

STUDY GUIDE

LM

CONTROL ELECTRONICS SECTION
AND ABORT GUIDANCE SECTION

COURSE NO. 30317

For Training Purposes Only



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Preface

This document is designed to support
The Control Electronics Section and
Abort Guidance Section Familiarization
Course Number 30317.

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LM Familiarization Manual	LMA 790-1
LM ATCA Training Course Manual	LTM-(P)-1700-6
LM DECA Training Course Manual	LTM-(P)-1700-16
LM Rate Gyro Assembly Familiarization Manual	
Logic Description AEA Computer MOD C5B	
Logic Description Data Entry and Display Assembly	
Operation and Support Instructions ASA Support Manual	
LEVEL 2A Drawings	LDW-540-21000-21 (Sheets IV, V, VI, and VII)

SECTION I

CONTROL ELECTRONICS SECTION

I. General Introduction to Control Electronics Section (CES)

The LM Control Electronics Section is part of the Guidance Navigation and Control Subsystem (GN & CS). The CES is designed to control vehicle attitude and translation, about or along all axes, during the LM mission. Vehicle attitude and small translations are controlled by means of the 16 RCS jets mounted on the ascent stage. Major translations are accomplished by means of the main propulsion, i.e., ascent or descent engines.

The LM Guidance Navigation and Control Subsystem contains two independent guidance sections. The Primary Guidance and Navigation Section (PGNS) is the primary control of the vehicle. The Abort Guidance Section (AGS) is designed to guide the LM to the Command and Service Modules (CMS) in case of failure of the PGNS.

The Control Electronics Section operates in both the PGNS mode and the AGS mode. 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 LM Guidance Computer (LGC) as follows:

1. Converts reaction control jet commands to the required electrical power to operate the Reaction Control Subsystem jet solenoid valves.
2. 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 the ON command is removed.
3. Accepts both LM Guidance Computer and manual engine ON/OFF commands and routes them to propulsion to fire or stop the descent or ascent engine.
4. Accepts LM Guidance Computer and manual thrust commands to control the thrust of the descent engine.

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

1. Accepts attitude error signals from the Abort Guidance Section or manual attitude commands and fires the proper Reaction Control jets to achieve attitude control.

2. Accepts manual translation commands and fires RCS jets to accelerate the LM in the desired direction.
3. Automatically rotates the gimballed descent engine for trim control.
4. Accepts Abort Guidance Section and manual engine ON/OFF commands and routes them to the descent or ascent engine.
5. Accepts manual throttle commands to control the thrust of the descent engine.

Control Electronics Section Interfaces:

The CES receives the following signals from the PGNS:

1. ON/OFF commands for each of the 16 reaction control jets.
2. ON/OFF commands for the ascent or descent engine.
3. Descent engine trim commands.
4. Thrust magnitude commands for the descent engine.
5. 800 cycle per second power to excite the hand controller.

The following signals are set to the PGNS:

1. Proportional attitude rate commands.
2. Gimbal fail signals.
3. Translation ON/OFF commands.
4. Attitude controller out of detent.

The CES provides the following to the descent engine:

1. Ignition and shut-down commands.
2. Automatic and manual throttling commands.
3. Rotation of the gimballed engine.

The CES also interfaces with the:

1. Electrical Power Subsystem (EPS)---The CES receives required electrical power from the EPS.

2. Reaction Control Subsystem (RCS)---The CES provides the signals to actuate the RCS jet solenoids.
3. Ascent Engine---The CES provides commands for ascent engine ignition and shut-down.
4. Displays and Control Subsystem---The CES provides inputs to the appropriate controls and displays to enable control and monitoring of the CES.
5. Abort Guidance Section (AGS)---The CES provides vehicle status signals to the AGS and receives steering signals and engine commands.
6. Instrumentation Subsystem---CES provides signals to the Instrumentation Subsystem for in-flight monitoring.
7. Environmental Control Subsystem (ECS)---The ECS provides mounting surfaces and thermal protection for the CES equipment.
8. Structure Subsystem---The Structure Subsystem provides the area and mounting accommodations to house the CES equipment within the structure.
9. Explosive Devices Subsystem (EDS)---The CES interfaces with the EDS for stage status information.

