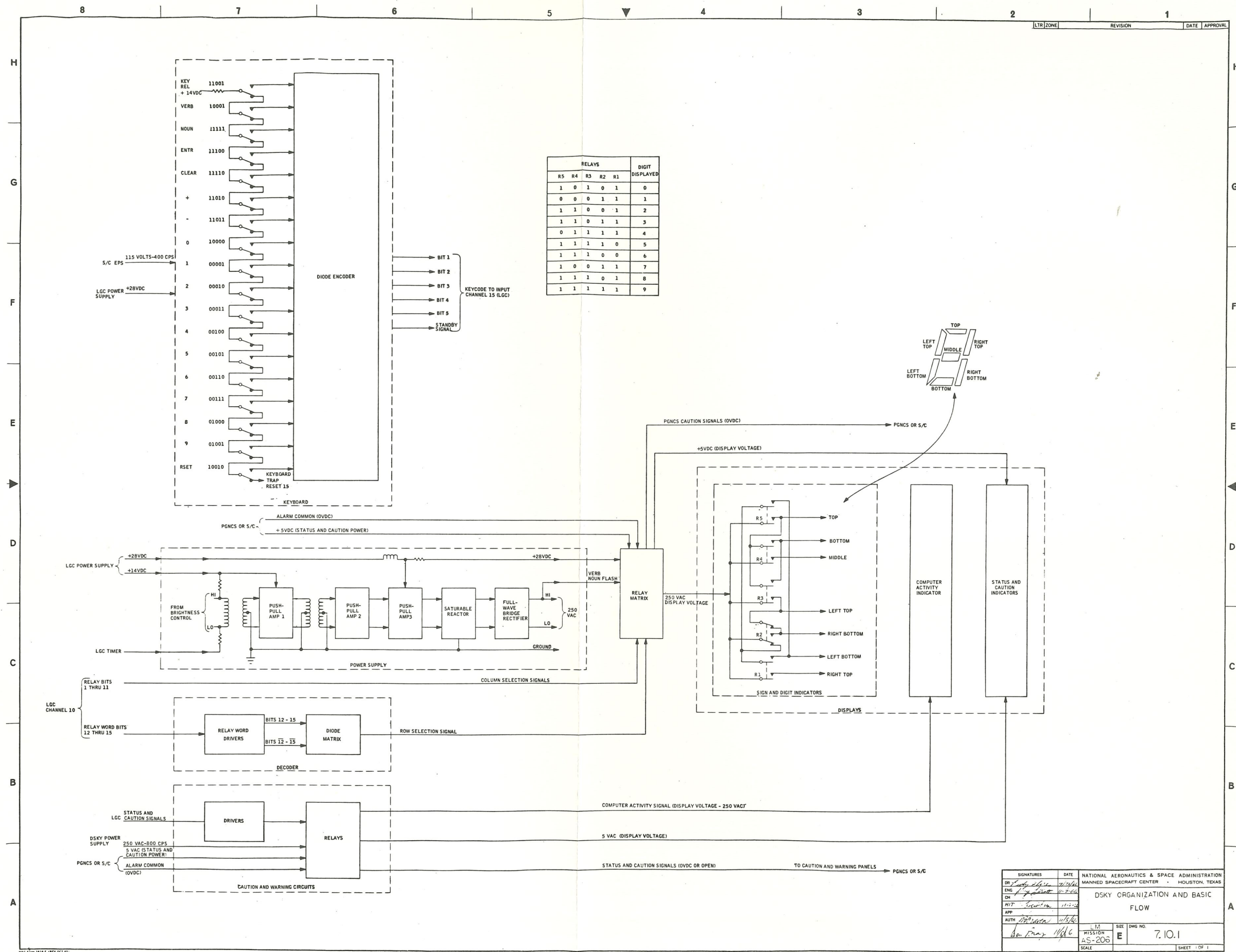




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SAEC	<i>[Signature]</i>	11-1-66		
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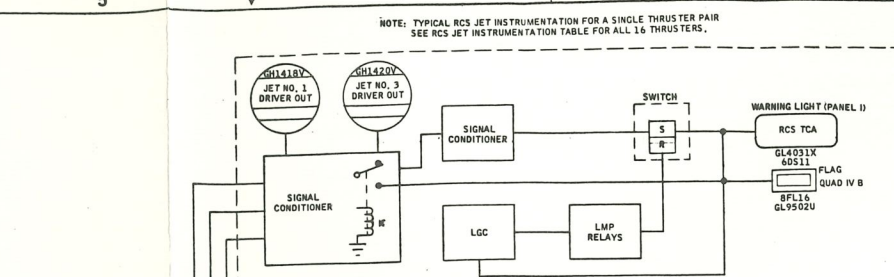
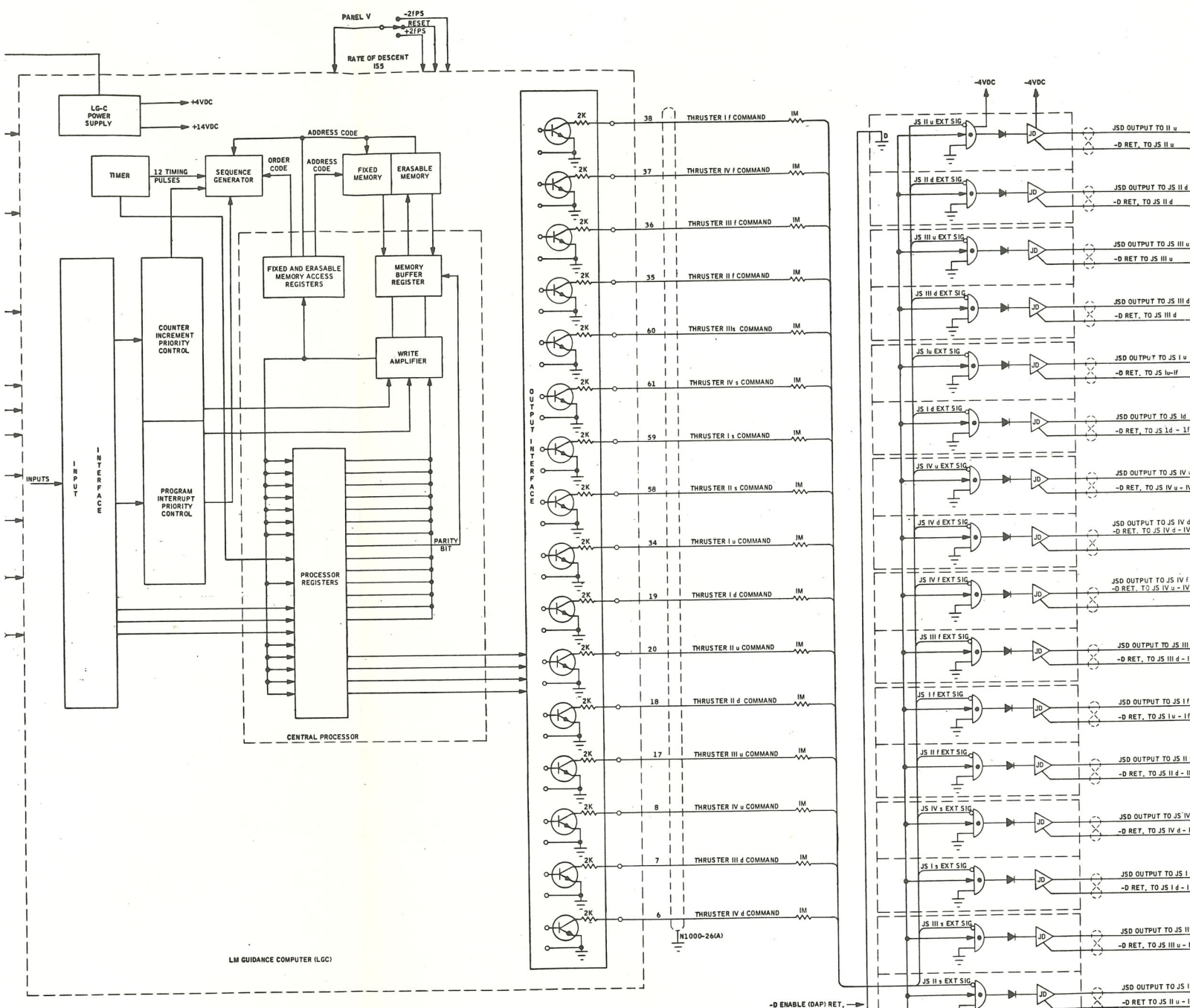




RELAYS					DIGIT DISPLAYED
R5	R4	R3	R2	R1	
1	0	1	0	1	0
0	0	0	1	1	1
1	1	0	0	1	2
1	1	0	1	1	3
0	1	1	1	1	4
1	1	1	1	0	5
1	1	1	0	0	6
1	0	0	1	1	7
1	1	1	0	1	8
1	1	1	1	1	9

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AP: <i>[Signature]</i>	10/5/66	
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DR: <i>[Signature]</i>	10/5/66	
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SCALE		SHEET 1 OF 1





RCS JET INSTRUMENTATION

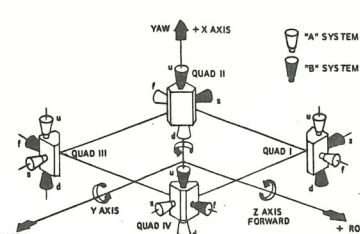
JET	JET DRIVER OUT	SWITCH SET/RESET	FLAG	QUAD
40	GH1419V	GR9661V	8 FL16 GL9502V	IV A
45	GH1421V	GR9661V	8 FL14 GL9501V	IV A
4U	GH1418V	GR9662V	8 FL16 GL9502V	IV B
4F	GH1420V	GR9662V	8 FL16 GL9502V	IV B
3U	GH1422V	GR9663V	8 FL13 GL9503V	III A
3S	GH1423V	GR9663V	8 FL13 GL9503V	III A
3D	GH1423V	GR9664V	8 FL15 GL9504V	III B
3F	GH1424V	GR9664V	8 FL15 GL9504V	III B
2U	GH1427V	GR9665V	8 FL10 GL9505V	II A
2F	GH1428V	GR9665V	8 FL12 GL9506V	II B
2U	GH1426V	GR9666V	8 FL12 GL9506V	II B
2S	GH1429V	GR9666V	8 FL12 GL9506V	II B
1U	GH1430V	GR9667V	8 FL9 GL9507V	I A
1F	GH1432V	GR9667V	8 FL9 GL9507V	I A
1D	GH1431V	GR9668V	8 FL11 GL9508V	I B
1S	GH1433V	GR9668V	8 FL11 GL9508V	I B

REFERENCE DRAWING IN 6.3.5 INSTRUMENTATION

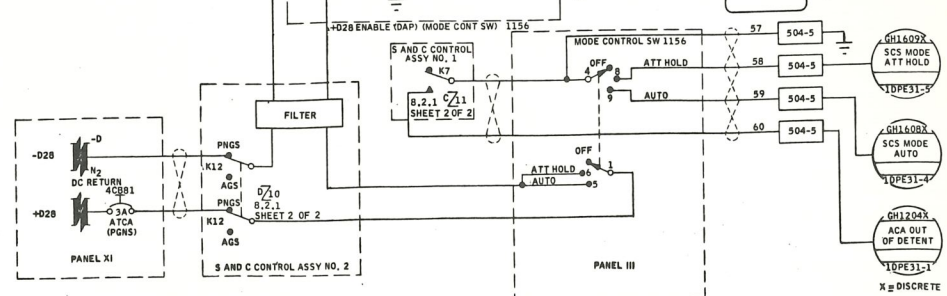
"ON" FAILED ENGINE

ENGINE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1																
2																
3																
4																
5																
6																
7																
8																
9																
10																
11																
12																
13																
14																
15																
16																

RCS TCA "ON" FAILURE DETECTION



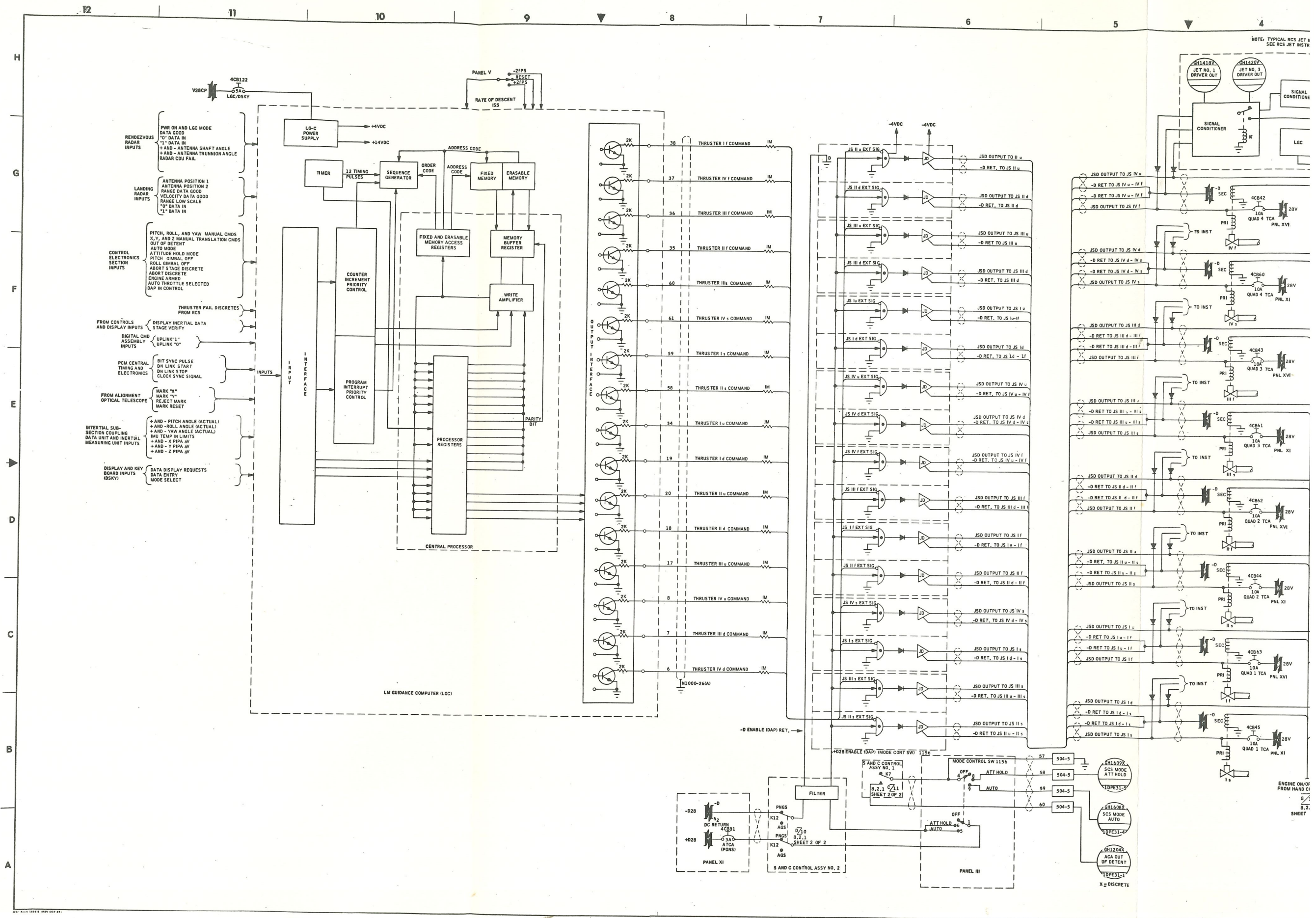
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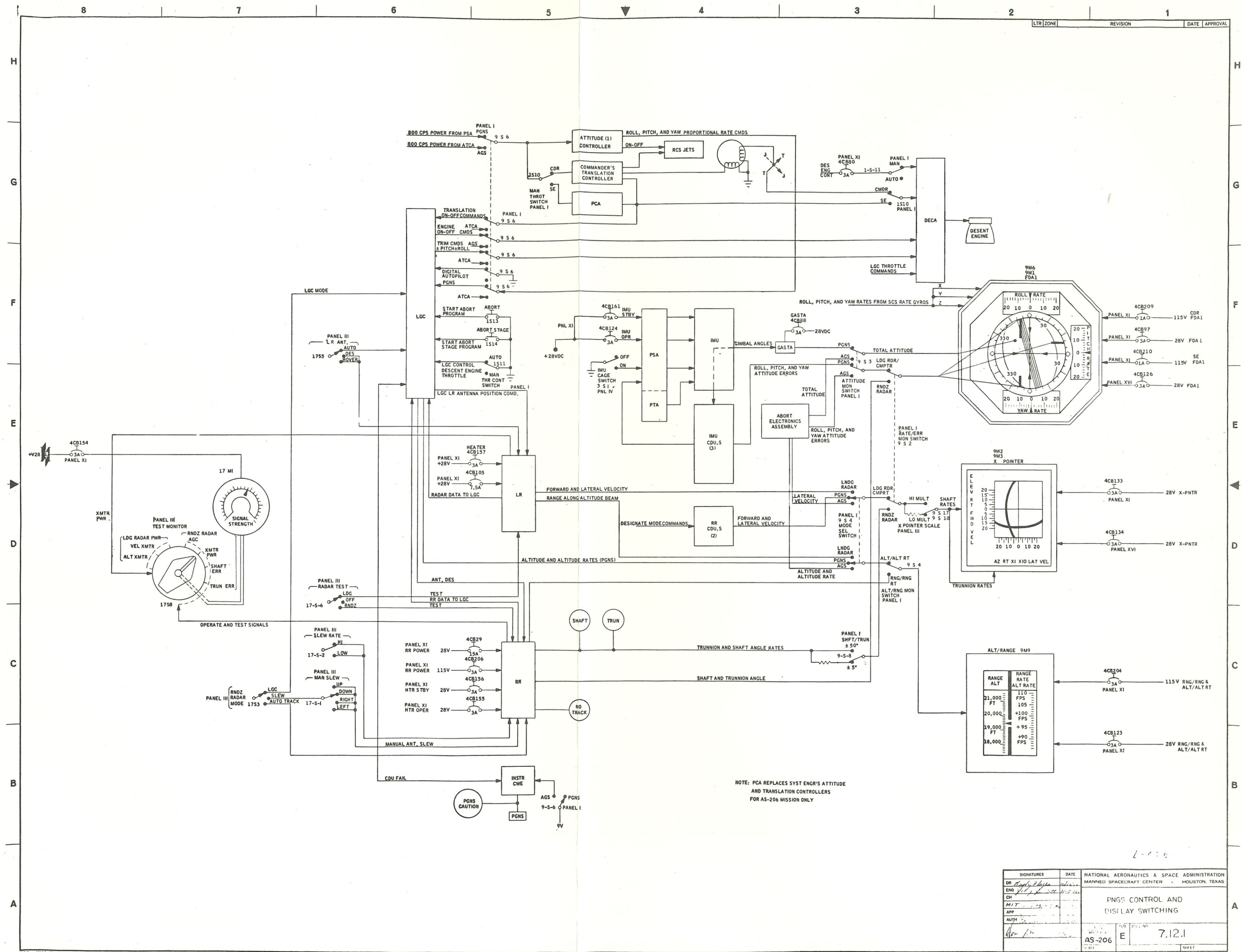
ENGINE ON/OFF COMMANDS FROM HAND CONTROLLER

SHEET 2 OF 2













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SECTION 8  
CONTROL

LM  
AS-206  
REV A

8.1 GENERAL

8.1.1 Control Electronics Section (CES) Functions

The CES operates in both the primary guidance control path and the abort guidance control path.

When operating as part of the primary guidance control path in conjunction with the PGNS, the CES provides the implementation of the control signals originating from the LGC as follows:

- A. Converts reaction control jet commands to the required electrical power to operate the RCS jet solenoid valves.
- B. Accepts discrete (ON/OFF) descent engine rotation commands. Upon receipt of an ON command, the descent engine is rotated about its gimbal axes at a constant angular rate until receipt of an OFF command.
- C. Accepts both LGC and manual engine ON/OFF commands and routes them to propulsion to fire or stop the descent or ascent engine.
- D. Accepts LGC and manual thrust commands to throttle the descent engine 10 to 100 percent of its range.

When operating in the abort guidance control path the CES performs the following functions:

- A. Accepts attitude error signals from the AGS or manual attitude commands as well as rate damping signals from the RGA's and fires the proper RCS jets to achieve attitude control
- B. Accepts manual translation commands and fires RCS jets to accelerate the LM in the desired direction.
- C. Automatically rotates the gimballed descent engine for trim control.
- D. Accepts AGS and manual engine ON/OFF commands and routes them to the descent or ascent engine.
- E. Accepts manual throttle commands to control the thrust of the descent engine.



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LM  
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#### 8.1.2 Modes of Attitude Control

Four basic modes of attitude control are provided by the CES and are selectable on the control panel. One mode is fully automatic, one is semiautomatic, and two provide open loop control of the reaction jets.

- A. Automatic Mode - The automatic mode provides fully automatic attitude control of the LM.
- B. Attitude Hold Mode - This is a semiautomatic mode in which the pilot commands an angular rate proportional to the displacement of the attitude controller. The vehicle will hold attitude when the controller is in the neutral position.
- C. Pulse Mode - This mode is selectable on an individual axis basis and commands a fixed low frequency pulse signal to the RCS system whenever the attitude controller is out of detent. This is an open loop mode and commands an acceleration about the selected axis when the controller is out of detent.
- D. Direct Mode - The direct mode is also an open loop attitude control mode and is selectable on an individual axis basis. Acceleration commands are sent directly to the secondary solenoids of the RCS from the attitude controller.

Manual Override - Manual override can be activated in any mode by displacing the attitude controller to its full travel. This commands operation of the RCS secondary solenoids.

#### 8.1.3 Translation Control (RCS)

Both automatic and manual translational control in all three axes using the RCS thrusters are available. Automatic control consists of jet commands from the LGC to the jet drivers in the ATCA. These are used for translations of small velocity increments and ullage settling prior to main engine ignition after coasting phases. Manual control in PGNS operation consists of ON/OFF commands from the TTCA by way of the LGC. In AGS operation only manual control is available. Control consists of ON-OFF commands from the TTCA to the jet logic in the ATCA. The voltage is sufficient to saturate the pulse ratio modulators and give ON/OFF

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control of the RCS jets. Plus X-axis RCS thrust is also available from a switch on the control panel. The secondary solenoids of the four downward firing RCS thrusters will be energized as long as the +X TRANSLATION switch is depressed.

#### 8.1.4 Attitude and Translation Control Assembly (ATCA)

The ATCA supplies the signals which control the firing of the reaction jets and the signals for automatic trim of the gimbaled descent engine in AGS operation. The dc voltages required in all of the CES subassemblies and the synchronized ac voltage for the RGA, AGS and controllers are also generated within this assembly. The input signals from the AGS, hand controllers and the RGA are processed in the ATCA and are directed to the appropriate jets and the descent engine control assembly.

Drawing 8.2.1 Sheet 1 of 2 shows a schematic diagram of the ATCA. In PGNS operation, only the LGC preamplifiers are enabled by the guidance selector switch. LGC jet commands are amplified by the preamplifiers and jet drivers and sent to the primary solenoids of the RCS. In AGS operation, only the abort preamplifiers are enabled and jet signals from the pulse ratio modulators are amplified and drive the RCS primary solenoids. Pitch, roll, and yaw signals are processed in three similar channels. Attitude error signals from the AGS are applied to the ATCA in automatic mode and attitude hold mode with the ACA's in detent. In narrow deadband operation the error signals are first passed through limiters to prevent excessive vehicle rates. The error signals are next summed with rate damping signals from the RGA. In attitude hold mode with an ACA out of neutral, proportional attitude rate commands are summed with the RGA rate damping signals. The gains of the summing amplifiers are changed when the LM is staged to account for the change in vehicle moment of inertia. The summed ac signals are changed to dc by keyed demodulators and filters.

In the roll and pitch channels the demodulator output is sent to the DECA to control the trim of the gimbaled descent engine. The deadband circuitry provides for either a wide deadband ( $\pm 50$ ) or a



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narrow deadband ( $\pm 0.3$  degrees) depending on the mission phase. In automatic and attitude hold modes, the signals from the deadband circuits are applied to the jet select logic. In pulse mode, dc voltages from the ACA's are sent directly to the jet select logic circuitry. The jet select logic combines the attitude and translation inputs, determines whether two or four jets will fire to control rotation and X-axis translation, and applies the resultant signals to eight pulse ratio modulators generate pulses which vary in width and frequency depending on the input voltage in order to control the duty ratio of the RCS jets. Each pulse ratio modulator controls two opposing jets. The jet to be fired is determined by the sign of the pulse ratio modulator input voltage.

#### 8.1.5 Descent Engine Control Assembly (DECA)

The DECA contains circuitry for controlling three functions of the descent engine. Engine throttling commands from the PGNS and crew are processed and sent to the descent engine. PGNS or ATCA signals are processed for positioning the Gimbal Drive Actuators to control engine trim. ON-OFF commands are processed in the DECA to control descent engine ignition and shutdown. The schematic diagram of the DECA is shown in drawing 8.3.1.

Manual throttle commands can be applied to the descent engine with the throttle control switch on the control panel in either the manual or automatic position. Manual throttle commands consist of AC voltages, proportional to TTCA X-axis displacement, applied to the DECA. The DECA demodulates and filters the signal and sends a proportional DC throttle voltage to the descent engine.

Automatic throttle signals can only be applied to the descent engine when the throttle control switch is in the automatic position. The LGC sends automatic throttle commands to the DECA in the form of pulses on one of two lines. Pulses on one line advance a forward-backward counter while pulses on the other line decrease the count. A dc voltage proportional to the count is generated and sent to the descent

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engine for automatic throttle control.

In PGNS operation automatic trim control is provided by the LGC. When the LGC determines descent engine trim is required, it sends a trim command to the DECA on either a trim positive or a trim negative line for the roll or pitch axis. The trim signal is routed through a malfunction logic circuit to a power switching circuit. The power switching circuit applies 400 cycle, 115 volts power to the proper Gimbal Drive Actuator. The GDA rotates the descent engine and sends a 400 cycle signal proportional to its position back to the DECA. The DECA demodulates and differentiates the feedback signal and applies it back to the malfunction logic circuit. If the GDA is not moving in the commanded direction, the malfunction logic generates a trim failed signal. This signal removes the 400 cycle power from the power switching circuit and sends TRIM FAILED signals to the LGC and Instrumentation.

In abort guidance operation, roll and pitch trim signals, are received from the roll and pitch error channels in the ATCA. A comparator and threshold circuit in the DECA generates trim negative or trim positive commands and sends them to the malfunction logic. The malfunction logic controls the power switching circuits the same as in PGNS operation.

#### 8.1.6 Gimbal Drive Actuator (GDA)

The two GDA's are low-speed electromechanical devices each containing a 115V 400 cps ac motor driving a screw jack and a position transducer. Under control of the DECA the GDA's rotate the descent engine about the pitch and roll axes so that the thrust vector goes through the LM center of gravity. One GDA controls the pitch gimbal and the other controls the roll gimbal.

Each GDA is capable of extending or retracting two inches from the mid-position and will gimbal the descent engine a maximum of plus or minus six degrees about the LM Y and Z-axis. The position transducer receives 115V 400 cps, 7.5 volts per inch travel from the mid-position; in-phase when extended and 180° out-of-phase when retracted



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past the mid-position. The transducer output is sent back to the DECA malfunction logic.

#### 8.1.7 Attitude Controller Assembly (ACA)

Vehicle attitude changes can be commanded manually by the use of either one of the two three-axis, pistol-grip, right-hand attitude controllers. One attitude controller is used by each astronaut. The attitude controller is installed with its longitudinal axis approximately parallel to the LM X-axis so that vehicle rotations will correspond to astronaut hand movements. Clockwise or counter-clockwise rotation of the controller about its longitudinal axis will command vehicle yaw left or yaw right rotation about the X-axis. Forward or backward movement of the controller will command vehicle pitch-down or pitch-up rotation about the Y-axis. Movement of the controller to the left or right will command a roll-left or a roll-right rotation about the Z-axis. The ACA is used for closed loop proportional rate commands in attitude hold mode and open loop acceleration commands in pulse, direct, and hardover operation.

ACA proportional control is shown in Drawing 8.2.1 Sheet 2 of 2. Twenty-eight V 800 cps is applied to each of three proportional transducers. The secondary voltage of each transducer is proportional to hand grip displacement about its input axis, i.e., one transducer each for roll, pitch, and yaw axis. When hand grip displacement exceeds 0.5 degrees the out of detent switch closes. One contact sends an out of detent signal to the LGC and the AGS. The other contact sends the proportional secondary voltage to either the LGC or the ATCA. The output voltage is 0.28 volts per degree hand displacement from 1 to 11 degrees displacement. Positive rotation commands will generate in phase voltage and negative commands 180 degrees out of phase voltage.

When pulse mode is selected for an axis, plus and minus dc voltages are applied to a pair of switches. When the hand grip is displaced 2.5 degrees or greater from neutral, either a positive or negative dc voltage is sent to the ATCA. A positive voltage commands a positive acceleration (pulsed) about the axis and a negative voltage commands a negative

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acceleration.

When direct mode is selected, +28V DC is applied to two RCS secondary solenoids when the hand controller is displaced more than 2.5 degrees. In any mode, if the hand controller is displaced past the soft stops (12 degrees) the handover switches will send +28V dc four RCS secondary solenoids.

Mounted on the ACA is a push-to-talk switch for the astronaut's audio system.

#### 8.1.8 Thrust Translation Controller Assembly (TTCA)

This is a three-axis, tee-handle, left-hand controller used by the astronaut to command vehicle translations by the reaction jets and to throttle the descent engine between 10 and 100 percent maximum thrust magnitude. A manually operated lever is provided on the controller to engage either all translation capability or translation in the Y and Z directions with throttling capability of the descent engine. Two controllers are installed in the LM, one available for each astronaut. Due to the controller's mounting position, vehicle translations correspond approximately to astronaut hand motions. Motion of the controller to the left or right will command translations along the Y-axis, and movement of the controller forward or backward will result in translations along the Z-axis.

The TTCA translation interface is shown in drawing 8.2.1 Sheet 2 of 2. One pair of switch contacts in each axis sends the desired command to the LGC when the hand grip is displaced approximately 0.25 inches. Another pair of contacts sends a positive or negative dc voltage to the ATCA to command an acceleration in the desired direction. The X-axis switches are mechanically disconnected when the selector lever is in the throttle position.

When the TTCA is used for throttle control, 800 cps power is applied to the primary of the position transducer. See Drawing 8.2.1 Sheet 2 of 2. Depending on the position of the Manual Throttle Switch either the Commander or Systems Engineer will be able to generate manual throttle commands. The secondary winding of the transducer will pick up a voltage depending

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on the X-axis displacement of the hand controller. This voltage is sent to the DECA where it is used for controlling the thrust of the descent engine.

#### 8.1.9 CES Interfaces:

The CES receives the following signals from the PGNS:

- A. ON/OFF commands for each of the 16 reaction control jets.
- B. ON/OFF commands for the ascent or descent engine.
- C. Descent engine trim commands.
- D. Thrust magnitude commands for the descent engine.
- E. 800 cycle per second power to excite the hand controller.

The CES feeds the following signals to the PGNS in the primary mode.

- A. Proportional attitude rate commands.
- B. Gimbal fail signals.
- C. Translation ON/OFF Commands
- D. Attitude controller out of detent.

The CES provides the following to the descent engine:

- A. Ignition and shutdown commands.
- B. Automatic and manual throttling commands.
- C. Rotation of the gimbal engine.

The CES also interfaces with the:

- A. Electrical Power Subsystem (EPS) - The CES receives required electrical power from the EPS.
- B. Reaction Control Subsystem (RCS) - The CES provides the signals to actuate the RCS jet solenoids.
- C. Ascent Engine - The CES provides commands for ascent engine ignition and shutdown.
- D. Displays and Controls Subsystem - The CES provides inputs to the appropriate controls and displays to enable control and monitoring of the SCS.
- E. Abort Guidance Section (AGS) - The CES provides vehicle status



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signals to the AGS and receives steering signals and engine commands for AGS.

- F. Instrumentation Subsystem - CES provides signals to the Instrumentation Subsystem for inflight monitoring.
- G. Environmental Control Subsystem (ECS) - The ECS provides mounting surfaces and thermal protection for the CES equipment.
- H. Structure Subsystem - The Structure Subsystem provides the area and mounting accommodations to house the CES equipment within the structure.
- I. Explosive Devices Subsystem (EDS) - The CES interfaces with the EDS for stage status information.

## 8.2 CONTROL ELECTRONICS SYSTEM GENERAL NOTES

- A. The Control Electronics System (CES) will have power applied and will be operating prior to launch and remain on throughout the mission. The primary guidance will utilize only a portion of the CES for control of the LM. The complete Abort Guidance System portion of CES will not be used on the AS-206A Mission. However, the fourth Ascent Propulsion System burn will check the attitude hold mode of the AGS.
- B. Manual throttling of the Descent Engine System in degrees of 10, 30, 50, and 100 percent throttle settings can be tested if the PGNS fails AS-206 by the PRA. The reset position of the throttle is 30 percent.
- C. The three axis controller rates are  $\pm 15$  degrees per second and  $\pm 5$  degrees per second.
- D. There will not be an automatic closed loop guidance for the PRA/AGS control during DPS and APS burns. Should a failure occur in the PGNS, the PRA will perform a minimum alternate propulsion test. The requirements for using the PRA/AGS control for a propulsion test will depend upon the time of failure of PGNS.
- E. The following RTC capability will be provided by the PCA:
  1. Descent Engine Arm (00B, K0151)  
Descent engine is selected and armed. An arming signal is routed to the DECA, and an engine arm discrete is routed to the LGC. Manual descent engine start circuit is enabled. Overrides engine stop override to arm the engine. Overrides Prime Relay (K0101) which has the same function but so implemented that engine stop override de-arms the engine. Ascent engine arm by Prime Relay (K0102) is inhibited.
  2. Descent Engine Arm Release (01 B, K0151, Preset)  
Releases descent engine arm function to Prime Relay control remaining armed or being de-armed, depending on the state of the Prime Relay (K0101).

## 3. Engine Fire Override (14B, K0153)

Provides manual start signal to the armed descent engine or to the armed ascent engine. Overrides Prime Relay (K0103), which has the same function. To utilize the engine fire override function for the armed ascent engine, the Descent Engine Arm Relays (K0101 and K0151) must be in the reset state.

## 4. Engine Fire Override Release (15B, K0153, preset)

Releases fire override function to Prime Relay (K0103) control. Does not terminate engine thrusting. Enables engine stop override function for the descent and ascent engines, providing Prime Relay (K0103) is in the reset state.

## 5. Engine Stop Override (10B, K0154)

Terminates descent engine thrusting. Terminates ascent engine thrusting initiated by auto engine ON command from the LGC, providing the ascent was armed and the firing circuit was prepared by Prime Relay (K0102). Terminates ascent engine thrusting initiated by the manual circuit, providing the engine fire override relays (K0103 and K0153) are in the reset state. Termination of ascent engine thrusting, initiated by auto engine ON and the ascent engine armed by the abort stage prime relay, requires a master reset of the prime relays. Relay K0154 overrides Prime Relay K0104.

### NOTE

To terminate ascent engine thrusting for K0103 or K0153 in the set state requires a Descent Engine Arm.

## 6. Engine Stop Override Release (11B, K0154, present) Release Engine Stop Override function to prime relay control.



7. +X FIRE (60B, K0155)  
Initiates 4-jet, +X-axis, Reaction Control System (RCS) thrusting by energizing the secondary solenoid coils in the +X-axis thrusters. Backup for LM separation and ullage settling maneuvers. Overrides primary solenoid thruster on commands. No associated prime relay.
8. +X STOP (61B, K0155, preset)  
Terminates +X-axis thrusting (if started by +X Fire) by deenergizing thruster secondary coils. No associated prime relay.
9. TRANSLATION DISABLE (21B, K0163, preset to enable)  
Disables manual translation capability by the LGC or PRA along the  $\pm X$ ,  $\pm Y$ , and  $\pm Z$ -axis by removing excitation to the following translation prime relays:
- a. (K0119) +X
  - b. (K0120) -X
  - c. (K0121) +Y
  - d. (K0122) -Y
  - e. (K0123) +Z
  - f. (K0124) -Z
10. + PITCH INITIATE (02A, K0156)
11. + PITCH STOP (03A, K0156, preset)
12. - PITCH INITIATE (00A, K0157)
13. - PITCH STOP (01A, K0157, preset)
14. + YAW INITIATE (06A, K0158)
15. + YAW STOP (07A, K0158, preset)
16. - YAW INITIATE (04A, K0159)
17. - YAW STOP (05A, K0159, preset)
18. + ROLL INITIATE (12A, K0160)
19. + ROLL STOP (13A, K0160, preset)
20. - ROLL INITIATE (10A, K0161)
21. - ROLL STOP (11A, K0161, preset)

- Commands 10, 12, 14, 16, 18, and 20 produce an out-of-detent signal and provide for the establishment of a 5-degree-per-second rate about the X, Y, or Z body axis. Commands 11, 13, 15, 17, 19, and 21 provide for removing the associated rate input and restore the in-detent condition.
22. ATTITUDE DISABLE (20B, K0162, preset to enable)  
Disables LGC or PRA capability for attitude control about the X, Y, and Z body axis by removing excitation to the following attitude control prime relays:
- a. (K0106, K0113) + Pitch (Y) Hi/Lo rate
  - b. (K0107, K0114) - Pitch (Y) Hi/Lo rate
  - c. (K0108, K0115) + Yaw (X) Hi/Lo rate
  - d. (K0109, K0116) - Yaw (X) Hi/Lo rate
  - e. (K0110, K0117) + Roll (Z) Hi/Lo rate
  - f. (K0111, K0118) - Roll (Z) Hi/Lo rate
23. AUTO MODE SELECT (30B, K1153)  
Selects auto mode during either PGNS or AGS operation when Prime Relay (K1101) is selected to attitude hold.

NOTE

Attitude hold mode relay contact (K1151) must be in the reset position.

24. AUTO MODE RELEASE (25B, K1151, preset)  
Releases mode select function from auto to Prime Relay (K1101) control.
25. ATTITUDE HOLD MODE SELECT (24B, K1151)  
Selects attitude hold mode during PGNS OR AGS operation when Prime Relay (K1101) is selected to AUTO.

NOTE

Auto mode relay contact (K1153) must be in the reset position.



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26. ATTITUDE HOLD MODE RELEASE (31B, K1153, preset)  
Releases mode select function from attitude hold to Prime Relay (K1101) control.
27. MINIMUM DEADBAND SELECT (74B, K1152)  
Selects the minimum attitude control deadband for operations requiring accurate pointing during AGS control.
28. MINIMUM DEADBAND RELEASE (75B, K1152, preset)  
Releases minimum deadband select function to Prime Relay (K1102) control.

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8.3 ATTITUDE AND TRANSLATION ELECTRONICS SCHEMATIC NOTES  
(Drawing 8.2.1 Sheet 1 of 2)

NOTES:

- A. All latching relays are shown in the reset configuration and all non-latching relays are shown in the de-energized configuration, unless noted.
- B. These relays are shown in the energized configuration. The relay coils are energized until ascent staging on the lunar surface.
- C. The wires are separated upon descent staging from the lunar surface.
- D. These relays are not used in the Yaw channel.

Sheet 2 of 2

NOTES:

- A. All latching relays are shown in the reset configuration and all non-latching relays are shown in the de-energized configuration, unless noted.

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#### 8.4 DESCENT ELECTRONICS SCHEMATIC NOTES (Drawing 8.3.1)

##### NOTES:

- A. All latching relays are shown on the reset position and all non-latching relays are shown on the de-energized position, unless noted.
- B. This switch must be pushed to energize and again pushed to de-energize.

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8.5 ASCENT ELECTRONICS SCHEMATIC NOTES (Drawing 8.4.1)

NOTES:

- A. This switch must be pushed to energize and then pushed again to de-energize.
- B. All latching relay contacts are shown in the reset configuration, unless noted.
- C. All non-latching relays are shown in the de-energized configuration, unless noted.



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## 8.6 PROGRAMMER INTERFACE SCHEMATIC NOTES (Drawing 8.5.1)

### NOTES:

- A. This relay is not resetable after LM liftoff because it can only be reset through a ground umbilical plug.
- B.  $A_1$ ,  $A_2$ , and  $B_1$ ,  $B_2$  notation for relay contacts denotes physically different relays which are operated by the same command. For example K0159A1 and K0159A2 are contacts of the same relay whereas K0159B1 is a physically different relay but is operated by the same command which operates K0159A1.