Primary Control Path

When the PGNS mode of guidance is selected, the LM Guidance Computer (LGC) and the crew control the RCS jets, descent engine, and ascent engine.

1. RCS jet control

The LGC generates discrete (ON-OFF) commands for each of the 16 RCS jets to control LM attitude and translation. The Attitude and Translation Control Assembly amplifies these commands to the level required by the RCS primary solenoids.

2. Descent - ascent engine ON-OFF control

LGC and manual engine ON-OFF commands are processed in the CES and routed to the descent or ascent engine.

3. Descent engine throttle control

The descent engine can be throttled from 10% to its maximum thrust automatically or manually. Automatic throttle signals from the LGC are processed by the Descent Engine Control Assembly and directed to the descent engine. The automatic throttle can be manually overridden to increase engine thrust by advancing the Thrust Translation Controller Assembly (TTCA). The crew can select complete manual thrust control with a switch on the control panel.

4. Descent engine trim control

The Descent Engine Control Assembly receives discrete (ON-OFF) rotation commands from the LGC and mechanically gimbals the descent engine. The descent engine will be rotated at a constant angular rate about the pitch or roll axis in the direction commanded for the duration of the ON command.

Abort Control Path

When abort guidance control path is in operation, the Abort Guidance Section (AGS) and the crew control the RCS and Propulsion Subsystem through the CES.

1. RCS jet control

The AGS generates attitude error signals for the pitch, roll, and yaw axes. The Attitude and Translation Control Assembly processes these error signals and fires the proper RCS jets to reduce the error. Manual attitude and translation commands are also processed by the ATCA and the proper RCS jets are fired.

2. Descent - ascent engine ON-OFF control

AGS and manual engine ON-OFF commands are processed in the CES and routed to the descent or ascent engine.

3. Descent engine throttle control

There is no provision for automatic throttle control in AGS operation. The crew can manually control the descent engine thrust with the Thrust Translation Controller Assemblies.

4. Descent engine trim control

In AGS operation, gimbal trim commands are derived from the roll and pitch attitude error channels in the ATCA. The DECA processes these commands and commands rotations of the descent engine to provide the required trim.

Modes of Attitude Control

1. Automatic mode

The automatic mode provides fully automatic attitude control of the LM. In primary guidance control the LGC generates the required jet commands and sends them directly to the primary preamplifiers in the Attitude and Translation Control Assembly (ATCA). The preamplifiers control jet drivers which fire the RCS primary solenoids. In abort guidance control, roll, pitch, and yaw attitude error signals are generated in the Abort Guidance Section (AGS) and sent to the ATCA. These AGS error signals are passed through limiters combined with damping signals from the Rate Gyro Assembly (RGA), demodulated, passed through selectable deadbands, jet select logic circuits, pulse ratio modulators and jet driver amplifiers which fire the RCS jets. The jet select logic determines which jets will fire to correct the attitude errors.

2. Attitude Hold Mode

This is a semi-automatic mode in which either crewman commands an angular rate proportional to the displacement of his Attitude Controller Assembly (ACA). The vehicle will hold attitude when the controller is in the neutral position. In primary guidance control, rate commands proportional to the controller displacement are sent to the LGC. The LGC operates on these commands and provides signals to the jet drivers in the ATCA to command rotational rates of the LM by means of the RCS. When the controller is returned to the neutral position, the vehicle rotation is stopped and maintained at its new position by the LGC. In AGS control, with the attitude controllers in neutral, the vehicle will hold attitude by means of AGS error signals. When a controller is moved out of the detent position the attitude error signals from the AGS are set to zero. Rate commands from the controller are processed in the ATCA and the RCS jets are fired until the vehicle rate is proportional to the controller displacement. When the hand controller is returned to the neutral position the vehicle rate will be reduced to zero and the AGS will hold the vehicle in the new attitude.

3. Pulse Mode

Pulse mode can be selected in PGNS operation via the Display and Keyboard. When this mode is selected the LM Guidance Computer will generate one RCS pulse command to accelerate the LM about the selected axis each time a hand controller (ACA) is moved out of detent.

In AGS operation Pulse mode may be selected on an individual axis basis. When selected, the automatic attitude control is disabled about the selected axis and a fixed train of RCS pulses is generated when the attitude controller is displaced. To change attitude in this mode the pilot moves the attitude controller out of detent commanding an acceleration about the selected axis. To stop the rotation of the spacecraft it is necessary to command an opposite acceleration about the same axis.

4. Direct Mode

The Direct Mode is also an open loop acceleration mode and selectable on an individual axis basis. The automatic abort guidance attitude control is disabled about the selected axis and 2 jet direct commands are sent to the RCS secondary solenoids when the controller is displaced. The RCS jets will fire continuously until the attitude controller is returned to the neutral position.

5. Manual Override

In the event of a failure, an emergency 4 jet direct mode can be implemented immediately in any axis by moving the attitude controller to the hardover position. This operates limit switches applying voltages directly to the secondary RCS solenoids.

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 a Thrust Translation Controller Assembly (TTCA) by way of the LGC. In AGS operation only manual control is available. Control consists of ON-OFF commands from a TTCA to the jet logic in the ATCA. The voltage is sufficient to saturate the pulse ratio modulators and give ON-OFF 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.

Descent Engine Control

1. Ignition and Shutdown

The descent engine arming and ignition is controlled by the automatic guidance equipment and the crew through the S & C Control Assemblies and Descent Control Assembly (DECA). A descent engine arm signal is sent to the S & C Control Assemblies when the engine arm switch is in the "descent" position. Engine ON signals from the LGC or AGS are sent to the DECA through the S & C Control Assemblies. The DECA turns on the descent engine upon receiving both the ARM and the ON signal. The engine will remain on until an engine OFF command is received from the automatic guidance equipment. The crew can manually generate engine ON and OFF commands which override the automatic commands.