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TABLE 8-1  
RCS PROPELLANT USEAGE FOR LM AUTOPILOT

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### a. Ascent Engine Burn 1.0 degree dead-band

Torque/Inertia	Disturbance Torque	RMS Attitude Error	Propellant Usage Rate
0.2 rad/sec <sup>2</sup>	0 ft. lb	0 deg	0.000030 lb/sec
	350	0.511	0.240
	850	0.664	0.566
0.3 rad/sec <sup>2</sup>	0	0	0.000044 lb/sec
	350	0.511	0.242
	850	0.664	0.566
0.5 rad/sec <sup>2</sup>	0	0	0.000074 lb/sec
	350	0.511	0.246
	850	0.664	0.568
0.7 rad/sec <sup>2</sup>	0	0	0.001030 lb/sec
	350	0.511	0.249
	850	0.664	0.572

### b. Rotational Maneuvers

Torque/Inertia	Maneuver Rate	Propellant Usage
0.04 rad/sec <sup>2</sup>	0.2 deg/sec	0.15 lb
	3.0	1.93
	5.0	3.2
	10.0	6.4
0.10 rad/sec <sup>2</sup>	0.2 deg/sec	0.07
	3.0	0.8
	5.0	1.3
	10.0	2.6
0.30 rad/sec <sup>2</sup>	0.2 deg/sec	0.032
	3.0	0.29
	5.0	0.46
	10.0	0.88
0.80 rad/sec <sup>2</sup>	0.2 deg/sec	--
	3.0	0.12
	5.0	0.19
	10.0	0.35

c. Attitude Hold		
Torque/Inertia	Deadband	Propellant Usage Rate
0.04 rad/sec <sup>2</sup>	0.3 deg	0.012 lb/min
	5.0	0.0007
0.10 rad/sec <sup>2</sup>	0.3 deg	0.030 lb/min
	5.0	0.0018
0.30 rad/sec <sup>2</sup>	0.3 deg	0.09 lb/min
	5.0	0.0053
0.80 rad/sec <sup>2</sup>	0.3 deg	0.24 lb/min
	5.0	0.014

TABLE 8-2

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MOMENT OF INERTIA (Slug-ft <sup>2</sup> )	L/O WEIGHT 32,900 lb	1st DPS Burn 32,400 lb	2nd DPS BURN 9,860 lb	1st APS BURN 9,800 lb	2nd APS BURN 5,600 lb	3rd APS BURN 5,500 lb	4th APS BURN 5,400 lb
I Pitch (Y) I Roll (Z) I Yaw (X)	25,300 25,700 23,300	25,000 25,600 23,100	5,700 3,300 6,200	5,700 3,300 6,200	2,800 2,300 3,200	2,800 2,200 3,200	2,800 2,100 3,100
MOMENT ARM (ft)  Pitch (Y) Roll (Z) Yaw (X)	  5.5 5.5 5.5	  5.5 5.5 5.5	  5.5 5.5 5.5	  5.5 5.5 5.5	  5.5 5.5 5.5	  5.5 5.5 5.5	  5.5 5.5 5.5
CENTER OF GRAVITY (station)  Pitch (Y) Roll (Z) Yaw (X)	  186	  186	  242.5	  242.5	  252	  252.5	  253
ANGULAR ACCELERATION (deg/sec <sup>2</sup> )  Pitch (Y) Roll (Z) Yaw (X)	  1.245 1.228 1.352	  1.260 1.230 1.363	  5.53 9.55 5.08	  5.53 9.55 5.08	  11.25 13.70 9.85	  11.25 14.3 9.85	  11.25 15.00 10.15
VELOCITY (deg/sec)  Pitch (Y) Roll (Z) Yaw (X)	  0.0249 0.0245 0.0272	  0.0252 0.0246 0.02726	  0.1105 0.1910 0.1016	  0.1105 0.1910 0.1016	  0.225 0.274 0.197	  0.225 0.286 0.197	  0.225 0.300 0.2015
TIME TO CROSS DEADBAND ONCE (sec)  Pitch (Y) Narrow D/B ± 0.3° Pitch (Y) Wide D/B ± 5.0°  Roll (Z) Narrow D/S ± 0.3° Roll (Z) Wide D/B ± 5.0°  Yaw (X) Narrow D/B ± 0.3° Yaw (X) Wide D/B ± 5.0°	  24.1 sec 402 sec=6.7 min  24.5 sec 408 sec=6.82 min  22.05 sec 368 sec=6.13 min	  23.8 sec 397 sec=6.62 min  24.4 sec 407 sec=6.78 min  22 sec 366.3 sec=6.12 min	  5.43 sec 90.5 sec=1.51 min  3.14 sec 52.4 sec  5.9 sec 98.5 sec=1.64 min	  5.43 sec 90.5 sec=1.51 min  3.14 sec 52.4 sec  5.9 sec 98.5 sec=1.64 min	  2.67 sec 44.5 sec  2.19 sec 36.5 sec  3.04 sec 50.7 sec	  2.67 sec 44.5 sec  2.10 sec 35 sec  3.04 sec 50.7 sec	  2.67 sec 44.5 sec  2.00 sec 33.3 sec  2.96 sec 49.3 sec



\* TABLE 8-3 LMP PRIME COMMAND RELAY CROSS REFERENCE "B"

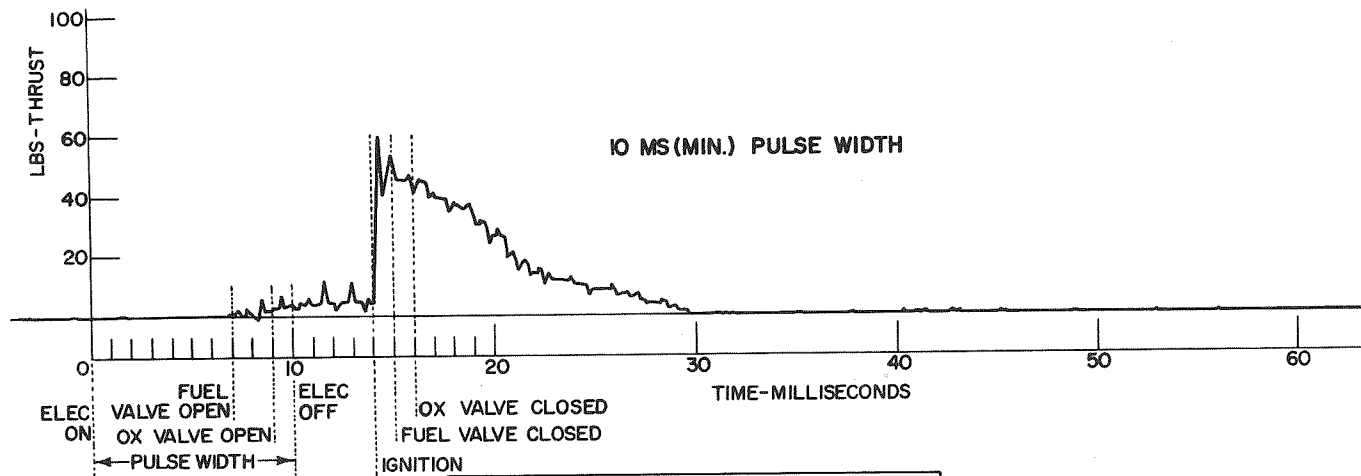
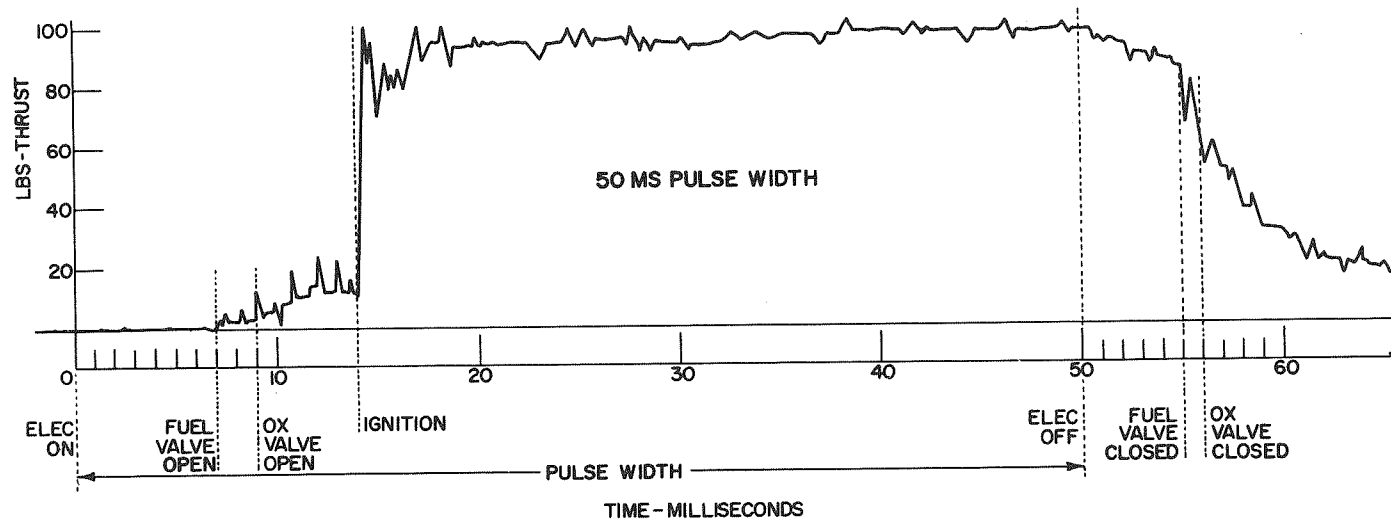
RELAY FUNCTIONAL DESIGNATION	RELAY DESIGNATION	RELAY FUNCTIONAL DESIGNATION	RELAY DESIGNATION	RELAY FUNCTIONAL DESIGNATION	RELAY DESIGNATION
K0001	A6K1	K0109A,B	A7K19,11	K0822A	A13K11
K0002	A6K2	K0110A,B	A8K23,15	K0823A	A16K2
K0003	A6K3	K0111A,B	A8K19,11	K0824A	A16K1
K0004	A6K4	K0113A,B	A6K22,14	K0825A	A17K2
K0005	A6K6	K0114A,B	A6K20,12	K0826A	A17K4
K0006	A6K7	K0115A,B	A7K22,14	K0827A	A15K7
K0007	A6K8	K0116A,B	A7K20,12	K0828A	A15K10
K0008	A7K1	K0117A,B	A8K22,14	K1001A	A15K4
K0009	A7K2	K0118A,B	A8K20,12	K1002A	A15K13
K0010	A7K3	K0119A,B	A6K24,25	K1003A	A8K8
K0011	A7K4	K0120A,B	A6K16,27	K1004A	A8K7
K0012	A7K6	K0121A,B	A7K24,25	K1005A	A8K6
K0013	A7K7	K0122A,B	A7K16,27	K1006A	A8K4
K0014	A7K8	K0123A,B	A8K24,25	K1101A,B	A11K18,25
K0015	A8K1	K0124A,B	A8K16,27	K1102A	A11K27
K0016	A8K2	K0125A	A9K18	K1103A	A11K22
K0017	A8K3	K0126A	A1K21	K1104A	A11K11
K0022	A10K24	K0127A	A9K20	K1301A	A15K5
K0023	A10K23	K0201A,B	A11K12,13	K1302A	A11K23
K0024	A10K8	K0202A,B	A11K14,15	K1701A	A9K1
K0025	A10K15	K0203A,B	A10K27,21	K1702A	A12K26
K0026	A10K16	K0204A,B	A10K13,14	K2001A	A12K3
K0027	A10K22	K0205A,B,C	A10K3,4,5	K2001B	A13K14
K0028	A11K26	K0601A	A9K25	K2005	A12K17
K0029	A11K19	K0701A	A9K26	K2006A	A12K20
K0030	A11K20	K0703A	A17K6	K2006B	A13K16
K0031	A11K21	K0704A	A15K3	K2006C	A12K12
K0032	A12K1	K0801A,B	A13K18,22	K2010A	A17K5
K0033	A12K6	K0802A,B	A13K13,21		
K0034	A12K14	K0803A,B	A14K18,22		
K0035	A14K15	K0804A,B	A14K13,21		
K0036	A14K16	K0805A	A13K3		
K0037	A14K17	K0806A	A13K4		
K0038	A15K18	K0807A	A14K3		
K0039	A16K10	K0808A	A14K4		
K0040	A16K17	K0809A	A16K12		
K0041	A17K3	K0810A	A16K11		
K0042	A17K8	K0811A	A14K8		
K0043	A17K13	K0812A	A14K10		
K0044	A17K10	K0813A	A13K8		
K0101A,B,C	A9K14,6,22	K0814A	A13K10		
K0102A,B,C	A9K15,7,23	K0815A	A16K3		
K0103A	A9K10	K0816A	A16K4		
K0104B	A9K4	K0817A	A16K14		
K0105A	A9K27	K0818A	A16K13		
K0106A,B	A6K23,15	K0819A	A14K9		
K0107A,B	A6K19,11	K0820A	A14K11		
K0108A,B	A7K23,15	K0821A	A13K9		

\* TABLE 8-4 LMP REAL-TIME COMMAND RELAY CROSS REFERENCE

FUNCTIONAL DESIGNATION	RELAY DESIGNATION	FUNCTIONAL DESIGNATION	RELAY DESIGNATION
K0151A,B	A9K16,8	K1153A,B	A11K2,10
K0151C	A9K14	K1154A	A11K16
K0153A	A9K11	K1155A	A11K24
K0154A,B	A9K13,5	K1351A	A15K14
K0155A,B	A17K7,12	K1352A	A15K1
K0156A,B	A6K18,10	K1751A	A9K2S
K0157A,B	A6K17,9	K1752A	A9K3S
K0158A,B	A7K18,10	K2051A	A12K2
K0159A,B	A7K17,9	K2051B	A13K15
K0160A,B	A8K18,10	K2055A	A12K9
K0161A,B	A8K9,17	K2055B	A12K25S
K0162A,B	A9K9,17S	K2056A	A12K19
K0163A,B	A8,A6K26R	K2056B	A13K17
K0163C	A7K26R	K2056C	A12K11
K0251A,B	A11K4,5	K2057A,C	A16K5,15
K0252A,B	A11K6,7	K2059A,B	A16K17,9
K0253A,B	A10K17,18	K2059C,D	A16K16,8
K0203C,D	A10K19,20	K2059E	A11K3
K0254A,B	A10K9,10	K2060A	A17K9
K0254C	A10K11	K2060B	A17K1S
K0255A,B	A10K1,6S		
K0256A,B	A10K2,7S		
K0451A	A12K7S		
K0452A	A12K8S		
K0453A	A12K16S		
K0454A	A12K16S		
K0455A	A12K21S		
K0456A	A12K22S		
K0457A	A12K23S		
K0458A	A12K24S		
K0459A	A12K13S		
K0751A	A17K14		
K0752A	A17K11		
K0753A	A15K2		
K0851A,B	A13K6,5		
K0851C	A13K20		
K0852A,B	A13K2,1		
K0852C	A13K19		
K0853A,B	A14K6,5		
K0853C	A14K20		
K0854A,B	A14K2,1		
K0854C	A14K19		
K0855A,B	A15K8,17		
K0856A,B	A15K9,19		
K1051A	A15K15		
K1051B	A15K12S		
K1052A	A14K14		
K1151A,B	A11K19		
K1151C	A11K17		
K1152A	A11K8		



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GRAPH, THRUST VS. TIME, RCS

FIGURE 8-1

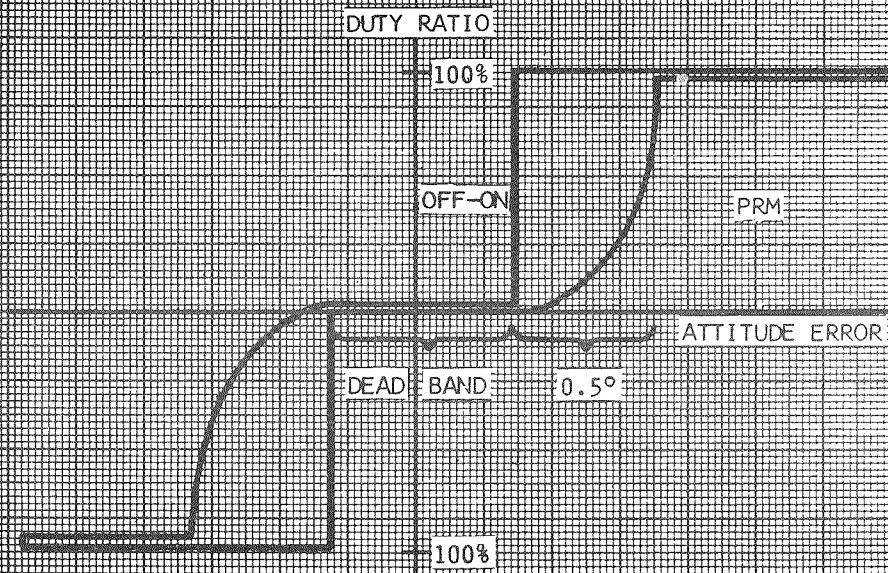


FIGURE 8-2 SWITCHING CHARACTERISTICS OF PULSE-RATIO MODULATOR

8-2-8

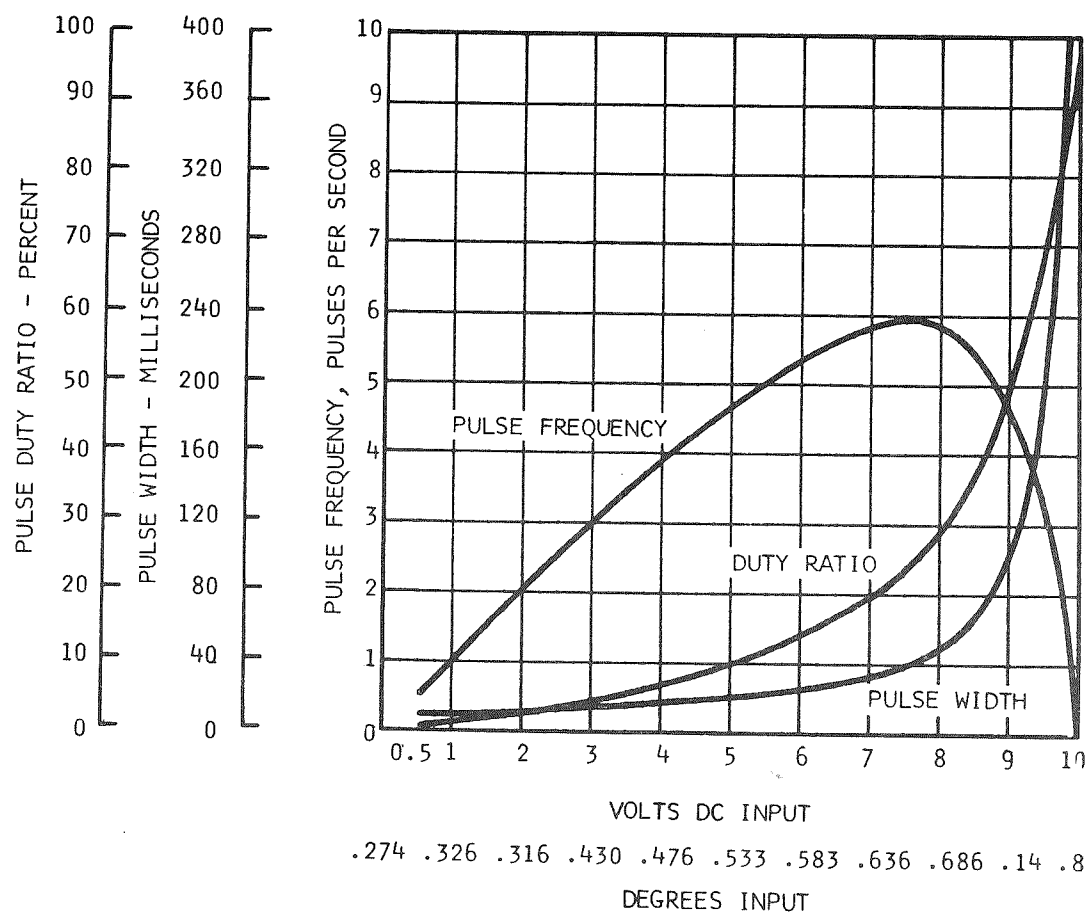
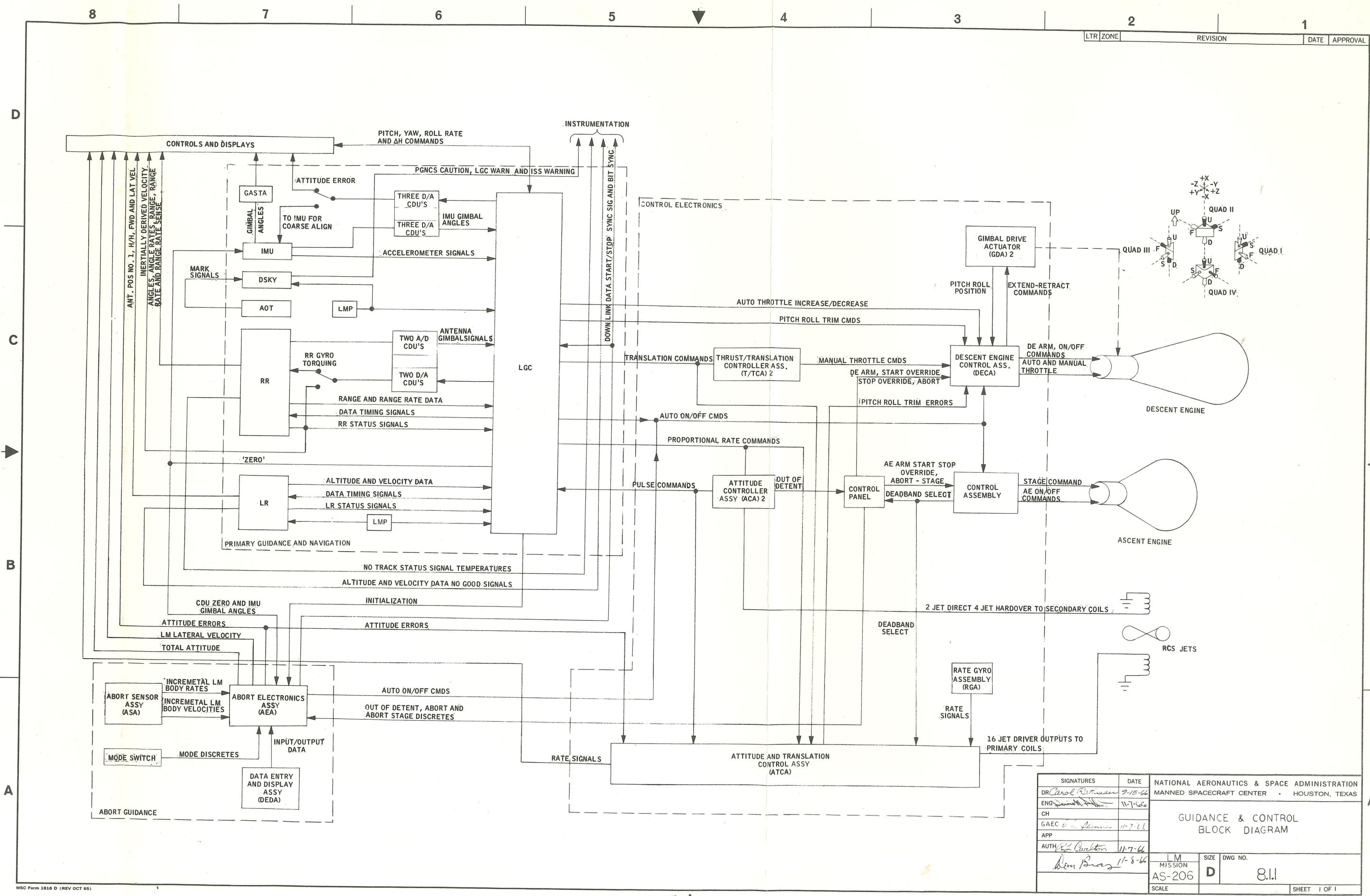


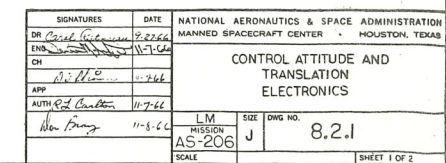
FIGURE 8-3 PERFORMANCE OF PULSE, RATIO MODULATOR.



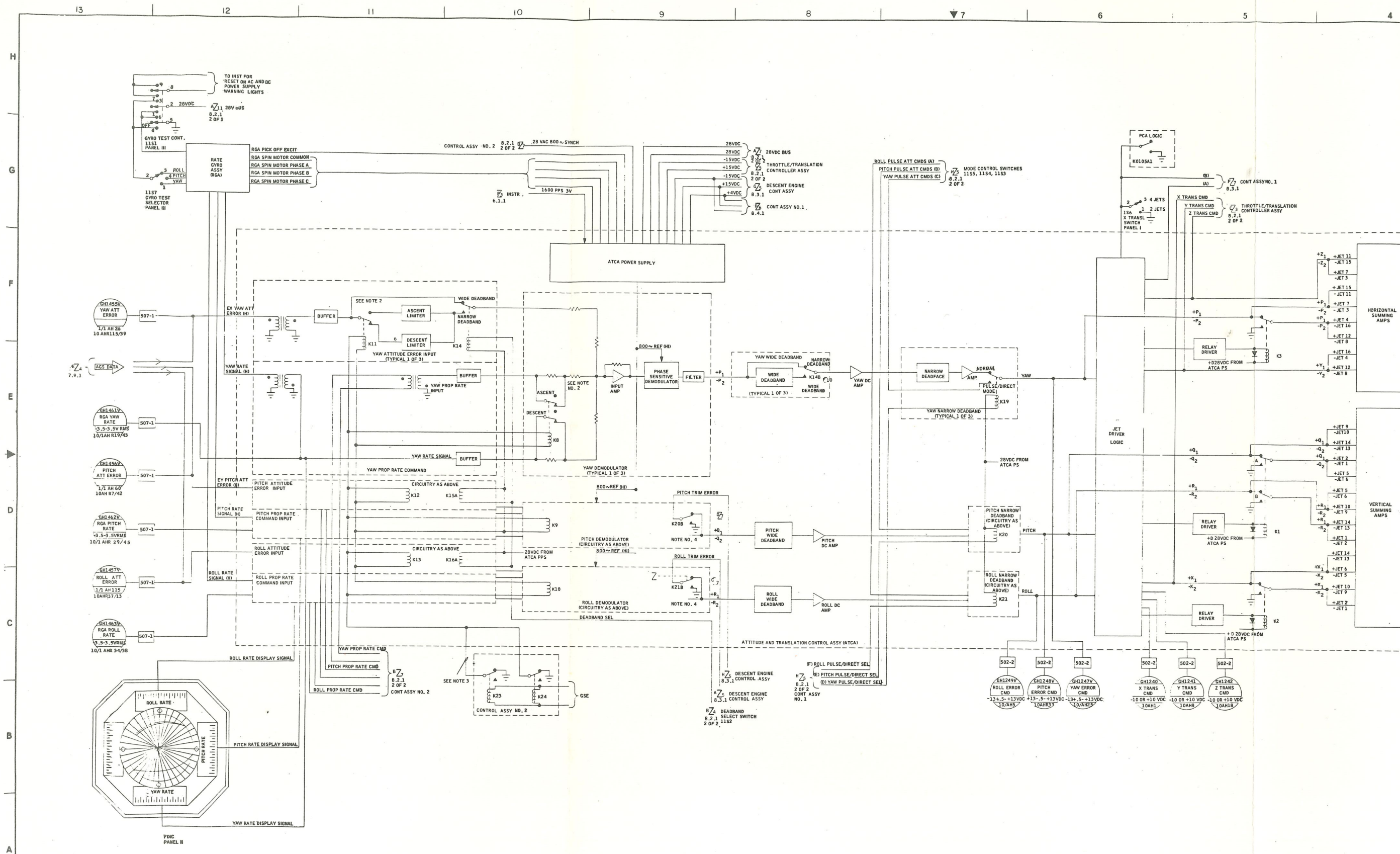


SIGNATURES		DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION	
DR. Carol R. ...		9-15-66	MANNED SPACECRAFT CENTER • HOUSTON, TEXAS	
ENG. ...		11-7-66	GUIDANCE & CONTROL BLOCK DIAGRAM	
CH				
GAEC ...		11-7-66		
APP				
AUTH. ...		11-7-66		
...		11-8-66		
MISSION		AS-206	SIZE	DWG NO.
SCALE				8.11
				SHEET 1 OF 1

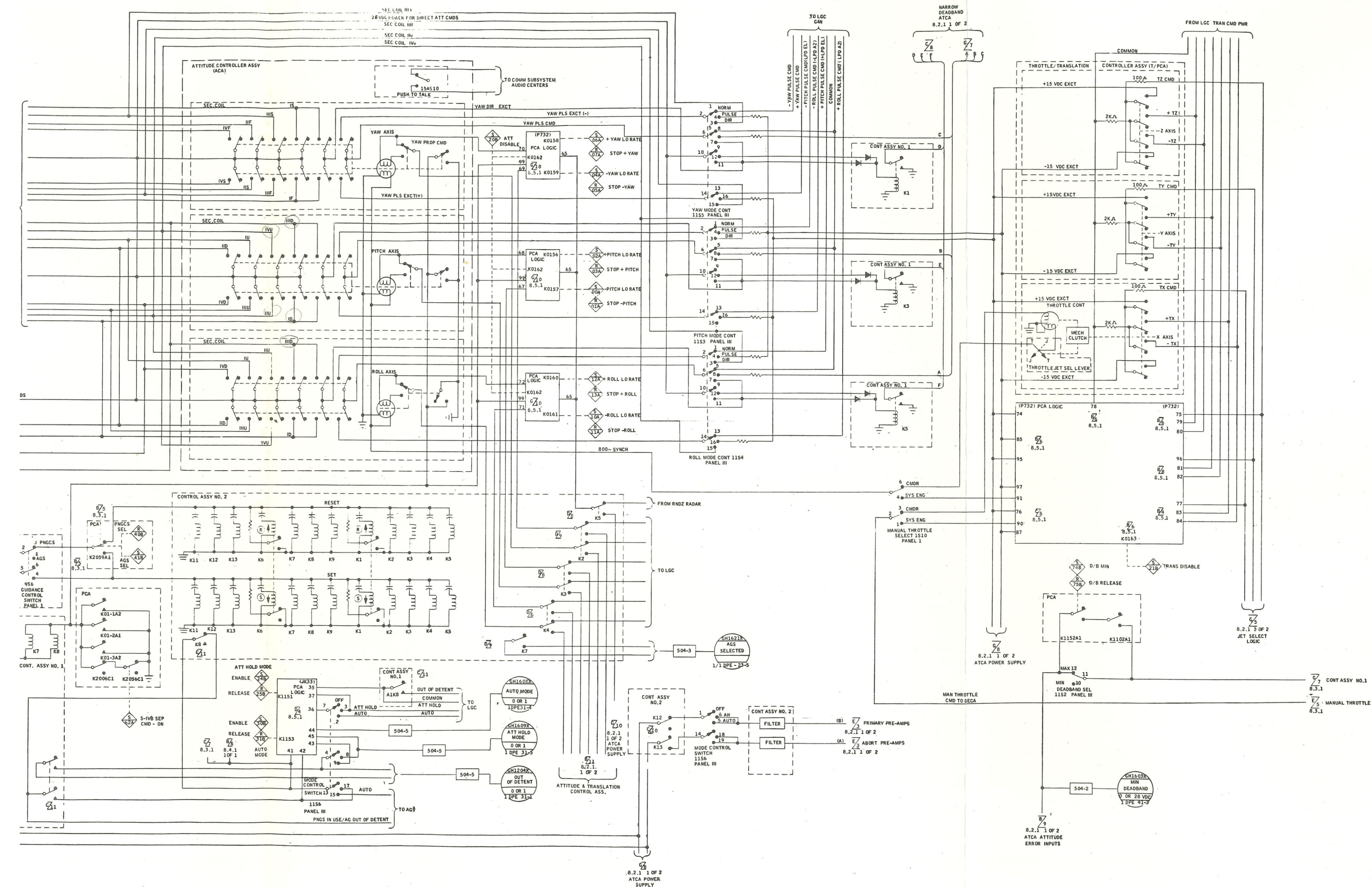








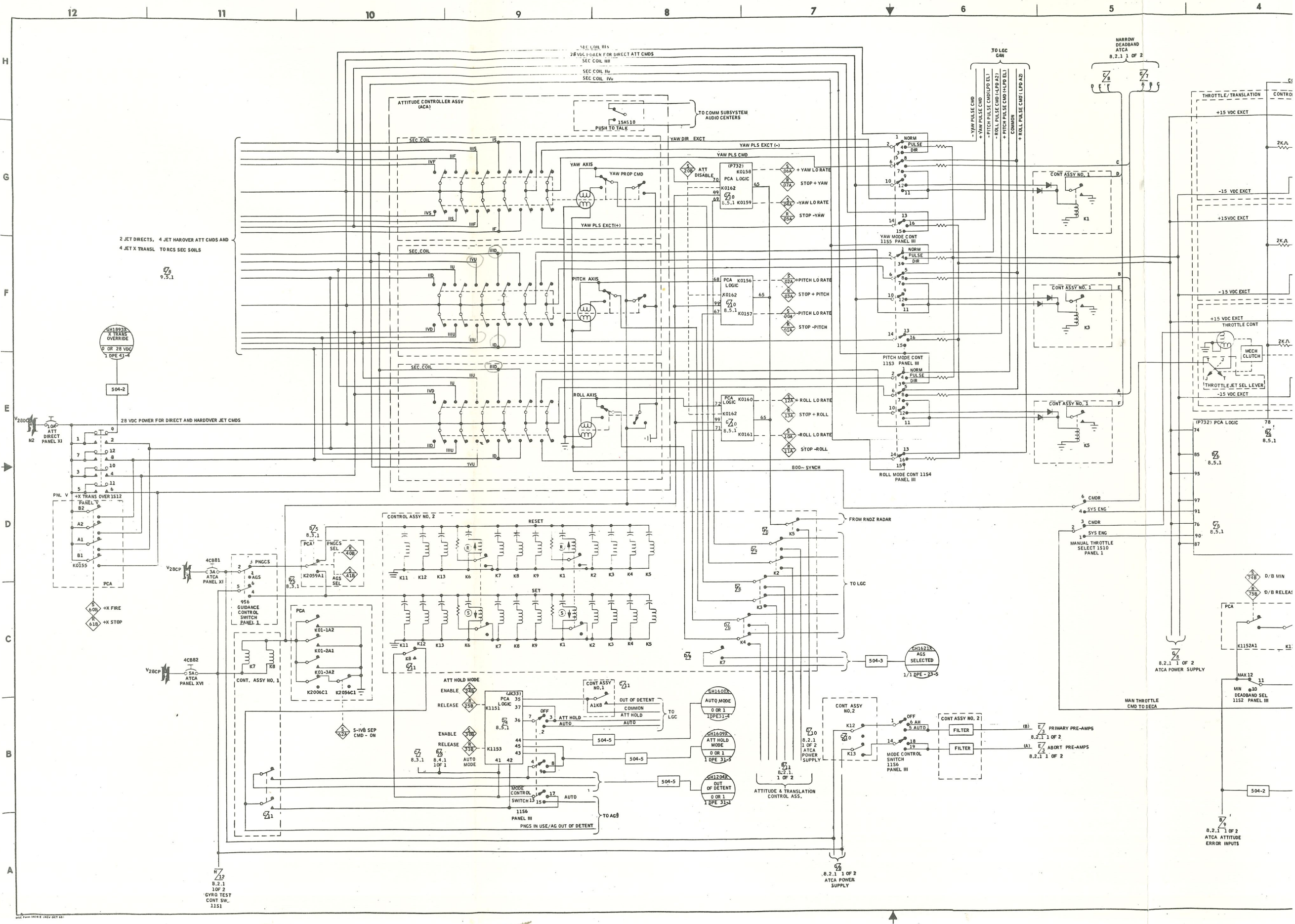




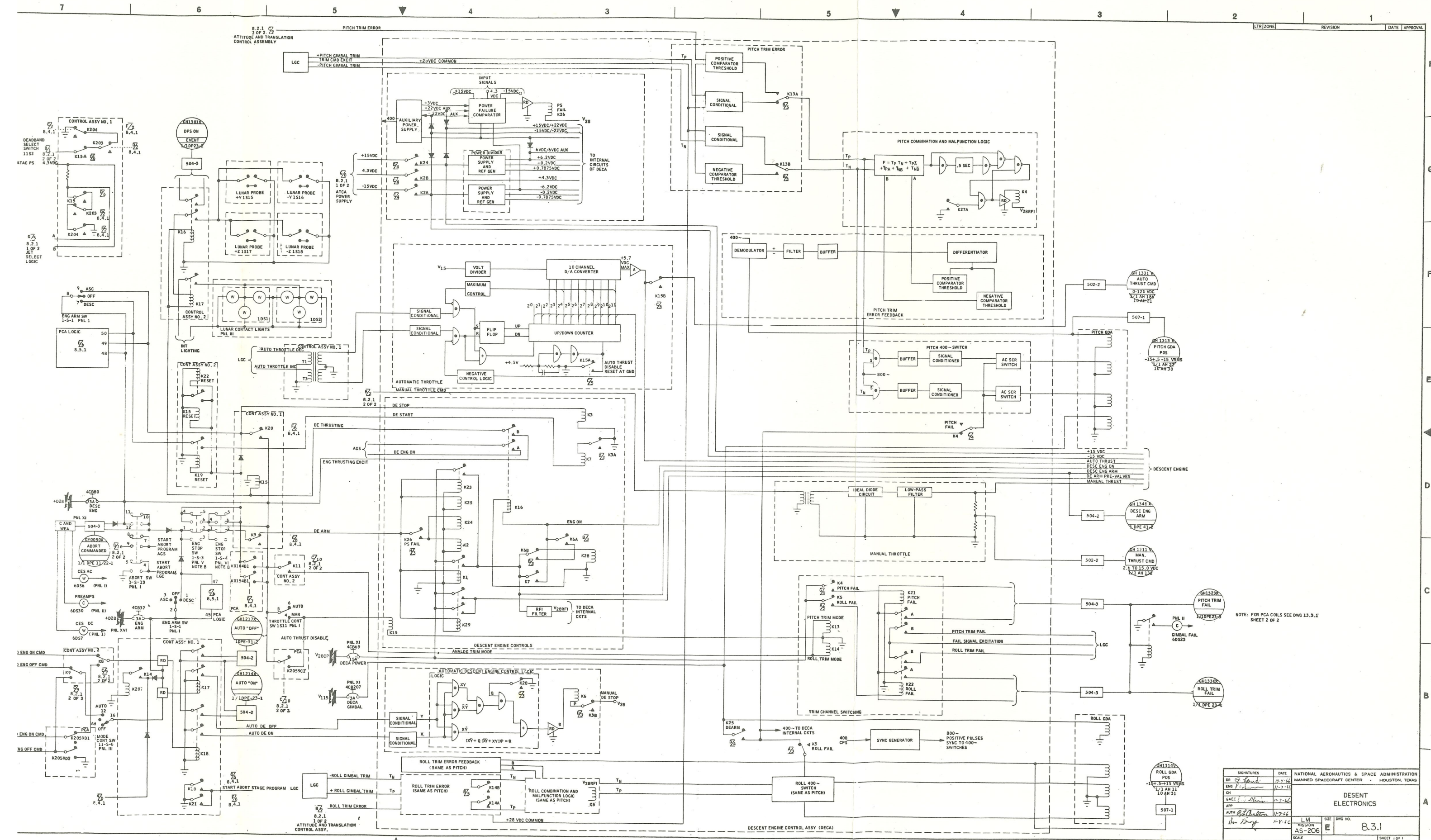
NOTE: FOR PCA COILS  
SEE DWG NO. 13.3.1  
SHEET 2 OF 2

SIGNATURES	DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION
DR. <i>[Signature]</i>	11-7-66	MANNED SPACECRAFT CENTER - HOUSTON, TEXAS
CH. <i>[Signature]</i>	11-7-66	
GAEC <i>[Signature]</i>	11-7-66	
APP. <i>[Signature]</i>	11-7-66	
AUTH. <i>[Signature]</i>	11-7-66	
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MISSION		J
AS 206		8.2.1
SCALE		SHEET 2 OF 2



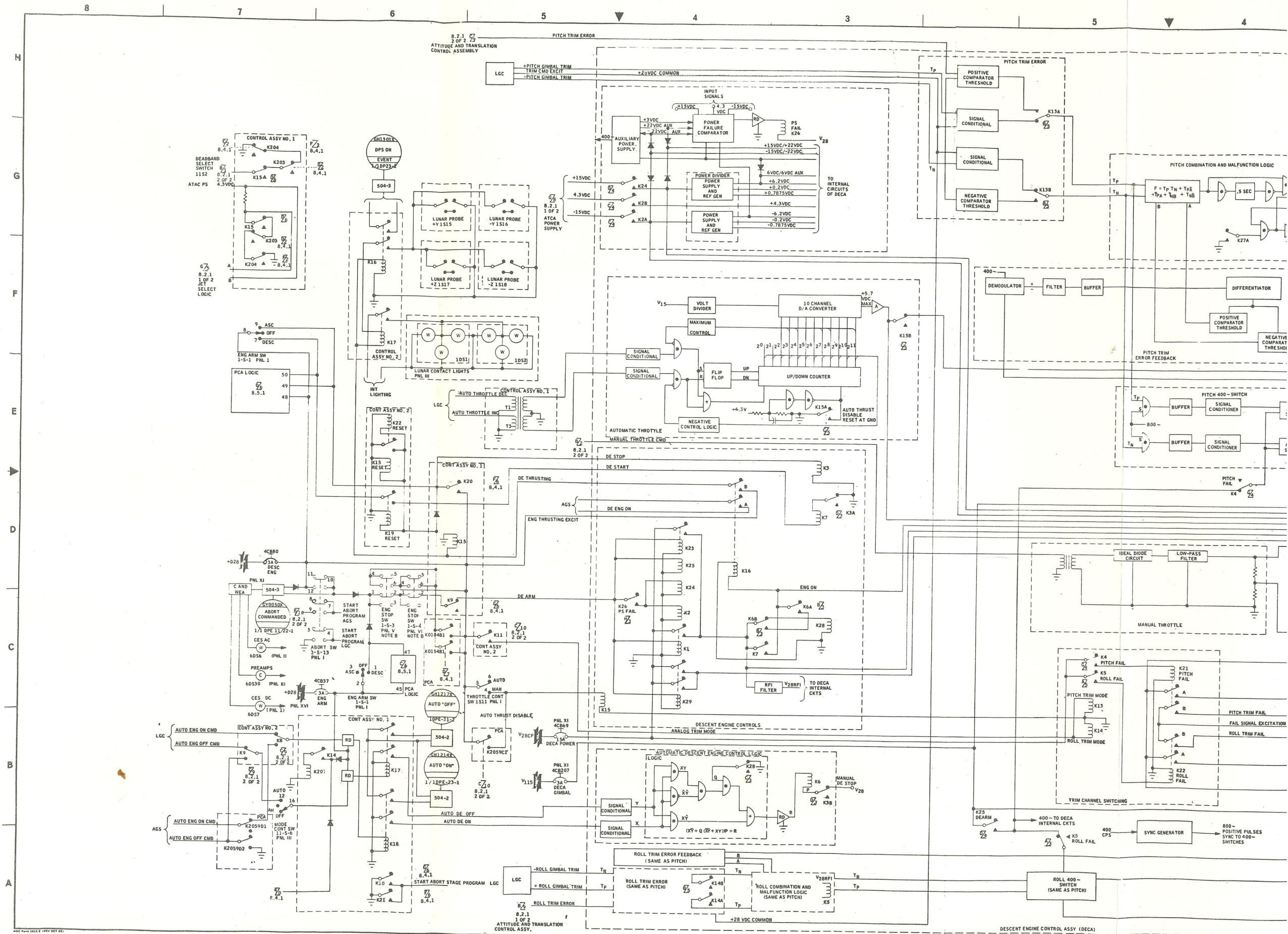




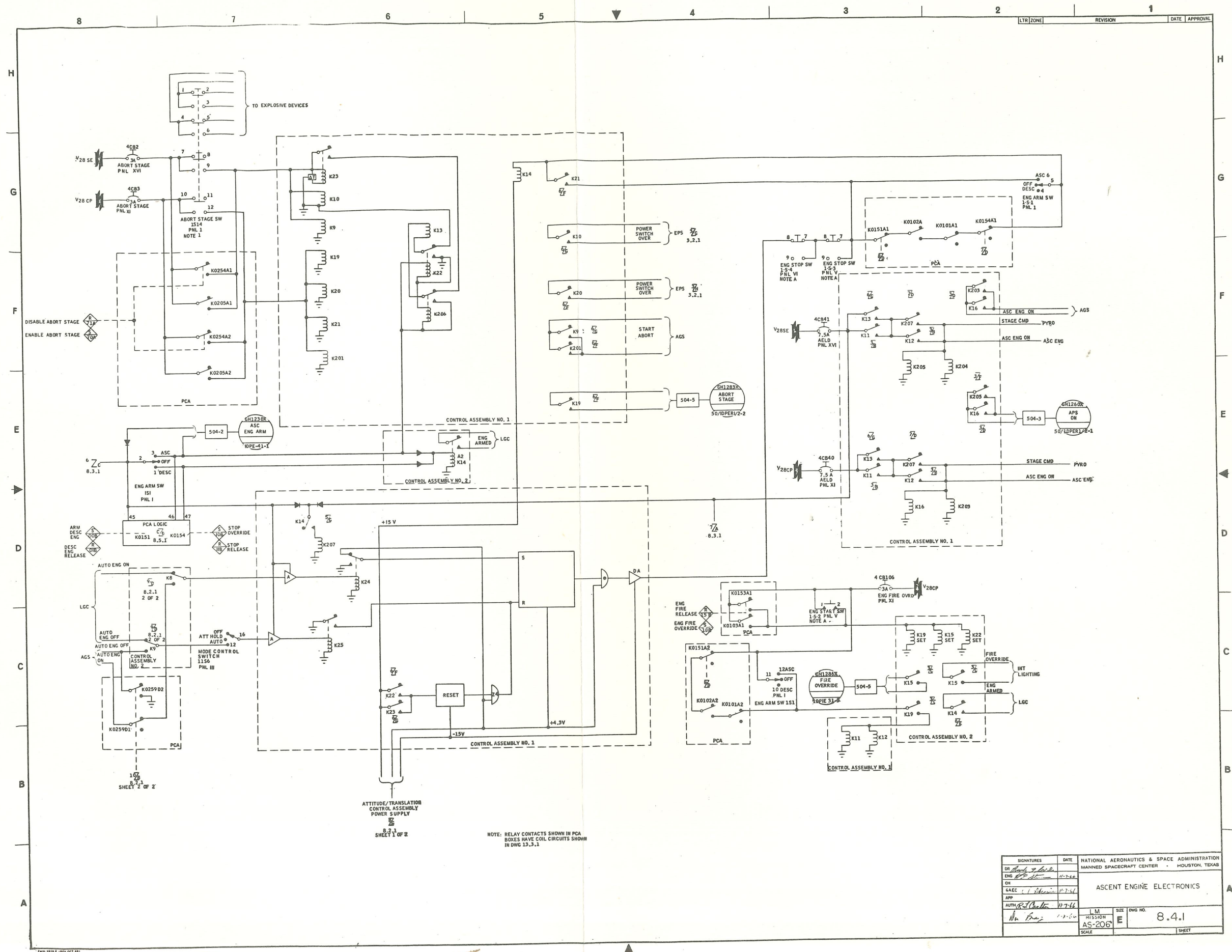


SIGNATURES		DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION MANNED SPACECRAFT CENTER - HOUSTON, TEXAS	
DR <i>P. Hark</i>		11-7-66	DESENT ELECTRONICS  L M SECTION AS-206 SCALE SIZE ENG. Dwg. <b>8.3.1</b> E SHEET 1 OF 1	
CH <i>W.C.</i>		11-7-66		
GACC <i>C. J. Blevins</i>		11-7-66		
APP				
AUTH <i>Bob Blevins</i>		11-7-66		
<i>Don Blevins</i>		11-7-66		

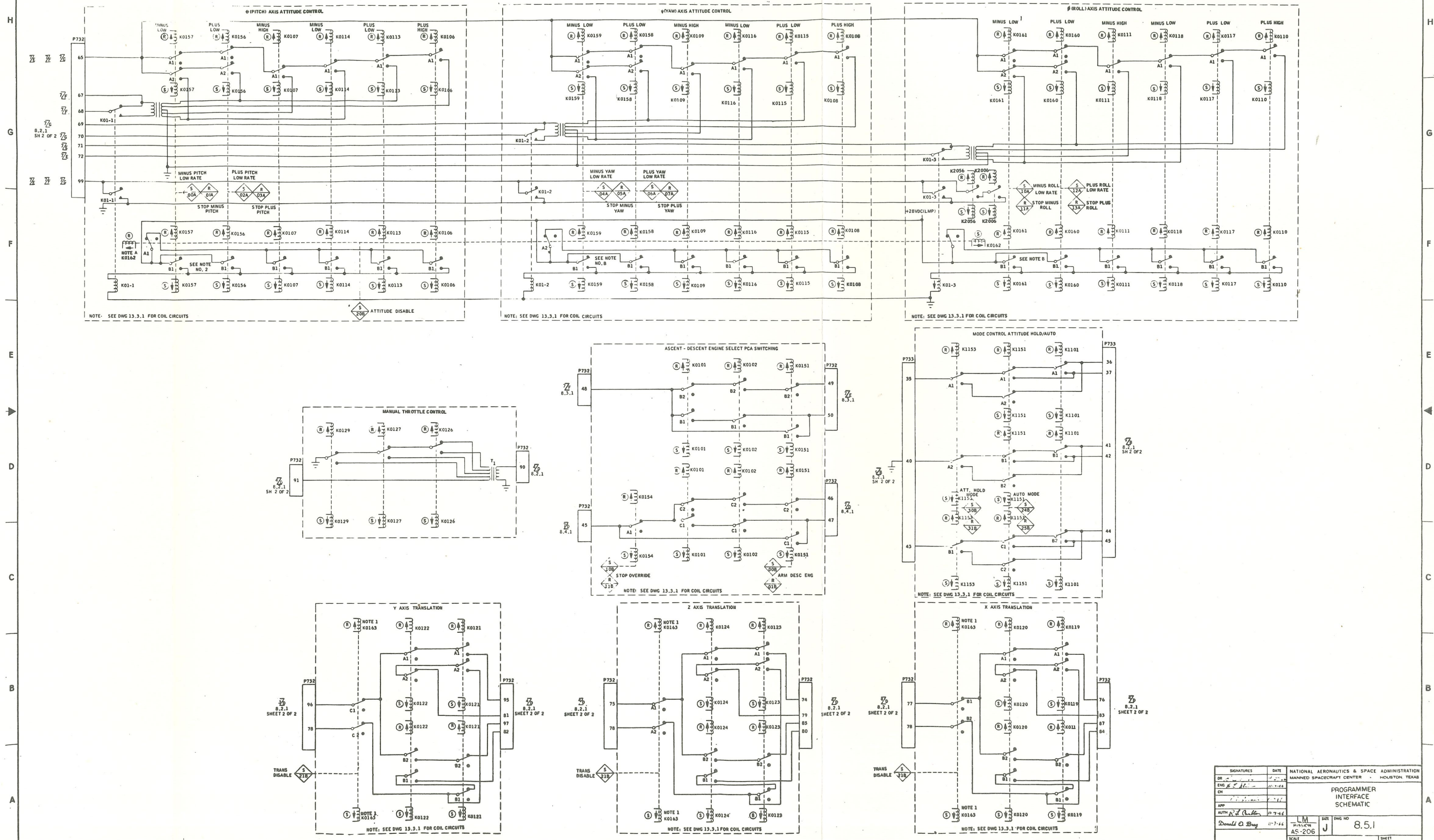














9. REACTION CONTROL  
SYSTEM

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SECTION 9  
REACTION CONTROL SUBSYSTEM

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### 9.1 GENERAL DESCRIPTION

The Reaction Control Subsystem (RCS) is composed of two parallel, independent systems ("A" system and "B" system). Each system contains identical components with the associated valves and plumbing necessary to deliver the propellants to the thrust chamber assemblies. Normally both systems are operated together, but the arrangement of the engines is such that complete control in all axes is possible despite a failure of either system.

Helium pressurization is accomplished by an electrical RCS pressurization command to two parallel squib actuated isolation valves in each system. The two squibs in each system are redundant, and all are opened simultaneously by the LM Guidance Computer (LGC), Program Reader Assembly (PRA), or a Real-Time Command (RTC).

Downstream are two series helium regulators which reduce the helium supply pressure for proper propellant tank pressurization. In normal operation, the upstream regulator is in control and reduces the pressure to the proper level, while the downstream regulator senses a demand and remains open as the sensed demand is below the setting. If the upstream regulator fails open, control is obtained by the downstream regulator and is of no consequence as the upstream regulator is already in control.

If either regulator fails closed, engine operation in the blowdown mode will continue briefly until the helium pressure drops below the point where propellants can be injected into the engine combustion chamber. If both regulators fail open, the burst disc will rupture and a relief valve will vent the helium overboard. Engine operation in the blowdown mode will continue as above. In both cases of malfunction, the use of the eight thrusters in the failed system is lost. However, the eight thrusters of the other system remain in operation and are capable of providing attitude and translation control of the vehicle at reduced efficiency. Also, crossfeeding the remaining systems propellants into the failed system's eight thrusters is possible.

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Normally open propellant shutoff valves, located just downstream of the propellant tanks in each system, are capable of isolating the propellant tanks of either system in case of an upstream malfunction or depletion of propellants. These valves are operated in pairs (fuel and oxidizer) for each system by prime commands from the LGC, backup commands from the PRA, or RTC backup commands from the ground.

Normally closed fuel and oxidizer manifold crossfeed valves exist which can be opened to supply either system's propellants to all sixteen thrusters in case of a failed system. These two valves are operated as a pair by prime commands from the LGC or backup commands from the PRA. No RTC control exists for the crossfeed valves.

In addition, normally closed ascent feed valves, connecting ascent propellants to both systems fuel and oxidizer manifolds independently, may be opened to conserve RCS propellants. It should be emphasized that ascent propellants may be utilized in the RCS thrusters only during positive "X" axis acceleration. These ascent interconnect feed valves are operated in pairs for each system by prime programmed commands from the LGC or by backup commands from the PRA. No RTC control is available for these valves. Also, during ascent feed operation, the main shutoff valves of the appropriate systems must be closed and the crossfeed valves should be opened.

Normally open isolation valves exist in the propellant lines feeding thruster pairs, allowing the isolation of a thruster pair containing a failed open thruster. Through an onboard failure detection logic, the LGC senses a failed thruster and automatically closes the appropriate isolation valves to isolate the failed pair. No PRA or RTC control of this function is available. The LGC is also capable of controlling the vehicle's attitude and translation without using the isolated thruster pair.

The RCS performs the following functions:

- A. Provides small thrust impulses to stabilize the LM during descent and ascent burns.

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- B. Provides necessary thrust impulses to control the vehicle attitude and translation during all maneuvers.
- C. Provides necessary thrust impulses to accomplish separation maneuvers.
- D. Provides necessary thrust impulses to accomplish accelerations for ullage settling for the descent and ascent propellant tanks when required.

The RCS is capable of operating in either a pulsed or a steady-state mode and is controllable by the LGC, Abort Guidance Computer, or by a manual Attitude Controller Assembly (ACA) during manned flights. In "Normal" mode, attitude and translational maneuvers are accomplished by commands from either computer of variable frequency and pulse width to the primary coils of the engines. In "Pulsed" mode, the LGC sends one pulse for each out-of-detent movement of the ACA to the primary coils and in "Direct" mode, the ACA sends commands directly to the secondary coils of the RCS engines.



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## 9.2 DESCENT PROPULSION SYSTEM (DPS)

### 9.2.1 General

- A. The descent engine is a throttleable engine over a 10:1 range and develops 10,500 pounds of thrust in a vacuum at full throttle and 1,050 pounds minimum thrust. It consists primarily of an ablative lined thrust chamber with a crushable, radiation cooled nozzle extension; a variable area injector; a pair of flow control valves; four electromechanical flow control actuators; and eight propellant shutoff valves. It is mounted in the center compartment of the descent stage and is pivoted at the throat of the combustion chamber on a gimbal ring that is an integral portion of the engine assembly. The ring is suspended in the structure, pivoted in a line 90 degrees opposite to the engine pivots, so that the engine is capable of being gimballed  $\pm 6$  degrees in any direction by means of vehicle mounted gimbal actuators.
- The mechanical throttling scheme utilizes variable-area, cavitating venturi flow control valves mechanically linked to a variable area injector in order to separate propellant flow control and propellant injector functions so that each may be optimized without compromising the other, and to ensure that propellant flow rates are made insensitive to downstream pressure variations in the injector and combustion chamber. At maximum thrust, operation is conventional. At approximately 70 percent minimum thrust cavitation commences in the valve throats. From this level down to minimum thrust, the valve functions as a cavitating venturi. As thrust is reduced, the actuator reduces the flow at the control valves and moves the injector sleeve to reduce the injector apertures.
- B. The engine is activated and throttled by the LM Guidance Computer, which starts a sequence of events resulting in firing squibs and igniting the engine.

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The propellants are nitrogen tetroxide and a 50/50 blend of Unsymmetrical Dimethyl Hydrozine (UDMH) and hydrazine called Aerozine 50. The freezing point of nitrogen tetroxide at standard conditions is 12°F; the boiling point is 70°F. The freezing point of Aerozine 50 at standard pressure is 21°F and the boiling point is 170°F.

### 9.2.2 Helium Storage Tank

Supercritical helium is stored in a double walled cryogenic storage container. It consists of an inner spherical tank with an outer jacket; the void between the tank and its jacket is filled with aluminized mylar insulation and evacuated to minimize heat transfer. The material used is titanium. The tank has associated fill and vent ports and a pressure relief device consisting of two burst discs, in series. Inside the inner tank is a helium/helium heat exchanger constructed of titanium tubing.

### 9.2.3 The Propellant Shutoff Valves

The shutoff valves are fuel pressure-actuated ball valves, fuel is introduced to the valve actuators through solenoid operated pilot valves, all of which are energized simultaneously during engine startup. During the start, the solenoids unseat the caged balls from the actuator inlet ports and seat them against the overboard vent ports. Fuel enters the actuator cavities; the actuator pistons connected to rack and pinion linkages twist the ball valves 90 degrees to the open position, permitting flow to the injector. The series parallel redundancy in the valve arrangement provides for positive start and cutoff. During shutdown, the solenoids are de-energized, opening the vent ports. The spring loaded actuators close the shutoff valves and residual actuating fuel is vented overboard into space. A mismatch circuitry is tied in with this system. It takes the output of eight microswitches and puts them through a summing network. The output of this network is then telemetered to ground indicating any disparity in valve positions.

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#### 9.2.4 Propellant Quantity Gaging System (PQGS)

A capacitance type quantity gaging system is used to provide propellant quantity information via telemetry to the ground during positive "G" conditions. The PQGS will be a continuous gaging system with capabilities for gaging propellants in each descent stage tank between 95 percent of propellants remaining and one inch of the tank bottom. The accuracy of the system between 95 percent and 25 percent of the propellants remaining is  $\pm 1.0$  percent of full tank capacity. Between 25 percent of propellants remaining and one inch of the tank bottom, the system accuracy is  $\pm 0.5$  percent of full tank capacity. Due to component heating in a vacuum, the system is constrained to 15 minutes of operation at any one time, however, the total operating life is 5000 hours. The LGC is programmed to automatically turn the PQGS ON and OFF before and after each burn. In addition the PQGS will provide a discrete signal when the propellant level is a predetermined distance from the tank bottom, corresponding to 120 seconds engine operating time remaining at 25 percent thrust.

#### 9.2.5 Fuel/Helium Heat Exchanger

This heat exchanger absorbs heat from the engine fuel which has been circulated from the fuel tanks directly to the heat exchanger, before its ultimate delivery to the engine. It is a two pass heat exchanger, that is, helium from the storage tank absorbs heat from the fuel on the first pass. Then flows back to the helium/helium heat exchanger inside of the storage tank, then is reheated on the second pass.

#### 9.2.6 Thrust Chamber

The thrust chamber consists of a composite ablative cooled nozzle extension (area ratio of 16:1) a crushable radiation cooled nozzle extension (area ratio of 49:1) and a gimbal ring assembly. The ablative components are encased in a continuous titanium shell and jacketed in a stainless steel foil/glass wool composite thermal blanket. The radiation cooled nozzle extension is made from stainless steel. The nozzle extension is flanged to the titanium chamber shell. The gimbal assembly is located at the chamber throat plane and provides for a  $\pm 6$  degree gimbal of the

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thrust vector during flight. The assembly is manufactured from aluminum alloy, except for the bearings, which are made of high strength steel.

#### 9.2.7 Flow Control Valves

Flow control valves are non-redundant venturis with movable pintle sleeves. Engine throttling is initiated by an electrical signal to the throttle actuator commanding an increase or decrease in engine thrust. Operation of the throttle actuator drives the linkage cross beam to a new position, thus repositioning the pintles in the flow control valves. This axial movement of the pintles results in decreasing or increasing the pintle flow areas the precise amounts to control propellant weight flow rate and thrust.

#### 9.2.8 Throttle Actuator

The throttle actuator is an electromechanical linear servoactuator powered by redundant motors. It is located between the fuel and oxidizer flow control valves on the engine head end. The output shaft of the actuator is attached to the throttle linkage. Three torque motors drive the jack screw. The actuator is designed to operate within specification using two motors, or at a reduced rate using only one. The actuator case is hermetically sealed to prevent cold welding in a vacuum environment. Although the actuator could operate without lubrication, a compound with a known off-gasing rate is included to maintain a small positive pressure if the actuator case leaks. Performance redundancy is provided by designing each of the three separate servo channels to have equal output performance. For a null-type or inoperative failure, two separate servo channels failing can be tolerated. The two malfunctioning motors will be driven along with the load by the one operating motor. In the case of a saturated or hardover-type failure of one servo channel, the load is effectively increased by the two operating motors which have the capability of overriding the malfunction and providing the required output performance.

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#### 9.2.9 Pressure Regulators

There are two regulators, one in each parallel leg of the system, the primary leg being normally open and providing helium at 245 psia downstream. Each leg has a solenoid valve upstream of the regulator which is controlled from the cabin or maybe commanded from the ground. The secondary leg is normally closed (but may be opened as required). It also provides 245 psi downstream.

#### 9.2.10 Quadcheck Valves

There are two such valves, one in each of the lines leading to the propellant tanks. They are made up of four check valves arranged in a series - parallel configuration, the primary purpose being to prevent propellant vapors from mixing in the upstream manifold.

#### 9.2.11 Propellant Tanks (Titanium)

There are four propellant tanks, two each for oxidizer and fuel. They are interconnected on top and on bottom, within each system to insure equal usage and pressure. Each tank has a volume of 63 cubic feet.

#### 9.2.12 Supercritical Helium

The helium pressure timeline begins with the DPS propellant loading. This occurs at about 18 hours before nominal liftoff when the supercritical helium loading pressure is approximately 100 psia. Due to the heat transfer from the surroundings, the helium pressure increases at the rate of approximately 10 psi per hour until the descent engine is fired. During low level thrust, the pressure builds up at a rate of 100 psi per minute. Subsequently, after engine shutdown, the pressure rises sharply at about 150 psi per hour for one hour, after which time, the pressure again increases at a rate of 10 psi per hour. Since the minimum DE turn-on pressure is 400 psia, approximately 15 hours from nominal liftoff are required before this pressure is achieved.

The time range between 33 and 130 hours from DPS propellant loading or 400 to 1400 psia, respectively, defines the region which will safely allow normal engine operation at the maximum throttle duty cycle.



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Ignition of the descent engine during low supercritical helium tank pressures (i.e., below about 350 psia) results in a "blowdown or degraded engine operating mode. Too high a pressure (above  $1920 \pm 50$  psia) could rupture the burst disc, thus terminating pressurization which results in degraded "limited blowdown" mode.

- C. Regulator Shutoff Valves. There are two latching type shutoff valves, one for each regulation leg. They are used to shut off helium flow through their respective leg should the pressure regulation component in the leg fail open. Both valves are normally open, and are closed to provide isolation of helium regulator failure.
- D. Pressure Reducing Regulators. This regulating system uses four regulators in a series parallel arrangement, two regulators in each leg. This arrangement provides the overall regulation system with added redundancy. Each regulator contains a pilot valve and seat assembly which modulates inlet pressure to control the opening of a main poppet valve and seat assembly, and has the ability to reduce the upstream pressure to that required to provide correct propellant tank pressurization. Minimum operating inlet pressure is 400 psi.
- E. Quadcheck Valves. This assembly consists of four check valves arranged in a series parallel configuration. The purpose is to prevent the mixing of propellants or propellant fumes in the upstream pressurization manifold.
- F. Burst Discs and Relief Valves. This assembly is installed to prevent propellant tank damage in case of overpressurization. The burst disc serves the function of preventing leakage through the relief valve during normal operation, and will burst at a pressure slightly above the nominal relief valve setting. Above the nominal relief valve setting, helium is dumped overboard through a thrust neutralizer which eliminates thrust generated by the escaping gas. When pressure drops below the nominal setting, the relief valve closes, permitting a resumption of normal pressurization.
- G. Explosive Valves. Located between the quadcheck valve assembly and the propellant tanks in each leg are two, normally closed, squib valves in a parallel arrangement. These valves serve the purpose of forming a positive seal and make it

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### 9.3 ASCENT PROPULSION SYSTEM

#### 9.3.1 General

- A. The ascent propulsion subsystem is wholly contained in the ascent stage and uses a fixed, constant thrust engine which provides the thrust for a powered ascent from the lunar surface and provides the thrust for any orbit adjustments that may be necessary for successful rendezvous with the Command/Service Module. In addition, the ascent propulsion subsystem provides propellant to the RCS during APS operation. It is a fixed thrust, non-gimbaling, hyperbolic type engine which develops 3500 pounds of thrust. Propellants used are nitrogen tetroxide and a blend of UDMH and hydrazine 50 under helium pressurization.
- B. The ascent engine system is activated by the automatic "ON-OFF" commands originating in the LM Guidance Computer or the Abort Electronics or manually by manual "ON-OFF" commands originated by the astronauts at control panel switches. Either method initiates a sequence of events which results in firing pro-technics and igniting the engine.

#### 9.3.2 Notes

- A. Helium Storage Tanks. Gaseous helium is stored under high pressure (3500 psi) in two spherical titanium storage tanks. This helium is used as a pressurant to expel the propellants from the propellant storage tanks during periods of engine operation. The helium sources are isolated by explosive squib valves in both the primary and redundant pressurization system.
- B. Helium Isolation Valve. A normally closed, explosively operated squib valve isolates the helium supply in its tanks until propellant tank pressurization is required. These valves are opened by an electrical signal from the control panel. They are one shot valves, once opened they cannot be closed again.

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- C. Regulator Shutoff Valves. There are two latching type shut-off valves, one for each regulation leg. They are used to shut off helium flow through their respective leg should the pressure regulation component in the leg fail open. Both valves are normally open, and are closed to provide isolation of helium regulator failure.
- D. Pressure Reducing Regulators. This regulating system uses four regulators in a series parallel arrangement, two regulators in each leg. This arrangement provides the overall regulation system with added redundancy. Each regulator contains a pilot valve and seat assembly which modulates inlet pressure to control the opening of a main poppet valve and seat assembly, and has the ability to reduce the upstream pressure to that required to provide correct propellant tank pressurization. Minimum operating inlet pressure is 400 psi.
- E. Quadcheck Valves. This assembly consists of four check valves arranged in a series parallel configuration. The purpose is to prevent the mixing of propellants or propellant fumes in the upstream pressurization manifold.
- F. Burst Discs and Relief Valves. This assembly is installed to prevent propellant tank damage in case of overpressurization. The burst disc serves the function of preventing leakage through the relief valve during normal operation, and will burst at a pressure slightly above the nominal relief valve setting. Above the nominal relief valve setting, helium is dumped overboard through a thrust neutralizer which eliminates thrust generated by the escaping gas. When pressure drops below the nominal setting, the relief valve closes, permitting a resumption of normal pressurization.
- G. Explosive Valves. Located between the quadcheck valve assembly and the propellant tanks in each leg are two, normally closed, squib valves in a parallel arrangement. These valves serve the purpose of forming a positive seal and make it



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impossible for any propellant fumes to reach the quadcheck valves during the period from propellant tank servicing prior to earth launch until just prior to ascent engine operation. It is a one shot valve. After it has been opened, and during subsequent periods of ascent engine shutdown, the quadcheck valve assemblies will be depended upon to prevent propellant fume leakage.

- H. Actuator Isolation Valves. Because of the possibility of fuel leakage at the ascent engine propellant shutoff valves actuators; actuator isolation valves have been installed in the fuel line between the fuel tanks and these actuators. These valves will be opened immediately prior to engine start, simultaneously with the engine shutoff valves. To provide redundancy, two valves are used, in a parallel arrangement.
- I. Trim Orifices. These orifices are placed in both propellant lines downstream of the tanks. Their function is to meter the propellants and so insure engine interface pressure requirements for proper propellant utilization.
- J. Propellant Shutoff Valves
  - 1. The primary function of the propellant shutoff valves is to initiate propellant flow to the engine during the start-up sequence, and to terminate the flow during engine shutdown. This component is exposed to the full pressure of the propellant feed system prior to engine firing.
  - 2. The propellant shutoff valves are mechanically linked, pilot operated, fuel actuated ball valves. Each valve contains a series parallel arrangement of balls. Fuel and oxidizer are completely isolated in separate valve bodies, with actuation of the oxidizer valve accomplished by a mechanical linkage driven from the fuel valve. The purpose of the series parallel, or quad arrangement is to insure continued operation of the engine and/or to prevent loss of

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propellant in the event of malfunction. The parallel arrangement provides redundancy for valve opening (engine firing). The series arrangement provides redundancy for valve closing (engine shutdown). All ball valves are supported by ball bearings.

3. The fuel and actuator housing contains actuator pistons and springs, solenoids, solenoid connector, two-position three-way pilot valves, and the associated actuation and vent ports.
4. The solenoid-operated pilot valves controlling the actuation fluid (fuel) and the main ball valves are normally closed. In the closed position, all solenoids are de-energized and the actuation fuel is shut off by action of the spring-loaded solenoid plungers on the ball poppets seated in the lower pilot valve seats. The back side of the actuator pistons are vented to preclude air lock. In the open position, all solenoids are energized, and fuel actuation forces at 165 psi, act against the spring-loaded plunger, thus permitting fuel to flow to the actuator pistons to initiate oxidizer and fuel valve opening. At this point, the pilot valves are forced against the upper valve seats, thus sealing off the vent port. When the electrical signal is removed, the pilot valves are returned to their lower seat position to seal off the actuation pressure. Closing of the main propellant ball valves is accomplished by the return spring action of the actuator piston springs which expel the entrapped fuel in the cylinders and pilot passages out through the pilot vent port.
5. All shutoff valves are opened simultaneously at engine start; all are closed simultaneously at engine shutdown. The time from signal initiation to full open or from signal cutoff to full closed is 150 milliseconds. Switches

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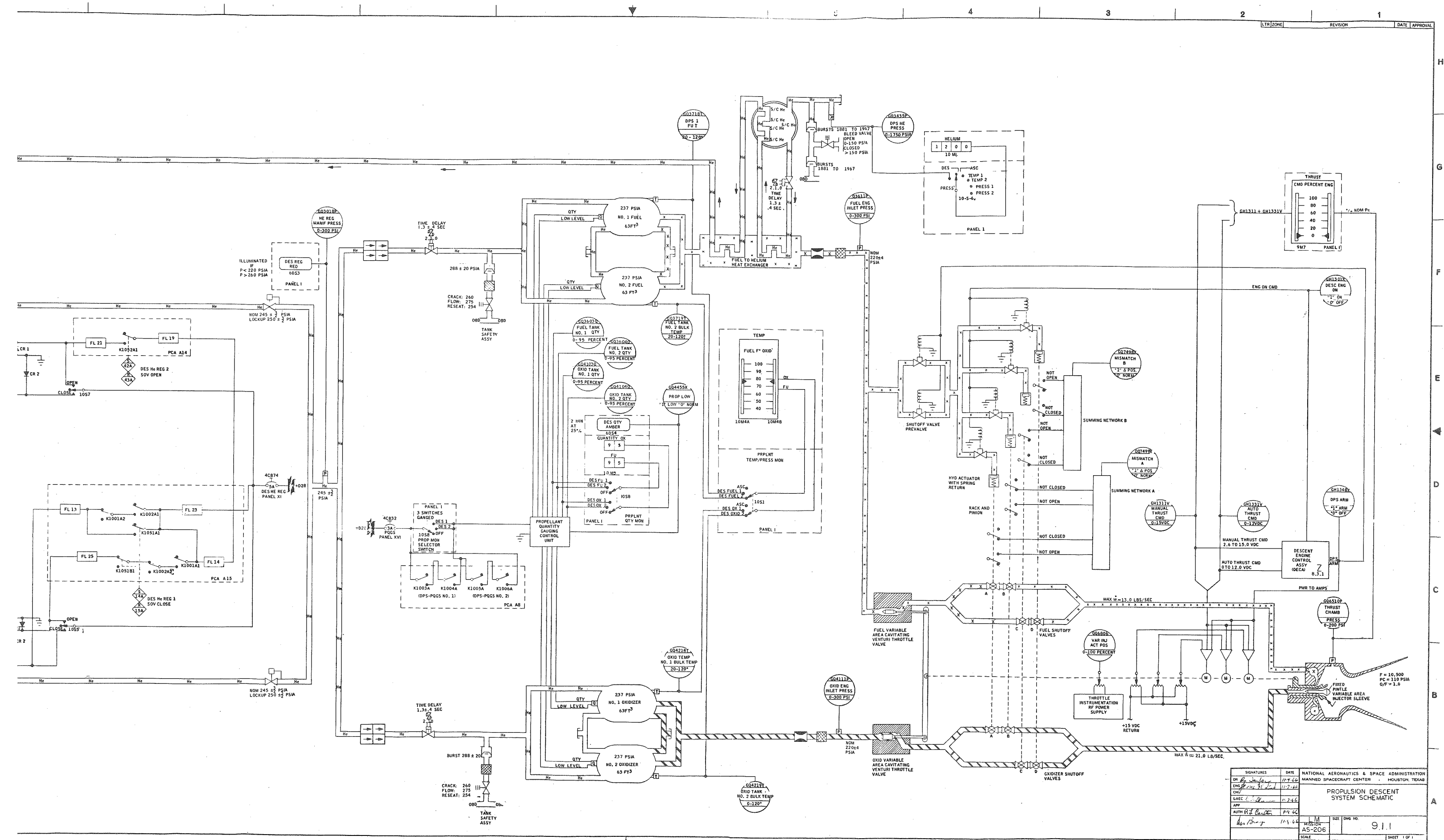
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REV A

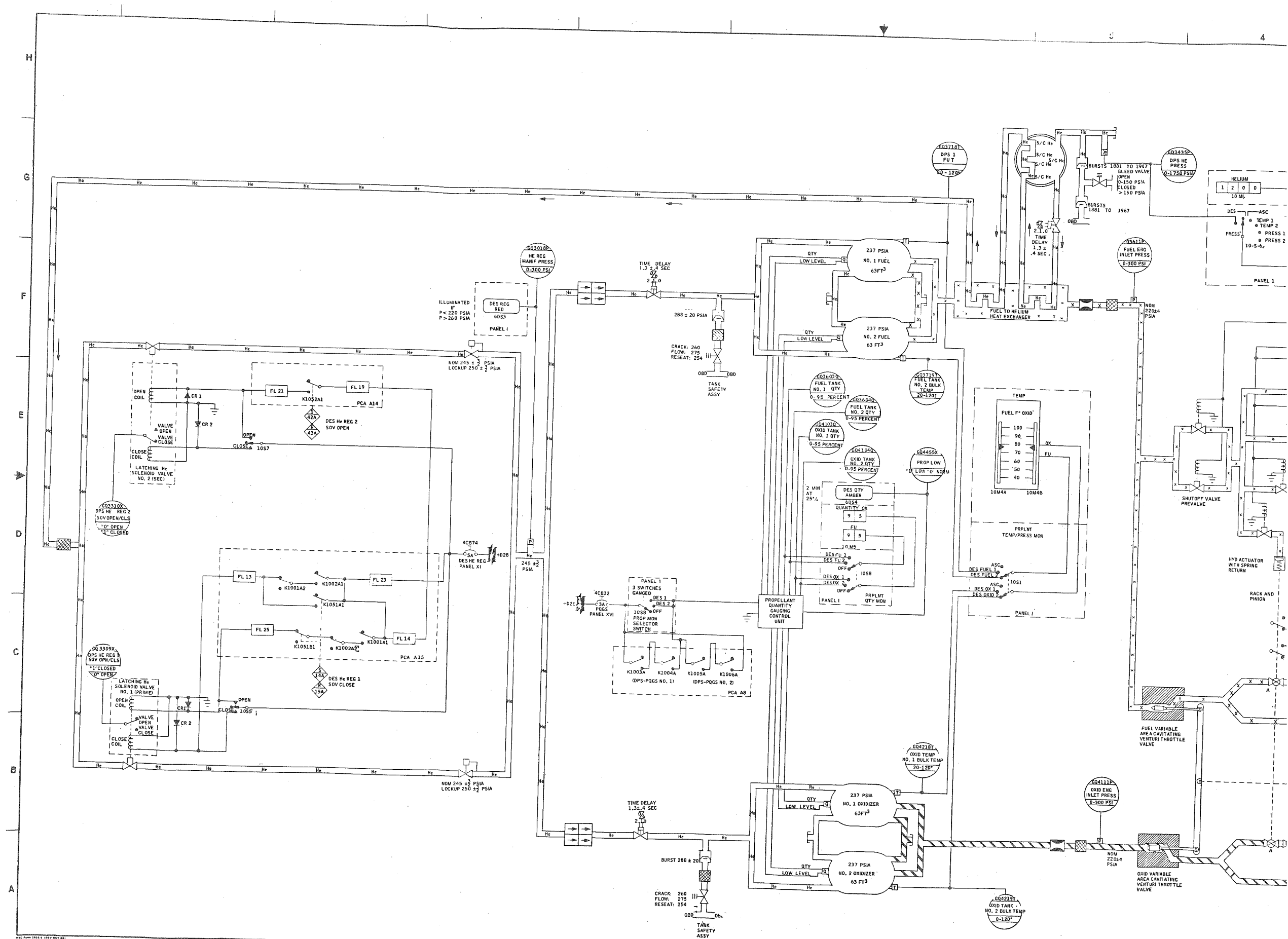
are installed in the oxidizer housing to provide a cockpit indication of valve position.

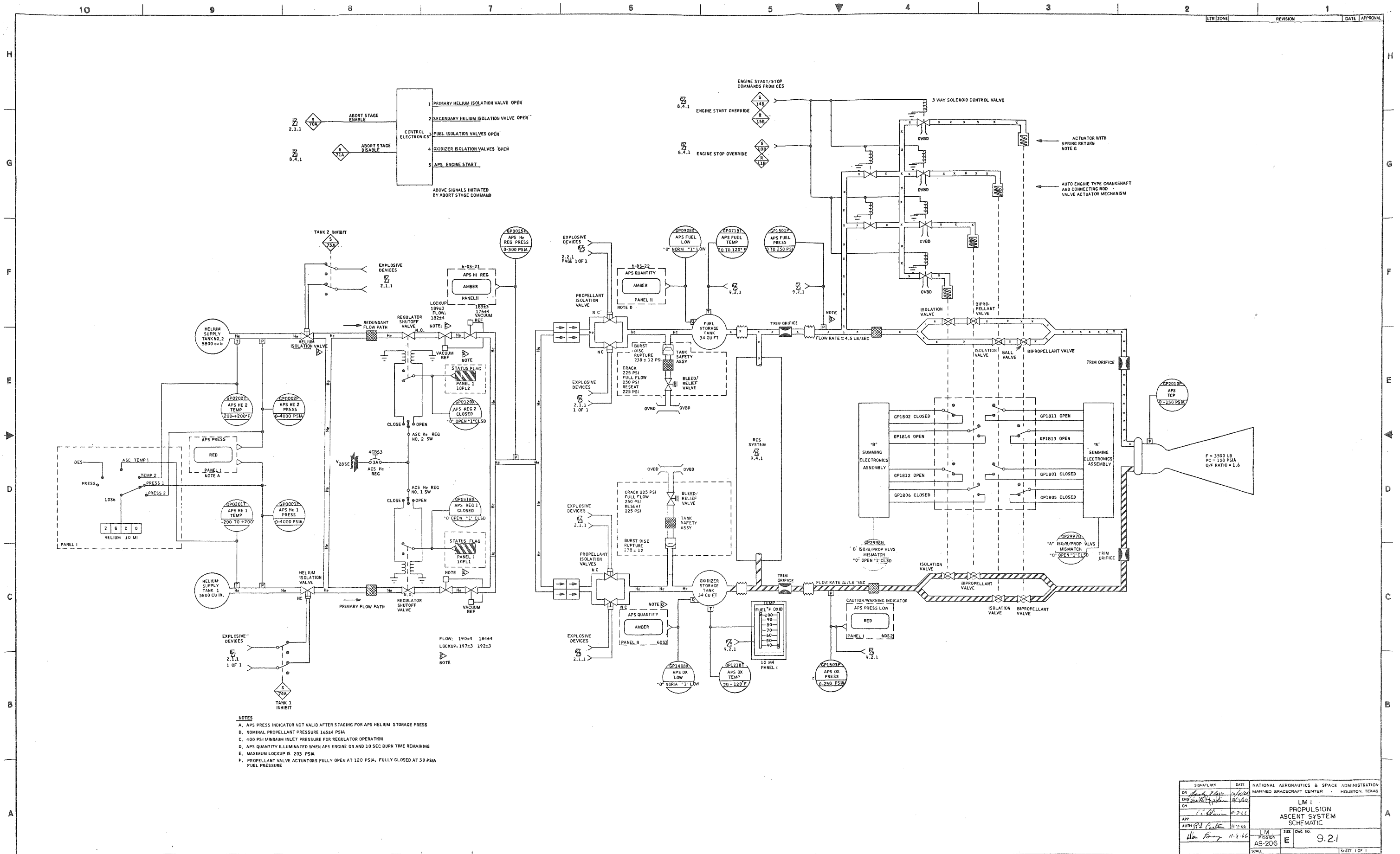
6. Eight microswitches (four open and four closed) make up the summing electronics for system "A" and system "B". An open and close microswitch is used for each crank actuator. In case of a mismatch signal, flow is diverted from the malfunctional path to the parallel flow path.

- K. Ascent Propulsion Low Press. Warning Light. The (ASC PRESS.) warning light is illuminated if either: 1. the pressure in either of two ascent helium tanks falls below 3000 psia prior to staging, or 2. if the blanket pressure in the fuel or oxidizer lines at the bipropellant valves of the ascent stage decays below 120 psia. If illuminated by a low helium pressure, this light is extinguished by a signal from a dead face switch resulting from staging if illuminated by low fuel or oxidizer pressure, the light is extinguished only by restoration of pressure.
- L. Ascent Propellant Low Quantity Caution Light. The (ASC QTY) caution light is illuminated if the level of ascent fuel or oxidizer in the ascent tanks reaches a value such that approximately 10 seconds burning time remains. The signal is intended to permit the crew to manually shut down the ascent engine to avoid possible explosive effects resulting from depletion of either fuel or oxidizer before the other, and to indicate that ascent engine thrusting is not available for midcourse correction or rendezvous braking. These low level signals are enabled only if the ascent engine is on.

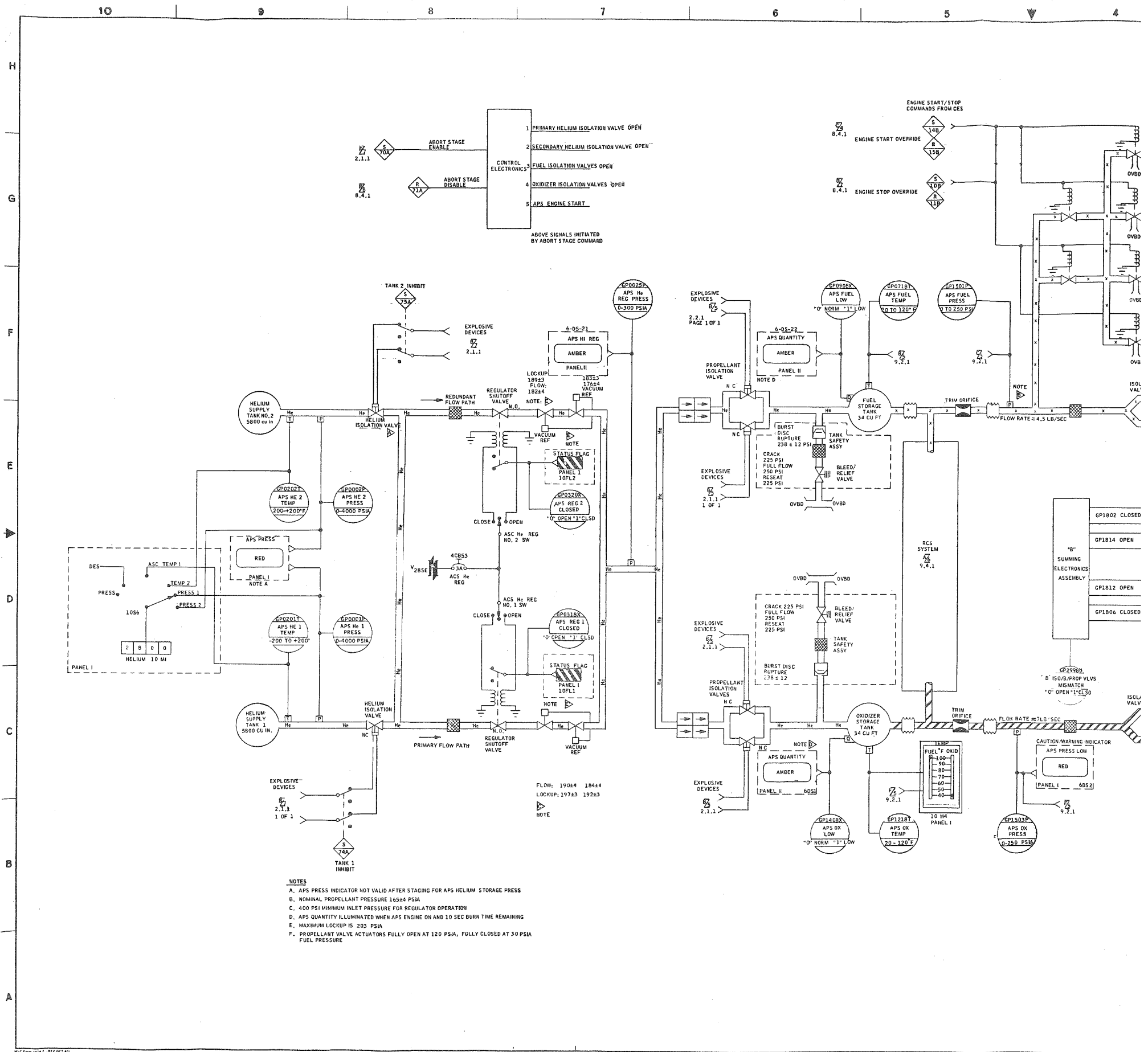












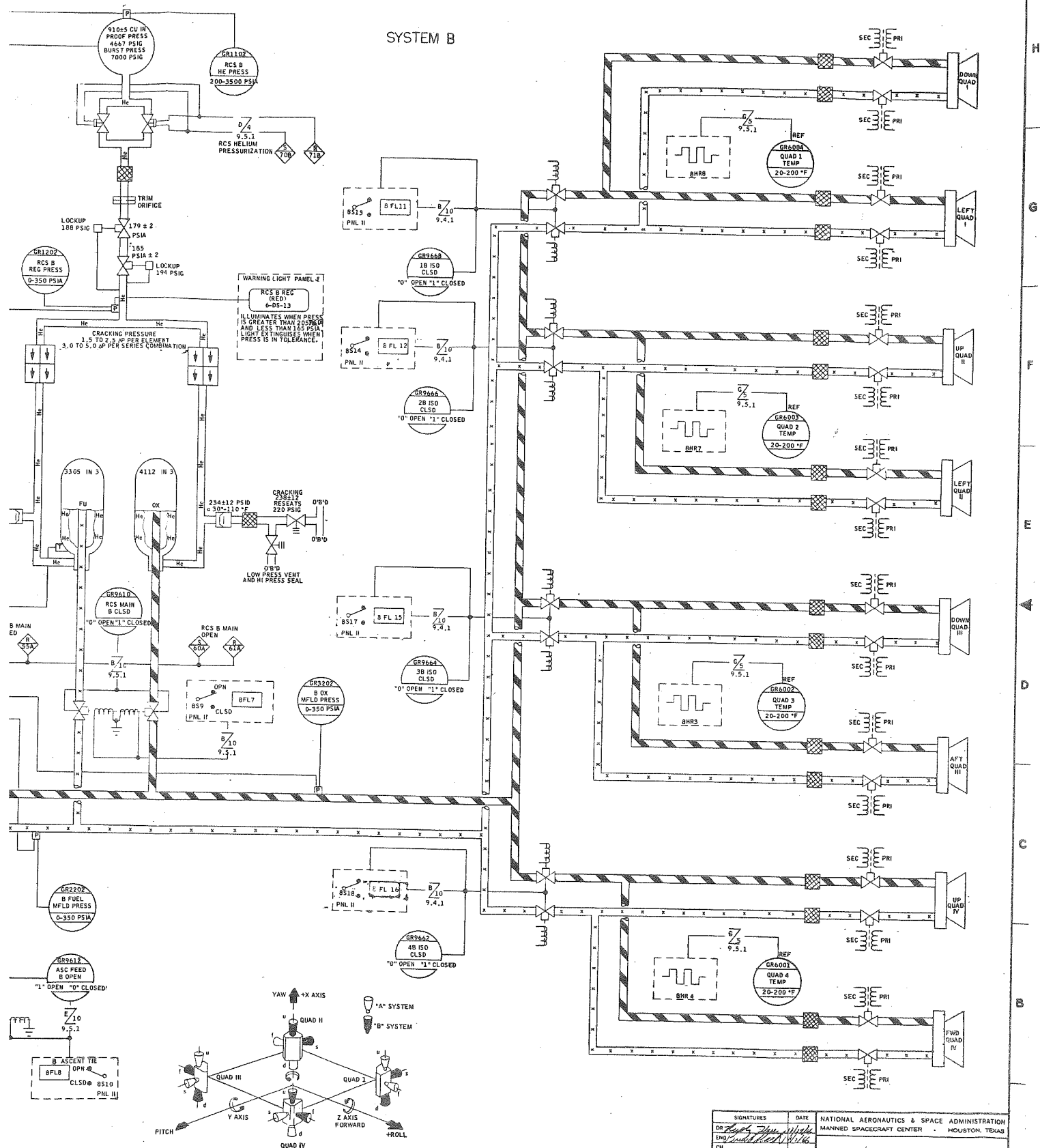
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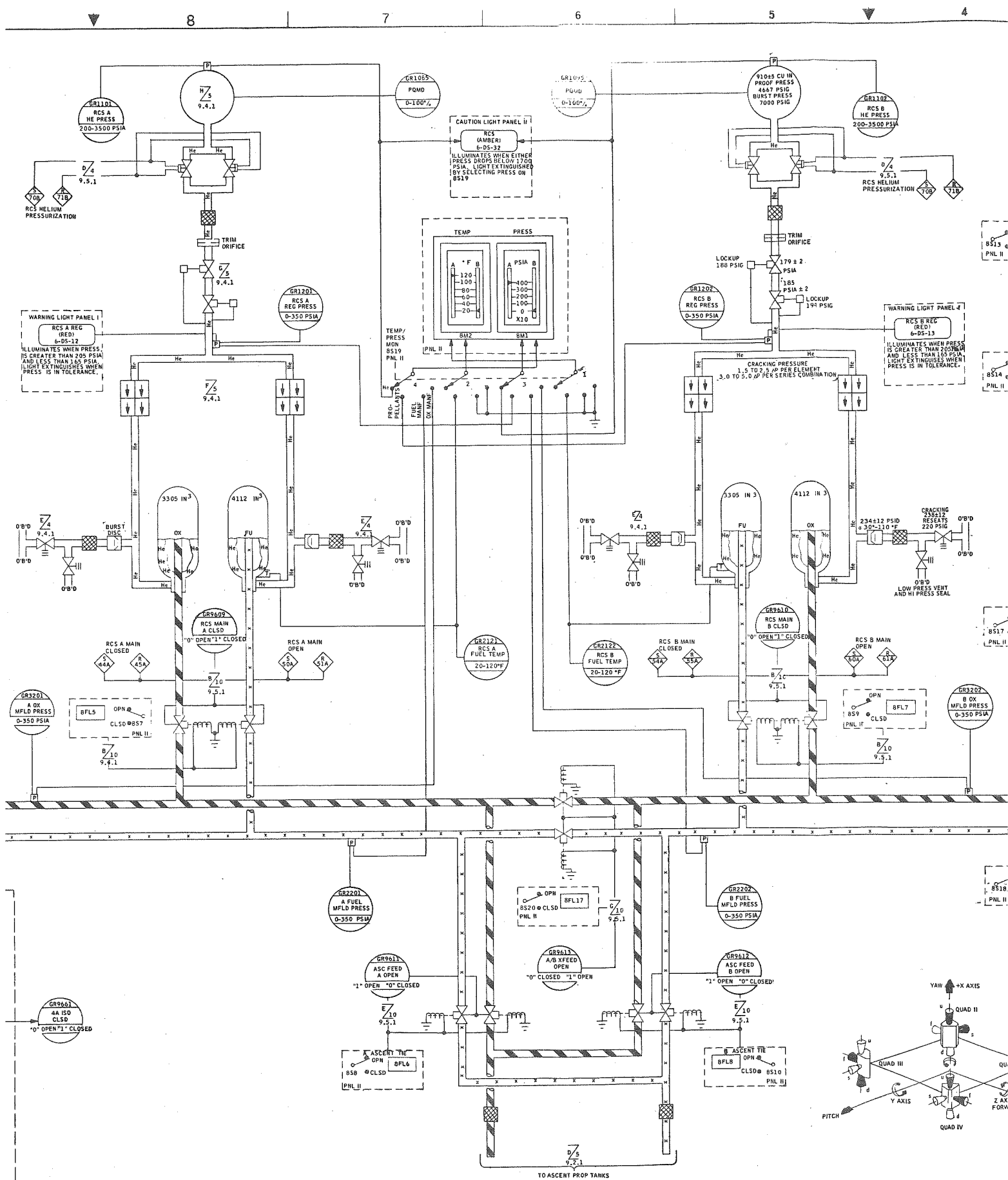
DRAWING 9.3.1

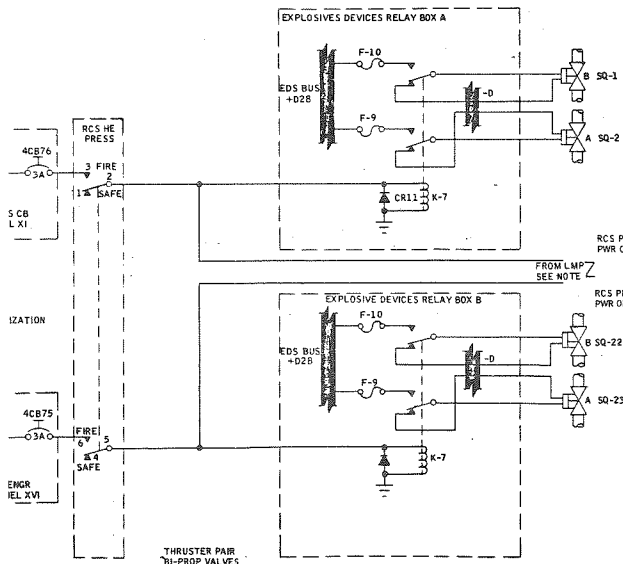
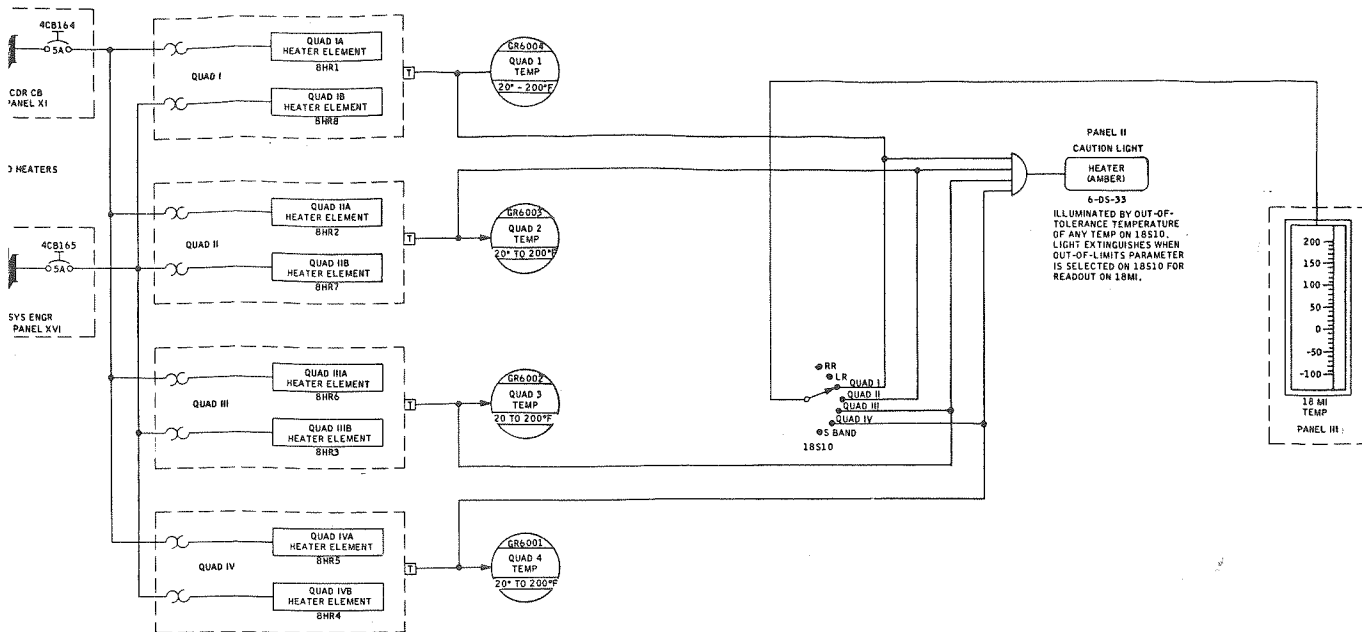
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## SYSTEM B