2. Throttle Control

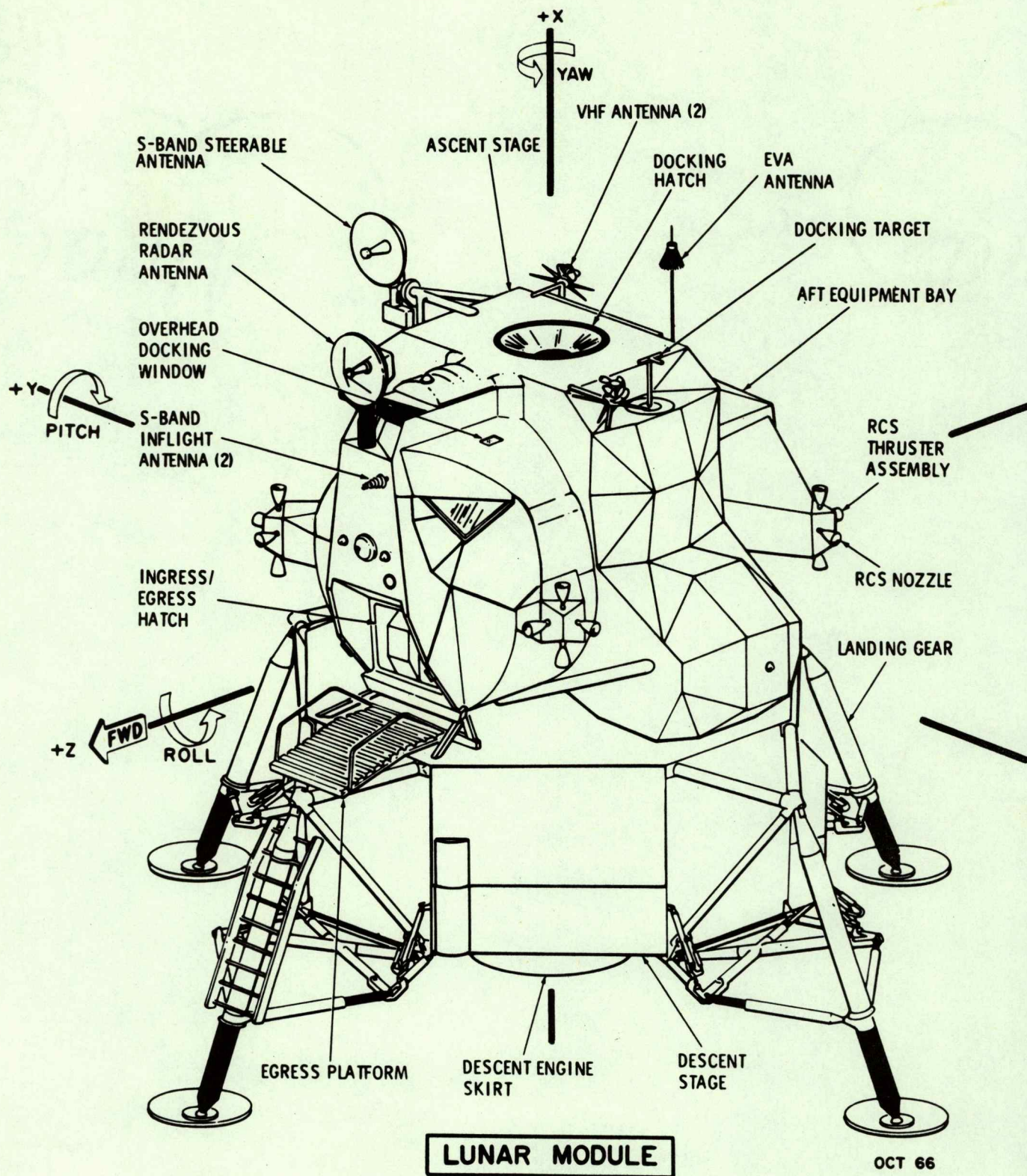
The descent engine throttle can be controlled by the PGNS and the crew. Automatic throttle increase/decrease signals from the LGC are sent to an integrating counter in the DECA. The analog output of the DECA controls the thrust of the descent engine from 10% to its maximum thrust. The TTCA's can be used by the crew to increase descent engine throttle while in automatic throttle. In manual throttle the crew has complete control over the descent engine thrust. If a TTCA is used for descent engine throttle, its manual X-axis RCS commands are disabled.