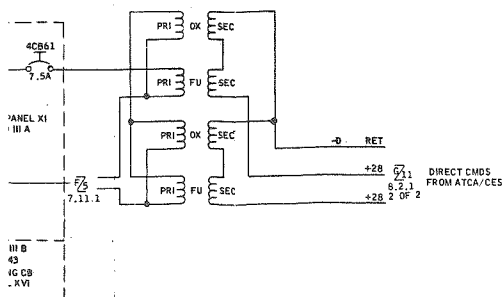








	PRIME RELAY	PRIME CODE	RTC RELAY	RTC CODE
RCS PRESS PWR OFF	K0202A, B	6	K0252A, B	70B
	K0202A, B	7	K0252A, B	71B

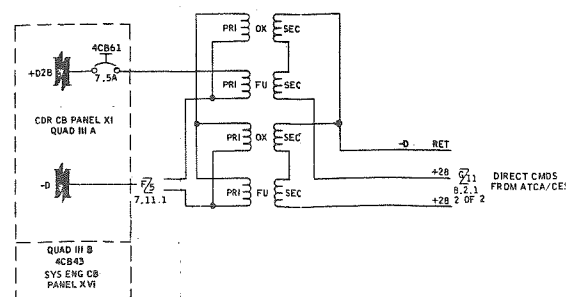


QUAD	CDR CB PNL XI SYS A	SYS ENGR CB PNL XVI SYS B
I	4CB63	4CB45
II	4CB62	4CB44
III	4CB61	4CB43
IV	4CB60	4CB42

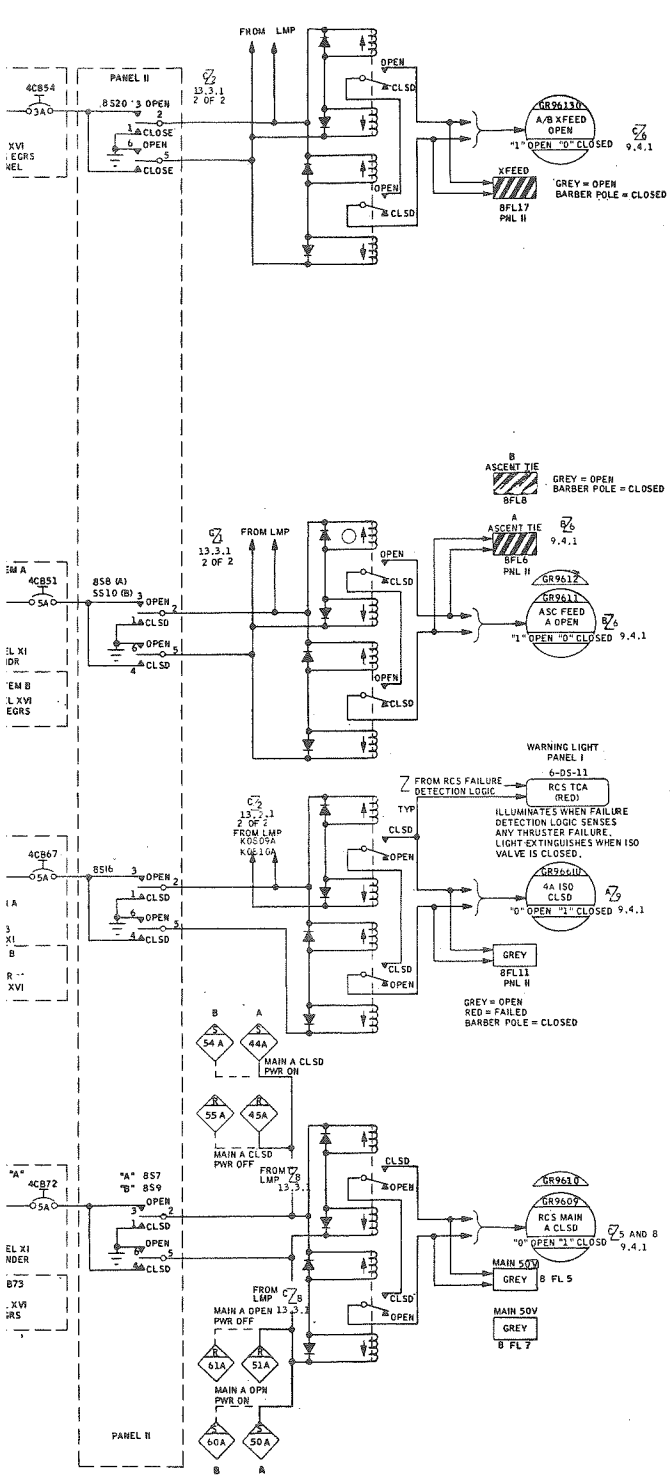
SIGNATURES		DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION MANNED SPACECRAFT CENTER • HOUSTON, TEXAS		
DR	<i>[Signature]</i>	11/16/66	RCS ELECTRICAL		
ENG	<i>[Signature]</i>	11/16/66			
CH	<i>[Signature]</i>	11/16/66			
QAEC	<i>[Signature]</i>	11/16/66			
APP	<i>[Signature]</i>	11-7-66	LM		
1000 Proj		11-8-66	MISSION	SIZE	DWG NO
			AS-206	E	9.5.1
			SCALE	SHEET	

L 5

NAME	LMP RELAY	PRIME CODE	RTC RELAYS	RTC CODE
A OPEN	K0R01A, B	100	K0R51 A,B,C	50A
PWR OFF	K0R01A, B		K0R51 A,B,C	51A
B OPEN	K0R03A, B	100	K0R53 A,B,C	60A
PWR OFF	K0R03A, B	191	K0R53 A,B,C	61A
A CLSD	K0R02A, B	172	K0R52 A,B,C	44A
PWR OFF	K0R02A, B	173	K0R52 A,B,C	45A
B CLSD	K0R04A, B	174	K0R54 A,B,C	56A
PWR OFF	K0R04A, B	175	K0R54 A,B,C	55A





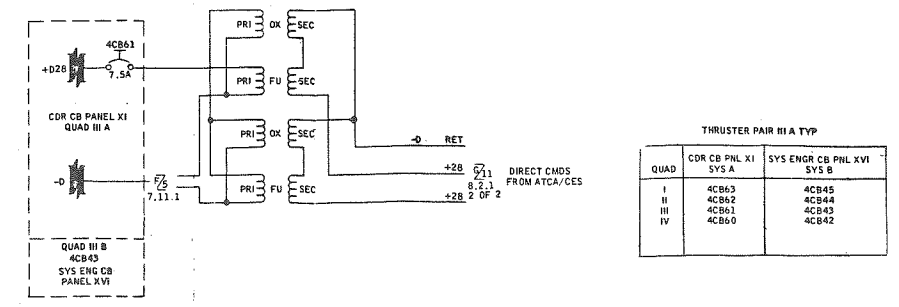
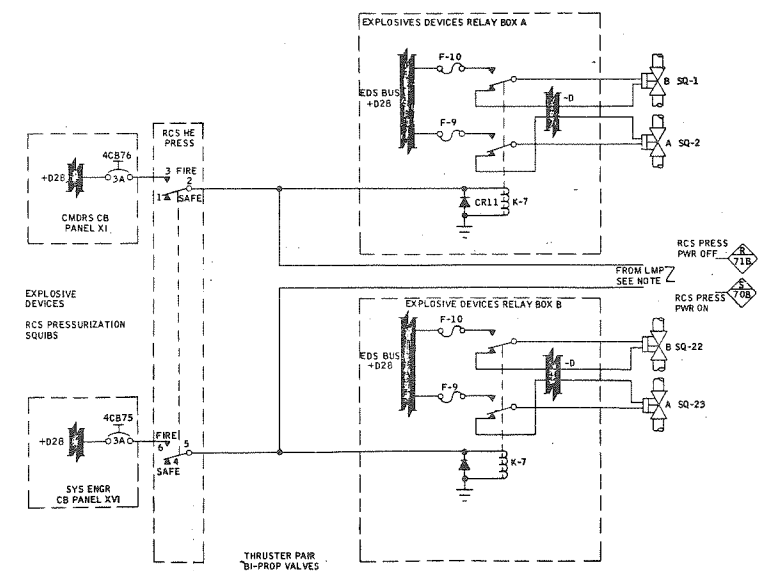
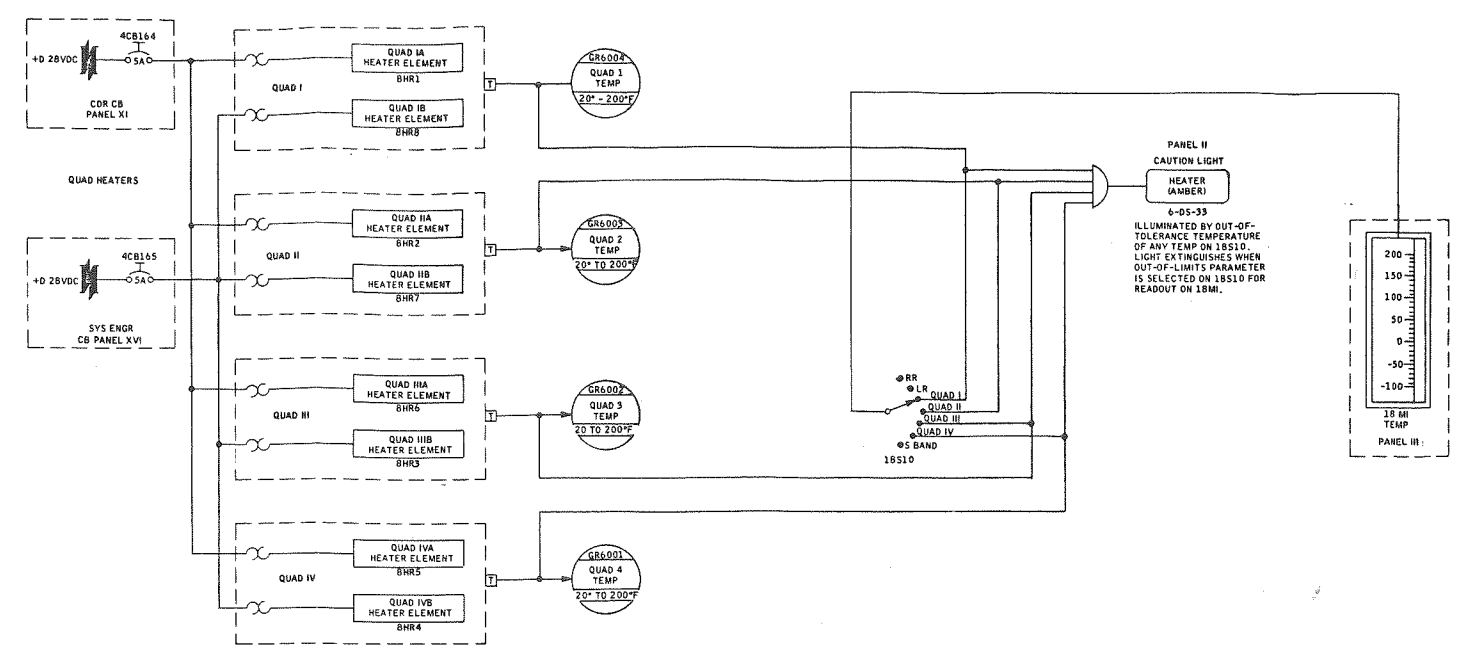


OPEN	LMP RELAY	CODE
PWR ON	K0825A	252
PWR OFF	K0825A	253
CLOSE	K0826A	254
PWR ON	K0826A	255

OPEN	LMP RELAY	CODE
A OPEN	K0805A	60
A PWR OFF	K0805A	61
B OPEN	K0807A	62
B PWR OFF	K0807A	63
CLOSED	K0806A	76
A PWR OFF	K0806A	77
B PWR OFF	K0806A	78
B PWR OFF	K0806A	79

THRUSTERS	SWITCHES	PNL II INDICATIONS	FLAGS	CIRCUIT BREAKER	LOCATION	LMP RELAY	OPEN	CODE	LMP RELAY	CLOSE	CODE	OXIDIZER	FUEL	T/M	VLVS SUMMED
IB D AND S	BS13	8FL11	4CB49 PNL XVI	K0821A	28	K0822A	108	109	GR4276K	GR4268K	GR9668U				
IA U AND F	BS11	8FL9	4CB67 PNL XI	K0813A	12	K0814A	92	93	GR4275X	GR4267X	GR9667U				
IB U AND S	BS14	8FL12	4CB49 PNL XVI	K0823A	136	K0824A	120	121	GR4274X	GR4266X	GR9666U				
IIA D AND F	BS12	8FL10	4CB67 PNL XI	K0815A	152	K0816A	168	169	GR4273X	GR4265X	GR9665U				
IIIB D AND F	BS17	8FL15	4CB49 PNL XVI	K0819A	30	K0820A	110	111	GR4272X	GR4264X	GR9664U				
IIIA U AND S	BS15	8FL13	4CB67 PNL XI	K0811A	14	K0812A	94	95	GR4271X	GR4263X	GR9663U				
IVB U AND F	BS18	8FL16	4CB49 PNL XVI	K0817A	184	K0818A	200	201	GR4270K	GR4262K	GR9662U				
IVA D AND S	BS16	8FL14	4CB67 PNL XI	K0809A	216	K0810A	232	233	GR4269K	GR4261K	GR9661U				

NAME	LMP RELAY	PRIME CODE	RTC RELAYS	RTC CODE
A OPEN	K0801A, B	150	K0851 A,B,C	50A
PWR OFF	K0801A, B	151	K0851 A,B,C	51A
B OPEN	K0803A, B	190	K0853 A,B,C	60A
PWR OFF	K0803A, B	191	K0853 A,B,C	61A
A CLSD	K0802A, B	172	K0852 A,B,C	44A
PWR OFF	K0802A, B	173	K0852 A,B,C	45A
B CLSD	K0804A, B	174	K0854 A,B,C	56A
PWR OFF	K0804A, B	175	K0854 A,B,C	55A



QUAD	CDR CB PNL XI	SYS A	SYS ENGR CB PNL XVI	SYS B
I	4CB63	4CB45	4CB45	4CB45
II	4CB62	4CB44	4CB44	4CB44
III	4CB61	4CB43	4CB43	4CB43
IV	4CB60	4CB42	4CB42	4CB42

RCS PRESS	PRIME RELAY	PRIME CODE	RTC RELAY	RTC CODE
PWR OFF	K0202A,B	7	K0252A,B	70B
	K0202A,B	7	K0252A,B	71B

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H

G

F

E

D

C

B

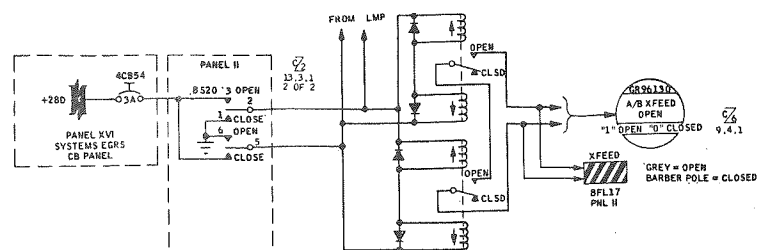
A

A/B CROSSFEED VALVES

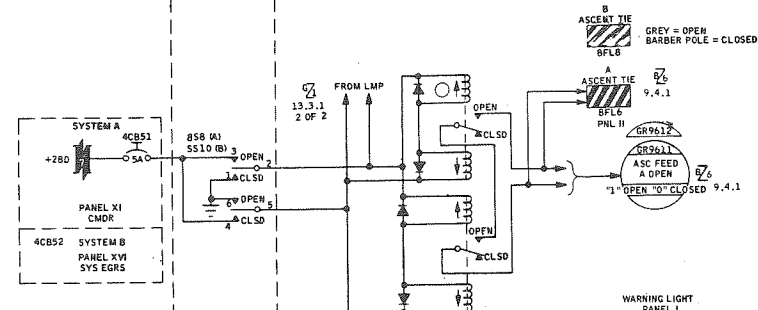
ASCENT INJECT VALVE\*

THRUSTER ISOLATION VALVES

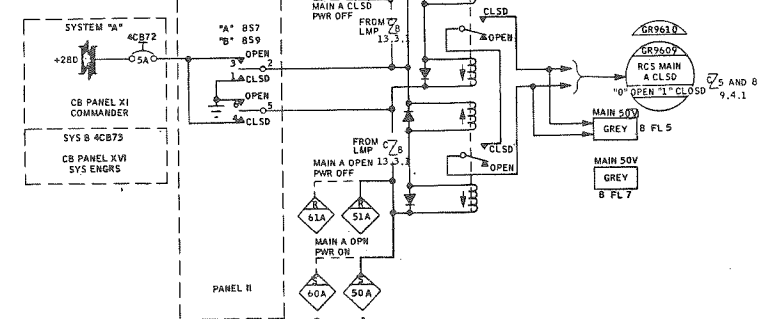
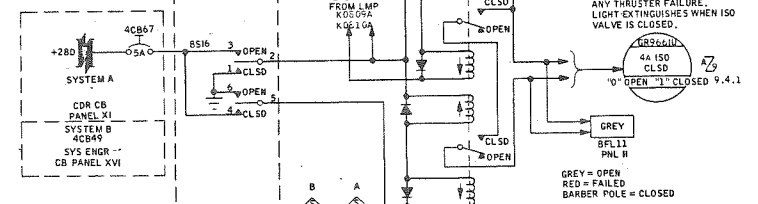
MAIN SHUTOFF VALVES



OPEN	LMP RELAY	CODE
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PWR OFF	K0825A	253
CLOSE	K0826A	254
PWR ON	K0826A	255
PWR OFF	K0826A	256

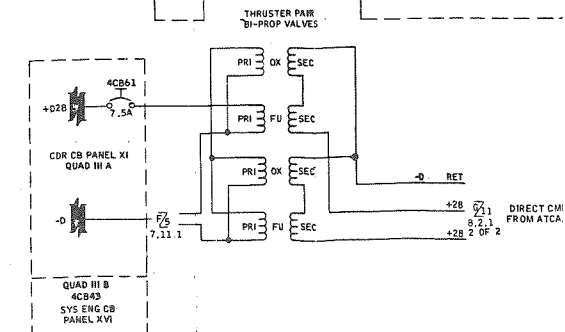
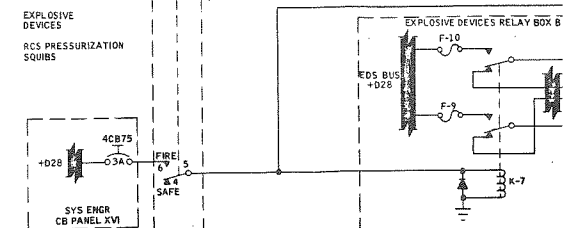
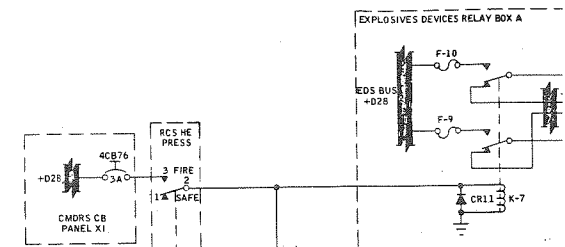
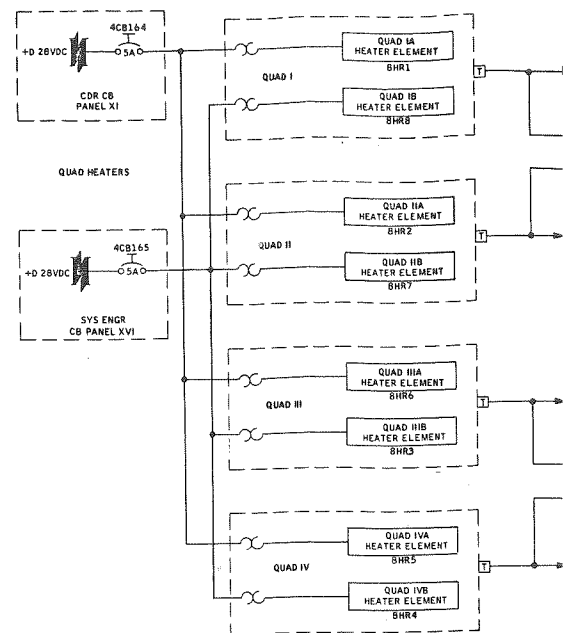


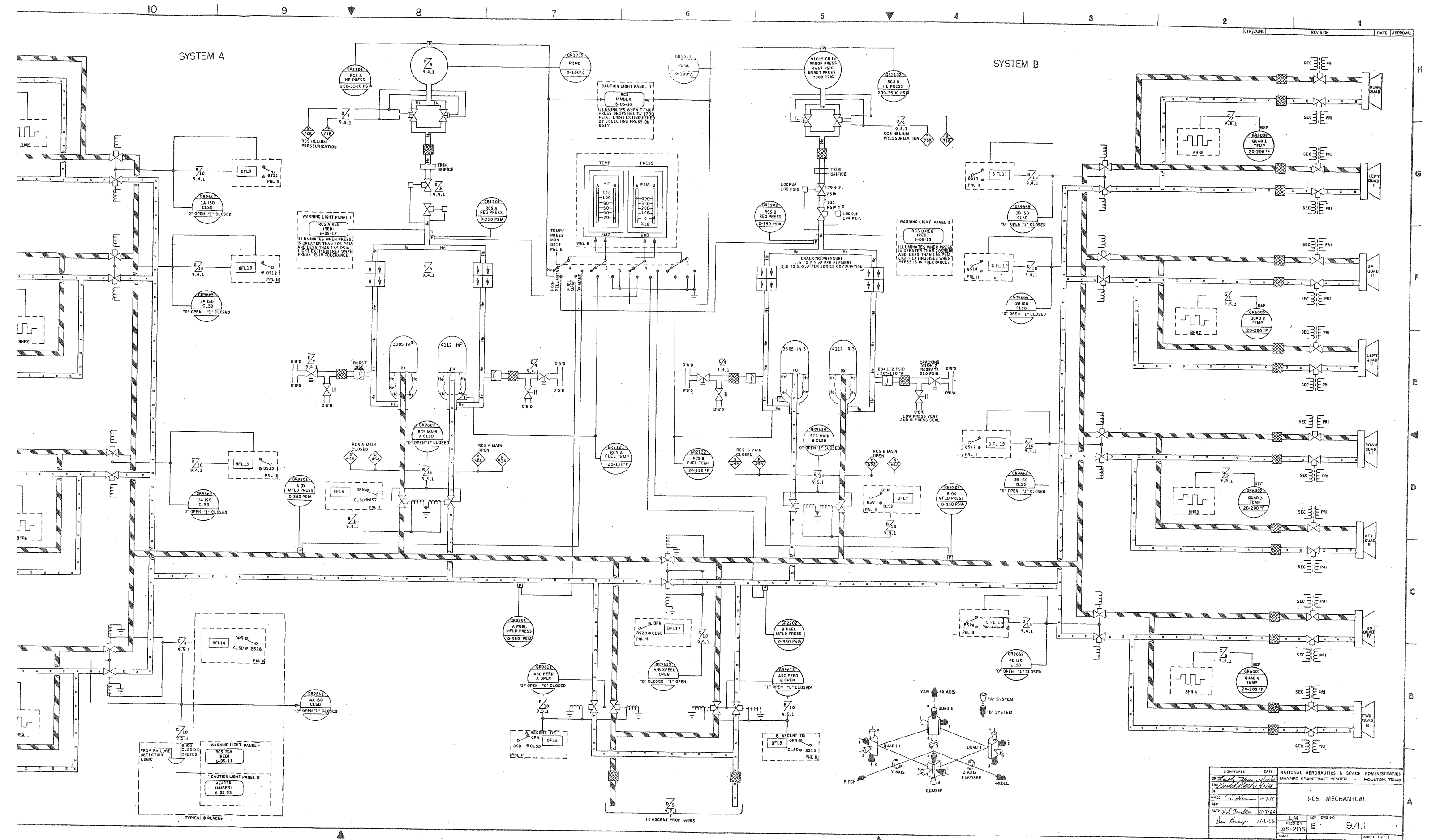
OPEN	LMP RELAY	CODE
A OPEN	K0805A	60
A PWR OFF	K0805A	61
B OPEN	K0807A	62
B PWR OFF	K0807A	63
CLOSED	K0806A	76
A PWR OFF	K0806A	77
B PWR OFF	K0806A	78
B PWR OFF	K0806A	79



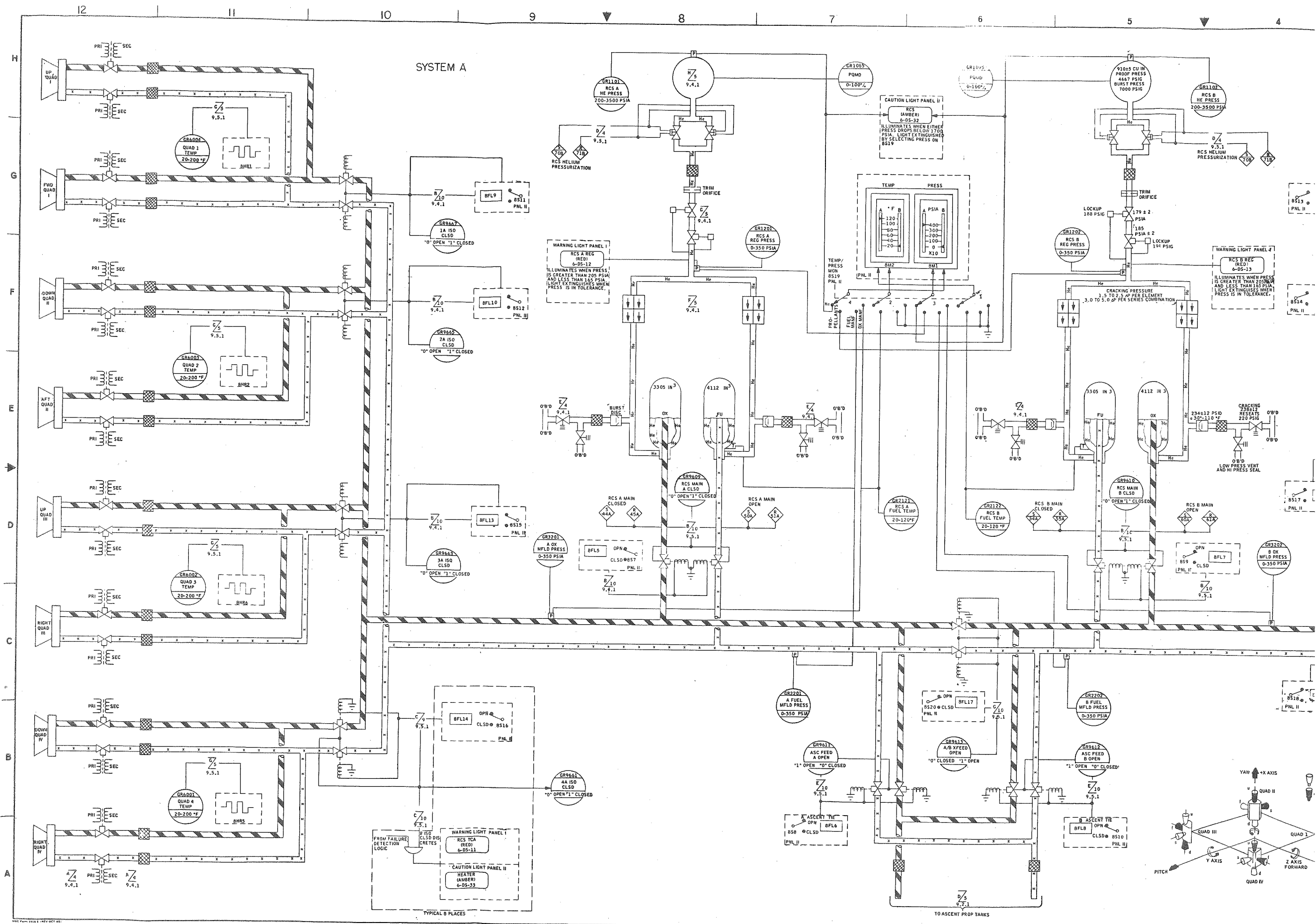
THRUSTERS	SWITCHES	INDICATIONS	CIRCUIT BREAKER	OPEN	CODE	CLOSE	CODE	OXIDIZER	FUEL	VLVS SUMMED
IB D AND S	BS13	BFL11	4CB49 PNL XVI	K0821A	28	K0822A	108	GR4276X	GR4268X	GR9668U
IA U AND F	BS11	BFL9	4CB49 PNL XVI	K0813A	12	K0814A	92	GR4275X	GR4267X	GR9667U
IB U AND S	BS14	BFL12	4CB49 PNL XVI	K0823A	137	K0824A	121	GR4274X	GR4266X	GR9666U
IIA D AND F	BS12	BFL10	4CB49 PNL XVI	K0815A	152	K0816A	168	GR4273X	GR4265X	GR9665U
IIIB D AND F	BS17	BFL15	4CB49 PNL XVI	K0819A	30	K0820A	110	GR4272X	GR4264X	GR9664U
IIIA U AND S	BS15	BFL13	4CB49 PNL XVI	K0811A	14	K0812A	94	GR4271X	GR4263X	GR9663U
IVB U AND F	BS18	BFL16	4CB49 PNL XVI	K0817A	184	K0818A	200	GR4270X	GR4262X	GR9662U
IVA D AND S	BS16	BFL14	4CB49 PNL XVI	K0809A	216	K0810A	232	GR4269X	GR4261X	GR9661U

NAME	LMP RELAY	PRIME CODE	RTC RELAYS	RTC CODE
A OPEN	K0801A, B	171	K0851 A, B, C	50A
PWR OFF	K0801A, B	172	K0851 A, B, C	51A
B OPEN	K0803A, B	170	K0853 A, B, C	60A
PWR OFF	K0803A, B	171	K0853 A, B, C	61A
A CLSD	K0802A, B	172	K0852 A, B, C	45A
PWR OFF	K0802A, B	173	K0852 A, B, C	46A
B CLSD	K0804A, B	174	K0854 A, B, C	54A
PWR OFF	K0804A, B	175	K0854 A, B, C	55A











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SECTION 10  
STRUCTURES

LM  
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REV A

10.1 SYSTEM DESCRIPTION

10.1.1 Stage Description

The Lunar Module (LM) consists of two stages, the Ascent Stage and the Descent Stage. The stages are joined together by four explosive bolts and an interstage umbilical. Both stages will function as a single unit or the Ascent Stage will function alone. Separation of the stages is accomplished by explosively blowing the bolts and by explosively severing the interstage umbilical.



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#### 10.1.2 Structural Makeup

- A. The Ascent Stage's structural makeup is divided into five structural areas; the Crew Compartment, Midsection, Aft Equipment Bay, tank and equipment mountings and the outer skin and insulation. Aluminum alloys are used in the construction of the Ascent Stage with some titanium used for bracketry and fasteners.

The Crew Compartment Section is constructed as a pressure tight unit, approximately 92 inches in diameter.

The Forward Midsection bulkhead provides the structural interface between the Crew Compartment and midsection. These two sections, mated and sealed, constitute the entire pressurized volume available for crew operation in the LM.

The Aft Equipment Bay is constructed of an aluminum alloy frame, secured to the aft midsection bulkhead by a trusswork of aluminum alloy tubing. The entire compartment is unpressurized. The frame contains a series of cold rails for structural mounting and thermal control of electronic equipment. In addition, tubular trusses are provided for structural support of the tankage located within the compartment.

The complete LM Ascent Stage is covered with a thermal and micrometeoroid shield. This shield is a composite of an outer sheet of thin aluminum or aluminized mylar or both.

- B. The primary load carrying structure of the Descent Stage consists of two pairs of parallel beams arranged in a cruciform, plus upper and lower decks and end enclosure bulkheads. The beams, decks, and bulkheads are of the conventional skin and stringer construction. These are formed from aluminum alloy. The skins, or webbing is chem-milled to reduce weight. All joints are secured together with standard mechanical fasteners. The center compartment, formed by the beams cruciform construction, contains the Descent Engine. The areas on either

LM  
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REV A

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side of the center section, formed by the beams (along the Z and Y axis), house the four main propellant tanks for the Descent Engine.

Additional support and strut assemblies are secured to the main beams forming diagonal bays or quadrants. The entire Descent Stage (top view) is shaped to form a modified octagon aluminum alloy. Outriggers extend from the ends of each of the two pairs of beams, providing support and attachment for the four landing gears.

- C. The landing gear is of the cantilever type consisting of four sets of legs connected to outriggers extending from the ends of the Descent Stage structural beams. The legs extend from the front (+Z), rear (-Z) and both sides (+Y and -Y) of the LM. Each landing gear assembly consists of a primary strut and a 37 inch diameter foot pad, two secondary struts, a pyrotechnic uplock assembly, two drive-out mechanisms (spring bungees), two down lock mechanisms and a cross truss assembly. All struts are packed with crushable aluminum honeycomb as the shock absorbing medium. The primary strut absorbs compression loads only, while the secondary struts absorb both compression and tension loads. The foot pads also contain the crushable honeycomb to give additional shock absorption.

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## 10.2 SYSTEM DATA

VEHICLE WEIGHTS	
SECTION	WEIGHT, LB
LM Ascent Stage (DRY)	5,096
LM Descent Stage (DRY)	4,669
RCS Propellants	539
DPS Propellants	17,513
APS Propellants	5,070
TOTAL	32,887

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REV A

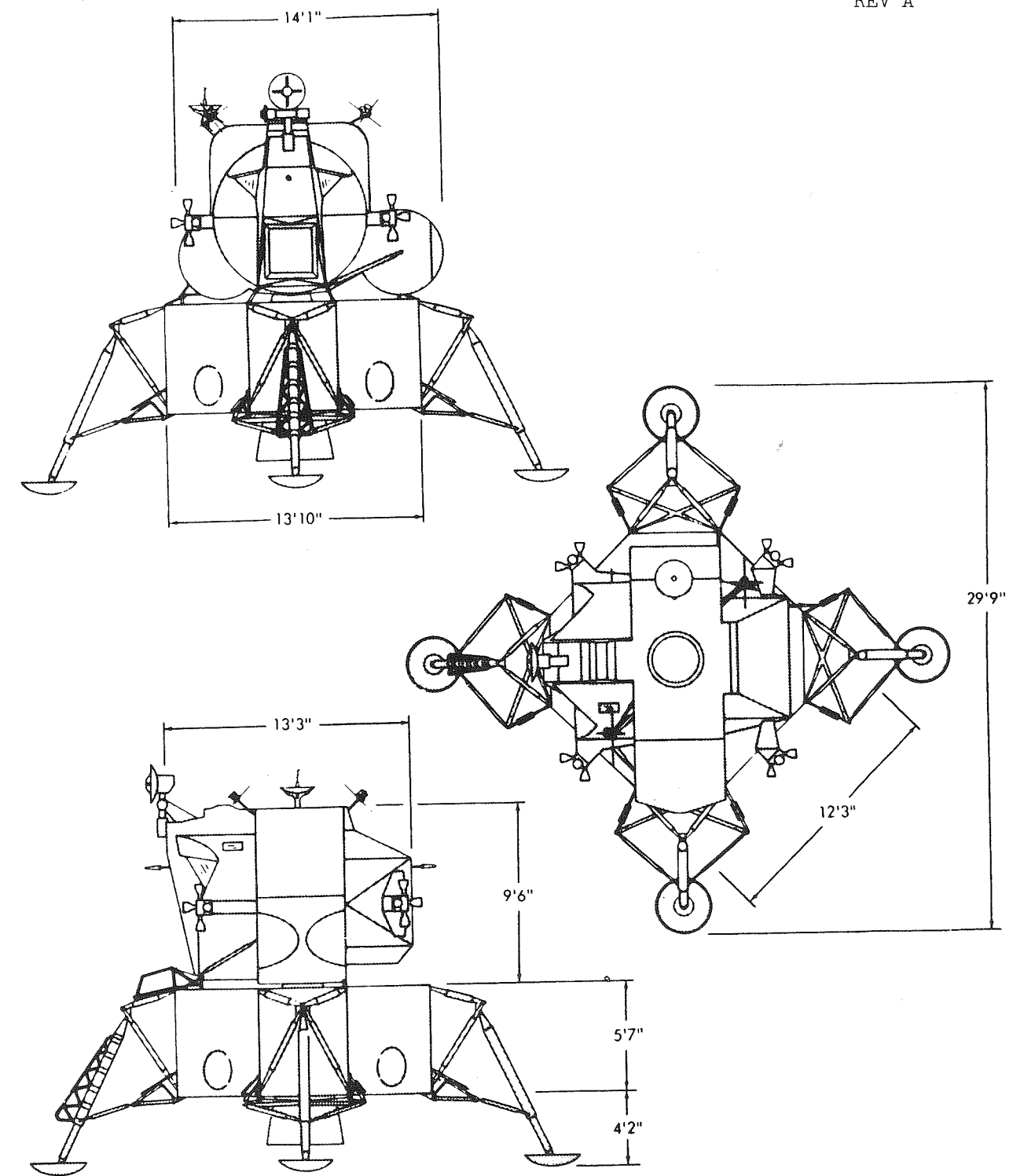


Figure 10-1 LM Dimensions

LM  
AS-206  
REV A

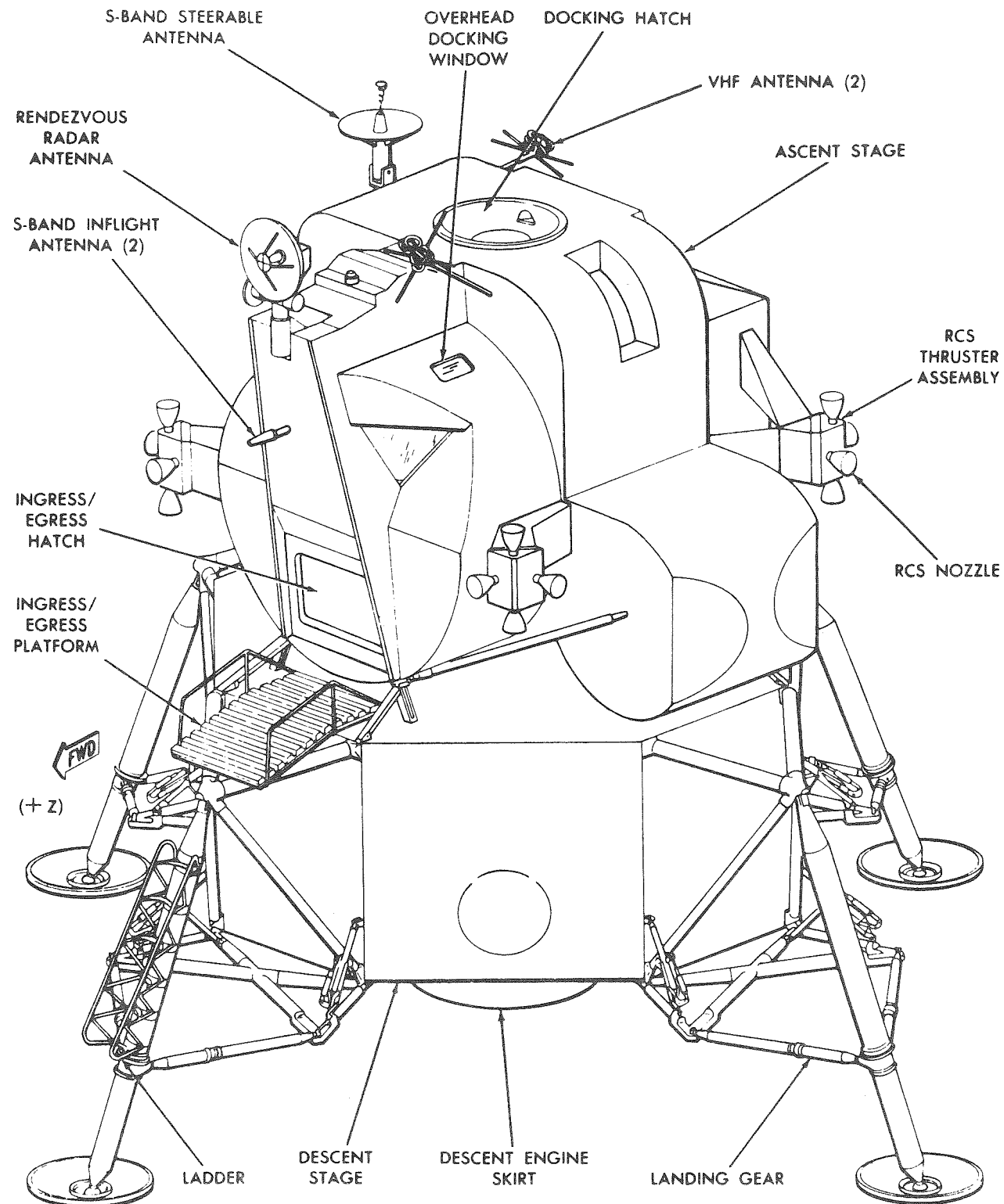


Figure 10-2 LM Structure  
10-6

LM  
AS-206  
REV A

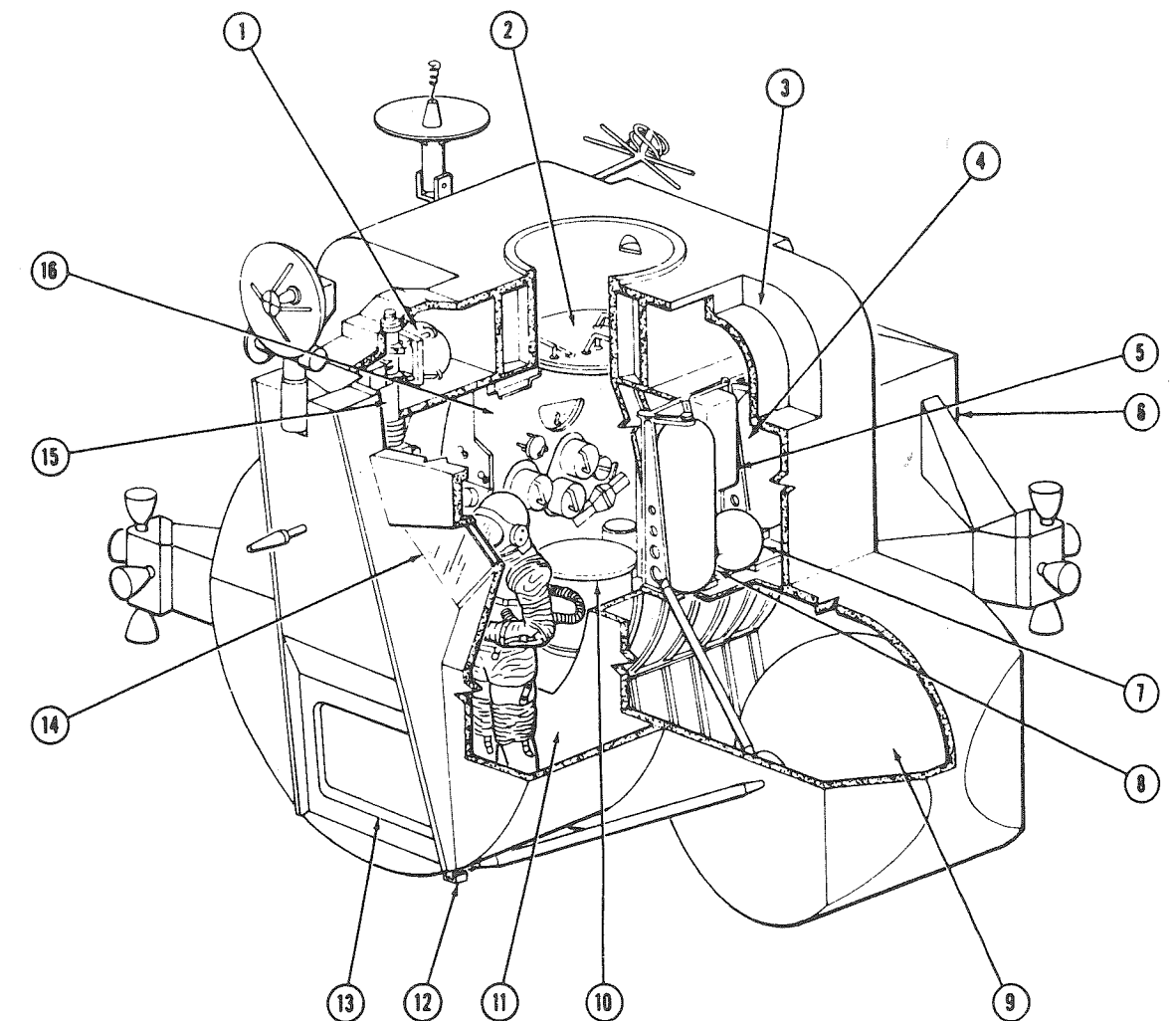
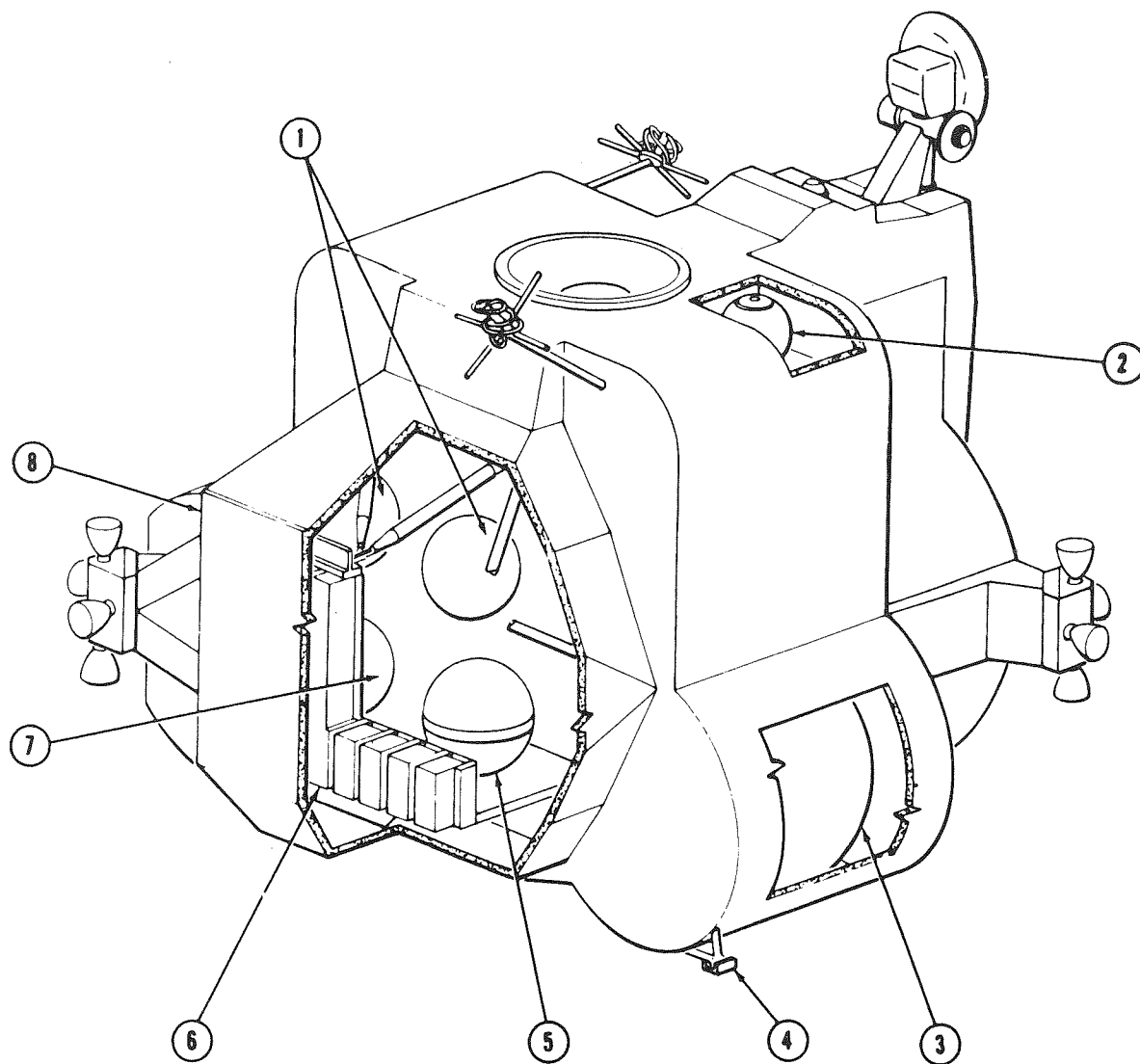


Figure 10-3 Ascent Stage (Sheet 1 of 2)

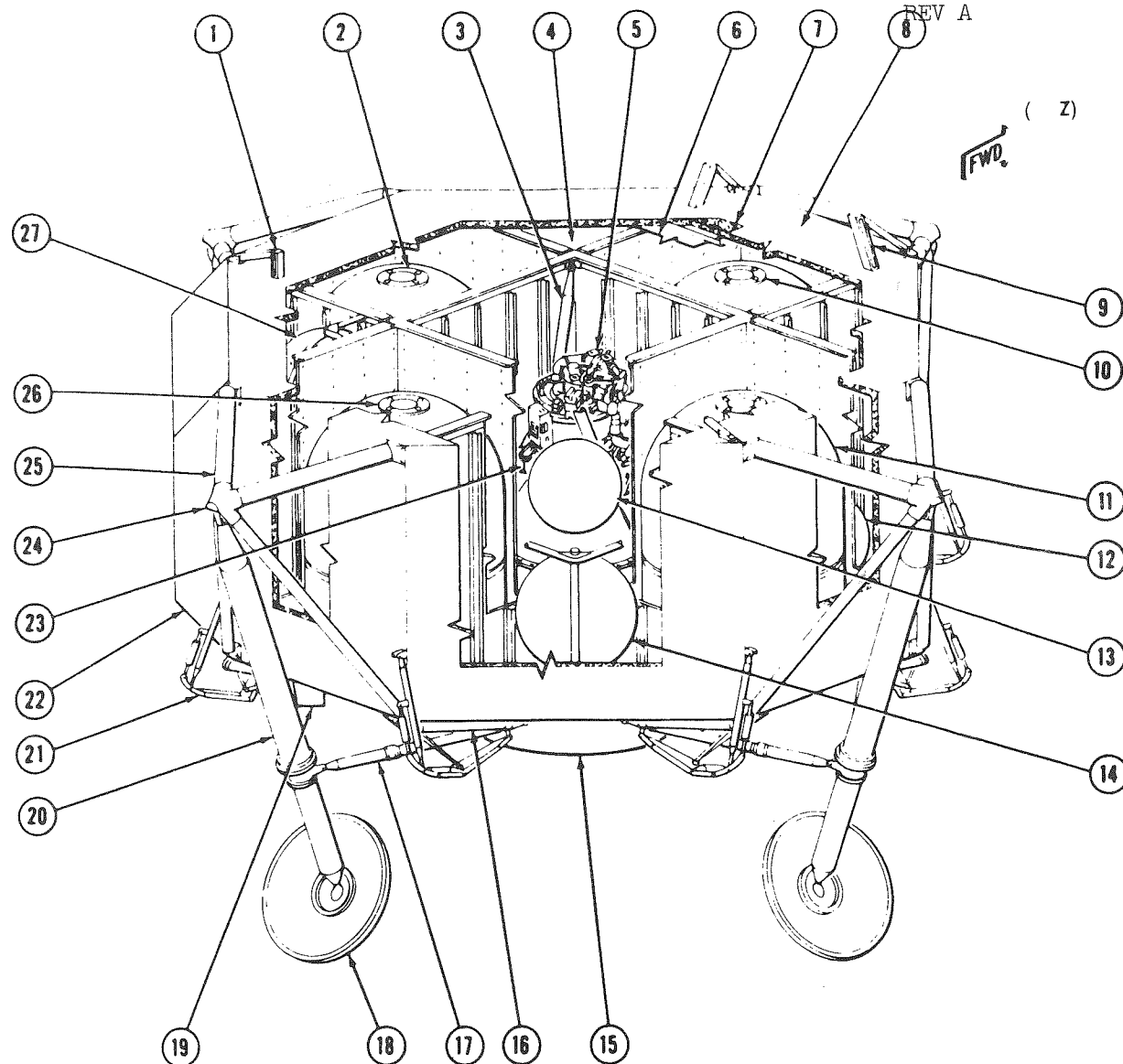




- 1. GASEOUS OXYGEN TANKS
- 2. WATER TANKS (2)
- 3. OXIDIZER TANK
- 4. AFT INTERSTAGE FITTING (2)
- 5. HELIUM TANK

- 6. ELECTRONIC REPLACEABLE ASSEMBLY
- 7. HELIUM TANK
- 8. AFT EQUIPMENT BAY

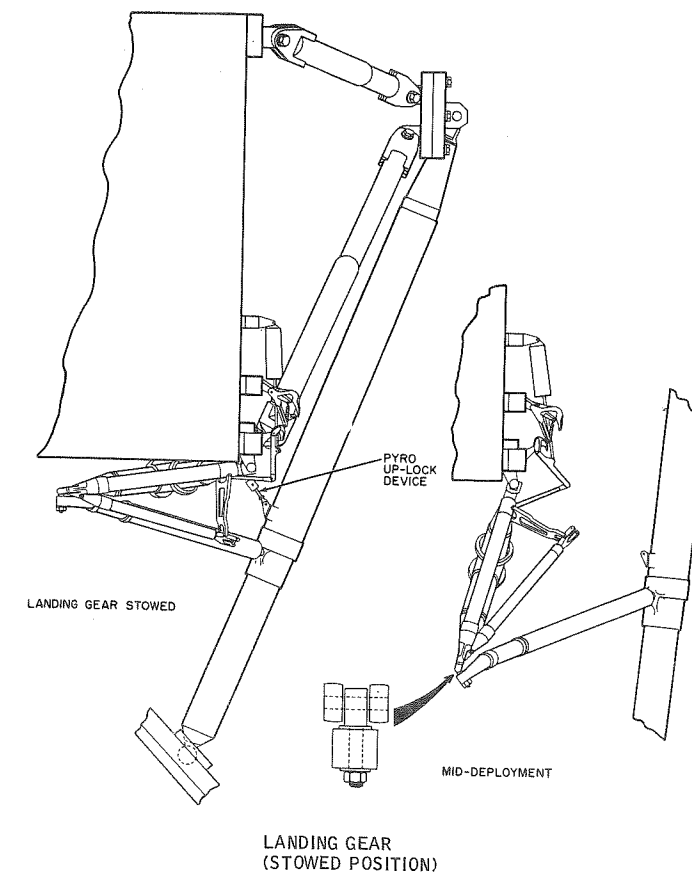
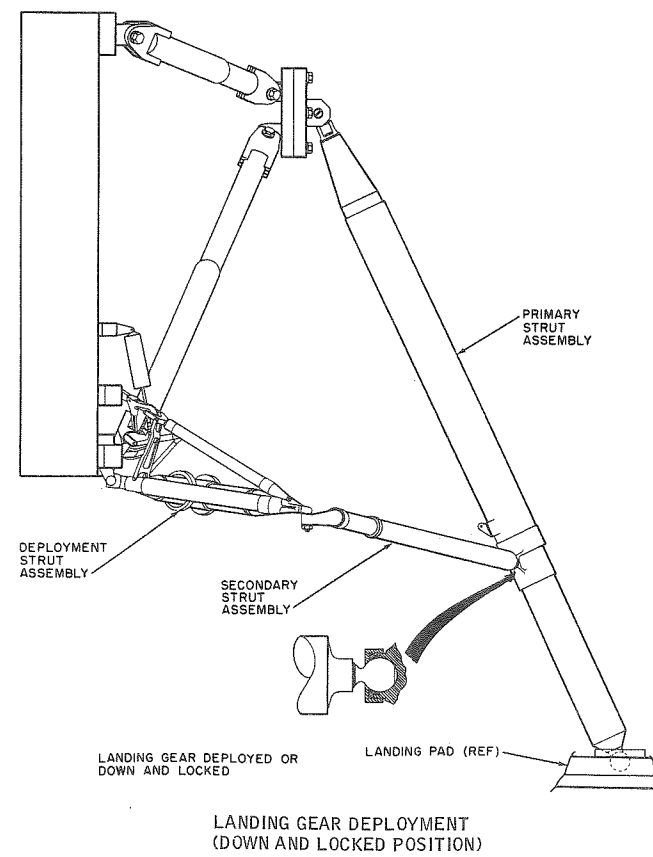
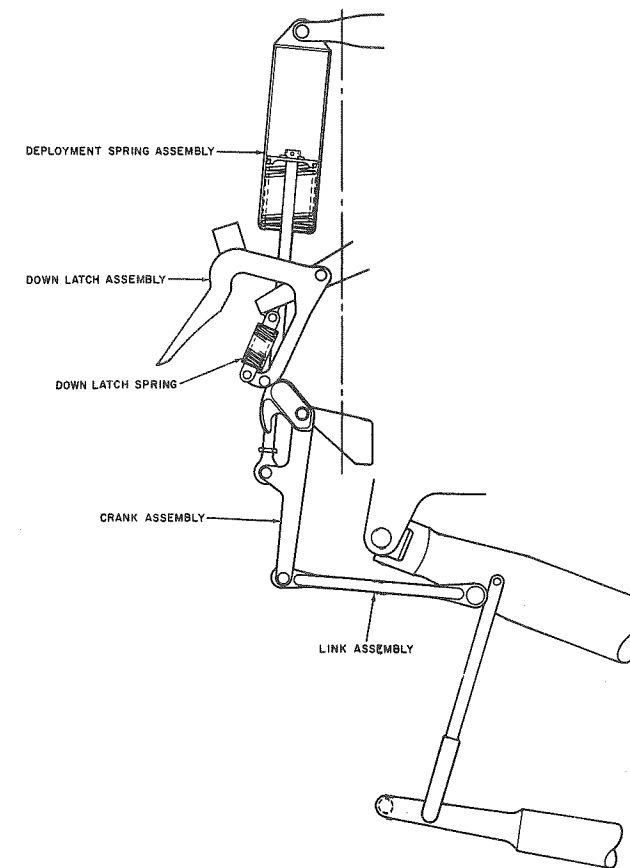
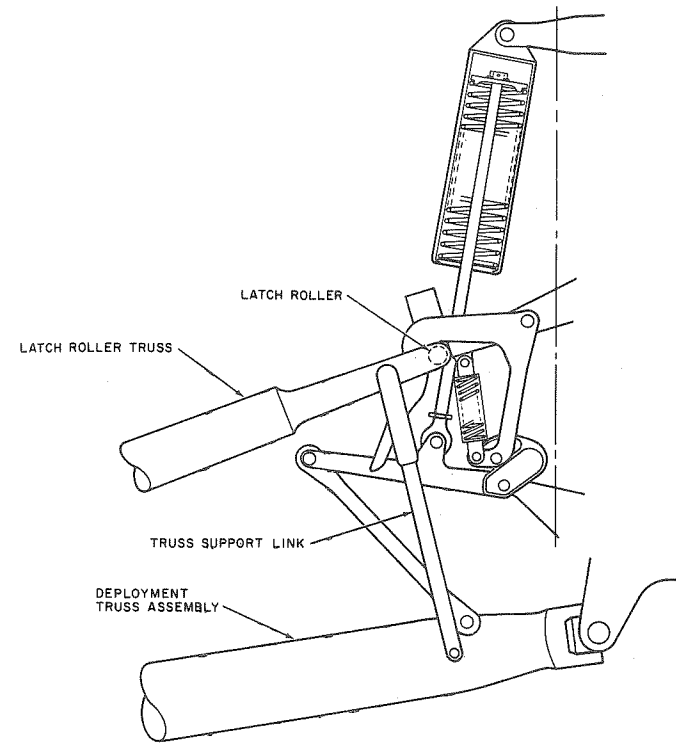
Figure 10-3 Ascent Stage (Sheet 2 of 2)



- |  |                              |
|--|------------------------------|
| 1. AFT INTERSTAGE FITTING              | 14. HELIUM TANK/CRYOGENIC    |
| 2. FUEL TANK                           | 15. DESCENT ENGINE SKIRT     |
| 3. ENGINE MOUNT                        | 16. TRUSS ASSEMBLY (LDG GR)  |
| 4. PLSS, S-BAND ANTENNA<br>STORAGE BAY | 17. SECONDARY STRUT (LDG GR) |
| 5. DESCENT ENGINE                      | 18. PAD (LDG GR)             |
| 6. STRUCTURAL SKIN                     | 19. LANDING RADAR ANTENNA    |
| 7. INSULATION                          | 20. PRIMARY STRUT (LDG GR)   |
| 8. THERMAL SHIELD                      | 21. LOCK ASSEMBLY (LDG GR)   |
| 9. FORWARD INTERSTAGE FITTING          | 22. SCIENTIFIC EQUIPMENT BAY |
| 10. OXIDIZER TANK                      | 23. GIMBAL RING              |
| 11. FUEL TANK                          | 24. ADAPTER ATTACHMENT POINT |
| 12. BATTERY STORAGE BAY                | 25. OUTRIGGER                |
| 13. OXYGEN TANK                        | 26. OXIDIZER TANK            |
|  | 27. WATER TANK               |

NOTE:  
LANDING GEAR SHOWN IN  
RETRACTED POSITION

Figure 10-4 Descent Stage



LM LANDING GEAR SYSTEM

FIGURE 10-5





SECTION 11

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REV A

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MISCELLANEOUS

11.1 GENERAL NOTES

This section is reserved for future use.





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SECTION 12  
SPACECRAFT LM ADAPTER

LM  
AS-206  
REV A

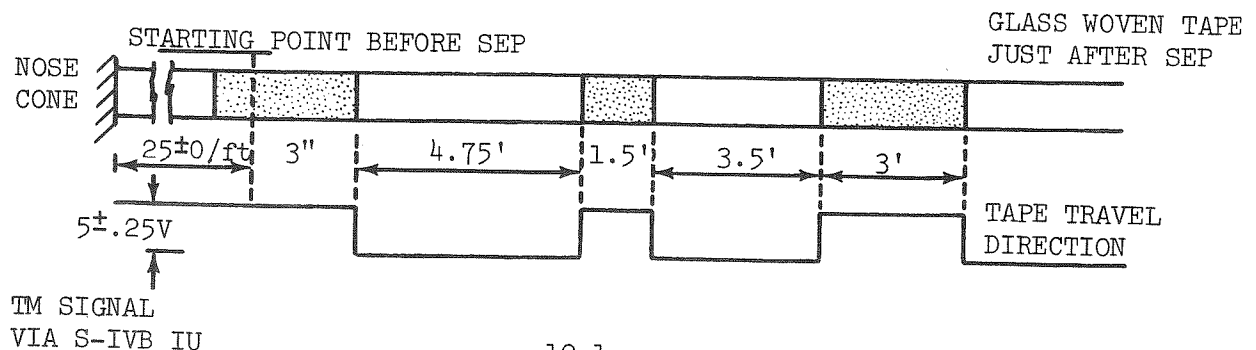
## 12.1 SYSTEM DESCRIPTION

### 12.1.1 LM Adapter

The Spacecraft LM Adapter (SLA) connects the nose cap to the S-IVB Instrumentation Unit (IU). It also houses the LM SLA Spacecraft Jettison Controller (SJC) and power supplies.

### 12.1.2 Nose Cap

- A. The nose cap will be separated from the SLA by 16 springs which are positioned symmetrically around the base circumference of the nose cap and the forward SLA panels. The metallic interface between the nose cap and SLA will be sheared by a Mild Detonating Fuse (MDF) (Figure 12-2) and ignited by two detonators 180 degrees from one another upon programed command from the S-IVB IU sequencer (or by backup RTC), via the SJC logic.
- B. There are two transducers to indicate nose cap physical separation (AA8198X and AA8199X). They are located near the top of the forward set of SLA panels, 180 degrees from one another. As the nose cap is separated from the SLA, these transducers sense the conductivity or non-conductivity of a woven glass tape which is attached between the nose cap and the transducer itself in the SLA. The tape travels through the sensor from a conductive starting point to a length of about 18 feet. The following results as the tape is pulled through the sensor.  
(Shaded areas: conductive).



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#### 12.1.3 SLA

- A. The SLA is a truncated conic structure with a cone element of 29 feet and a X axis length of 28 feet. The forward diameter is 12.8 feet and the aft diameter is 21 feet. The SLA is divided into two sets of four panels. The aft set is fixed and the forward set is deployable (Figure 12-1). The panels consist of 1.7 inch aluminum-alloy honeycomb bonded to face sheets of aluminum of varying thickness.
- B. The SLA panels will be deployed upon programed command from the S-IVB IU sequencer (or by backup RTC) via the SJC logic. The SLA panels will deploy  $45_{-11}^{+5}$  degrees with the momentum to do this created by three elements:
1. The explosive devices that shear the panels from one another at the seam lines provide 20 percent of the force required (See Figure 12-3).
  2. The eight thrusters located at the corners of the panels which provide two degrees of panel movement or another 20 percent of the same required. (See Figure 12-3).
  3. The four cable spring loaded exterior pulley assemblies (one per panel) provide the remaining 60 percent of the same required. (See Figure 12-4).
- C. The momentum of the SLA panels is stopped by eight attenuator struts located between the aft panels and forward panels (Figure 12-4). These struts contain crushable aluminum honeycomb core to absorb the energy. After the panels have reached the deployed position, they are retained in that position by a clutch on each spring loaded pulley assembly.

#### 12.1.4 LM/SLA Separation

The LM is attached within the aft adapter at four points by straps which coincide with the panel hinge positions (Figure 12-1). After the forward panels have properly separated and deployed, the LM +X Reaction Control System (RCS) thrusters will be ignited and within 5 seconds a

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signal will be sent from the LM mission programmer (or by backup RTC) which will sever these straps by the SLA pyrotechnic devices. Thirteen additional seconds of RCS burn move the LM away from the SLA/S-IVB with a resultant delta velocity of about five ft/sec.

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## 12.2 SYSTEM DATA

### 12.2.1 SJC Logic Buses

- A. The SJC Logic Battery minimum capacity is five amp hour at a two amp rate. End life voltage shall be 26.0 volts or greater.
- B. No load voltage limits:  $31.5 \text{ volts} \pm 2.0 \text{ volts}$ .
- C. Transient voltage limits: 26 to 35.5 V with recovery to steady state within one second.

### 12.2.2 SJC Pyro Buses

- A. The SJC pyro battery minimum capacity is 0.75 amp hour at an intermittent rate.
- B. No load voltage limits:  $36 \pm 1.8 \text{ volts}$ .
- C. Transient voltage limits: 26 to 37.8 volts with recovery to steady state within one second.

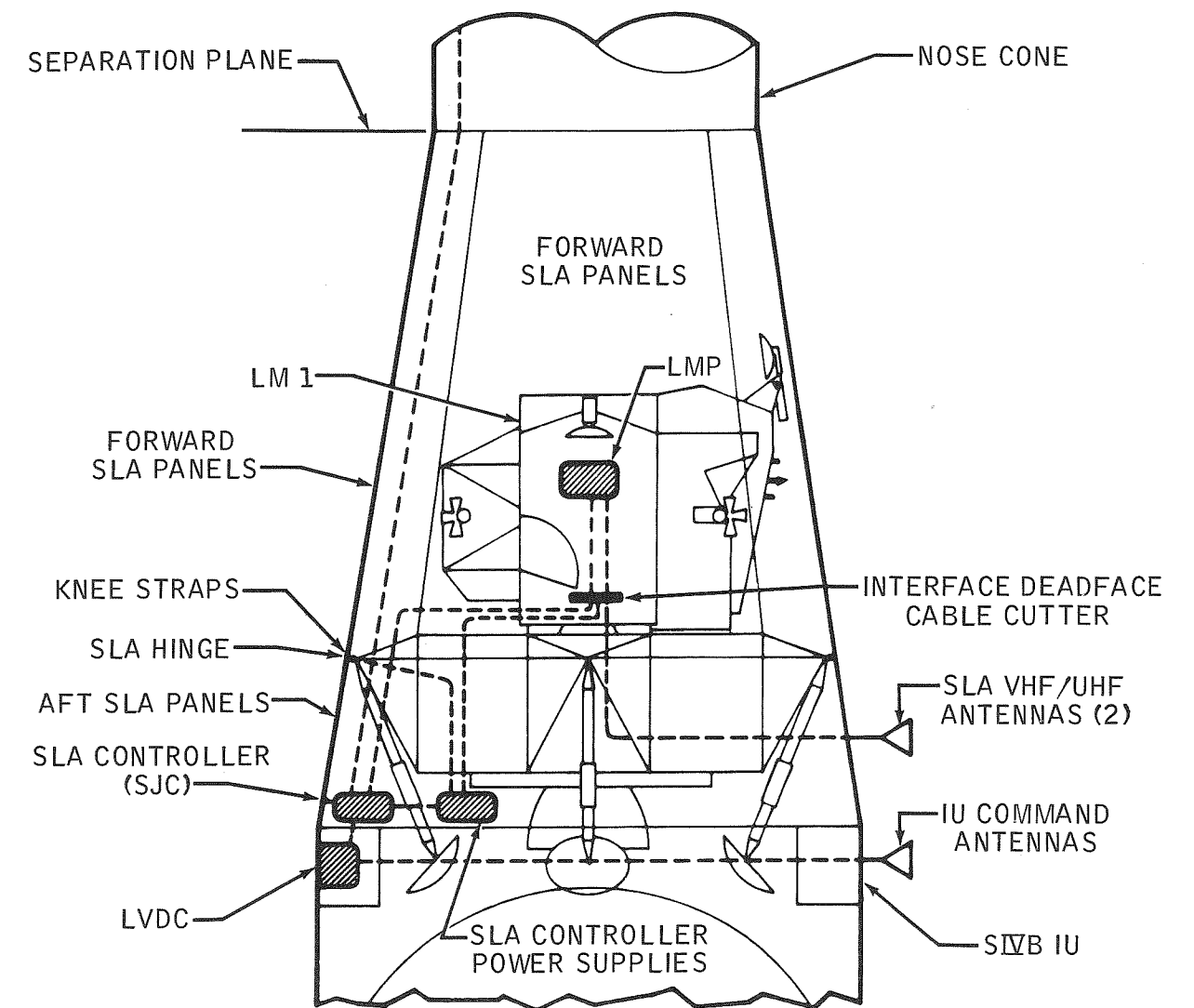


FIGURE 12-1. - NOSE CONE/SLA/LM/SIVB CONFIGURATION



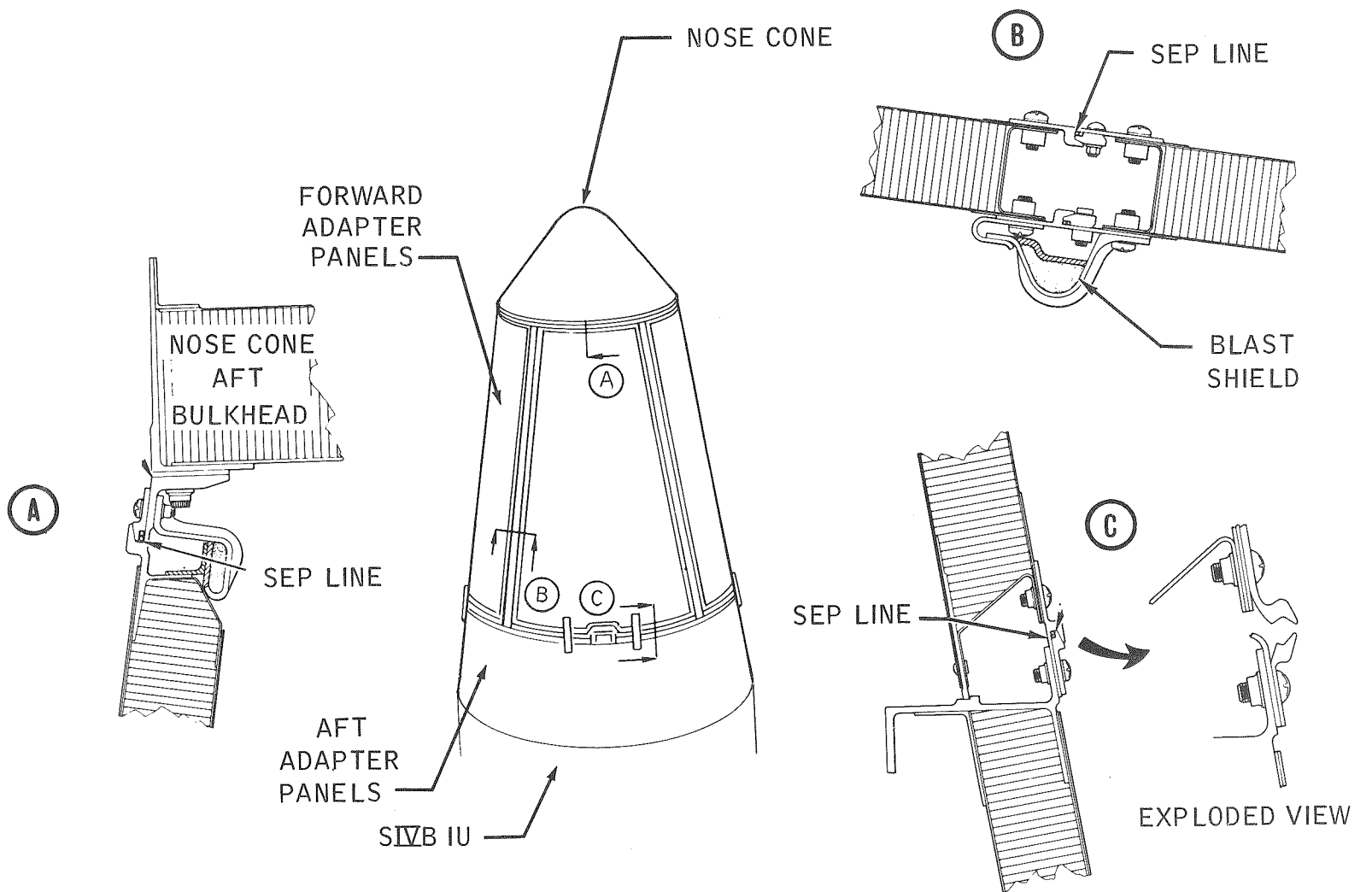


FIGURE 12-2. - ADAPTER PANEL SEPARATION LINE

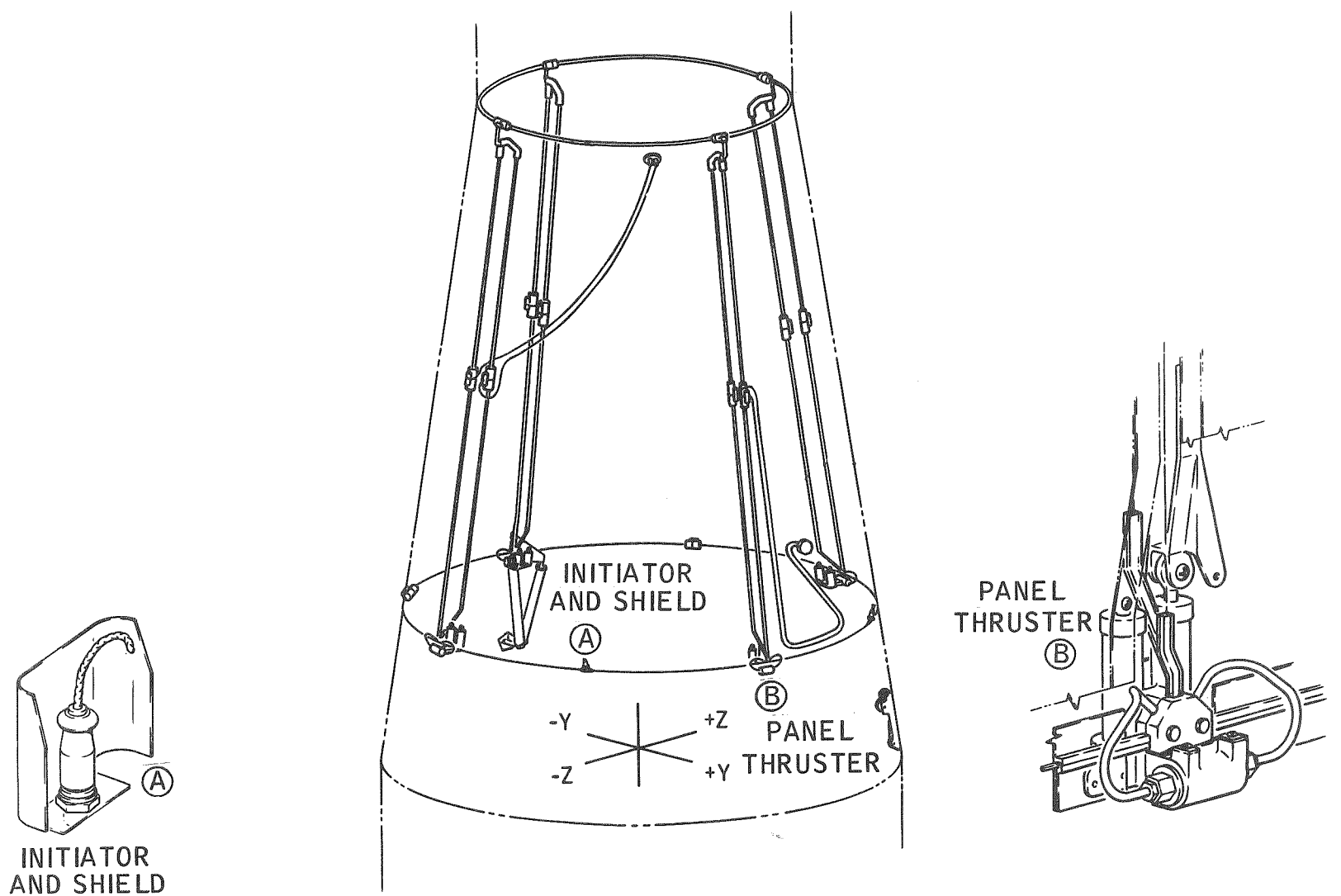


FIGURE 12-3. - ADAPTER SEPARATION SYSTEM

12-8

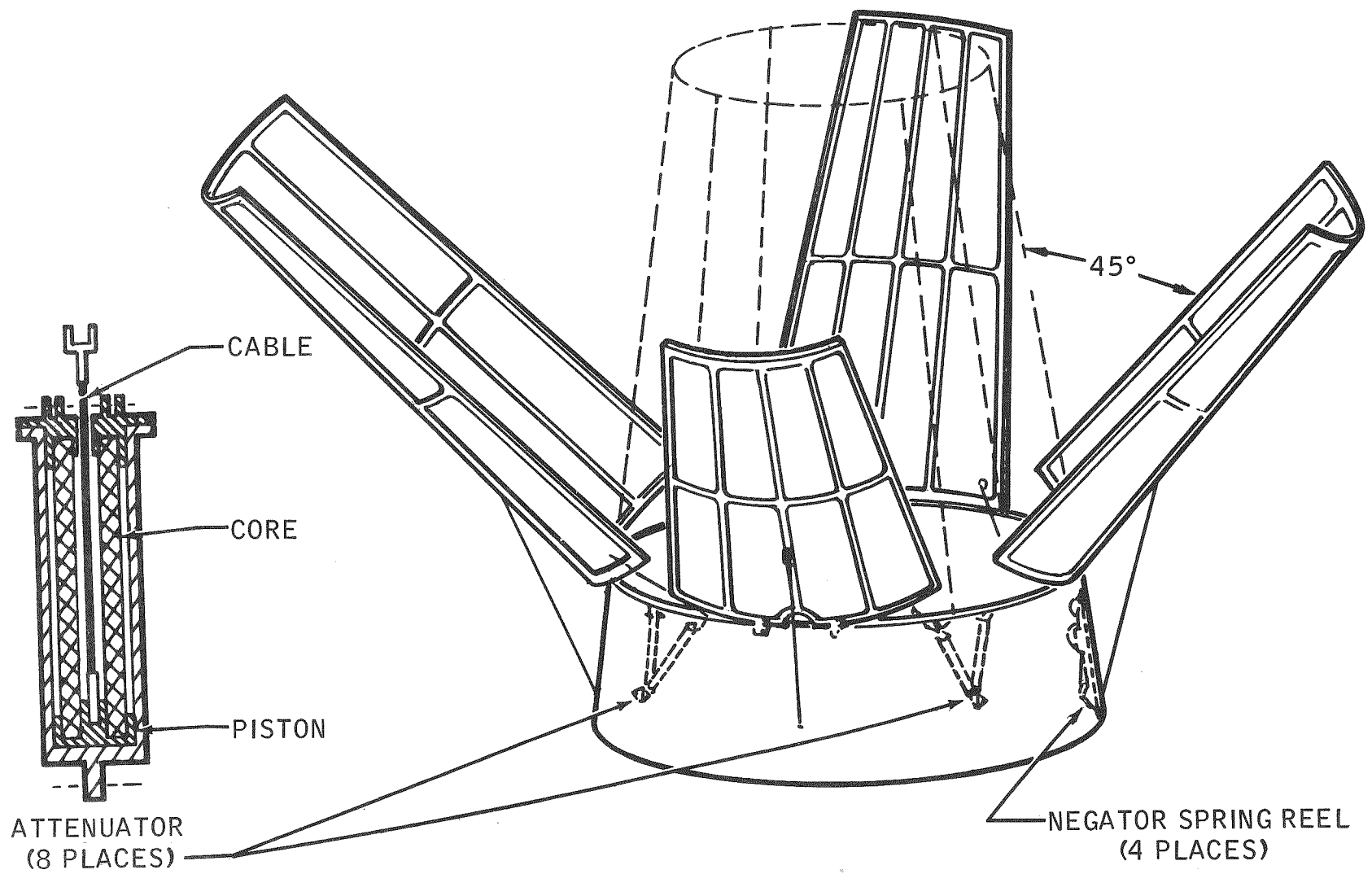


FIGURE 12-4. - SLA PANEL DEPLOYMENT.





13. PROGRAMER LM  
MISSION

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SECTION 13  
LM MISSION PROGRAMER

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13.1 INTRODUCTION

The LM Mission Programer (LMP) is a semi-automatic package in which ground commands or LM Guidance Computer (LGC) commands will enable control normally provided by the astronaut, this will allow the LM to meet the requirements for unmanned near-earth orbit missions.

The LMP consists of four basic units:

- A. The Program Reader Assembly (PRA) contains a contingency program (on fixed tape) to be used in the event of failure of the prime mode (i.e., the LGC) (fixed tape contains a maximum of 64 addressable sequences).
- B. The Digital Command Assembly (DCA) provides an uplink capability so that ground commands can be routed to the LGC, PRA, PCA and then to the basic LM subsystem for control.
- C. The Program Coupler Assembly (PCA) provides coupling of the LGC, PRA and certain DCA commands to control the basic LM subsystems.
- D. The Power Distribution Assembly (PDA) provides the 28 VDC power distribution and current protection for the LMP components.

The basic operation of the LMP will be LGC to PCA to LM subsystems. Backup or test modes will be ground to DCA to LGC to PCA to LM subsystems. ground to DCA to PRA to PCA to LM subsystems. Under normal operation the computer will command the LMP to perform various operations normally performed by the astronaut. However, in case the LGC fails, the PRA will backup under a limited capacity those functions normally provided by the LGC. The ground control through PRA and PCA is limited and control of this normally man vehicle cannot be compared with those vehicles which are designed for ground control only.

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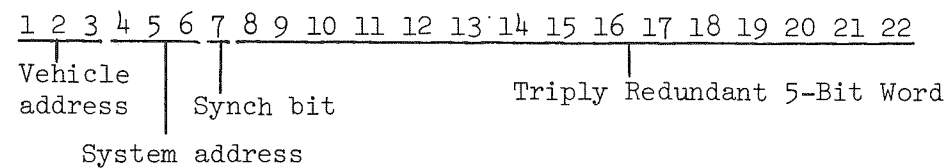
### 13.2 LM MISSION PROGRAMER (LMP) SYSTEM GENERAL NOTES

#### A. Digital Command Assembly (DCS)

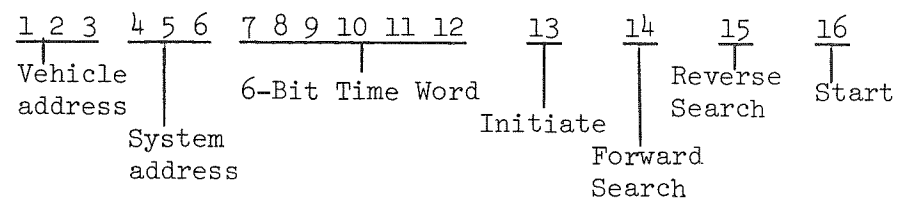
##### 1. DCA Uplink

The DCS provides the capability to update and/or command the LGC, command the Program Reader Assembly (PRA), and actuate certain relays in the Program Coupler Assembly (PCA).

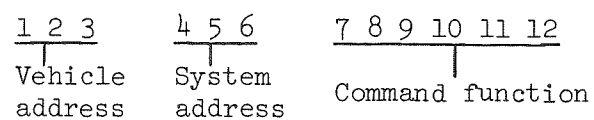
- a. An LGC updata word is a 22-bit word configured as follows:



- b. A PRA updata word is a 16-bit word configured as follows:



- c. A Real-Time Command (RTC) word is a 12-bit word configured as follows:



##### 2. Telemetry Measurements

There are two measurements downlinked from the DCA: LMP Message Acceptance Pulse (MAP) and UHF Receiver (RCVR) Signal (SIG) Strength (STR).

- a. The LMP MAP (GT0441X) indicates that the uplink word has been received and decoded in the DCA.
- b. The UHF RCVR SIG STR (GT0619V) is indicative of the DCA's ability to distinguish a good signal from a bad signal. The measurement will vary depending upon the circuit margin.

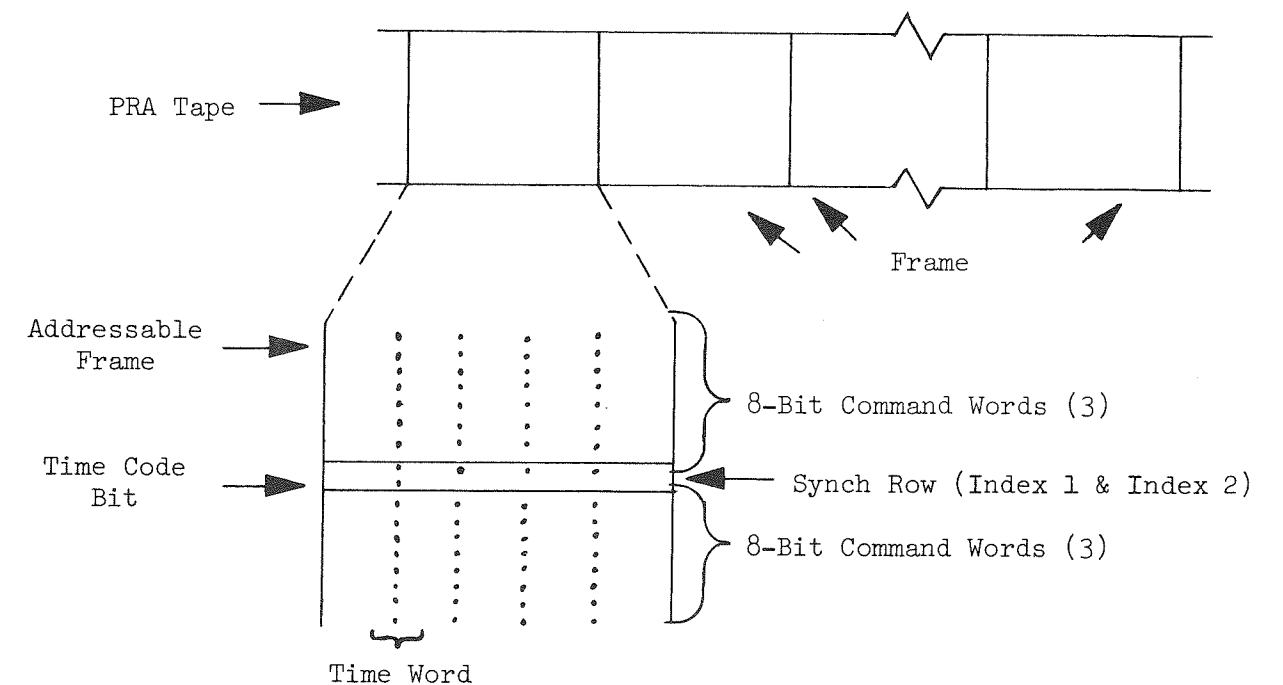
#### B. Program Reader Assembly (PRA)

##### 1. PRA Modes

- a. In the "standby" mode, the PRA electronics are powered up, but the tape is not running.
- b. In the "search" mode, the reader searches the tape for a particular preprogramed addressable frame selected by the ground (see Section B.3.b herein). When the frame is found the tape stops, a compare pulse is emitted, and the PRA goes to the "standby" mode.
- c. In the "operate" mode, the tape moves by the read head and the commands are executed through the prime relays in the PCA.

##### 2. PRA Tape

The PRA tape may contain up to 1000 frames, 64 of which can be addressable. Each frame contains a time word and up to six commands.





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When the PRA is operating, the tape moves by the read head and stops when a time word appears. This 16-bit time word is entered into a 16-bit register and compared with the contents of a 16-bit timer counter. The timer counter is incremented by a 1-pps clock and when the counter and register compare, a compare pulse is emitted. Upon reception of the compare pulse, the tape is moved one frame by the read head until the next time word appears. As the tape passes under the read head each command on the frame is processed and routed to the PCA prime relays.

### 3. PRA Control

- a. The PRA may be operated from the ground at any time, but the outputs to the PCA prime relays will not be effective while PGNS is in control. To enable PRA control of the LM, the AGS must be selected by an ISS Fail or LGC Warn discrete, or by an AGS SELECT RTC. This will stop the PRA and put it in the "stand-by" mode.
- b. Three 16-bit PRA updata words (see A.1.b herein) are necessary to locate and start a subroutine.
  - (1) The first 16-bit word contains the vehicle and system addresses, a six-bit time word to preset the six most significant bits in the timer counter to compare with the time word on the desired addressable frame, a binary "1" in the "initiate" location to zero the PRA clock so it may be preset, and binary "0's" in all other locations.
  - (2) The second 16-bit word contains the vehicle and system addresses, the six-bit "time" word in the time word locations, a binary "1" in the "forward (reverse) search" location to cause the tape to be searched for the desired frame, and

binary "0's" in all other locations.