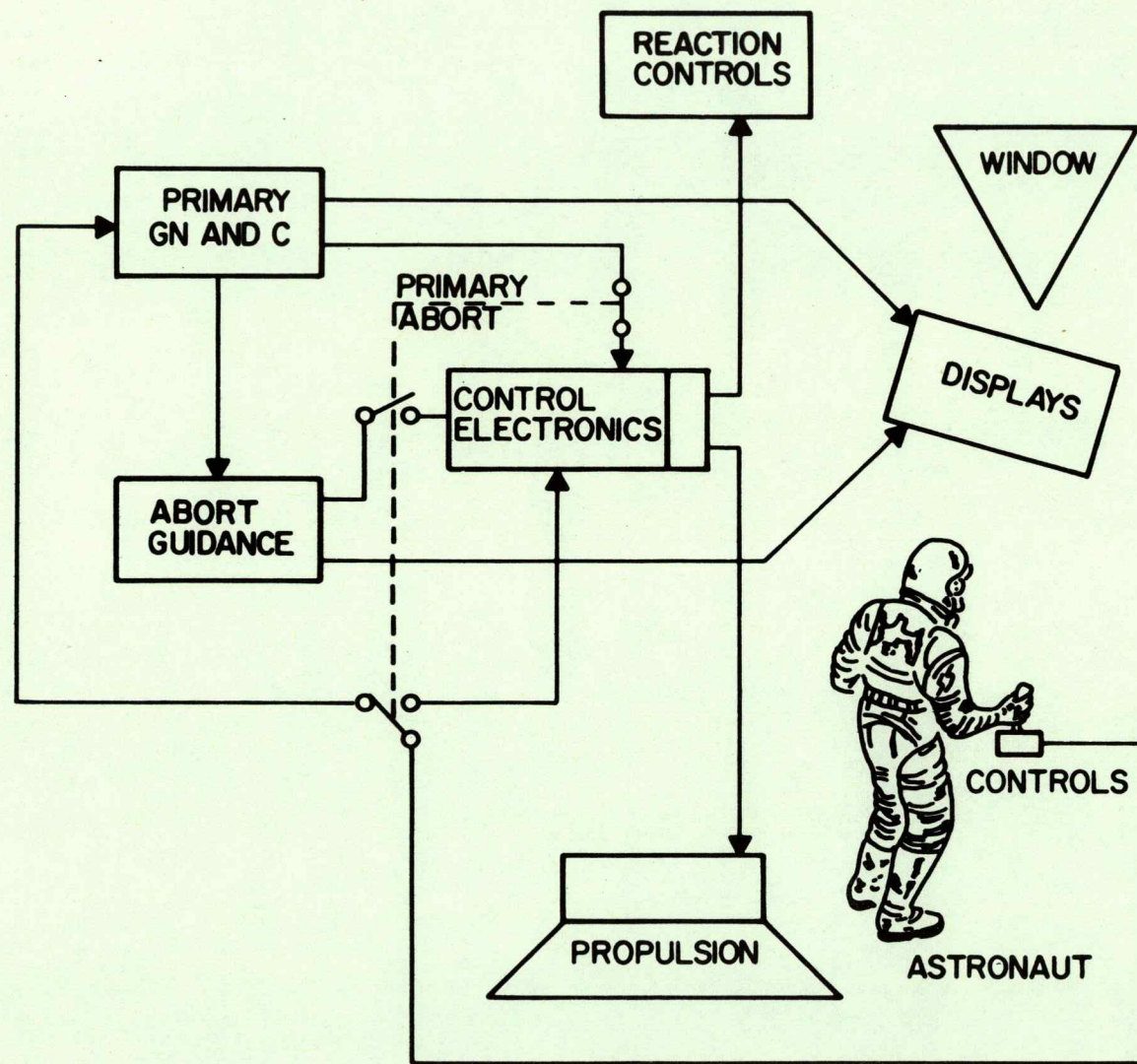
3. Trim Control

The descent engine gimbal trim is automatically controlled in both PGNS and AGS operations to compensate for center of gravity offsets during descent engine operation. In PGNS operation the LGC sends trim ON-OFF signals in two directions for each gimbal axis to the DECA. These signals operate power control circuitry which drives the Gimbal Drive actuators. In AGS operation Y and Z axes error signals from the ATCA are sent to the DECA for driving the GDA's. The two Gimbal Drive Actuators rotate the descent engine about the Y and Z axes a maximum of 6 degrees from the center position.