- (3) The third 16-bit word contains the vehicle and system addresses, the six-bit "time" word in the time word locations, a binary "1" in the "start" location causing the PRA to begin reading the tape (see B.2 herein), and binary "0's" in all other locations.

- c. To effectively stop the PRA while it is operating, the AGS SELECT RTC may be sent or a large time word [see B.3.b.(1) herein] may be uplinked.

### 4. Telemetry Measurements

- a. The PRA COMPARE (GW5151V) indicates that the time word in the 16-bit register (derived from a frame on the tape) has compared with the time word in the timer counter (derived from a PRA updata word or from a 1 pps clock. This measurement should be used for verification of the reception and execution of the first PRA updata word [see B.3.b.(1) herein].
- b. The PRA CLOCK ON (GW5153V) indicates the 1 pps clock pulses are being fed to the timer counter and should appear upon PRA reception of the third PRA updata word [see B.3.b.(3) herein].

### C. Program Coupler Assembly (PCA)

#### 1. Prime Relay Matrix

The Prime Relay Matrix contains 254 prime relays, any one of which may be actuated at a time. All prime relays are operable by either the PRA or the LGC and provide the necessary switching functions normally performed by astronauts.

#### 2. RTC Relay Matrix

The RTC Relay Matrix contains 95 relays, any one of which may be actuated at a time by uplink through the DCA (see A.1.c herein).

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### 3. Relay Nomenclature

#### a. Prime or RTC Relays

Ex.    K 01    63  
          |    |  
      Subsystem    Relay  
      Code        Number  
      [see C.3(c) herein].

Prime Relays: Nos. 1-49

RTC Relays: Nos. 51-99

#### b. Interlock Relays

Ex.    K08-1

#### c. Subsystem Code

- 01 Attitude and Engine Control
- 02 Pyrotechnic Devices
- 04 Electrical Power
- 06 Instrumentation
- 07 Environmental Control
- 08 Reaction Control
- 10 Propulsion
- 11 Control Electronics
- 13 Communications
- 20 Development Flight Instrumentation

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### 13.3 LM MISSION PROGRAMMER (LMP) SYSTEM SCHEMATIC NOTES

- A. The MASTER RESET function resets all prime relays except the following:
  - 1. DFI Switchover
  - 2. C-Band Transponder (On/Off)
  - 3. Attitude Control Mode Select (Auto/Attitude Hold)
- B. The automatic guidance switchover function switches from PGNS to AGS, enables the prime relay matrix to accept PRA commands and put the PRA in the "standby" mode.
- C. LM/SLA antenna switchover is an automatic function occurring at LM/SLA separation. Microswitches on two of the LM legs enable the switchover contacts at separation.
- D. LMP Operational Capabilities
  - 1. APS started by LGC/PRA can be stopped by "engine stop override" ground or prime relay command.
  - 2. DPS can be started from ground by descent arm and engine start override.
  - 3. DPS started by ground can be stopped by "engine stop override."
  - 4. APS started by LGC abort stage prime relay cannot be stopped by ground engine stop override. To stop APS in this mode a prime relay master reset or PGNS/AGS - AGS select is required from the ground. An LGC updata instruction to the LGC to issue an auto engine off will stop the the engine in this mode.
  - 5. APS cannot be started by a ground abort stage function when PGNS/AGS switch is in AGS.
  - 6. APS may be started by an ascent arm prime relay and an engine start override RTC. An engine stop override RTC will stop the APS.
  - 7. APS may be started by an ascent arm prime relay and an ascent on prime relay. An engine stop override RTC will

stop the APS.

8. An APS started by PRA while in AGS select mode requires a ground descent engine arm to stop the ascent engine by RTC.
9. In the AGS mode, the FITH is accomplished with an "engine arm" of the ascent engine by prime relay and an "engine start override" by prime or RTC relays.
10. While in the AGS select mode, the normal "abort stage" function on the present LMP configured vehicle cannot be performed by either ground or prime relay.
11. The ground relays in the PCA must be in the initial "reset" position if the LGC/PRA mode is to operate normally. Except as listed below, all ground relays set by ground should be reset at the end of each operation.
12. The reset position of the manual throttle is 30 percent thrust in the LMP. A master reset RTC will perform this.
13. An abort stage signal should be sent prior to ascent engine operation. This provides for ascent helium pressurization on the unmanned LM.
14. If the ground isolates both ascent helium Tanks 1 and 2, the ascent propulsion system cannot be pressurized by either real-time ground commands, LMP, prime relays, or by an astronaut onboard.
15. A prime relay failure will require the PGNS/AGS switch to be in PGNS and an "abort stage" by ground command to start APS by the updata link control.
16. A PCA total power failure (circuit breaker) will disable the auto switchover from PGNS to AGS and will disable all prime relay control.
17. A PCA power supply failure will disable all prime relay control and will necessitate complete backup of the LM by ground commands. The auto function for direct interface from the LGC to LM would still function normally while in the PGNS mode of control.



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#### 13.4 LGC/PCA COMMAND LIST

The LGC/PCA Command List will be supplied at a later date.

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### 13.5 PRA SEQUENCES

The enclosed PRA functional sequences (Table 13-1) and command/code Timeline (Table 13-2) represent a GAEC/MSC synthesis of LM-1 (AS-206) backup mission requirements. They have been derived from the MSC approved functional sequences, subsequent GAEC/MSC coordinated expansion of these sequences, MSC and GAEC critique of the original release of LMO-611-32, and the nomenclature. At the February 9, 1966 NASA/MSC-GAEC review of the LM-1 PRA flight program, it was mutually agreed that the flight program would consist of eight addressable PRA sequences. Subsequent to this review meeting, it was agreed that the number of sequences would be increased to 15, thereby expanding both the capability and flexibility of the PRA program. This number has been further increased to sixteen as a result of MSC review of the original LMO-611-32. The MSC critique has been received only verbally to date, but official commentary will be forthcoming.

The detailed timeline (Table 13-2) includes the following considerations:

- A. All "DFI TM Calibrate" commands have been excluded in accordance with instructions received from C. Wasson (NASA/MSC/GN&C) and R. Sinderson (NASA/MSC/IESD). Their reasoning is that modulator package drift will be too small (approximately 1/2% in 14 hours) to warrant any calibration commands being included in the PRA tape.
- B. The "ECS Primary Water Valve" and "C-Band Transponder" activation commands have been excluded since they are discrete commands not associated with any specific functional sequence. Ground command control of these functions currently exists to satisfy the operational requirements.
- C. Sequentially dependent commands have been spaced at greater intervals wherever possible in compliance with MSC/FOD requests for additional time for ground control response.
- D. Precautionary commands (e.g., repeated selection of the four Jet translation mode) have been included wherever these functions are critical to the performance of the sequence.

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The following items summarize the revisions to the original version of LMO-611-32:

- A. The preset time words for the individual sequences have been arranged in descending order (i.e., Sequence I is addressed as 17:55:12 in decimal form or 111111 + 10 zeros in binary form; Sequence X is addressed as 15:21:36 and 110110, respectively) in compliance with the MSC/FOD critique. The time words within any given sequence advance in ascending order (i.e., To + 1, 2, etc.). The purpose of this is to preclude inadvertent PRA operation if a PRA Stop Command is not sent at the conclusion of a scheduled sequence. The clock would have to completely recycle before it would compare with the next time word.
- B. An "ECS/Ascent Interconnect Shutdown Sequence" (Sequence XVI) has been added in compliance with the MSC/FOD critique. The purpose is to protect the RCS from helium ingestion in the event of an inadvertent APS shutdown during interconnect operations.
- C. ECS Ascent Water Valve operation, which was inadvertently omitted from the original version, has been added prior to all FITH operations.
- D. The sequences containing either RCS venting and pressurization or RCS/Ascent Interconnect operations have been revised to reflect the change in RCS configuration.
- E. The use of precautionary commands has been limited to the start of sequences in compliance with the MSC/FOD critique.
- F. Master C&W Alarm Reset has been added to the beginning of Sequences I and II in compliance with the MSC/FOD critique.
- G. The FITH operations have been expanded to approximate basic LM Abort Stage timing by placing the critical commands (e.g., Abort Stage On; Descent Engine Arm Off; and Ascent Engine Arm On) at specific points within the command frame and filling in the remaining command slots with non-acting commands.

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- H. The manual selection of minimum deadband has been deleted from the "APS Restart Sequence" (Sequence XV) in compliance with the MSC/FOD critique. The purpose is to allow verification of automatic selection of minimum deadband at engine ignition.
- I. Wherever possible, all sequences have been standardized with respect to order of commands, time between "set" and "reset" of each relay, and time differential between commands.

The selection, combination, and augmentation of the addressable sequences via ground command provides the capability of performing a backup mission ranging from the Minimum Requirements Sequence (Sequence III) to full duration propulsion operations.

It should be noted that the terminology used in Table 13-2 is based upon the LMP Command nomenclature.

It should be further noted that the sequences contained herein do not constitute the total content of the PRA flight tape. In addition to the Mission Control Sequences, a portion of the tape will be utilized for prelaunch checkout and in-house integration purposes.

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REV A

#### 13.6 MISSION PROGRAMER SCHEMATIC NOTES (Drawing 13.3.1 Sheet 2 of 2)

- A. Relay K2059E is a non-latching relay. This relay is energized only by command 40B AGS SELECT.
- B. All latching relays are shown in the reset configuration and all non-latching relays are shown in the de-energized configuration, unless noted.



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TABLE 13-1 LM-1 (AS-206A) PRA FUNCTIONAL SEQUENCES

LM  
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SEQUENCE NUMBER	DESCRIPTION
I	Nominal LM-S-IVB Separation Sequence (incl. RCS Vent & Press.)
II	LM/S-IVB Separation Sequence
III	Minimum Requirements Sequence
IV	FITH Abort Sequence (Abort From Max Thrust DPS)
V	FITH Sequence (DPS Inactive)
VI	DPS Throttling Sequence
VII	Powered Ascent Sequence
VIII	Positive Yaw Maneuver
IX	Negative Yaw Maneuver
X	Positive Pitch Maneuver
XI	Negative Pitch Maneuver
XII	Positive Roll Maneuver
XIII	Negative Roll Maneuver
XIV	LMP-SCS Sequence
XV	APS Restart Sequence (5 sec APS Burn)
XVI	RCS/Ascent Interconnect Shutdown Sequence

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TABLE 13-2 LM-1 (AS-206A) PRA COMMAND/CODE TIMELINE

LM  
AS-206  
REV A (S)=Set  
(R)=Reset

SEQUENCE NUMBER	DECIMAL TIME WORD	BINARY * TIME WORD	OPERATIONAL STATEMENT	RELAY DESIGNATION	RELA. DEC. CODE	
I	17:55:12	111111	1. Master C&W Alarm Reset <u>On</u>	A9K25 (S)	198	
	17:55:14		2. Master C&W Alarm Reset <u>Off</u>	A9K25 (R)	199	
	17:55:15		3. 2 Jet/4 Jet Select <u>4 Jet</u>	A9K27 (R)	71	
	17:55:16		4. Positive X-Axis Translation <u>On</u>	A6K24 (S)	128	
	17:55:56		5. Positive X-Axis Translation <u>Off</u>	A6K24 (R)	129	
	17:56:01		6. RCS Main Shutoff Valves System "A" - Open <u>Power On</u>	A13K18 (S)	188	
	17:56:02		7. RCS Main Shutoff Valves System "B" - Open <u>Power On</u>	A14K18 (S)	190	
			8. ED Battery Activation <u>Arm</u>	A11K12 (S)	4	
			9. RCS Main Shutoff Valves System "A" - Open <u>Power Off</u>	A13K18 (R)	189	
			10. RCS Main Shutoff Valves System "B" - Open <u>Power Off</u>	A14K18 (R)	191	
			17:56:11	11. RCS Helium Pressurization <u>Fire</u>	A11K14 (S)	6
	17:56:12		12. RCS Helium Pressurization <u>Off</u>	A11K14 (R)	7	
	17:56:41		13. ED Battery Activation <u>Safe</u>	A11K12 (R)	5	
	17:56:51		14. Control Mode Select <u>Attitude Hold</u>	A11K18 (S)	2	
			15. Deadband Select <u>Min</u>	A11K27 (R)	37	
			16. Positive X-Axis Translation <u>On</u>	A6K24 (S)	128	
			17:56:52	17. S-Band Primary XCVR/PA <u>On</u>	A15K5 (S)	138
			17:56:55	18. LM/S-IVB Separation Command <u>Arm</u>	A12K3 (S)	58
			17:56:56	19. LM/S-IVB Separation Command <u>Fire</u>	A12K20 (S)	90
			17:57:09	20. Positive X-Axis Translation <u>Off</u>	A6K24 (R)	129
			21. LM/S-IVB Separation Command <u>Arm-Off</u>	A12K3 (R)	59	
			22. LM/S-IVB Separation Command <u>Fire-Off</u>	A12K20 (R)	91	
			17:57:19	23. Deadband Select <u>Max</u>	A11K27 (S)	36
	17:57:29		24. Master C&W Alarm Reset <u>On</u>	A9K25 (S)	198	
	17:57:31		25. Master C&W Alarm Reset <u>Off</u>	A9K25 (R)	199	
II	17:38:08	111110	1. Master C&W Alarm Reset <u>On</u>	A9K25 (S)	198	
	17:38:10		2. Master C&W Alarm Reset <u>Off</u>	A9K25 (R)	199	
	17:38:11		3. Control Mode Select <u>Attitude Hold</u>	A11K18 (S)	2	
	17:38:21		4. Deadband Select <u>Min</u>	A11K27 (R)	37	
			5. 2 Jet/4 Jet Select <u>4 Jet</u>	A9K27 (R)	71	
			6. Positive X-Axis Translation <u>On</u>	A6K24 (S)	128	
			17:38:22	7. S-Band Primary XCVR/PA <u>On</u>	A15K5 (S)	138
			17:38:25	8. LM/S-IVB Separation Command <u>Arm</u>	A12K3 (S)	58
	17:38:26		9. LM/S-IVB Separation Command <u>Fire</u>	A12K20 (S)	90	
	17:38:39		10. Positive X-Axis Translation <u>Off</u>	A6K24 (R)	129	
	17:38:49		11. LM/S-IVB Separation Command <u>Arm-Off</u>	A12K3 (R)	59	
			12. LM/S-IVB Separation Command <u>Fire-Off</u>	A12K20 (R)	91	
			13. Deadband Select <u>Max</u>	A11K27 (S)	36	
			17:38:59	14. Master C&W Alarm Reset <u>On</u>	A9K25 (S)	198
			17:39:01	15. Master C&W Alarm Reset <u>Off</u>	A9K25 (R)	199
*16 Bits: First six bits listed, last 10 bits always binary zero.						

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TABLE 13-2 LM-1 (AS-206A) PRA COMMAND/CODE TIMELINE (Cont'd)

LM  
AS-206  
REV A

(S)=Set  
(R)=Reset

SEQUENCE NUMBER	DECIMAL TIME WORD	BINARY TIME WORD	OPERATIONAL STATEMENT	RELAY DESIGNATION	RELAY DEC. CODE
III	17:21:04	111101	1. Master C&W Alarm Reset <u>On</u>	A9K25 (S)	198
	17:21:06		2. Master C&W Alarm Reset <u>Off</u>	A9K25 (R)	199
	17:21:07		3. ED Battery Activation <u>Arm</u>	A11K12 (S)	4
			4. Control Mode Select <u>Attitude Hold</u>	A11K18 (S)	2
			5. Deadband Select <u>Min</u>	A11K27 (R)	37
			6. 2 Jet/4 Jet Select <u>4 Jet</u>	A9K27 (R)	71
	17:21:12		7. Landing Gear Deploy <u>Fire</u>	A10K21 (S)	8
	17:21:13		8. Landing Gear Deploy <u>Off</u>	A10K21 (R)	9
	17:21:14		9. Engine Select-Descent Arm <u>On</u>	A9K6 (S)	150
	17:21:22		10. Positive X-Axis Translation <u>On</u>	A6K24 (S)	128
			11. Manual Throttle - 30% Thrust <u>On</u>	A9K21 (R)	87
	17:21:28		12. Engine Start Override <u>On</u>	A9K10 (S)	214
	17:21:29		13. Engine Start Override <u>Off</u>	A9K10 (R)	215
	17:21:31		14. Manual Throttle - 10% Thrust <u>On</u>	A9K21 (S)	86
	17:21:33		15. Positive X-Axis Translation <u>Off</u>	A6K24 (R)	129
			16. ED Battery Activation <u>Safe</u>	A11K12 (R)	5
	17:21:54		17. Manual Throttle - 100% Thrust <u>On</u>	A9K18 (S)	30
	17:22:04		18. Engine Stop Override <u>On</u>	A9K4 (S)	166
	17:22:06		19. Engine Stop Override <u>Off</u>	A9K4 (R)	167
			20. Manual Throttle - 100% Thrust <u>Off</u>	A9K18 (R)	231
			21. Manual Throttle - 30% Thrust <u>On</u>	A9K21 (R)	87
	17:22:09		22. Engine Select-Descent Arm <u>Off</u>	A9K6 (R)	151
			23. Master C&W Alarm Reset <u>On</u>	A9K25 (S)	198
	17:22:11		24. Master C&W Alarm Reset <u>Off</u>	A9K25 (R)	199
			25. Deadband Select <u>Max</u>	A11K27 (S)	36
	17:22:29		26. Engine Select - Descent Arm <u>On</u>	A9K6 (S)	150
			27. Deadband Select <u>Min</u>	A11K27 (R)	37
	17:22:30		28. Positive X-Axis Translation <u>On</u>	A6K24 (S)	128
	17:22:36		29. Engine Start Override <u>On</u>	A9K10 (S)	214
	17:22:37		30. Engine Start Override <u>Off</u>	A9K10 (R)	215
	17:22:39		31. Manual Throttle - 10% Thrust <u>On</u>	A9K21 (S)	86
	17:22:41		32. Positive X-Axis Translation <u>Off</u>	A6K24 (R)	129
	17:23:02		33. Manual Throttle - 100% Thrust <u>On</u>	A9K18 (S)	230
	17:23:19		34. Crossover Ascent Water Coolant Valve Open <u>Power On</u>	A17K6 (S)	222
	17:23:20		35. Crossover Ascent Water Coolant Valve Open <u>Power Off</u>	A17K6 (R)	223
	17:23:32		36. LM/S-IVB Separation Command <u>Arm Off</u>	A12K3 (R)	59
			37. RCS Pressurization <u>Off</u>	A11K14 (R)	7
			38. Abort Stage <u>Enable</u>	A1CK3 (S)	38
			39. Engine Select-Descent Arm <u>Off</u>	A9K6 (R)	151
			40. LM/S-IVB Separation Command <u>Fire Off</u>	A12K20 (R)	91
			41. Engine Select-Ascent Arm <u>On</u>	A9K7 (S)	134
	17:23:38		42. Engine Stop Override <u>On</u>	A9K4 (S)	166
	17:23:39		43. Manual Throttle - 100% Thrust <u>Off</u>	A9K18 (R)	231
			44. Manual Throttle - 30% Thrust <u>On</u>	A9K21 (R)	87
	17:23:40		45. Abort Stage <u>Disable</u>	A10K3 (R)	39

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TABLE 13-2 LM-1 (AS-206A) PRA COMMAND/CODE TIMELINE (Cont'd)

LM  
AS-206  
REV A  
(S)=Set  
(R)=Reset

SEQUENCE NUMBER	DECIMAL TIME WORD	BINARY TIME WORD	OPERATIONAL STATEMENT	RELAY DESIGNATION	RELAY DEC. CODE
III (Cont'd)	17:23:40		46. Engine Select-Ascent Arm <u>Off</u>	A9K7 (R)	135
			47. Engine Stop Override <u>Off</u>	A9K4 (R)	167
			48. Deadband Select <u>Max</u>	A11K27 (S)	36
	17:23:54		49. Master C&W Alarm Reset <u>On</u>	A9K25 (S)	198
	17:23:56		50. Master C&W Alarm Reset <u>Off</u>	A9K25 (R)	199
	17:23:59		51. Engine Select-Ascent Arm <u>On</u>	A9K7 (S)	134
	17:24:04		52. Deadband Select <u>Min</u>	A11K27 (R)	37
	17:24:05		53. Positive X-Axis Translation <u>On</u>	A6K24 (S)	128
	17:24:07		54. Engine Start Override <u>On</u>	A9K10 (S)	214
	17:24:08		55. Engine Start Override <u>Off</u>	A9K10 (R)	215
	17:24:12		56. Positive X-Axis Translation <u>Off</u>	A6K24 (R)	129
	17:24:16		57. RCS Manifold Crossfeed Valves Open <u>Power On</u>	A17K2 (S)	252
	17:24:17		58. RCS Ascent Feed; System A - Open <u>Power On</u>	A13K3 (S)	60
			59. RCS Ascent Feed; System B - Open <u>Power On</u>	A14K3 (S)	62
			60. RCS Manifold Crossfeed Valves Open <u>Power Off</u>	A17K2 (R)	253
	17:24:18		61. RCS Ascent Feed; System A - Open <u>Power Off</u>	A13K3 (R)	61
			62. RCS Ascent Feed; System B - Open <u>Power Off</u>	A14K3 (R)	63
	17:24:27		63. RCS Main Shutoff Valves System A - Close <u>Power On</u>	A13K13 (S)	172
			64. RCS Main Shutoff Valves System B - Close <u>Power On</u>	A14K13 (S)	174
	17:24:28		65. RCS Main Shutoff Valves System A - Close <u>Power Off</u>	A13K13 (R)	173
			66. RCS Main Shutoff Valves System B - Close <u>Power Off</u>	A14K13 (R)	175
	17:25:27		67. RCS Main Shutoff Valves System A - Open <u>Power On</u>	A13K18 (S)	188
			68. RCS Main Shutoff Valves System B - Open <u>Power On</u>	A14K18 (S)	190
	17:25:28		69. RCS Main Shutoff Valves System A - Open <u>Power Off</u>	A13K18 (R)	189
			70. RCS Main Shutoff Valves System B - Open <u>Power Off</u>	A14K18 (R)	191
	17:25:37		71. RCS Ascent Feed; System A - Close <u>Power On</u>	A13K4 (S)	76
			72. RCS Ascent Feed; System B - Close <u>Power On</u>	A14K4 (S)	78
	17:25:38		73. RCS Manifold Crossfeed Valves Close <u>Power On</u>	A17K4 (S)	254
			74. RCS Ascent Feed; System A Close <u>Power Off</u>	A13K4 (R)	77
			75. RCS Ascent Feed; System B Close <u>Power Off</u>	A14K4 (R)	79



\* TABLE 13-2 LM-1 (AS-206A) PRA COMMAND/CODE TIMELINE (Cont'd)

LM  
AS-206  
REV A  
(S)=Set  
(R)=Reset

SEQUENCE NUMBER	DECIMAL TIME WORD	BINARY TIME WORD	OPERATIONAL STATEMENT	RELAY DESIGNATION	RELAY DEC. CODE
III (Cont'd)	17:25:39		76. RCS Manifold Crossfeed Valves Close <u>Power Off</u>	A17K4 (R)	255
	17:25:47		77. Engine Stop Override <u>On</u>	A9K4 (S)	166
	17:25:48		78. Engine Select-Ascent Arm <u>Off</u>	A9K7 (R)	135
			79. Engine Stop Override <u>Off</u>	A9K4 (R)	167
	17:25:54		80. Deadband Select <u>Max</u>	A11K27 (S)	36
	17:25:59		81. Master C&W Alarm Reset <u>On</u>	A9K25 (S)	198
	17:26:01		82. Master C&W Alarm Reset <u>Off</u>	A9K25 (R)	199
IV	17:04:00	111100	1. Manual Throttle - 100% Thrust <u>On</u>	A9K18 (S)	230
			2. Crossover Ascent Water Coolant Valve-Open <u>Power On</u>	A17K6 (S)	222
	17:04:01		3. Crossover Ascent Water Coolant Valve- Open <u>Power Off</u>	A17K6 (R)	223
	17:04:02		4. LM/S-IVB Separation Command <u>Arm Off</u>	A12K3 (R)	39
			5. RCS Pressurization <u>Off</u>	A11K14 (R)	7
			6. Abort Stage <u>Enable</u>	A10K3 (S)	38
			7. Engine Select-Descent Arm <u>Off</u>	A9K6 (R)	151
			8. LM/S-IVB Separation Command <u>Fire Off</u>	A12K20 (R)	91
			9. Engine Select-Ascent Arm <u>On</u>	A9K7 (S)	134
	17:04:08		10. Engine Stop Override <u>On</u>	A9K4 (S)	166
	17:04:09		11. Manual Throttle - 100% Thrust <u>Off</u>	A9K18 (R)	231
			12. Manual Throttle - 30% Thrust <u>On</u>	A9K21 (R)	87
	17:04:10		13. Abort Stage <u>Disable</u>	A10K3 (R)	39
			14. Engine Select-Ascent Arm <u>Off</u>	A9K7 (R)	135
			15. Engine Stop Override <u>Off</u>	A9K4 (R)	167
			16. Deadband Select <u>Max</u>	A11K27 (S)	36
	17:04:24		17. Master C&W Alarm Reset <u>On</u>	A9K25 (S)	198
	17:04:26		18. Master C&W Alarm Reset <u>Off</u>	A9K25 (R)	199
	17:04:29		19. Engine Select-Ascent Arm <u>On</u>	A9K7 (S)	134
	17:04:34		20. Deadband Select <u>Min</u>	A11K27 (R)	37
	17:04:35		21. Positive X-Axis Translation <u>On</u>	A6K24 (S)	128
	17:04:37		22. Engine Start Override <u>On</u>	A9K10 (S)	214
	17:04:38		23. Engine Start Override <u>Off</u>	A9K10 (R)	215
	17:04:42		24. Positive X-Axis Translation <u>Off</u>	A6K24 (R)	129
	17:04:46		25. RCS Manifold Crossfeed Valves - Open <u>Power On</u>	A17K2 (S)	252
	17:04:47		26. RCS Ascent Feed; System A - Open <u>Power On</u>	A13K3 (S)	60
			27. RCS Ascent Feed; System B - Open <u>Power On</u>	A14K3 (S)	62
			28. RCS Manifold Crossfeed Valves - Open <u>Power Off</u>	A17K2 (R)	253
	17:04:48		29. RCS Ascent Feed; System A - Open <u>Power Off</u>	A13K3 (R)	61
			30. RCS Ascent Feed; System B - Open <u>Power Off</u>	A14K3 (R)	63

\* TABLE 13-2 LM-1 (AS-206A) PRA COMMAND/CODE TIMELINE (Cont'd)

LM  
AS-206  
REV A  
(S)=Set  
(R)=Reset

SEQUENCE NUMBER	DECIMAL TIME WORD	BINARY TIME WORD	OPERATIONAL STATEMENT	RELAY DESIGNATION	RELAY DEC. CODE
IV (Cont'd)	17:04:57		31. RCS Main Shutoff Valves System A - Close <u>Power On</u>	A13K13 (S)	172
			32. RCS Main Shutoff Valves System B - Close <u>Power On</u>	A14K13 (S)	174
	17:04:58		33. RCS Main Shutoff Valves System A - Close <u>Power Off</u>	A13K13 (R)	173
			34. RCS Main Shutoff Valves System B - Close <u>Power Off</u>	A14K13 (R)	175
	17:05:57		35. RCS Main Shutoff Valves System A - Open <u>Power On</u>	A13K18 (S)	188
			36. RCS Main Shutoff Valves System B - Open <u>Power On</u>	A14K18 (S)	190
	17:05:58		37. RCS Main Shutoff Valves System A - Open <u>Power Off</u>	A13K18 (R)	189
			38. RCS Main Shutoff Valves System B - Open <u>Power Off</u>	A14K18 (R)	191
	17:06:07		39. RCS Ascent Feed; System A - Close <u>Power On</u>	A13K4 (S)	76
			40. RCS Ascent Feed; System B - Close <u>Power On</u>	A14K4 (S)	78
	17:06:08		41. RCS Manifold Crossfeed Valves- Close <u>Power On</u>	A17K4 (S)	254
			42. RCS Ascent Feed; System A- Close <u>Power Off</u>	A13K4 (R)	77
			43. RCS Ascent Feed; System B - Close <u>Power Off</u>	A14K4 (R)	79
	17:06:09		44. RCS Manifold Crossfeed Valves - Close <u>Power Off</u>	A17K4 (R)	255
			45. Engine Stop Override <u>On</u>	A9K4 (S)	166
	17:06:18		46. Engine Select-Ascent Arm <u>Off</u>	A9K7 (R)	135
			47. Engine Stop Override <u>Off</u>	A9K4 (R)	167
	17:06:24		48. Deadband Select <u>Max</u>	A11K27 (S)	36
	17:06:29		49. Master C&W Alarm Reset <u>On</u>	A9K25 (S)	198
	17:06:31		50. Master C&W Alarm Reset <u>Off</u>	A9K25 (R)	199
V	16:46:56	111011	1. Master C&W Alarm Reset <u>On</u>	A9K25 (S)	198
	16:46:58		2. Master C&W Alarm Reset <u>Off</u>	A9K25 (R)	199
	16:46:59		3. Control Mode Select <u>Attitude Hold</u>	A11K18 (S)	2
			4. Deadband Select <u>Min</u>	A11K27 (R)	37
			5. 2 Jet/4 Jet Select <u>4 Jet</u>	A9K27 (R)	71
			6. Engine Select-Descent Arm <u>Off</u>	A9K6 (R)	151
	16:47:03		7. Positive X-Axis Translation <u>On</u>	A6K24 (S)	128
	16:47:09		8. Engine Select-Ascent Arm <u>On</u>	A9K7 (S)	134
			9. RCS Helium Pressurization <u>Off</u>	A11K14 (R)	7
			10. Abort Stage <u>Enable</u>	A10K3 (S)	38
			11. LM/S-IVB Separation Command <u>Arm Off</u>	A12K3 (R)	59
			12. LM/S-IVB Separation Command <u>Fire Off</u>	A12K20 (R)	91
			13. Engine Start Override <u>On</u>	A9K10 (S)	214

\* LM  
AS-206  
REV A  
(S)=Set  
(R)=Reset

TABLE 13-2 LM-1 (AS-206A) PRA COMMAND/CODE TIMELINE (Cont'd)

SEQUENCE NUMBER	DECIMAL TIME WORD	BINARY TIME WORD	OPERATIONAL STATEMENT	RELAY DESIGNATION	RELAY DEC. CODE
V (Cont'd)	16:47:11		14. Positive X-Axis Translation Off	A6K24 (R)	129
			15. Engine Start Override Off	A9K10 (R)	215
	16:47:15		16. Engine Stop Override On	A9K4 (S)	166
	16:47:17		17. Abort Stage Disable	A10K3 (R)	39
			18. Engine Select-Ascent Arm Off	A9K7 (R)	135
			19. Engine Stop Override Off	A9K4 (R)	167
			20. Deadband Select Max	A11K27 (S)	36
	16:47:31		21. Master C&W Alarm Reset On	A9K25 (S)	198
	16:47:33		22. Master C&W Alarm Reset Off	A9K25 (R)	199
	16:47:36		23. Engine Select-Ascent Arm On	A9K7 (S)	134
	16:47:41		24. Deadband Select Min	A11K27 (R)	37
	16:47:42		25. Positive X-Axis Translation On	A6K24 (S)	128
	16:47:44		26. Engine Start Override On	A9K10 (S)	214
	16:47:45		27. Engine Start Override Off	A9K10 (R)	215
	16:47:49		28. Positive X-Axis Translation Off	A6K24 (R)	129
	16:47:53		29. RCS Manifold Crossfeed Valves Open	A17K2 (S)	252
			30. RCS Ascent Feed; System A - Open	A13K3 (S)	60
	16:47:54		31. RCS Ascent Feed; System B - Open	A14K3 (S)	62
			32. RCS Manifold Crossfeed Valves Open	A17K2 (R)	253
	16:47:55		33. RCS Ascent Feed; System A - Open	A13K3 (R)	61
			34. RCS Ascent Feed; System B - Open	A14K3 (R)	63
	16:48:04		35. RCS Main Shutoff Valves, System A - Close	A13K13 (S)	172
			36. RCS Main Shutoff Valves, System B - Close	A14K13 (S)	174
	16:48:05		37. RCS Main Shutoff Valves, System A - Close	A13K13 (R)	173
			38. RCS Main Shutoff Valves, System B - Close	A14K13 (R)	175
	16:49:04		39. RCS Main Shutoff Valves, System A - Open	A13K18 (S)	188
			40. RCS Main Shutoff Valves, System B - Open	A14K18 (S)	190
	16:19:05		41. RCS Main Shutoff Valves, System A - Open	A13K18 (R)	189
			42. RCS Main Shutoff Valves, System B - Open	A14K18 (R)	191
	16:49:14		43. RCS Ascent Feed; System A - Close	A13K4 (S)	76
			44. RCS Ascent Feed; System B - Close	A14K4 (S)	78

\* LM  
AS-206  
REV A  
(S)=Set  
(R)=Reset

TABLE 13-2 LM-1 (AS-206A) PRA COMMAND/CODE TIMELINE (Cont'd)

SEQUENCE NUMBER	DECIMAL TIME WORD	BINARY TIME WORD	OPERATIONAL STATEMENT	RELAY DESIGNATION	RELAY DEC. CODE
V (Cont'd)	16:49:15		45. RCS Manifold Crossfeed Valves - Close	A17K4 (S)	254
			46. RCS Ascent Feed; System A - Close	A13K4 (R)	77
	16:49:16		47. RCS Ascent Feed; System B - Close	A14K4 (R)	79
			48. RCS Manifold Crossfeed Valves - Close	A17K4 (R)	255
	16:19:17		49. Engine Stop Override On	A9K4 (S)	166
	16:49:24		50. Engine Select - Ascent Arm Off	A9K7 (R)	135
	16:49:25		51. Engine Stop Override Off	A9K4 (R)	167
	16:49:31		52. Deadband Select Max	A11K27 (S)	36
	16:49:36		53. Master C&W Alarm Reset On	A9K25 (S)	198
	16:49:38		54. Master C&W Alarm Reset Off	A9K25 (R)	199
VI	16:29:52	111010	1. Manual Throttle - 10% Thrust On	A9K21 (S)	86
	16:30:02		2. Manual Throttle - 50% Thrust On	A9K20 (S)	102
			3. Manual Throttle - 30% Thrust On	A9K21 (R)	87
	16:30:05		4. Crossover Water Coolant Valve - Open	A17K6 (S)	222
			5. Crossover Water Coolant Valve - Open	A17K6 (R)	223
	16:30:12		6. Manual Throttle - 50% Thrust Off	A9K20 (S)	103
	16:30:22		7. Manual Throttle - 100% Thrust On	A9K18 (S)	230
	16:30:24		8. LM/S-IVB Separation Command Arm Off	A12K3 (R)	59
			9. RCS Helium Pressurization Off	A11K14 (R)	7
			10. Abort Stage Enable	A10K3 (S)	38
			11. Engine Select-Descent Arm Off	A9K6 (R)	151
			12. LM/S-IVB Separation Command Fire Off	A12K20 (R)	91
			13. Engine Select-Ascent Arm On	A9K7 (S)	134
	16:30:30		14. Engine Stop Override On	A9K4 (S)	166
	16:30:31		15. Manual Throttle - 100% Thrust Off	A9K18 (R)	231
	16:30:32		16. Abort Stage Disable	A10K3 (R)	39
			17. Engine Select-Ascent Arm Off	A9K7 (R)	135
			18. Engine Stop Override Off	A9K4 (R)	167
			19. Deadband Select Max	A11K27 (S)	36
	16:30:47		20. Master C&W Alarm Reset On	A9K25 (S)	198
	16:30:49		21. Master C&W Alarm Reset Off	A9K25 (R)	199
	16:30:52		22. Engine Select-Ascent Arm On	A9K7 (S)	134
	16:30:57		23. Deadband Select Min	A11K27 (R)	37
	16:30:58		24. Positive X-Axis Translation On	A6K24 (S)	128
	16:31:00		25. Engine Start Override On	A9K10 (S)	214
	16:31:01		26. Engine Start Override Off	A9K10 (R)	215
	16:31:05		27. Positive X-Axis Translation Off	A6K24 (R)	129
	16:31:09		28. RCS Manifold Crossfeed Valves - Open	A17K2 (S)	252
	16:31:10		29. RCS Ascent Feed; System A - Open	A13K3 (S)	60

TABLE 13-2 LM-1 (AS-206A) PRA COMMAND/CODE TIMELINE (Cont'd)

LM  
AS-206  
REV A  
(S)=Set  
(R)=Reset

(R)=Reset					
SEQUENCE NUMBER	DECIMAL TIME WORD	BINARY TIME WORD	OPERATIONAL STATEMENT	RELAY DESIGNATION	RELAY DEC. CODE
VI (Cont'd)	16:31:11		30. RCS Ascent Feed; System B - Open <u>Power On</u>	A14K3 (S)	62
			31. RCS Manifold Crossfeed Valves - Open <u>Power Off</u>	A17K2 (R)	253
			32. RCS Ascent Feed; System A - Open <u>Power Off</u>	A13K3 (R)	61
	33. RCS Ascent Feed; System B - Open <u>Power Off</u>		A14K3 (R)	63	
	16:31:20		34. RCS Main Shutoff Valves, System A - Close <u>Power On</u>	A13K13 (S)	172
			35. RCS Main Shutoff Valves, System B - Close <u>Power On</u>	A14K13 (S)	174
			36. RCS Main Shutoff Valves, System A - Close <u>Power Off</u>	A13K13 (R)	173
	16:31:21		37. RCS Main Shutoff Valves, System B - Close <u>Power Off</u>	A14K13 (R)	175
			38. RCS Main Shutoff Valves, System A - Open <u>Power On</u>	A13K18 (S)	188
			39. RCS Main Shutoff Valves, System B - Open <u>Power On</u>	A14K18 (S)	190
	16:32:20		40. RCS Main Shutoff Valves, System A - Open <u>Power Off</u>	A13K18 (R)	189
			41. RCS Main Shutoff Valves, System B - Open <u>Power Off</u>	A14K18 (R)	191
			42. RCS Ascent Feed System A - Close <u>Power On</u>	A13K4 (S)	76
	16:32:30		43. RCS Ascent Feed System B - Close <u>Power On</u>	A14K4 (S)	78
			44. RCS Manifold Crossfeed Valves, Close <u>Power On</u>	A17K4 (S)	254
			45. RCS Ascent Feed; System A - Close <u>Power Off</u>	A13K4 (R)	77
	16:32:31		46. RCS Ascent Feed; System B - Close <u>Power Off</u>	A14K4 (R)	79
			47. RCS Manifold Crossfeed Valves - Close <u>Power Off</u>	A17K4 (R)	255
			48. Engine Stop Override <u>On</u>	A9K4 (S)	166
	16:32:40		49. Engine Select-Ascent Arm <u>Off</u>	A9K7 (R)	135
	16:32:41		50. Engine Stop Override <u>Off</u>	A9K4 (R)	167
	16:32:47		51. Deadband Select <u>Max</u>	A11K27 (S)	36
	16:32:52		52. Master C&W Alarm Reset <u>On</u>	A9K25 (S)	198
	16:32:54		53. Master C&W Alarm Reset <u>Off</u>	A9K25 (R)	199
VII	16:12:48	111001	1. Master C&W Alarm Reset <u>On</u>	A9K25 (S)	198
	16:12:50		2. Master C&W Alarm Reset <u>Off</u>	A9K25 (R)	199
	16:12:51		3. Control Mode Select <u>Attitude Hold</u>	A11K18 (S)	2
			4. Deadband Select <u>Min</u>	A11K27 (R)	37
			5. 2 Jet/4 Jet Select <u>4 Jet</u>	A9K27 (R)	71
			6. Engine Select-Ascent Arm <u>On</u>	A9K7 (S)	134

TABLE 13-2 LM-1 (AS-206A) PRA COMMAND/CODE TIMELINE (Cont'd)

LM  
AS-206  
REV A  
(S)=Set  
(R)=Reset

(R)=Reset					
SEQUENCE NUMBER	DECIMAL TIME WORD	BINARY * TIME WORD	OPERATIONAL STATEMENT	RELAY DESIGNATION	RELAY DEC. CODE
VII (Cont'd)	16:12:55		7. Positive X-Axis Translation <u>On</u>	A6K24 (S)	128
	16:12:57		8. Engine Start Override <u>On</u>	A9K10 (S)	214
	16:12:58		9. Engine Start Override <u>Off</u>	A9K10 (R)	215
	16:13:02		10. Positive X-Axis Translation <u>Off</u>	A6K24 (R)	129
	16:13:06		11. RCS Manifold Crossfeed Valves - Open <u>Power On</u>	A17K2 (S)	252
	16:13:07		12. RCS Ascent Feed; System A - Open <u>Power On</u>	A13K3 (S)	60
			13. RCS Ascent Feed; System B - Open <u>Power On</u>	A14K3 (S)	62
			14. RCS Manifold Crossfeed Valves - Open <u>Power Off</u>	A17K2 (R)	253
	16:13:08		15. RCS Ascent Feed; System A - Open <u>Power Off</u>	A13K3 (R)	61
			16. RCS Ascent Feed; System B - Open <u>Power Off</u>	A14K3 (R)	63
	16:13:17		17. RCS Main Shutoff Valves, System A - Close <u>Power On</u>	A13K13 (S)	172
			18. RCS Main Shutoff Valves, System B - Close <u>Power On</u>	A14K13 (S)	174
	16:13:18		19. RCS Main Shutoff Valves, System A - Close <u>Power Off</u>	A13K13 (R)	173
			20. RCS Main Shutoff Valves, System B - Close <u>Power Off</u>	A14K13 (R)	175
	16:14:17		21. RCS Main Shutoff Valves, System A - Open <u>Power On</u>	A13K18 (S)	188
			22. RCS Main Shutoff Valves, System B - Open <u>Power On</u>	A14K18 (S)	190
	16:14:18		23. RCS Main Shutoff Valves, System A - Open <u>Power Off</u>	A13K18 (R)	189
			24. RCS Main Shutoff Valves, System B - Open <u>Power Off</u>	A14K18 (R)	191
	16:14:27		25. RCS Ascent Feed; System A - Close <u>Power On</u>	A13K4 (S)	76
			26. RCS Ascent Feed; System B - Close <u>Power On</u>	A14K4 (S)	78
	16:14:28		27. RCS Manifold Crossfeed Valves - Close <u>Power On</u>	A17K4 (S)	254
			28. RCS Ascent Feed; System A - Close <u>Power Off</u>	A13K4 (R)	77
			29. RCS Ascent Feed; System B - Close <u>Power Off</u>	A14K4 (R)	79
	16:14:29		30. RCS Manifold Crossfeed Valves - Close <u>Power Off</u>	A17K4 (R)	255
	16:14:37		31. Engine Stop Override <u>On</u>	A9K4 (S)	166
	16:14:38		32. Engine Select-Ascent Arm <u>Off</u>	A9K7 (R)	135
			33. Engine Stop Override <u>Off</u>	A9K4 (R)	167
	16:14:44		34. Deadband Select <u>Max</u>	A11K27 (S)	36
	16:14:49		35. Master C&W Alarm Reset <u>On</u>	A9K25 (S)	198



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TABLE 13-2 LM-1 (AS-206A) PRA COMMAND/CODE TIMELINE (Cont'd)

LM  
AS-206  
REV A  
(S)=Set  
(R)=Reset

SEQUENCE NUMBER	DECIMAL TIME WORD	BINARY TIME WORD	OPERATIONAL STATEMENT	RELAY DESIGNATION	RELAY DEC. CODE
VII (Cont'd)	16:14:51		36. Master C&W Alarm Reset <u>Off</u>	A9K25 (R)	199
VIII	15:55:44	111000	1. Control Mode Select <u>Attitude Hold</u>	A11K18 (S)	2
	15:55:47		2. Three Axis Attitude Controller Positive Yaw Lo (5°/sec) <u>On</u>	A7K14 (S)	82
			3. Three Axis Attitude Controller Positive Yaw Lo (5°/sec) <u>Off</u>	A7K14 (R)	83
IX	15:38:40	110111	1. Control Mode Select <u>Attitude Hold</u>	A11K18 (S)	2
	15:38:43		2. Three Axis Attitude Controller Negative Yaw Lo (5°/sec) <u>On</u>	A7K12 (S)	66
			3. Three Axis Attitude Controller Negative Yaw Lo (5°/sec) <u>Off</u>	A7K12 (R)	67
X	15:21:36	110110	1. Control Mode Select <u>Attitude Hold</u>	A11K18 (S)	2
	15:21:39		2. Three Axis Attitude Controller Positive Pitch Lo (5°/sec) <u>On</u>	A6K14 (S)	80
			3. Three Axis Attitude Controller Positive Pitch Lo (5°/sec) <u>Off</u>	A6K14 (R)	81
XI	15:04:32	110101	1. Control Mode Select <u>Attitude Hold</u>	A11K18 (S)	2
	15:04:35		2. Three Axis Attitude Controller Negative Pitch Lo (5°/sec) <u>On</u>	A6K12 (S)	64
			3. Three Axis Attitude Controller Negative Pitch Lo (5°/sec) <u>Off</u>	A6K12 (R)	65
XII	14:47:28	110100	1. Control Mode Select <u>Attitude Hold</u>	A11K18 (S)	2
	14:47:31		2. Three Axis Attitude Controller Positive Roll Lo (5°/sec) <u>On</u>	A8K14 (S)	84
			3. Three Axis Attitude Controller Positive Roll Lo (5°/sec) <u>Off</u>	A8K14 (R)	85
XIII	14:30:24	110011	1. Control Mode Select <u>Attitude Hold</u>	A11K18 (S)	2
	14:30:27		2. Three Axis Attitude Controller Negative Roll Lo (5°/sec) <u>On</u>	A8K12 (S)	68
			3. Three Axis Attitude Controller Negative Roll Lo (5°/sec) <u>Off</u>	A8K12 (R)	69
XIV	14:13:20	110010	1. Master C&W Alarm Reset <u>On</u>	A9K25 (S)	198
	14:13:22		2. Master C&W Alarm Reset <u>Off</u>	A9K25 (R)	199
	14:13:23		3. Control Mode Select <u>Attitude Hold</u>	A11K18 (S)	2
	14:13:33		4. Deadband Select <u>Max</u>	A11K27 (S)	36
	14:13:36		5. Three Axis Attitude Controller Positive Pitch Lo (5°/sec) <u>On</u>	A6K14 (S)	80
	14:13:37		6. Three Axis Attitude Controller Positive Pitch Lo (5°/sec) <u>Off</u>	A6K14 (R)	81
	14:13:38		7. Three Axis Attitude Controller Negative Pitch Hi (15°/sec) <u>On</u>	A6K11 (S)	48
			8. Three Axis Attitude Controller Negative Pitch Hi (15°/sec) <u>Off</u>	A6K11 (R)	49

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TABLE 13-2 LM-1 (AS-206A) PRA COMMAND/CODE TIMELINE (Cont'd)

LM  
AS-206  
REV A  
(S)=Set  
(R)=Reset

SEQUENCE NUMBER	DECIMAL TIME WORD	BINARY * TIME WORD	OPERATIONAL STATEMENT	RELAY DESIGNATION	RELAY DEC. CODE
XIV (Cont'd)	14:13:58		9. Three Axis Attitude Controller Positive Roll Lo (5°/sec) <u>On</u>	A8K14 (S)	84
	14:14:01		10. Three Axis Attitude Controller Positive Roll Lo (5°/sec) <u>Off</u>	A8K14 (R)	85
	14:14:02		11. Three Axis Attitude Controller Negative Roll Hi (15°/sec) <u>On</u>	A8K11 (S)	52
	14:14:03		12. Three Axis Attitude Controller Negative Roll Hi (15°/sec) <u>Off</u>	A8K11 (R)	53
	14:14:23		13. Three Axis Attitude Controller Positive Yaw Lo (5°/sec) <u>On</u>	A7K14 (S)	82
	14:14:26		14. Three Axis Attitude Controller Positive Yaw Lo (5°/sec) <u>Off</u>	A7K14 (R)	83
	14:14:27		15. Three Axis Attitude Controller Negative Yaw Hi (15°/sec) <u>On</u>	A7K11 (S)	50
	14:14:28		16. Three Axis Attitude Controller Negative Yaw Hi (15°/sec) <u>Off</u>	A7K11 (R)	51
	14:14:48		17. Deadband Select <u>Min</u>	A11K27 (R)	37
	14:15:48		18. Deadband Select <u>Max</u>	A11K27 (S)	36
	14:16:48		19. Positive X-Axis Translation <u>On</u>	A6K24 (S)	128
	14:16:51		20. Positive X-Axis Translation <u>Off</u>	A6K24 (R)	129
			21. Negative X-Axis Translation <u>On</u>	A6K16 (S)	112
	14:16:54		22. Negative X-Axis Translation <u>Off</u>	A6K16 (R)	113
	14:16:59		23. Positive Y-Axis Translation <u>On</u>	A7K24 (S)	130
	14:17:02		24. Positive Y-Axis Translation <u>Off</u>	A7K24 (R)	131
			25. Negative Y-Axis Translation <u>On</u>	A7K16 (S)	114
	14:17:05		26. Negative Y-Axis Translation <u>Off</u>	A7K16 (R)	115
	14:17:10		27. Positive Z-Axis Translation <u>On</u>	A8K24 (S)	132
	14:17:13		28. Positive Z-Axis Translation <u>Off</u>	A8K24 (R)	133
			29. Negative Z-Axis Translation <u>On</u>	A8K16 (S)	116
	14:17:16		30. Negative Z-Axis Translation <u>Off</u>	A8K16 (R)	117
	14:17:26		31. Master C&W Alarm Reset <u>On</u>	A9K25 (S)	198
	14:17:28		32. Master C&W Alarm Reset <u>Off</u>	A9K25 (R)	199
XV	13:56:16	110001	1. Master C&W Alarm Reset <u>On</u>	A9K25 (S)	198
	13:56:18		2. Master C&W Alarm Reset <u>Off</u>	A9K25 (R)	199
	13:56:19		3. Control Mode Select <u>Attitude Hold</u>	A11K18 (S)	2
			4. 2 Jet/4 Jet Select <u>4 Jet</u>	A9K27 (R)	71
			5. Engine Select-Ascent Arm <u>On</u>	A9K7 (S)	134
	13:56:23		6. Positive X-Axis Translator <u>On</u>	A6K24 (S)	128
	13:56:25		7. Engine Start Override <u>On</u>	A9K10 (S)	214
	13:56:26		8. Engine Start Override <u>Off</u>	A9K10 (R)	215
	13:56:28		9. Positive X-Axis Translation <u>Off</u>	A6K24 (R)	129
	13:56:30		10. Engine Stop Override <u>On</u>	A9K4 (S)	166
	13:56:31		11. Engine Select-Ascent Arm <u>Off</u>	A9K7 (R)	135
			12. Engine Stop Override <u>Off</u>	A9K4 (R)	167
	13:56:41		13. Master C&W Alarm Reset <u>On</u>	A9K25 (S)	198
	13:56:43		14. Master C&W Alarm Reset <u>Off</u>	A9K25 (R)	199

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TABLE 13-2 IM-1 (AS-206A) PRA COMMAND/CODE TIMELINE Concluded  
LM  
AS-206  
REV A  
(S)=Set  
(R)=Reset

SEQUENCE NUMBER	DECIMAL TIME WORD	BINARY * TIME WORD	OPERATIONAL STATEMENT	RELAY DESIGNATION	RELAY DEC. CODE
XVI	13:39:12	110000	1. 2 Jet/4 Jet Select <u>4 Jet</u>	A9K27 (R)	71
	2. Positive X-Axis Translation <u>On</u>		A6K24 (S)	128	
	3. Control Mode Select <u>Attitude Hold</u>		A11K18 (S)	2	
	13:39:13		4. RCS Main Shutoff Valves, System A - Open <u>Power On</u>	A13K18 (S)	188
	5. RCS Main Shutoff Valves, System B - Open <u>Power On</u>		A14K18 (S)	190	
	13:39:14		6. RCS Ascent Feed; System A - Close <u>Power On</u>	A13K4 (S)	76
	7. RCS Ascent Feed; System B - Close <u>Power On</u>		A14K4 (S)	78	
	13:39:15		8. RCS Main Shutoff Valves, System A - Open <u>Power Off</u>	A13K18 (R)	189
	9. RCS Main Shutoff Valves, System B - Open <u>Power Off</u>		A14K18 (R)	191	
	10. RCS Ascent Feed; System A - Close <u>Power Off</u>		A13K4 (R)	77	
	11. RCS Ascent Feed; System B - Close <u>Power Off</u>		A14K4 (R)	79	
	13:39:16		12. RCS Manifold Crossfeed Valves - Close <u>Power On</u>	A17K4 (S)	254
	13:39:17		13. RCS Manifold Crossfeed Valves - Close <u>Power Off</u>	A17K4 (R)	255
	13:39:22		14. Positive X-Axis Translation <u>Off</u>	A6K24 (R)	129
	13:39:32		15. Master C&W Alarm Reset <u>On</u>	A9K25 (S)	198
	13:39:34		16. Master C&W Alarm Reset <u>Off</u>	A9K25 (R)	199

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TABLE 13-3 LMP REAL-TIME COMMANDS BY FUNCTION

COMMAND TITLE	COMMAND NUMBER
<u>ENGINE &amp; MANEUVER CONTROLS</u>	
MANUAL PITCH ROTATION (-) 5°/SEC ON	00A
MANUAL PITCH ROTATION (-) 5°/SEC OFF	01A
MANUAL PITCH ROTATION (+) 5°/SEC ON	02A
MANUAL PITCH ROTATION (+) 5°/SEC OFF	03A
MANUAL YAW ROTATION (-) 5°/SEC ON	04A
MANUAL YAW ROTATION (-) 5°/SEC OFF	05A
MANUAL YAW ROTATION (+) 5°/SEC ON	06A
MANUAL YAW ROTATION (+) 5°/SEC OFF	07A
MANUAL ROLL ROTATION (-) 5°/SEC ON	10A
MANUAL ROLL ROTATION (-) 5°/SEC OFF	11A
MANUAL ROLL ROTATION (+) 5°/SEC ON	12A
MANUAL ROLL ROTATION (+) 5°/SEC OFF	13A
INHIBIT LMP ROTATIONAL COMMANDS (GSE RESET)	20B
INHIBIT LMP TRANSLATIONAL COMMANDS (GSE RESET)	21B
DESCENT ENGINE ARM ON	00B
DESCENT ENGINE ARM OFF	01B
MANUAL ENGINE START ON	14B
MANUAL ENGINE START RELAYS-POWER OFF	15B
MANUAL ENGINE STOP ON	10B
MANUAL ENGINE STOP RESET	11B
(+) X TRANSLATION OVERRIDE ON	60B
(+) X TRANSLATION OVERRIDE OFF	61B
<u>EXPLOSIVE DEVICES</u>	
ED MASTER ARM ON	64B
ED MASTER ARM OFF	65B
DEPLOY LANDING GEAR FIRE	64A
DEPLOY LANDING GEAR SAFE	65A
RCS PRESSURIZATION FIRE	70B
RCS PRESSURIZATION SAFE	71B
ABORT STAGE ON	70A
ABORT STAGE RESET	71A
INHIBIT ASCENT HELIUM TANK #1 PRESSURIZATION (GSE RESET)	74A
INHIBIT ASCENT HELIUM TANK #2 PRESSURIZATION (GSE RESET)	75A
<u>EPS</u>	
INVERTER #2 ON, INVERTER #1 OFF (GSE RESET))	16A
BATTERY #1 OFF (GSE RESET)	17A
BATTERY #2 OFF (GSE RESET)	22A
BATTERY #3 OFF (GSE RESET)	32A
BATTERY #4 OFF (GSE RESET)	37A
BATTERY #5 NORMAL OFF (GSE RESET)	26A
BATTERY #6 NORMAL OFF (GSE RESET)	23A
BATTERY #5 ALTERNATE ON (GSE RESET)	36A
BATTERY #6 ALTERNATE ON (GSE RESET)	27A



COMMAND TITLE	COMMAND NUMBER
<u>ECS</u>	
PRIMARY WATER VALVE OPEN	24A
PRIMARY WATER VALVE POWER OFF	25A
GLYCOL PUMP #2 ON, INHIBIT #1	50B
DISABLE GLYCOL PUMP #2, ENABLE #1	51B
ASCENT WATER VALVE OPEN	44B
ASCENT WATER VALVE POWER OFF	45B
<u>RCS</u>	
SYSTEM "A" MAIN SHUTOFF VALVES CLOSE & INHIBIT PRIME OPEN COMMANDS	44A
SYSTEM "A" MAIN SHUTOFF VALVES CLOSE COIL-POWER OFF	45A
SYSTEM "A" MAIN SHUTOFF VALVES OPEN & INHIBIT PRIME CLOSE COMMANDS	50A
SYSTEM "A" MAIN SHUTOFF VALVES OPEN COIL-POWER OFF	51A
SYSTEM "B" MAIN SHUTOFF VALVES CLOSE & INHIBIT PRIME OPEN COMMANDS	54A
SYSTEM "B" MAIN SHUTOFF VALVES CLOSE COIL-POWER OFF	55A
SYSTEM "B" MAIN SHUTOFF VALVES OPEN & INHIBIT PRIME CLOSE COMMANDS	60A
SYSTEM "B" MAIN SHUTOFF VALVES OPEN COIL-POWER OFF	61A
<u>PROPULSION</u>	
DESCENT ENGINE HELIUM REGULATOR VALVE #1 CLOSE, INHIBIT #1 OPEN	14A
DESCENT ENGINE HELIUM REGULATOR VALVE #1 CLOSE COIL-POWER OFF	15A
DESCENT ENGINE HELIUM REGULATOR VALVE #2 OPEN	42A
DESCENT ENGINE HELIUM REGULATOR VALVE #2 OPEN COIL-POWER OFF	43A
<u>FLIGHT CONTROLS</u>	
ATTITUDE CONTROL MODE - SELECT ATTITUDE HOLD	31B/24B
ATTITUDE CONTROL MODE - SELECT AUTO	25B/30B
ATTITUDE CONTROL MODE - ENABLE PRIME CONTROL	25B/31B
AGS STANDBY	66A/73A
AGS OPERATE	66A/72A
AGS WARMUP	67A
DEAD BAND-MIN	74B
DEAD BAND - ENABLE PRIME CONTROL	75B
<u>COMMUNICATION</u>	
S-BAND PRIMARY TRANSCEIVER & POWER AMP OFF & INHIBIT PRIME COMMANDS	30A
ENABLE PRIME CONTROL OF S-BAND PRIMARY TRANSCEIVER & POWER AMP	31A
S-BAND SECONDARY TRANSCEIVER & POWER AMP ON	20A
S-BAND SECONDARY TRANSCEIVER & POWER AMP OFF	21A
<u>RADAR</u>	
LANDING RADAR POWER ON (GSE RESET)	04B
LANDING RADAR POWER OFF (GSE RESET)	05B

COMMAND TITLE	COMMAND NUMBER
<u>R &amp; D EQUIPMENT CONTROL</u>	
LM/SLA SEPARATION ARM ON	46A
LM/SLA SEPARATION ARM RESET	47A
LM/SLA SEPARATION FIRE	62A
LM/SLA SEPARATION SAFE	63A
C-BAND XPONDER OFF	52A
C-BAND XPONDER ON & DISABLE PRIME CONTROL (GSE RESET OF DISABLE)	53A
R&D TELEMETRY CALIBRATION ON	54B
R&D TELEMETRY CLAIBRATION OFF & DISABLE PRIME CONTROL	55B
(GSE RESET OF DISABLE)	
PRA/AGS SELECT AND PRA STOP, SELECT MANUAL ENGINE THRUST,	40B
INHIBIT AUTO ENGINE ON	
LGC/PNGS SELECT, ENABLE AUTO ENGINE THRUST, REMOVE AUTO	41B
ENGINE ON INHIBIT	
PRIME RELAY MATRIX MASTER RESET ON	34B
PRIME RELAY MATRIX MASTER RESET OFF	35B

\* TABLE 13-4 LMP PRIME COMMANDS BY FUNCTION

LM  
AS-206  
REV A

COMMAND TITLE	COMMAND NUMBER
<u>ENGINE &amp; MANEUVER CONTROLS</u>	
↑ RTC MANUAL PITCH ROTATION (-) 5°/SEC ON	64
RTC MANUAL PITCH ROTATION (-) 5°/SEC OFF	65
RTC MANUAL YAW ROTATION (-) 5°/SEC ON	66
RTC MANUAL YAW ROTATION (-) 5°/SEC OFF	67
RTC MANUAL ROLL ROTATION (-) 5°/SEC ON	68
RTC MANUAL ROLL ROTATION (-) 5°/SEC OFF	69
RTC MANUAL PITCH ROTATION (+) 5°/SEC ON	80
RTC MANUAL PITCH ROTATION (+) 5°/SEC OFF	81
RTC MANUAL YAW ROTATION (+) 5°/SEC ON	82
RTC MANUAL YAW ROTATION (+) 5°/SEC OFF	83
RTC MANUAL ROLL ROTATION (+) 5°/SEC ON	84
RTC MANUAL ROLL ROTATION (+) 5°/SEC OFF	85
MANUAL PITCH ROTATION (-) 15°/SEC ON	48
MANUAL PITCH ROTATION (-) 15°/SEC OFF	49
MANUAL YAW ROTATION (-) 15°/SEC ON	50
MANUAL YAW ROTATION (-) 15°/SEC OFF	51
MANUAL ROLL ROTATION (-) 15°/SEC ON	52
MANUAL ROLL ROTATION (-) 15°/SEC OFF	53
MANUAL PITCH ROTATION (+) 15°/SEC ON	96
MANUAL PITCH ROTATION (+) 15°/SEC OFF	97
MANUAL YAW ROTATION (+) 15°/SEC ON	98
MANUAL YAW ROTATION (+) 15°/SEC OFF	99
MANUAL ROLL ROTATION (+) 15°/SEC ON	100
MANUAL ROLL ROTATION (+) 15°/SEC OFF	101
2 JET SELECT	70
4 JET SELECT	71
MANUAL THRUST 10% ON, 30% OFF	86
MANUAL THRUST 10% OFF, 30% ON	87
MANUAL THRUST 50% ON	102
MANUAL THRUST 50% OFF	103
MANUAL THRUST 100% ON	230
MANUAL THRUST 100% OFF	231
MANUAL TRANSLATION (-) X ON	112
MANUAL TRANSLATION (-) X OFF	113
MANUAL TRANSLATION (-) Y ON	114
MANUAL TRANSLATION (-) Y OFF	115
MANUAL TRANSLATION (-) Z ON	116
MANUAL TRANSLATION (-) Z OFF	117
↑ RTC MANUAL TRANSLATION (+) X ON	128
RTC MANUAL TRANSLATION (+) X OFF	129
MANUAL TRANSLATION (+) Y ON	130
MANUAL TRANSLATION (+) Y OFF	131
MANUAL TRANSLATION (+) Z ON	132
MANUAL TRANSLATION (+) Z OFF	133

\* TABLE 13-4 LMP PRIME COMMANDS BY FUNCTION (CONT'D)

LM  
AS-206  
REV A

COMMAND TITLE	COMMAND NUMBER
<u>ENGINE &amp; MANEUVER CONTROLS (CONT'D)</u>	
ASCENT ENGINE ARM ON	134
ASCENT ENGINE ARM OFF	135
RTC DESCENT ENGINE ARM ON	150
RTC DESCENT ENGINE ARM OFF	151
RTC MANUAL ENGINE STOP ON	166
RTC MANUAL ENGINE STOP RESET	167
RTC MANUAL ENGINE START ON	214
RTC MANUAL ENGINE START RELAYS-POWER OFF	215
<u>EXPLOSIVE DEVICES</u>	
RTC ED MASTER ARM ON	4
RTC ED MASTER ARM OFF	5
RTC RCS PRESSURIZATION FIRE	6
RTC RCS PRESSURIZATION SAFE	7
RTC LANDING GEAR DEPLOY FIRE	8
RTC LANDING GEAR DEPLOY SAFE	9
RTC ABORT STAGE ON	38
RTC ABORT STAGE RESET + 2 ON RTC	39
<u>INSTRUMENTATION</u>	
MASTER C&W ALARM RESET	198
MASTER C&W ALARM RESET OFF	199
<u>ECS</u>	
RTC ECS PRIMARY WATER VALVE OPEN	186
RTC ECS PRIMARY WATER VALVE OPEN COIL-POWER OFF	187
RTC ECS ASCENT WATER VALVE OPEN	222
RTC ECS ASCENT WATER VALVE POWER OFF	223
CABIN FAN #1 ON	246
CABIN FAN #1 OFF	247
<u>RCS</u>	
RCS MANIFOLD CONTROL VALVE SYSTEM "A" OPEN	60
RCS MANIFOLD CONTROL VALVE SYSTEM "A" OPEN COIL-POWER OFF	61
RCS MANIFOLD CONTROL VALVE SYSTEM "B" OPEN	62
RCS MANIFOLD CONTROL VALVE SYSTEM "B" OPEN COIL-POWER OFF	63
RCS MANIFOLD CONTROL VALVE SYSTEM "A" CLOSE	76
RCS MANIFOLD CONTROL VALVE SYSTEM "A" CLOSE COIL-POWER OFF	77
RCS MANIFOLD CONTROL VALVE SYSTEM "B" CLOSE	78
RCS MANIFOLD CONTROL VALVE SYSTEM "B" CLOSE COIL-POWER OFF	79
RCS-ASCENT INTERCONNECT VALVE OPEN	252
RCS-ASCENT INTERCONNECT VALVE OPEN COIL-POWER OFF	253
RCS-ASCENT INTERCONNECT VALVE CLOSE	254
RCS-ASCENT INTERCONNECT VALVE CLOSE COIL-POWER OFF	255

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TABLE 13- 4

LM  
AS-206  
REV A

LMP PRIME COMMANDS BY FUNCTION (CONT'D)

COMMAND	TITLE	COMMAND NUMBER
	RCS (Cont'd)	
RTC RCS SYSTEM "A"	MAIN SHUTOFF VALVES OPEN & INH PRIM CLOSED CMD	188
RTC RCS SYSTEM "A"	MAIN SHUTOFF VALVES OPEN COIL-POWER OFF	189
RTC RCS SYSTEM "B"	MAIN SHUTOFF VALVES OPEN INH PRIM CLOSED CMD	190
RTC RCS SYSTEM "B"	MAIN SHUTOFF VALVES OPEN COIL-POWER OFF	191
RTC RCS SYSTEM "A"	MAIN SHUTOFF VALVES CLOSE INH PRIM OPEN CMD	172
RTC RCS SYSTEM "A"	MAIN SHUTOFF VALVES CLOSE COIL-POWER OFF	173
RTC RCS SYSTEM "B"	MAIN SHUTOFF VALVES CLOSE INH PRIM OPEN CMD	174
RTC RCS SYSTEM "B"	MAIN SHUTOFF VALVES CLOSE COIL-POWER OFF	175
RCS QUAD I SYSTEM "A"	OPEN	12
RCS QUAD I SYSTEM "A"	OPEN COIL-POWER OFF	13
RCS QUAD I SYSTEM "B"	OPEN	28
RCS QUAD I SYSTEM "B"	OPEN COIL-POWER OFF	29
RCS QUAD I SYSTEM "A"	CLOSE	92
RCS QUAD I SYSTEM "A"	CLOSE COIL-POWER OFF	93
RCS QUAD I SYSTEM "B"	CLOSE	108
RCS QUAD I SYSTEM "B"	CLOSE COIL-POWER OFF	109
RCS QUAD II SYSTEM "A"	OPEN	152
RCS QUAD II SYSTEM "A"	OPEN COIL-POWER OFF	153
RCS QUAD II SYSTEM "B"	OPEN	136
RCS QUAD II SYSTEM "B"	OPEN COIL-POWER OFF	137
RCS QUAD II SYSTEM "A"	CLOSE	168
RCS QUAD II SYSTEM "A"	CLOSE COIL-POWER OFF	169
RCS QUAD II SYSTEM "B"	CLOSE	120
RCS QUAD II SYSTEM "B"	CLOSE COIL-POWER OFF	121
RCS QUAD III SYSTEM "A"	OPEN	14
RCS QUAD III SYSTEM "A"	OPEN COIL-POWER OFF	15
RCS QUAD III SYSTEM "B"	OPEN	30
RCS QUAD III SYSTEM "B"	OPEN COIL-POWER OFF	31
RCS QUAD III SYSTEM "A"	CLOSE	94
RCS QUAD III SYSTEM "A"	CLOSE COIL-POWER OFF	95
RCS QUAD III SYSTEM "B"	CLOSE	110
RCS QUAD III SYSTEM "B"	CLOSE COIL-POWER OFF	111
RCS QUAD IV SYSTEM "A"	OPEN	216
RCS QUAD IV SYSTEM "A"	OPEN COIL-POWER OFF	217
RCS QUAD IV SYSTEM "B"	OPEN	184
RCS QUAD IV SYSTEM "B"	OPEN COIL-POWER OFF	185
RCS QUAD IV SYSTEM "A"	CLOSE	232
RCS QUAD IV SYSTEM "A"	CLOSE COIL-POWER OFF	233
RCS QUAD IV SYSTEM "B"	CLOSE	200
RCS QUAD IV SYSTEM "B"	CLOSE COIL-POWER OFF	201

PROPULSION

	D.E. HELIUM REGULATOR VALVE #1-OPEN	202
	D.E. HELIUM REGULATOR VALVE #1-OPEN COIL-POWER OFF	203
RTC	D.E. HELIUM REGULATOR VALVE #1-CLOSE INH #1 OPEN	218
RTC	D.E. HELIUM REGULATOR VALVE #1-CLOSE COIL-POWER OFF	219



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TABLE 13- 4 LMP PRIME COMMANDS BY FUNCTION (CONCL'D)

COMMAND TITLE	COMMAND NUMBER
<u>FLIGHT CONTROLS</u>	
RTC ATTITUDE CONTROL MODE-ATTITUDE HOLD	2
RTC ATTITUDE CONTROL MODE-AUTOMATIC MODE	3
ASA STANDBY 1 OPERATE	32
ASA WARMUP	33
DEADBAND SELECT MAX	36
RTC DEADBAND SELECT MIN	37
AEA OPERATE	44
AEA WARMUP/STANDBY	45
<u>COMMUNICATIONS</u>	
S-BAND TRANSCEIVER RANGING ON	34
S-BAND TRANSCEIVER RANGING OFF	35
S-BAND PRIMARY TRANSCEIVER & POWER AMPLIFIER ON	138
RTC S-BAND PRIMARY TRANSCEIVER & POWER AMPLIFIER OFF	139
<u>RADAR</u>	
RTC LANDING RADAR POWER-ON	182
RTC LANDING RADAR POWER-OFF	183
LANDING RADAR SELF TEST ON	26
LANDING RADAR SELF TEST OFF	27
<u>R&amp;D EQUIPMENT CONTROL</u>	
RTC LM/SLA SEPARATION ARM ON	58
RTC LM/SLA SEPARATION ARM OFF	59
RTC LM/SLA SEPARATION FIRE	90
RTC LM/SLA SEPARATION SAFE	91
RTC C-BAND TRANSPONDERS ON & DISABLE PRIME CONTROL	106
RTC C-BAND TRANSPONDERS OFF	107
DFI T/M CALIBRATE ON	236
DFI T/M CALIBRATE OFF	237

LM 1 COMMANDS

COMMAND TITLE	PRIME		MATRIX LOC	RTC		DISCRETE TM VERIFICATION	ASSOCIATED ONBOARD VALVE/SWITCH/CB	FUNCTION
	CMD NO. DEC	OCT		CMD NO. OCT	MATRIX LOC			
PYROTECHNIC MASTER ARM ON	4	4	MO-L4	64B	13-3S	GY0111X GY0112X	2-S-7 MASTER ARM "ON"	CONNECTS THE PYRO BATTERIES TO THE PYRO BUSES. ZONE
MASTER ARM OFF	5	5	MO-L5	65B	13-3R	GY0111X GY0112X	2-S-7 MASTER ARM "OFF"	DISCONNECTS THE PYRO BATTERIES FROM THE PYRO BUSES. ZONE
LANDING GEAR DEPLOY	8	10	MO-L8	64A	13-1S	GW5154X GW5000U	2-S-10 LANDING GEAR DEPLOY "FIRE"	APPLIES POWER TO THE LAND- ING GEAR SQUIBS PROVIDING THE PYRO BUSES ARE ARMED. ZONE
LANDING GEAR DEPLOY RESET	9	10	MO-L9	65A	13-1R	GW5154X	2-S-10 LANDING GEAR DEPLOY "SAFE" (SW IS MOMEN- TARY)	REMOVES POWER FROM LANDING GEAR SQUIBS. ZONE
RCS PRESSURIZE	6	6	MO-L6	70B	14-3S	-	2-S-2 -- RCS PRESSURIZE "FIRE"	APPLIES POWER TO SQUIBS FOR RCS SYSTEMS A AND B PROVID- ING THE PYRO BUSES ARE ARMED ZONE
RCS PRESSURIZE POWER OFF	7	7	MO-L7	71B	14-3R	-	2-S-2 RCS PRESSURIZE "SAFE" (SW IS MOMENTARY)	REMOVES POWER FROM THE RCS QUIBS. ZONE
APS HE 1 INHIBIT	-	-	-	74A	15-1S	-	2-S-3 TANK SELECT SW "TANK 2"	OPENS THE POWER FEED TO THE SQUIB TO PRESSURIZE ASCENT ENGINE HE TANK 1. ZONE
APS HE 2 INHIBIT	-	-	-	75A	15-1R	-	2-S-3 TANK SELECT SW "TANK 1"	OPENS THE POWER FEED TO THE SQUIB TO PRESSURIZE ASCENT ENGINE HE TANK 2 ZONE

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\*GUIDANCE AND CONTROL PORTION OF THIS TABLE TO BE ADDED AT A LATER DATE.

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TABLE 13-5 LMP CMD INFORMATION\* (CONT'D)

LM 1 COMMANDS

COMMAND TITLE	PRIME			RTC		DISCRETE TM VERIFICATION	ASSOCIATED ONBOARD VALVE/SWITCH/CB	FUNCTION
	CMD NO. DEC	OCT	MATRIX LOC	CMD NO. OCT	MATRIX LOC			
<u>ELECTRICAL</u> BAT 1 OFF	-	-	-	17A	3-2R	GC4361 (0) GC4362 (0)	4-S-1 BAT #1 HI "OFF/ RESET" 4-S-5 BAT #1 LO "OFF/ RESET"	DISCONNECTS BAT #1 FROM SE BUS 3.2.1 ZONE E-7
BAT 2 OFF	-	-	-	22A	4-2S	GC4363 (0) GC4364 (0)	4-S-2 BAT #2 HI "OFF/ RESET" 4-S-6 BAT #2 LO "OFF/ RESET"	DISCONNECTS BAT #2 FROM SE BUS 3.2.1 ZONE E-7
BAT 3 OFF	-	-	-	32A	6-2S	GC4365 (0) GC4366 (0)	4-S-3 BAT #3 HI "OFF/ RESET" 4-S-7 BAT #3 LO "OFF/ RESET"	DISCONNECTS BAT #3 FROM CDR BUS 3.2.1 ZONE E-7
BAT 4 OFF	-	-	-	37A	7-2R	GC4367 (0) GC4368 (0)	4-S-4 BAT #4 HI "OFF/ RESET" 4-S-8 BAT #4 LO "OFF/ RESET"	DISCONNECTS BAT #4 FROM CDR BUS 3.2.1 ZONE E-8
BAT 5 NORM OFF	-	-	-	26A	5-2S	GC4371 (0)	4-S-10 BAT #5 NORM "OFF/RESET"	DISCONNECTS BAT #5 FROM SE BUS 3.2.1 ZONE E-7
BAT 6 NORM OFF	-	-	-	23A	4-2R	GC4370 (0)	4-S-11 BAT #6 NORM "OFF/RESET"	DISCONNECTS BAT #6 FROM CDR BUS 3.2.1 ZONE E-6
BAT 5 B/U CDR	-	-	-	36A	7-2S	GC4369 (1)	4-S-12 BAT #5 B/U "ON"	CONNECTS BAT #5 TO CDR BUS 3.2.1 ZONE E-7
BAT 6 B/U SE	-	-	-	27A	5-2R	GC4372 (1)	4-S-13 BAT #6 B/U "ON"	CONNECTS BAT #6 TO SE BUS 3.2.1 ZONE E-6
INVERT 2 SEL	-	-	-	16A	3-2S	-	4-S-14 AC PWR "INV 2"	CONNECTS INVERTER NO. 2 TO THE AC BUS. DISCONNECTS INVERTER NO. 1 3.3.1 ZONE

\*GUIDANCE AND CONTROL PORTION OF THIS TABLE TO BE ADDED AT A LATER DATE.

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TABLE 13-5 LMP CMD INFORMATION\* (CONT'D)

LM  
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REV A

LM 1 COMMANDS								
COMMAND TITLE	PRIME			RTC		DISCRETE TM VERIFICATION	ASSOCIATED ONBOARD VALVE/SWITCH/CB	FUNCTION
	CMD NO. DEC	OCT	MATRIX LOC	CMD NO. OCT	MATRIX LOC			
ENVIRONAMENTAL DES H <sub>2</sub> O FEED	186	272	M11-L10	24A	5-1S	GF4101P GF9998U	PRIMARY EVAPORATOR FLOW VALVE "OPEN"	ENERGIZES AND OPENS DESC WATER VALVE AND PERMITS WATER TO FLOW FROM THE DESCENT WATER TANK TO THE PRIMARY COOLANT LOOP WATER EVAPORATORS. 4.3.1 ZONE G-7
DES H <sub>2</sub> O RESET	187	273	M11-L11	25A	5-1R			DE-ENERGIZES DESC WATER VALVE WHICH REMAINS LATCHED OPEN 4.3.1 ZONE G-7
ASC H <sub>2</sub> O FEED	222	337	M13-L14	44B	9-3S	GF9998U	WATER TANK SELECT VALVE "ASC"	ENERGIZES AND OPENS ASC WATER VALVE AND PERMITS WATER TO FLOW FROM THE ASCENT WATER TANKS TO THE PRIMARY WATER EVAPORATORS. 4.3.1 ZONE E-7
ASC H <sub>2</sub> O RESET	223	340	M13-L15	45B	9-3R			DE-ENERGIZES ASC WATER VALVE WHICH REMAINS LATCHED OPEN. 4.3.1 ZONE F-7
PUMP 1 SEL	-	-	-	51B	10-3R	GF2021P GF9997U	7-S-3 GLYCOL PUMP SELECT SWITCH "1"	ENERGIZES GLYCOL PUMP NO. 1 AND DE-ENERGIZE PUMP NO. 2 THIS RTC IS INEFFECTIVE IF AN AUTOMATIC SWITCHOVER HAS OCCURRED. 4.3.1 ZONE D-5
PUMP 2 SEL	-	-	-	50B	10-3S	GF2021P GF9997U	7-S-3 GLYCOL PUMP SELECT SWITCH "2"	ENERGIZES GLYCOL PUMP NO. 2 AND DE-ENERGIZES PUMP NO. 1 PUMP NO. 2 IS SELECTED AUTO- MATICALLY IF PUMP ΔP FALLS BELOW 4 PSID. 4.3.1 ZONE D-5

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\*GUIDANCE AND CONTROL PORTION OF THIS TABLE TO BE ADDED AT A LATER DATE.

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TABLE 13-5 LMP CMD INFORMATION\* (CONT'D)

LM  
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REV A

LM 1 COMMANDS								
COMMAND TITLE	PRIME			RTC		DISCRETE TM VERIFICATION	ASSOCIATED ONBOARD VALVE/SWITCH/CB	FUNCTION
	CMD NO. DEC	OCT	MATRIX LOC	CMD NO. OCT	MATRIX LOC			
ENVIRONAMENTAL (CONCLUDED) CABIN FAN NO. 1 "ON"	246	346	M15-L6	-	-	-	4CB107 CIRCUIT BREAKER "CLOSE"	ENABLES CABIN FAN NO. 1 ZONE
CABIN FAN NO. 1 "OFF"	247	347	M15-L7	-	-	-	4CB107 CIRCUIT BREAKER "OPEN"	DISABLES CABIN FAN NO. 1 4.2.1 ZONE B-8

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\*GUIDANCE AND CONTROL PORTION OF THIS TABLE TO BE ADDED AT A LATER DATE.



LM 1 COMMANDS

COMMAND TITLE	PRIME		MATRIX LOC	RTC		DISCRETE TM VERIFICATION	ASSOCIATED ONBOARD VALVE/SWITCH/CB	FUNCTION
	CMD NO. DEC	OCT		CMD NO. OCT	MATRIX LOC			
COMMUNICATIONS S-BND RANG ON	34	42	M2-L2	-	-	-	13-S-1 RANGE/TV "RANGE"	ENABLES S-BAND RANGING FUNCTION - 5.1.1 ZONE B-3
S-BND RANGE OFF	35	43	M2-L3	-	-	-	13-S-1 RANGE/TV "TV"	DISABLES S-BAND RANGING FUNCTION 5.1.1 ZONE B-3
PRI S-BND ENABLE	138	212	M8-L10	31A	6-1R	-	13-S-8 XMTR/RCVR 'PRI' 13-S-2 PWR AMP "PRI"	TURNES ON THE PRI S-BAND XMTR, RCVR, AND PWR AMP DEPENDING UPON THE RELATION- SHIP BETWEEN THE PRIME RELAYS AND THE RTC RELAYS. 5.1.1 ZONE D-2
PRI S-BND OFF	139	213	M8-L11	30A	6-1S	-	13-S-8 XMTR/RCVR "OFF" 13-S-2 PWR AMP "OFF"	TURNES OFF THE PRI S-BAND EQUIPMENT. 5.1.1 ZONE D-2
SEC S-BND ON	-	-	-	20A	4-1S	-	13-S-8 XMTR/RCVR "SEC" 13-S-2 PWR AMP "SEC"	TURNES ON THE SEC S-BAND XMTR, RCVR, AND PWR AMP. SEC S-BAND ON SHOULD ALWAYS BE PROCEEDED BY PRI S-BND OFF. 5.1.1 ZONE D-1
SEC S-BND OFF	-	-	-	21A	4-1S	-	13-S-8 XMTR/RCVR "OFF" 13-S-2 PWR AMP "OFF"	TURNES OFF THE SEC S-BAND EQUIPMENT. 5.1.1 ZONE D-1
C-BND ON	106	152	M6-L10	53A	10-2R	-	C-BAND PWR "ON"	TURNES ON BOTH C-BAND BEACONS. IF THE RTC IS USED, THE ON/OFF FUNCTION BY PRIME RELAY IS PERMANENTLY INHIBITED. 5.2.1 ZONE D-4

\*GUIDANCE AND CONTROL PORTION OF THIS TABLE TO BE ADDED AT A LATER DATE.

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TABLE 13-5 LMP CMD INFORMATION\* (CONT'D)

LM 1 COMMANDS

COMMAND TITLE	PRIME		RTC		DISCRETE TM VERIFICATION	ASSOCIATED ONBOARD VALVE/SWITCH/CB	FUNCTION	
	CMD NO. DEC	OCT	MATRIX LOC	CMD NO. OCT				MATRIX LOC
COMMUNICATIONS (CONCLUDED) C-BND OFF	107	153	M6-L11	52A	10-25	-	C-BAND PWR "OFF"	Turns off the C-band beacons. 5.2.1 Zone D-4

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TABLE 13-5 LMP CMD INFORMATION\* (CONT'D)

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LM 1 COMMANDS

COMMAND TITLE	PRIME			RTC		DISCRETE TM VERIFICATION	ASSOCIATED ONBOARD VALVE/SWITCH/CB	FUNCTION
	CMD NO. DEC	OCT	MATRIX LOC	CMD NO. OCT	MATRIX LOC			
<u>INSTRUMENTATION</u> C&W RESET	198	306	M12-L6	-	-	GL4069	6-S-3 MASTER ALARM (DEPRESSED)	RESETS THE MASTER ALARM INDICATIONS. ZONE
C&W RESET OFF	199	307	M12-L7	-	-	GL4069	6-S-3 MASTER ALARM (RELEASED)	ENABLES THE MASTER ALARM INDICATIONS ZONE
DFI CAL ON	236	366	M14-L12	54B	11-3S	GL4221	R&D TM CAL "ON"	INTERRUPTS NORMAL SENSOR DATA FROM THE DFI TM SYSTEM AND REPLACES THE DATA WITH PRECISION VOLTAGES FOR SUBSEQUENT CALIBRATION OF DFI DATA. ZONE
DFI CAL OFF	237	367	M14-L13	55B	11-3R	GL4221	R&D TM CAL "OFF"	TURNS OFF CALIBRATION MODE AND RETURNS NORMAL DATA FLOW. THE RTC PERMANENTLY INHIBITS CONTROL OF THE DFI CAL FUNCTION BY PRIME RELAY. ZONE

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\*GUIDANCE AND CONTROL PORTION OF THIS TABLE TO BE ADDED AT A LATER DATE.

TABLE 13-5 LMP CMD INFORMATION\*(CONCLUDED)

LM  
AS-206  
REV A

## LM 1 COMMANDS

COMMAND TITLE	PRIME		MATRIX LOC	RTC		DISCRETE TM VERIFICATION	ASSOCIATED ONBOARD VALVE/SWITCH/CB	FUNCTION
	CMD NO. DEC	OCT		CMD NO. OCT	MATRIX LOC			
LM/SLA SEP CONTROL LM/SLA SEP ARM	58	72	M3-L10	46A	9-2S	GL4222	-	ENABLES LM/SLA SEP CMD. 12.1.1 ZONE B-5
SEP ARM RESET	59	73	M3-L11	47A	9-2R	-	-	RELEASES SEP ARM FUNCTION 12.1.1 ZONE B-5
LM/SLA SEP	90	132	M5-10	62A	12-2S	GL4222**	-	WHEN ENABLED BY THE LM/SLA SEP ARM, SIGNALS THE SLA SEQUENCER WHICH IN TURN FIRES THE RESTRAINING STAPS ALLOWING THE LM TO SEPARATE. EITHER SEP ARM AND SEP PRIME RELAYS OR SEP ARM AND SEP RTC RELAYS MUST BE USED BEFORE SEPARATION CAN OCCUR. 12.1.1 ZONE B-5
SEP RESET	91	133	M5-L11	63A	12-2R		-	RELEASES SEP FUNCTION. 12.1.1 ZONE B-5

\*\*\*GL4222 IS ACTIVATED BY PHYSICAL SEPARATION OF THE LM AND THE SLA.

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\*\*GUIDANCE AND CONTROL PORTION OF THIS TABLE TO BE ADDED AT A LATER DATE.