Ascent Engine Control

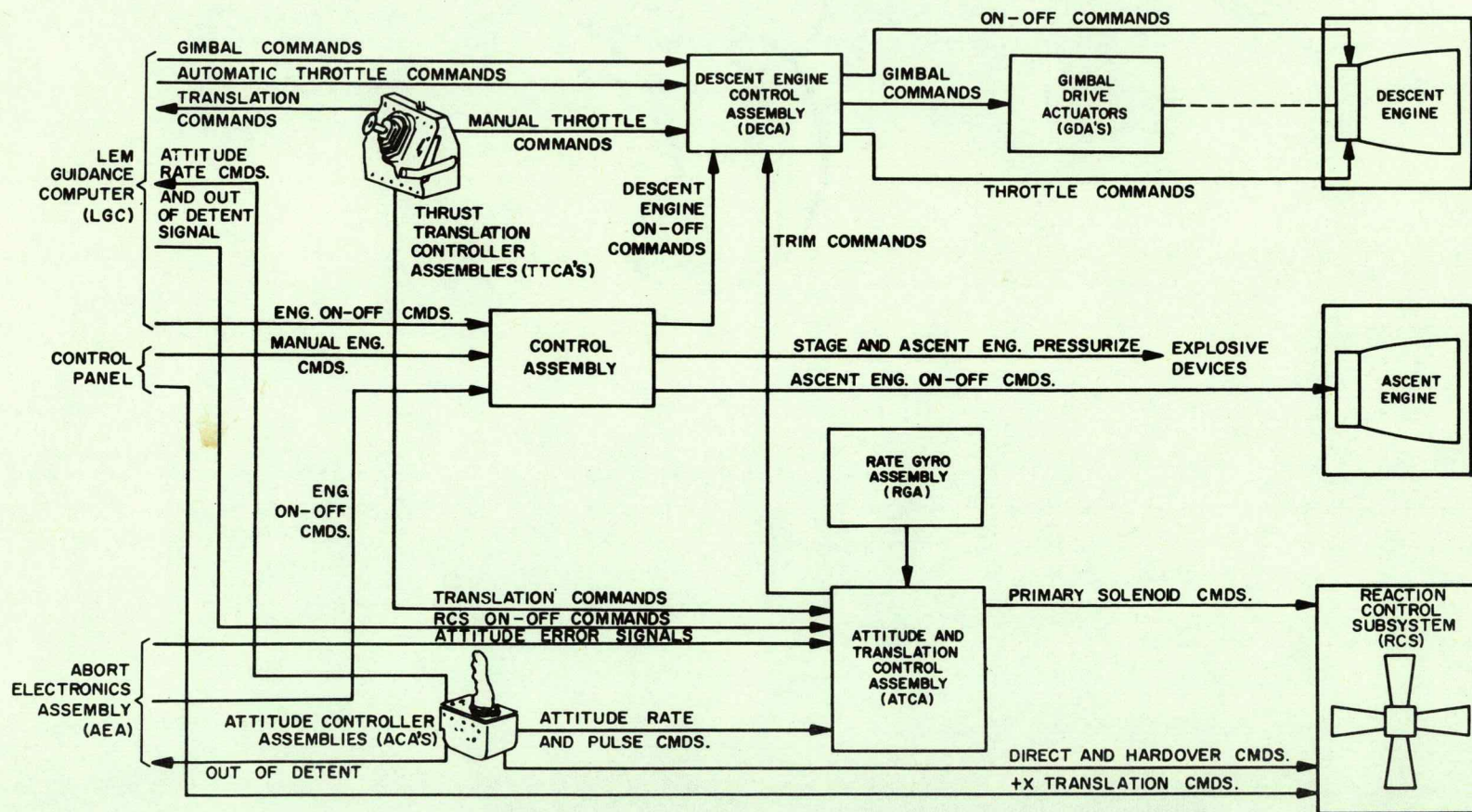
The ascent engine ignition and shutdown can be initiated by the PGNS, AGS, or crew. Automatic and manual commands are sent to the S & C Control Assemblies. The S & C Control Assemblies provides a logically ordered control of LM staging and engine ON-OFF commands. The command to the ascent engine comes from a latching device which provides a positive command for fail-safe purposes in the event that the engine ON command is interrupted. In the event of an abort stage command while the descent engine is firing the S & C Control Assemblies provide a time delay before commanding the LM to stage and ascent engine to fire. The delay is to insure the descent engine has completely stopped thrusting before the LM is staged.