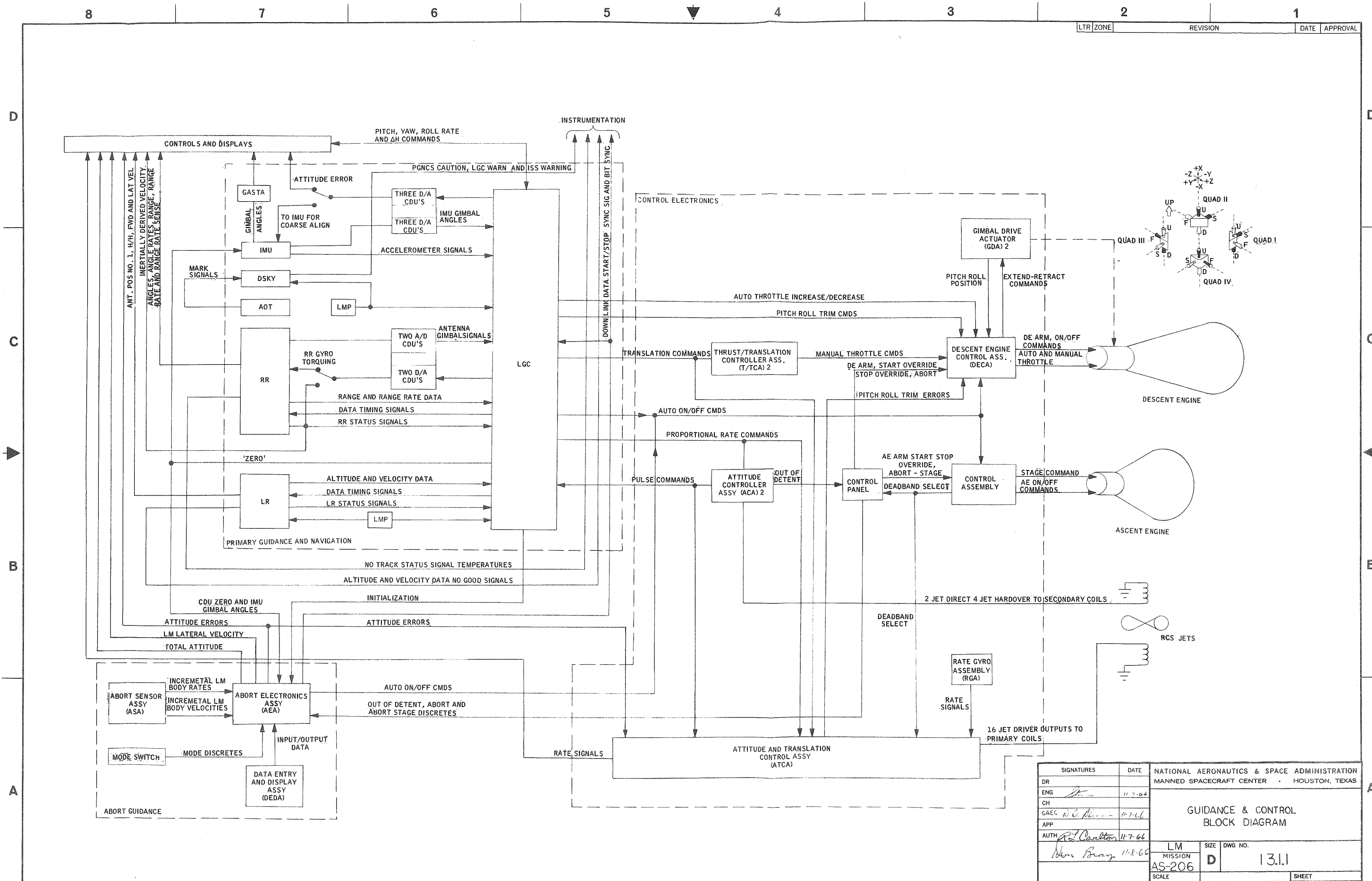


TABLE 13-6 GROUND RELAYS

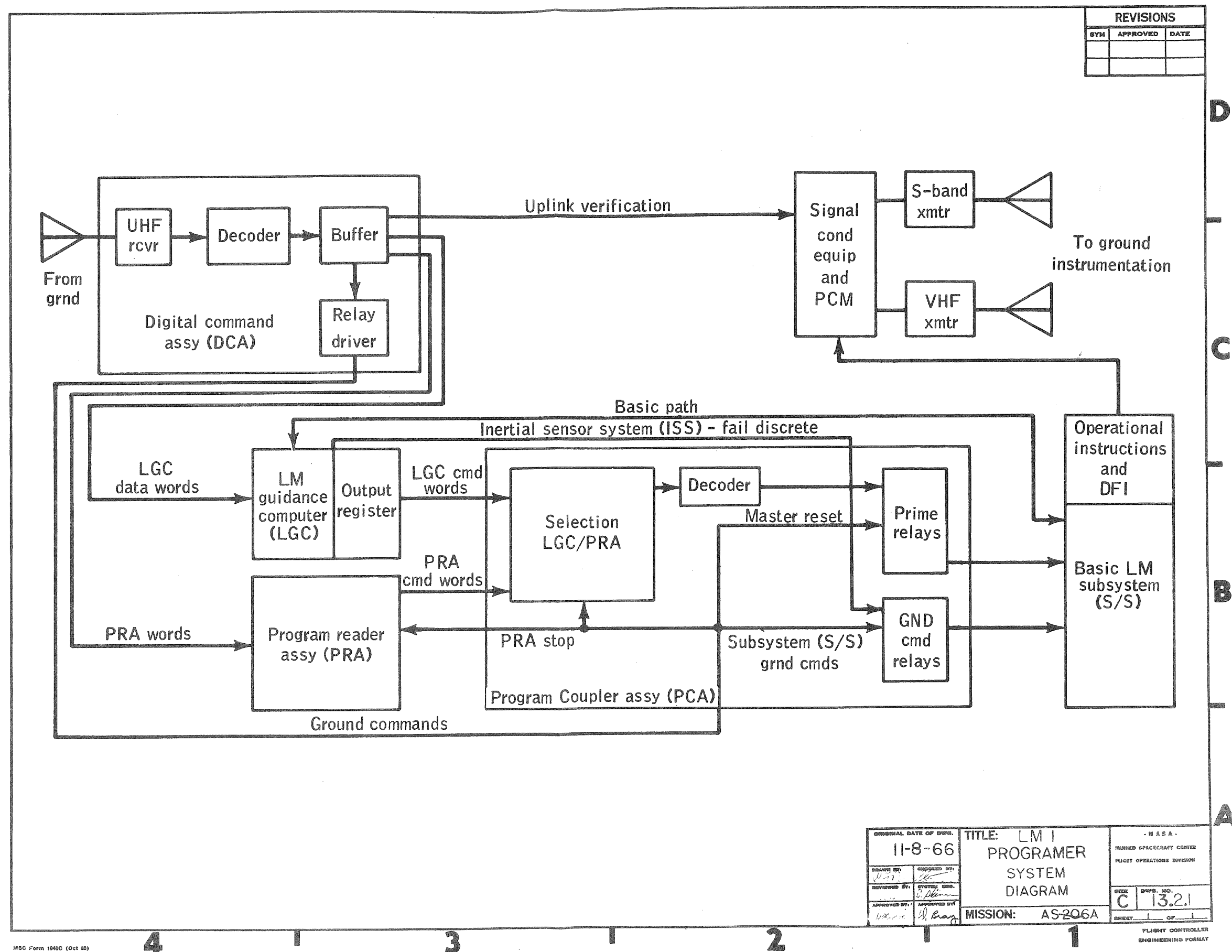
	00A	01A	02A	03A	01B	02B
0	(-) PITCH 5°/S ON	(-) PITCH 5°/S OFF	(+) PITCH 5°/S ON	(+) PITCH 5°/S OFF	DESC ARM	DES ARM OFF
1	(-) YAW 5°/S ON	(-) YAW 5°/S OFF	(+) YAW 5°/S ON	(+) YAW 5°/S OFF	LANDING RADAR ON	LANDING RADAR OFF
2	(-) ROLL 5°/S ON	(-) ROLL 5°/S OFF	(+) ROLL 5°/S ON	(+) ROLL 5°/S OFF	ENGINE STOP	ENGINE STOP OFF
3	DESC HE REG #1 SOV CLOSED	DESC HE REG #1 SOV CLOS OFF	INV #2 ON INV #1 OFF	EPS BATT #1 OFF	ENGINE START ON	ENGINE START OFF
4	S-BAND SEC ON	S-BAND SEC OFF	EPS BATT #2 OFF	EPS BATT #6 OFF	ATT INHIBIT	TRANS INHIBIT
5	PRIM H2O OPEN ON	PRIM H2O OPN OFF	EPS BATT #5 OFF	EPS BATT #6 ON	ATT HOLD	AUTO MODE ENABLE
6	S-BAND PRIM OFF	S-BAND PRIM ENABLE	EPS BATT #3 OFF	SPARE	AUTO MODE	ATT H ENABLE
7	SPARE	SPARE	EPS BATT #5 ON	EPS BATT #4 OFF	MASTER RESET ON	MASTER RESET OFF
8	SPARE	SPARE	DESC HE REG #2 SOV OPEN	DESC HE REG #2 SOV OPEN OFF	AGS	PNGS
9	RCS MAIN A CLOSED	RCS MAIN A CLOS OFF	LM/S-IVB SEP ARM	LM/S-IVB SEP ARM OFF	ASC H2O OPEN	ASC H2O OPN OFF
10	RCS MAIN A OPEN	RCS MAIN A OPN OFF	C-BAND OFF	C-BAND ON	#1 OFF GLYCOL #2 ON	#2 OFF GLYCOL #1 ON
11	RCS MAIN B CLOSED	RCS MAIN B CLOS OFF	SPARE	SPARE	DFI CAL ON	DFI CAL OFF
12	RCS MAIN B OPEN	RCS MAIN B OPN OFF	LM/S-IVB SEP FIRE	LM/S-IVB SEP FIRE OFF	X-TRANS ON	X-TRANS OFF
13	LANDING GEAR DOWN	LANDING GEAR DWN OFF	ASA OPERATE	ASA WARMUP	ED ARM ON	ED ARM OFF
14	ABORT STAGE	ABORT STAGE OFF	AEA OPERATE	AEA STANDBY	RCS PRESS ON	RCS PRESS OFF
15	ASC HE #1 INHIBIT	ASC HE #2 INHIBIT	SPARE	SPARE	DEADBND MIN	DEADBND MAX

TABLE 13-7 PRIME RELAYS

	LO	0	L1	1	L2	2	L3	3	L4	4	L5	5	L6	6	L7	7	L8	8	L9	9	L10	10	L11	11	L12	12	L13	13	L14	14	L15	15
M0					ATTITUDE HOLD			AUTO MODE		ED ARM		ED SAFE		RCS HE FIRE		RCS HE OFF		LANDING GEAR DOWN		LANDING GEAR OFF		SPARE		SPARE		RCS ISO 1A OPEN		RCS ISO 1A OPEN OFF		RCS ISO 111A OPEN		RCS ISO 111A OPEN OFF
M1		16		17		18		19		20		21		22		23		24		25		26		27		28		29		30		31
M1		SPARE		SPARE		SPARE		SPARE		SPARE		SPARE		SPARE		SAPRE		DPS HE PRESS FIRE		DPS HE PRESS FIRE OFF		LANDING RADAR SELF TEST ON		LANDING RADAR SELFTEST OFF		RCS ISO 1B OPEN		RCS ISO 1B OPEN OFF		RCS ISO 111B OPEN		RCS ISO 111B OPEN OFF
M2		32		33		34		35		36		37		38		39		40		41		42		43		44		45		46		47
M2		ASA OPER		ASA WARMUP		S-BAND RANGE		S-BAND RANGE OFF		DEADBAND MAX		DEADBAND MIN		ABORT STAGE		ABORT STAGE OFF		SPARE		SPARE		SPARE		SPARE		AEA OPERATE		AEA STBY		SPARE		SPARE
M3		48		49		50		51		52		53		54		55		56		57		58		59		60		61		62		63
M3		(-) PITCH/15°/S ON		(+) PITCH/15°/S OFF		(-) YAW/15°/S ON		(-) YAW/15°/S OFF		(-) ROLL/15°/S ON		(-) ROLL/15°/S OFF		SPARE		SPARE		SPARE		SPARE		LM/S-IVB SEP ARM		LM/S-IVB SEP ARM OFF		RCS ASC FEED A-OPEN		RCS ASC FEED A-OPEN OFF		RCS ASC FEED B-OPEN		RCS ASC FEED B-OPEN OFF
M4		64		65		66		67		68		69		70		71		72		73		74		75		76		77		78		79
M4		(-) PITCH/5°/S ON		(-) PITCH/5°/S OFF		(-) YAW/5°/S ON		(-) YAW/5°/S OFF		(-) ROLL/5°/S ON		(-) ROLL/5°/S OFF		2 JET		4 JET		SPARE		SPARE		SPARE		SPARE		RCS ASC FEED A-CLOS		RCS ASC FEED A-CLOS OFF		RCS ASC FEED B-CLOS		RCS ASC FEED B-CLOS OFF
M5		80		81		82		83		84		85		86		87		88		89		90		91		92		93		94		95
M5		(+) PITCH/5°/S ON		(+) PITCH/5°/S OFF		(+) YAW/5°/S ON		(+) YAW/5°/S OFF		(+) ROLL/5°/S ON		(+) ROLL/5°/S OFF		MAN THROT 10%		MAN THROT 30%		SPARE		SPARE		LM/S-IVB SEP OFF		LM/S-IVB SEP OFF		RCS ISO 1A CLOS		RCS ISO 1A CLOS OFF		RCS ISO 111A CLOS		RCS ISO 111A CLOS OFF
M6		96		97		98		99		100		101		102		103		104		105		106		107		108		109		110		111
M6		(+) PITCH/15°/S ON		(+) PITCH/15°/S OFF		(+) YAW/15°/S ON		(+) YAW/15°/S OFF		(+) ROLL/15°/S ON		(+) ROLL/15°/S OFF		MAN THROT 50% ON		MAN THROT 50% OFF		SPARE		SPARE		C-BAND ON		C-BAND OFF		RCS ISO 1B CLOS		RCS ISO 1B CLOS OFF		RCS ISO 111B CLOS		RCS ISO 111B CLOS OFF
M7		112		113		114		115		116		117		118		119		120		121		122		123		124		125		126		127
M7		(-) X-TRANS ON		(-) X-TRANS OFF		(-) Y-TRANS ON		(-) Y-TRANS OFF		(-) Z-TRANS ON		(-) Z-TRANS OFF		SPARE		SPARE		RCS ISO 11B CLOS		RCS ISO 11B CLOS OFF		SPARE		SPARE		SPARE		SPARE		SPARE		SPARE
M8		128		129		130		131		132		133		134		135		136		137		138		139		140		141		142		143
M8		(+) X-TRANS ON		(+) X-TRANS OFF		(+) Y-TRANS ON		(+) Y-TRANS OFF		(+) Z-TRANS ON		(+) Z-TRANS OFF		ASC ARM		ASC ARM OFF		RCS ISO 11B OPEN		RCS ISO 11B OPEN OFF		S-BAND PRIM ON		S-BAND PRIM OFF		SPARE		SPARE		SPARE		SPARE
M9		144		145		146		147		148		149		150		151		152		153		154		155		156		157		158		159
M9		SPARE		SPARE		SPARE		SPARE		SPARE		SPARE		DESC ARM		DESC ARM OFF		RCS ISO 11A OPEN		RCS ISO 11A OPEN OFF		SPARE		SPARE		SPARE		SPARE		SPARE		SPARE
M10		160		161		162		163		164		165		166		167		168		169		170		171		172		173		174		175
M10		SPARE		SPARE		SPARE		SPARE		SPARE		SPARE		ENGINE STOP ON		ENGINE STOP OFF		RCS A ISO 11A CLOS		RCS A ISO 11A CLOS OFF		SPARE		SPARE		RCS MAIN A CLOS		RCS MAIN A CLOS OFF		RCS MAIN B CLOS		RCS MAIN B CLOS OFF
M11		176		177		178		179		180		181		182		183		184		185		186		187		188		189		190		191
M11		SPARE		SPARE		SPARE		SPARE		SPARE		SPARE		LANDING RADAR ON		LANDING RADAR OFF		RCS ISO 1VB OPEN		RCS ISO 1VB OPEN OFF		PRIMARY H2O ON		PRIMARY H2O OFF		RCS MAIN A OPEN		RCS MAIN A OPEN OFF		RCS MAIN B OPEN		RCS MAIN B OPEN OFF
M12		192		193		194		195		196		197		198		199		200		201		202		203		204		205		206		207
M12		SPARE		SPARE		SPARE		SPARE		DPS #2 PQGS ENABLE		DPS #2 PQGS INHIBIT		MASTER CFW ON		MASTER CFW OFF		RCS ISO 1VB CLOS		RCS ISO 1VB CLOS OFF		DESC HE REG #1 OPEN		DESC HE REG #1 OPEN OFF		SPARE		SPARE		SPARE		SPARE
M13		208		209		210		211		212		213		214		215		216		217		218		219		220		221		222		223
M13		SPARE		SPARE		SPARE		SPARE		DPS PQGS #2 ON		DPS PQGS #2 OFF		ENGINE START ON		ENGINE START OFF		RCS ISO 1VB OPEN		RCS ISO 1VB OPEN		DESC HE REG #1 CLOS		DESC HE REG #1 CLOS OFF		SPARE		SPARE		ASC H2O OPEN		ASC H2O OPEN OFF
M14		224		225		226		227		228		229		230		231		232		233		234		235		236		237		238		239
M14		SPARE		SPARE		SPARE		SPARE		DPS PQGS #1 ENABLE		DPS PQGS #1 INHIBIT		MAN THROT 100% ON		MAN THROT 100% OFF		RCS ISO 1VA CLOS		RCS ISO 1VA CLOS OFF		SPARE		SPARE		DFI CAL ON		DFI CAL OFF		SPARE		SPARE
M15		240		241		242		243		244		245		246		247		248		249		250		251		252		253		254		255
M15		SPARE		SPARE		SPARE		SPARE		DPS PQGS #1 ON		DPS PQGS #1 OFF		CABIN FAN #1 ON		CABIN FAN #1 OFF		SPARE		SPARE		SPARE		SPARE		RCS X-OVER OPEN		RCS X-OVER OPEN OFF		RCS X-OVER CLOS		RCS X-OVER CLOS OFF

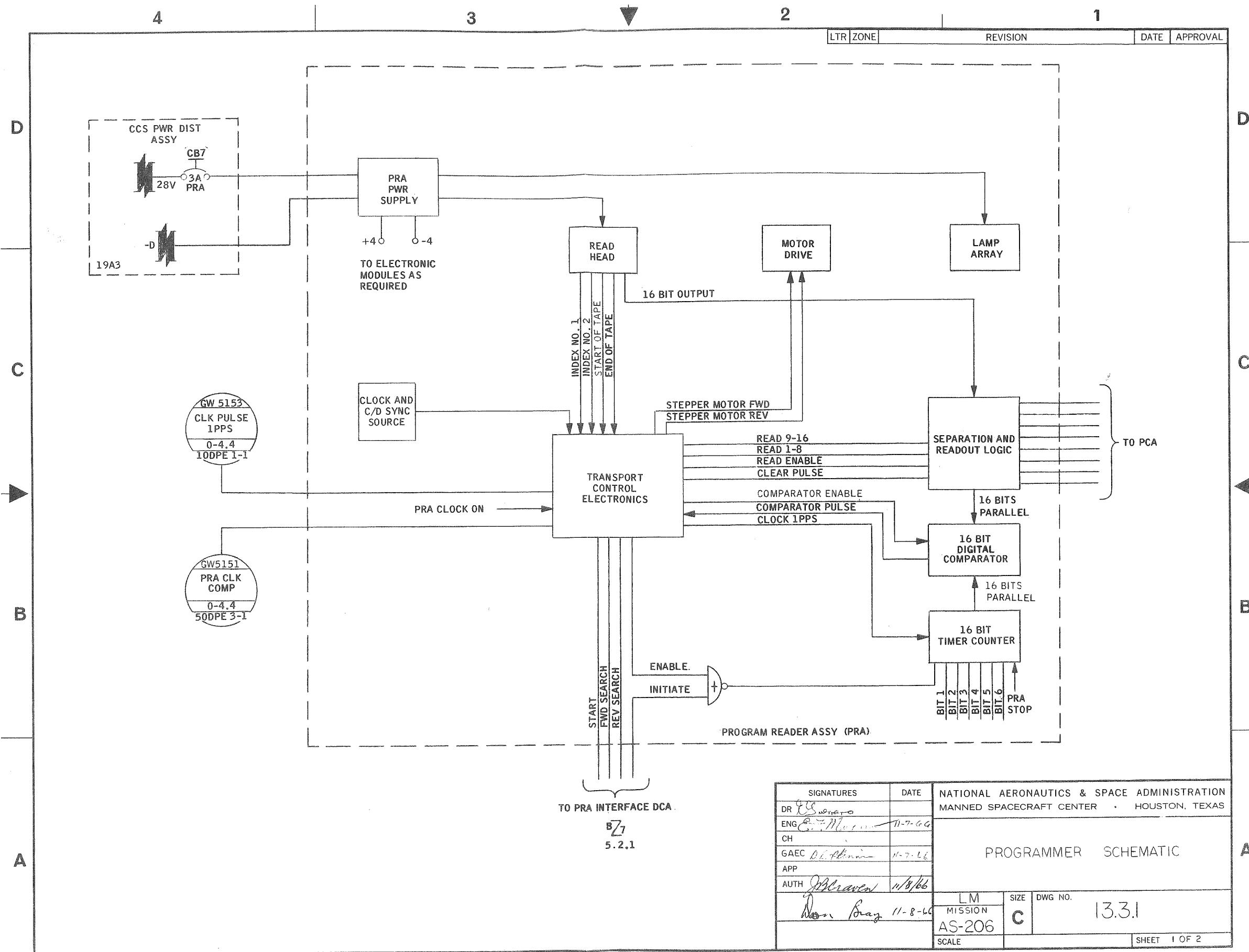


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ENG	<i>[Signature]</i>	11-7-66		
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ORIGINAL DATE OF DESG. <b>11-8-66</b>		TITLE: <b>LM I PROGRAMER SYSTEM DIAGRAM</b>		- NASA - MANNED SPACECRAFT CENTER FLIGHT OPERATIONS DIVISION	
DRAWN BY: <i>[Signature]</i>	CHECKED BY: <i>[Signature]</i>	DESIGNED BY: <i>[Signature]</i>	SYSTEMS ENG. <i>[Signature]</i>	SIZE <b>C</b>	SHEET NO. <b>13.2.1</b>
APPROVED BY: <i>[Signature]</i>		APPROVED BY: <i>[Signature]</i>		MISSION: <b>AS-206A</b>	
SHEET <b>1</b> OF <b>1</b>				FLIGHT CONTROLLER ENGINEERING FORMAT	





SIGNATURES		DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION	
DR	<i>[Signature]</i>		MANNED SPACECRAFT CENTER • HOUSTON, TEXAS	
ENG	<i>[Signature]</i>	11-7-66	PROGRAMMER SCHEMATIC	
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14. EXTRAVEHICULAR MOBILING  
UNIT



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SECTION 14  
EXTRAVEHICULAR MOBILING UNIT (EMU)

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14.1 EMU MAJOR COMPONENTS

The EMU consists of the following major components: Pressure Garment Assembly (PGA), Constant Wear Garment (CWG), Liquid Cooling Garment (LCG), Thermal Meteoroid Garment (TMG), Portable Life Support System (PLSS), Emergency Oxygen System (EOS), Extravehicular Visor Assembly (EVVA), and Waste Management System (WMS). The EMU provides the extravehicular crewman with a habitable environment for the required three hour 4800 BTU design mission task.

14.1.1 Pressure Garment Assembly (PGA)

The PGA consists of a helmet, torso and limb suit, gloves, and various controls and displays to provide the crewman with a controlled environment. The garment is designed to be worn for 115 hours at a regulated pressure of  $3.75 \pm 0.25$  psig in conjunction with either the LCG or CWG. The PGA design permits donning within a period of 15 minutes without assistance.

A. Helmet

The helmet is a detachable pressure enclosure with provisions for feeding and/or drinking, communications, EOS utilization, and EVVA attachment.

1. The helmet feed port allows easy access of a probe for administering drinking water and/or food to the PGA crewman while the helmet is donned.
2. The communications cap worn within the helmet provides redundant earphones and microphones for intravehicular and extravehicular communications.
3. The feed port is used for EOS oxygen flow to the helmet during emergency operations. This port contains a check valve and redundant sealing to maintain PGA integrity.
4. The helmet has provisions on each side for mounting the EVVA.

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#### B. Torso and Limb Suit

The torso and limb suit consists of a flexible pressure garment which encompasses the entire body, with the exception of the head and hands. This garment contains the necessary connectors and receptacles for the PLSS/PGA and ECS/PGA interface. The PGA connectors, with positive locking devices, can be connected and disconnected by an unassisted crewman.

##### 1. Gas Connectors (4)

The PGA design provides an oxygen inlet and exhaust connector on each side of the PGA front torso. Attached to the two oxygen inlet connectors are two body flow diverter valves.

##### 2. Liquid Connector (1)

The liquid connector is mounted on the PGA torso and serves as the interface between the LCG multiple water connector and PLSS multiple water connector. A protective external cover provides PGA pressure integrity when the LCG multiple water connector has been removed from the PGA multiple water receptacle.

##### 3. Electrical Connector (1)

An electrical connector is provided for electrical power and signals for communication, biomedical instrumentation, environmental sensors, and warning system components mounted within the PGA. This quick disconnect connector can be mated with spacecraft or PLSS electrical systems.

##### 4. Urine Connector (1)

The urine quick disconnect fitting is used to transfer urine from the urine collection bladder to the spacecraft waste management system.

#### C. Gloves

The intravehicular glove is designed to permit free movement of the hand and wrist when pressured. The pressure retaining

extravehicular gloves, in conjunction with the thermal meteoroid mittens, provide thermal and abrasion protection during extravehicular operations. One pair of the extravehicular gloves is stored onboard the LM and the other pair is stored onboard the CM.

#### D. Controls

All PGA controls are accessible to the crewman during extravehicular operations. The PGA controls consist of two body flow diverter valves and pressure relief and purge mechanisms.

##### 1. Body Flow Diverter Valve (2)

In the open position, the valve diverts the PGA inlet oxygen flow equally to the torso and helmet regions of the PGA.

During PLSS operation, the body flow diverter valves are closed allowing the entire ventilation gas flow to enter the helmet.

##### 2. Pressure Relief Valve (1)

The pressure relief valve, operating through the unused oxygen inlet connector, automatically prevents PGA internal pressure from exceeding  $5.25 \pm 0.25$  psig. The valve has manual override and is designed to vent overboard the flow rate from a failed open primary oxygen pressure regulator.

##### 3. Purge Valve (1)

The purge valve, operating through the unused PGA oxygen exhaust connector, provides a manual capability for oxygen purge of the PGA during emergency operations.

#### E. Displays

The PGA has provisions for internal pressure, time, and radiation dosage displays for use during extravehicular operations.

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#### 14.1.2 Constant Wear Garment (CWG)

The CWG is a cotton and dacron undergarment worn during intra-vehicular CM operation. It provides general comfort, perspiration absorption, and thermal transfer between the body and the cabin gas ventilation stream. It has provisions for biomedical instrumentation. In addition to the three garments worn by the crewmen, four spares are stored onboard the CM.

#### 14.1.3 Liquid Cooling Garment (LCG)

The LCG consists of an open mesh garment, water manifold, multiple water connector, provisions for biomedical instrumentation, and water transport ducts. The water transport ducts are divided into parallel flow paths providing maximum surface coverage for optimum cooling. Cooling during extravehicular operation is accomplished by the circulation of the liquid coolant. The open mesh garment also allows evaporative cooling via the spacecraft ECS or PLSS oxygen loop. Normally, the LCG will be donned by the crewmen prior to entry into the LM.

#### 14.1.4 Thermal Meteoroid Garment (TMG)

The TMG consists of a parka, trousers, lunar boots, and thermal mittens. This loose-fitting multi-layered over-garment protects against abrasion, meteoroid penetration and excessive thermal transfer to the PGA. It is comprised of an outer layer of white dacron, seven layers of aluminized mylar insulation, and two layers of neoprene coated nylon. The thermal mittens, worn over the PGA extravehicular gloves, may be removed for short intervals to increase manual dexterity. The TMG can be donned and doffed by an unassisted crewman in an unpressurized PGA or with assistance in a pressurized PGA. One TMG is stored onboard the LM and one onboard the CM.

#### 14.1.5 Portable Life Support System (PLSS)

The PLSS consists of the primary oxygen supply section, oxygen loop, feedwater supply system, coolant transport loop, electrical power system, and space suit communications.

#### A. Primary Oxygen Supply System

The primary oxygen supply system consists of an oxygen tank, recharge connector, flow limiting orifice, shutoff valve, single stage pressure regulator and flow rate sensor. This system provides and regulates oxygen required for the oxygen ventilation loop.

##### 1. Primary Oxygen Tank and Recharger Connector

The primary oxygen tank contains 0.92 pounds of expendable oxygen to satisfy metabolic consumption and EMU leakage for one extravehicular excursion. Multiple oxygen recharges are available from the high pressure spacecraft stores.

##### 2. Primary Pressure Regulator

This single stage pressure regulator regulates oxygen pressure to  $3.9 \pm 0.1$  psig. During purge flow failure mode, the primary pressure regulator is designed to be used in conjunction with the EOS. The regulator is designed to fail open.

##### 3. Flow Limiting Orifice, Flow Rate Sensor, and Oxygen Shutoff Valve

The flow limiting orifice limits the oxygen flow through the pressure regulator to the maximum flow passed by the PGA pressure relief valve. This maximum flow limitation protects the PGA against over-pressurization in the event of a failed open regulator. The flow rate sensor provides an audible warning tone when the oxygen flow rate exceeds 0.45 pounds per hour. All oxygen flow may be terminated by a manual shutoff valve.

#### B. Oxygen Loop

The oxygen loop consists of a porous plate sublimator, contaminant control canister, water separator, fan assembly, and PGA gas connectors. The loop reconditions and recirculates the oxygen through the PGA.



1. Contaminant Control Canister  
The contaminant control canister filters foreign particles and removes carbon dioxide and odors from the PLSS oxygen loop. An internal check valve within the canister maintains PGA pressure integrity during cartridge replacement. The LM has storage area for six contaminant control cartridges.
2. Sublimator and Water Separator  
The sublimator cools the oxygen and condenses excess water from the oxygen loop. The water separation removes the water vapor and directs the captured droplets to the feed water reservoir.
3. Fan Assembly  
The fan supplies a 6 cfm flow rate between the PLSS and PGA. A brushless dc motor powers the fan.
4. PGA Gas Connectors (4)  
The PGA gas connectors provide a PGA/PLSS and PGA/ECS interface.
- C. Coolant Transport Loop  
The coolant transport loop consists of an accumulator, water fill connector, pump assembly, water diverter valve, sublimator, and multiple water connector. The loop transfers heat from the LCG for dissipation in the sublimator.
1. Accumulator  
The rechargeable accumulator pressurizes the coolant loop to 22 psig and provides usable makeup water as required.
2. Pump Assembly  
The pump circulates the chilled water through the coolant loop and LCG at 4 lb/min.

3. Water Fill Connector  
The water fill connector permits initial charging of the loop and emergency top off charging during the mission.
4. Water Diverter Valve  
The water diverter valve permits the selection of three coolant water temperatures at the inlet to the LCG.
5. Sublimator  
The sublimator rejects heat from the coolant loop and oxygen loop by the sublimation of ice.
6. Multiple Water Connector  
The multiple water connector forms a single PGA penetration with dual passages for the liquid coolant.
- D. Feedwater Supply System  
The supply system consists of a reservoir and canister assembly, water fill and drain connectors, shutoff and relief valve, and water quantity sensor. The feed water loop supplies water to the sublimator for heat dissipation.
1. Reservoir  
The reservoir is a bladder-type tank which provides 7.3 pounds of expendable water for sublimation. Water from the water separators is directed to the volume outside the bladder and is pressurized by the oxygen loop.
2. Water Fill and Drain Connectors  
The water fill connector allows recharging of the PLSS water supply from the spacecraft. The water drain connector interfaces with the LM Waste Management Section. When recharging the PLSS water supply, both fill and drain operations should be performed simultaneously.
3. Shutoff and Relief Valve  
The water shutoff and relief valve provides manual ON/OFF feedwater and drain water control and provisions for relieving feedwater over-pressurization. The oxygen

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loop provides feedwater reservoir and loop pressurization.

4. Water Quantity Sensor

The water quantity sensor is a positive displacement flow meter.

E. Electrical Power System

The power supply consists of a single replaceable battery with a 240 watt-hour capacity at a nominal 16.8 volts. The LM has storage facilities for six batteries.

F. Spacesuit Communicator (SSC)

The SSC consists of primary and secondary VHF transceivers, transducers and signal conditioning and associated control functions. This system provides primary and secondary duplex voice communication and physiological and environmental telemetry capability.

1. Primary and Secondary VHF Transceivers

The primary and secondary duplex transceivers are identical with the exception of operating frequencies.

2. Transducers and Signal Conditioning

The transducer and signal conditioning provides seven telemetry channel inputs, PGA meter readout, and inputs to the audible tone generators.

3. Controls

The SSC mode selector switch provides primary duplex voice, primary duplex voice and telemetry, secondary duplex voice and off.

a. Primary Duplex Mode

This operational mode allows the EVA to transmit voice utilizing the spacecraft for relay to earth via S-Band.

b. Primary Duplex and Telemetry Mode

This operational mode allows simultaneous non-interfering transmission of voice and telemetry to the spacecraft for relay to earth via S-Band.

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c. Secondary Duplex Mode

This mode allows voice communications between multiple EVA and voice backup utilizing the spacecraft for relay to earth via S-Band.

The VHF link between LM/CM cannot be maintained simultaneously with the LM/EVA VHF link.

Audiable warning tones are operational in both secondary and primary duplex modes.

14.1.6 Emergency Oxygen System (EOS)

The EOS consists of an oxygen supply, single stage regulator, fill valve, pressure gauge, manual actuator (lanyard) and quick disconnect PLSS mounting device. It is a non-rechargeable unit containing sufficient oxygen to provide at least five minutes life support under a 2000 BTU/hour load in the event of a PLSS fan failure and/or a primary oxygen supply failure. It is activated by a lanyard, and supplies regulated oxygen at  $3.45 \pm 0.25$  psig directly to the helmet. There are two EOS units stored onboard the CM.

14.1.7 Extravehicular Visor Assembly (EVVA)

The EVVA is a detachable assembly which provides visual attenuation and thermal and meteoroid impact protection during extravehicular operations. A single crewman can attach or detach the EVVA from his helmet without the use of tools and with the helmet on or off. The two EVVA's are stored onboard the CM.

14.1.8 Waste Management System (WMS)

The WMS provides for a separate Urine Management System (UMS) and Fecal Containment System (FCS).

A. The UMS consists of a urine collection bladder and a urine transfer fitting.

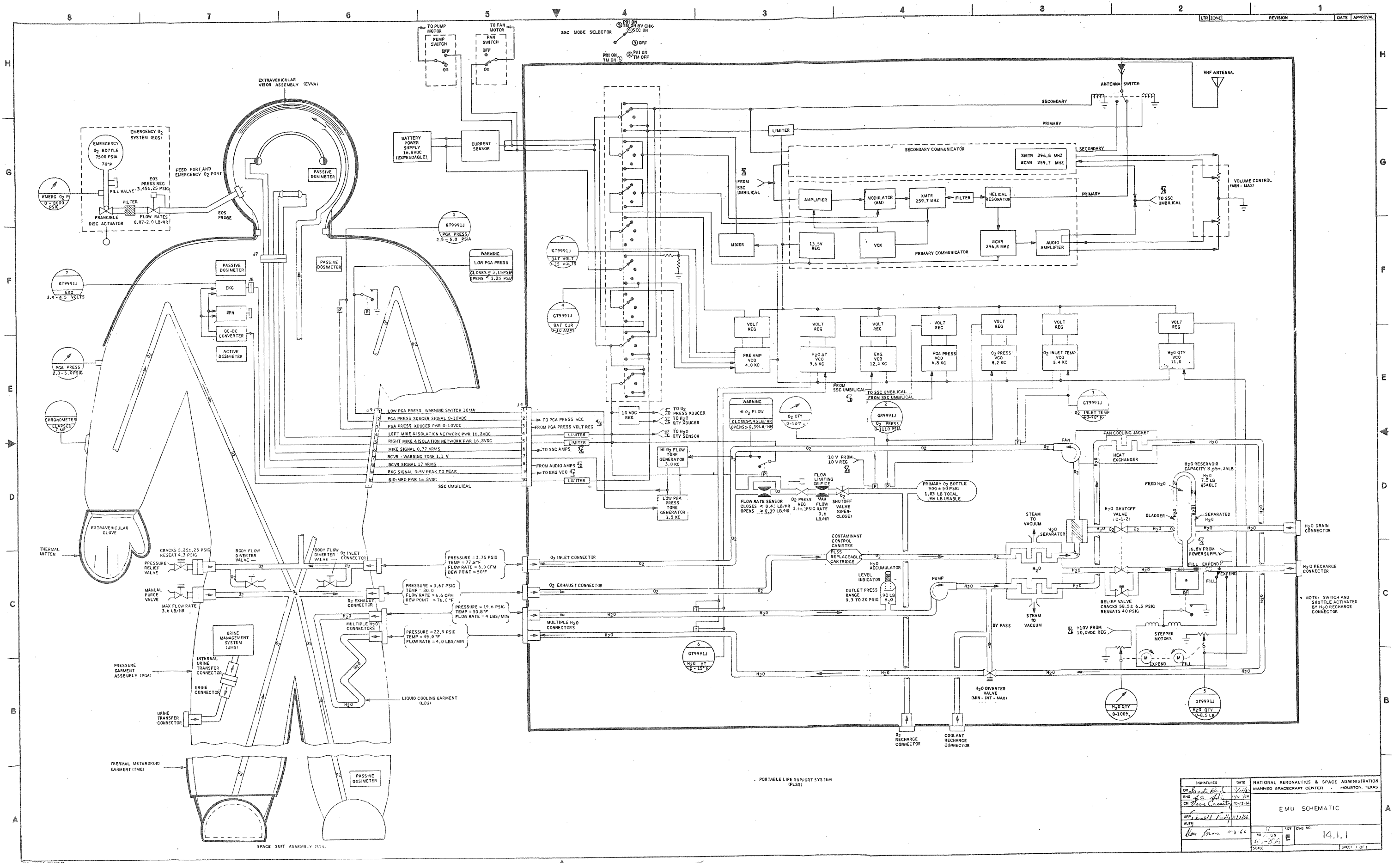
1. The PGA UMS provides the capability of collecting and storing urine without leakage or back flow.



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2. The PGA UMS permits urine transfer to CM and LM WMS for both pressurized and depressurized cabin operation.
- B. The FCS provides for defecation operations.
1. For normal defecation, the PGA will be doffed and the CM system will be utilized.
  2. For defecation in the LM, a fecal bag and glove will be utilized.
  3. A fecal containment garment worn under the PGA allows emergency defecation during extravehicular operation.







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SECTION 15  
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15.1 NOTES  
None

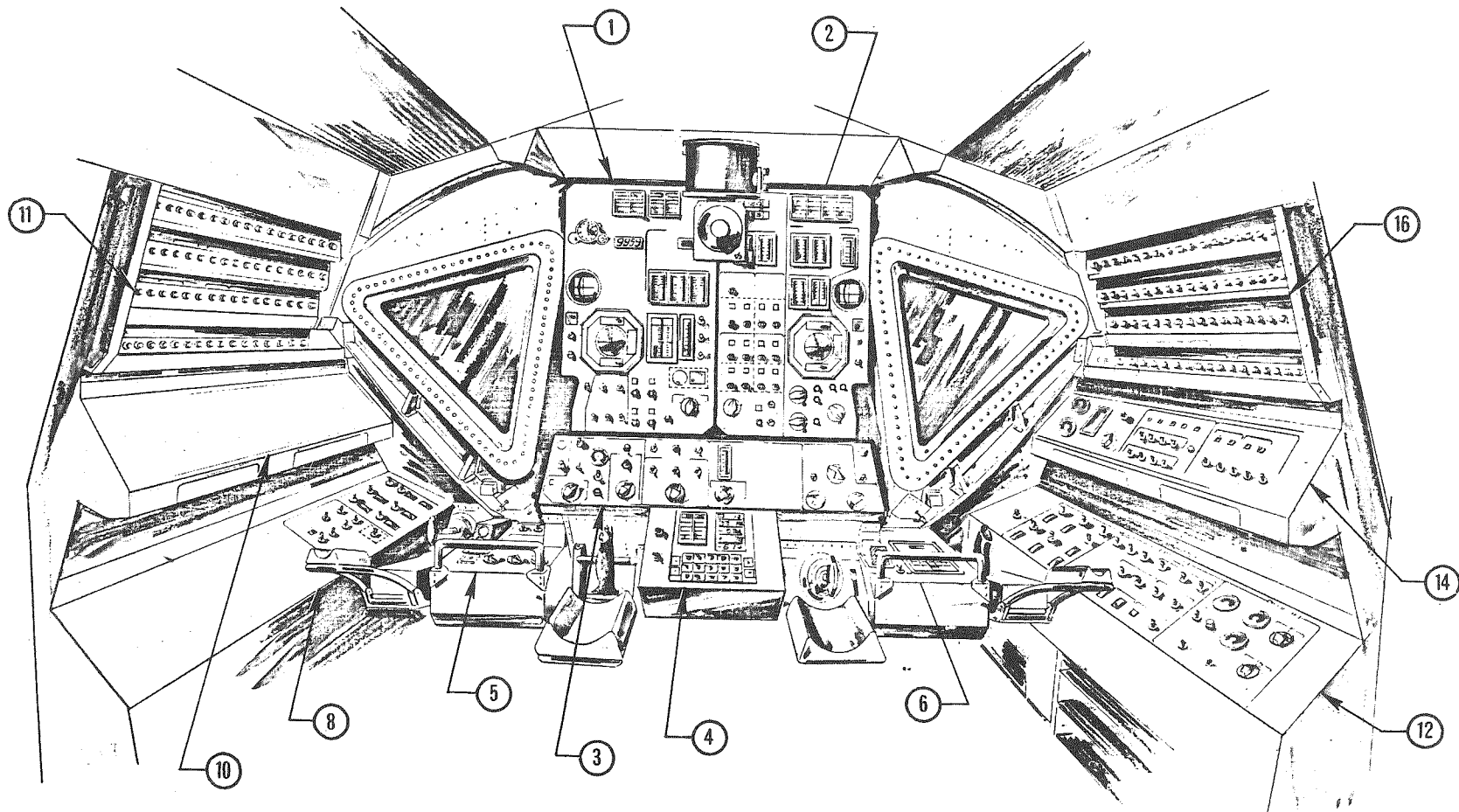


FIGURE 15-1 LM COCKPIT

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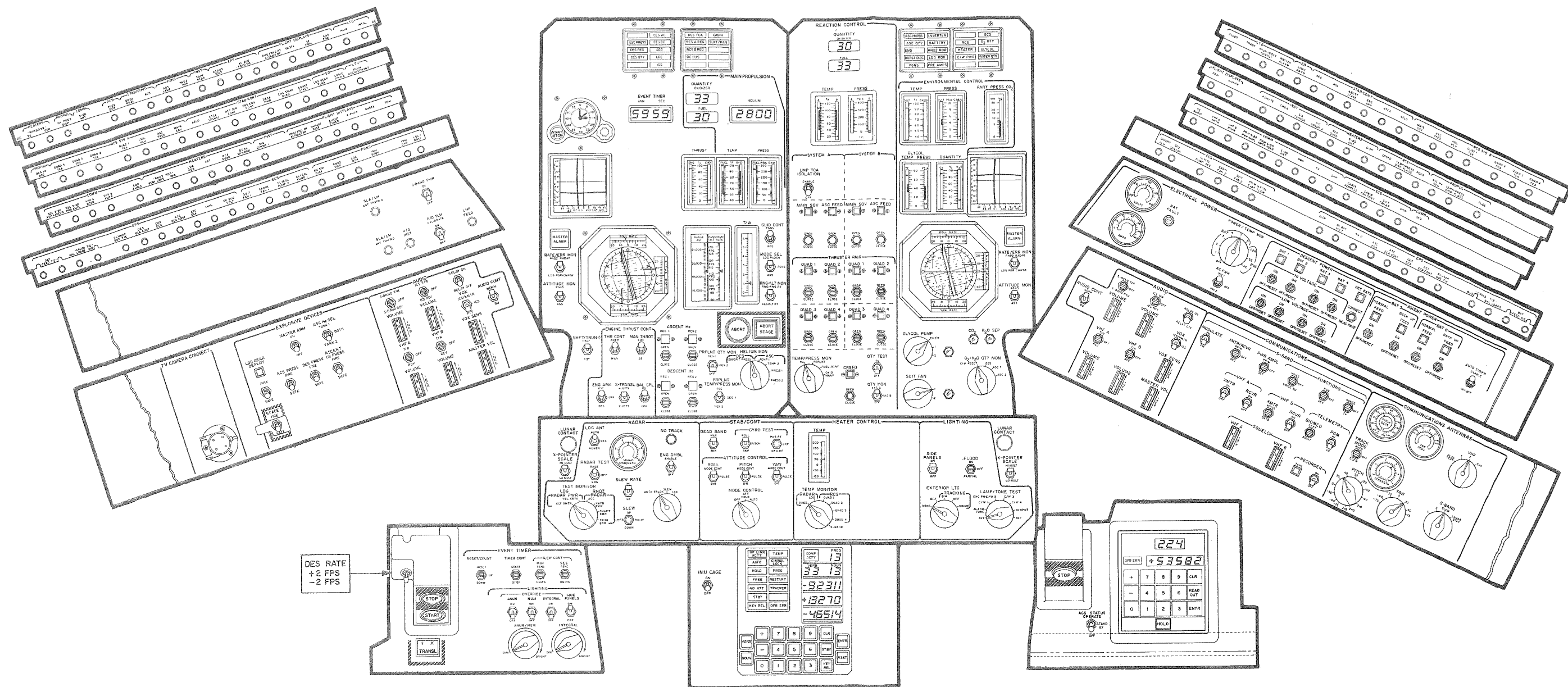
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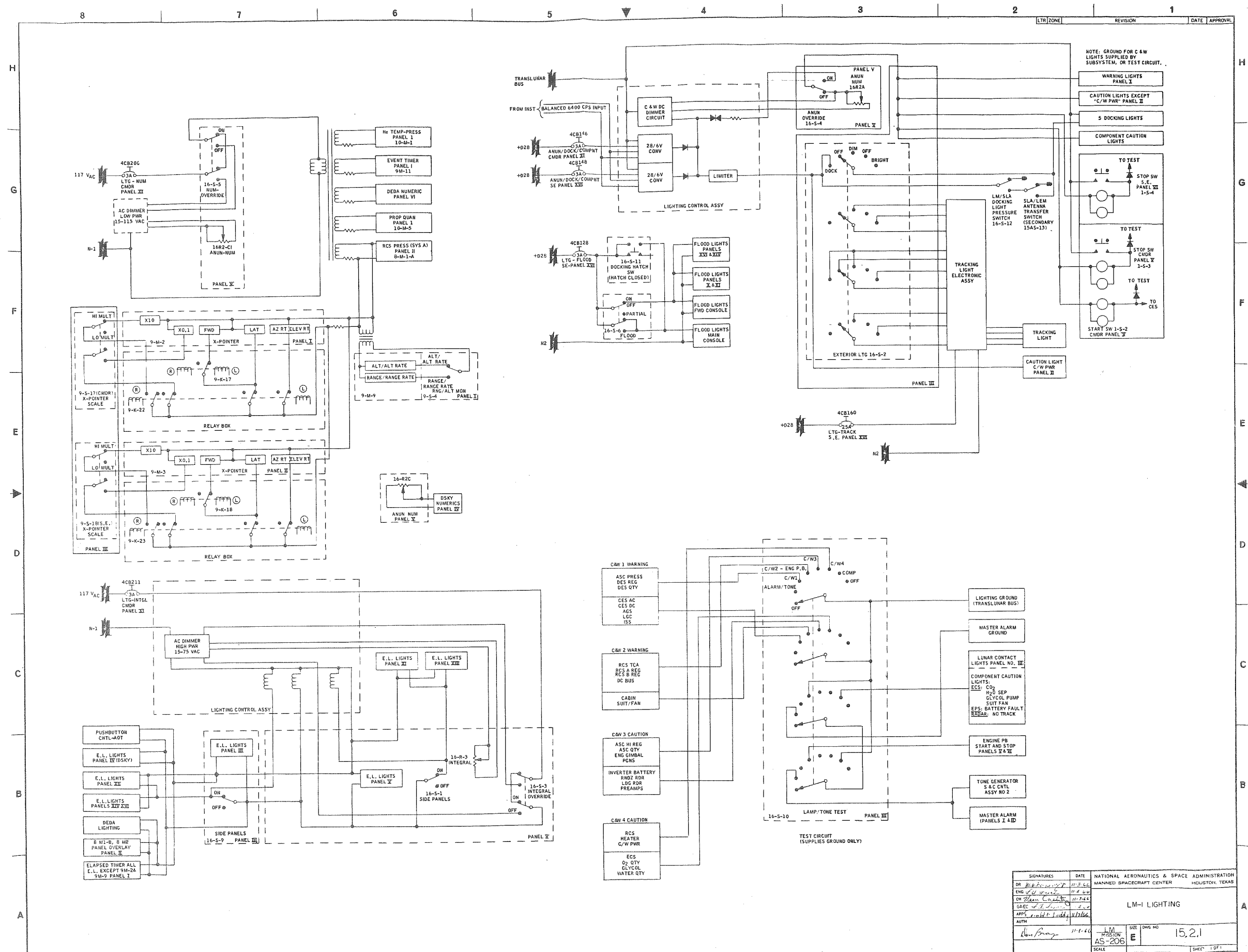
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SIGNATURES		DATE	NATIONAL AERONAUTICS & SPACE ADMINISTRATION MANNED SPACECRAFT CENTER • HOUSTON, TEXAS	
DR	W. L. ...	10-29-66	LM-1 PANEL LAYOUT	
ENG	S. J. ...	11-7-66		
CH				
GAEC	P. L. ...	11-7-66		
APP	Donald R. ...	11/7/66	LM MISSION AS-206	
AUTH	Don ...	11-8-66		
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