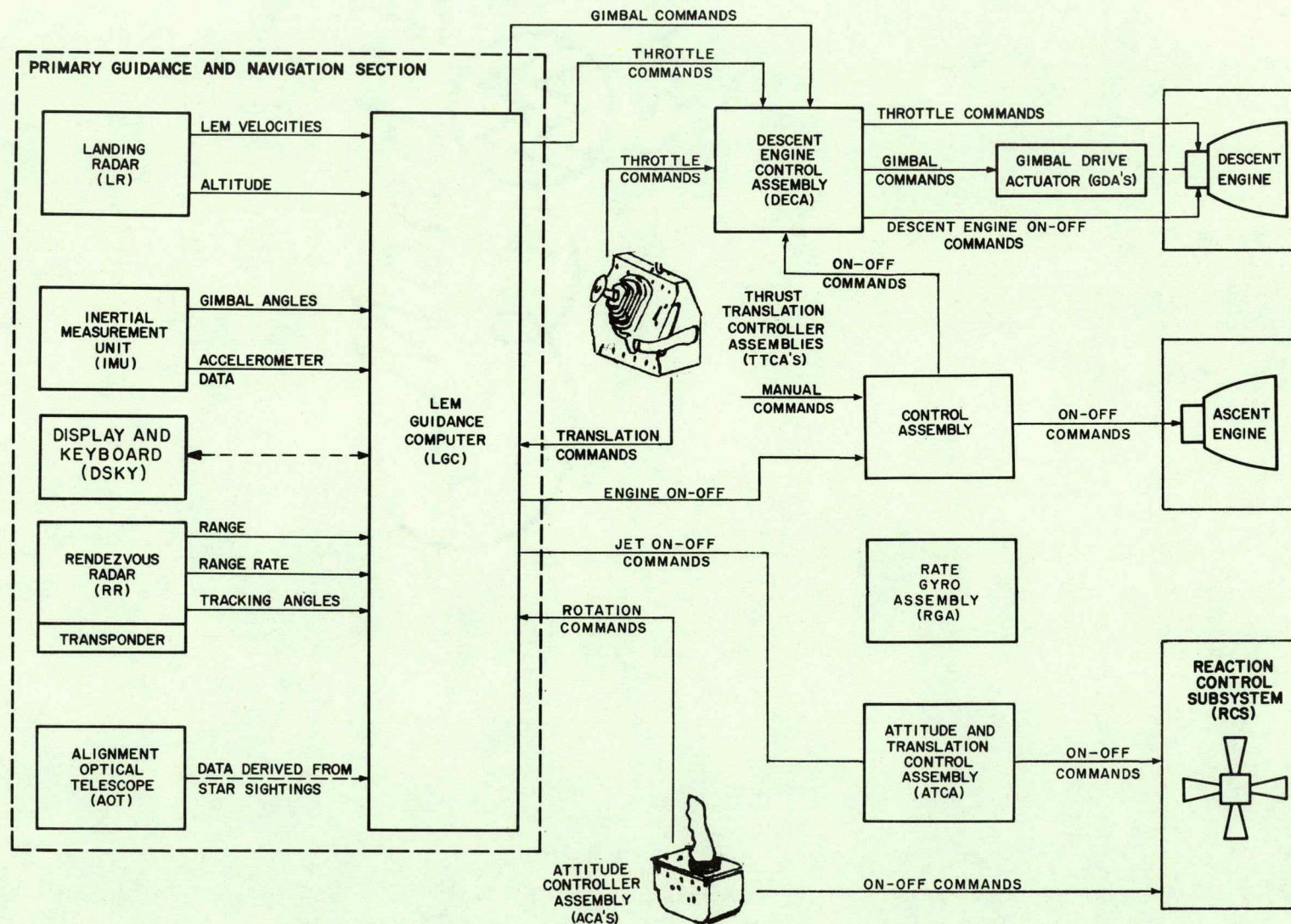
INTEGRATED FLIGHT CONTROL SUBSYSTEM

T30312-17
APRIL 66



CONTROL ELECTRONICS SECTION BLOCK DIAGRAM

T 30312-24
MAY 66



PRIMARY GUIDANCE PATH SIMPLIFIED BLOCK DIAGRAM

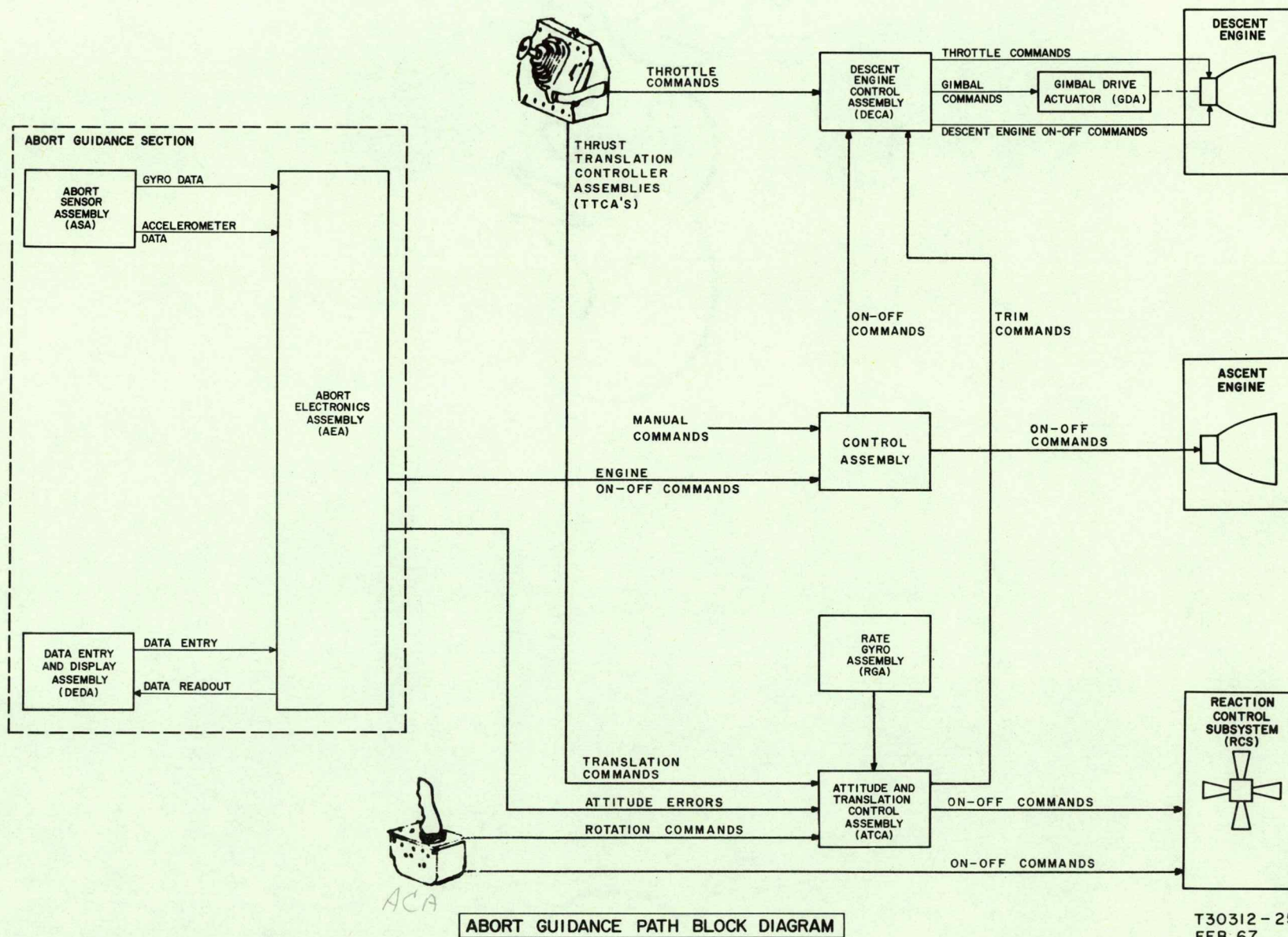
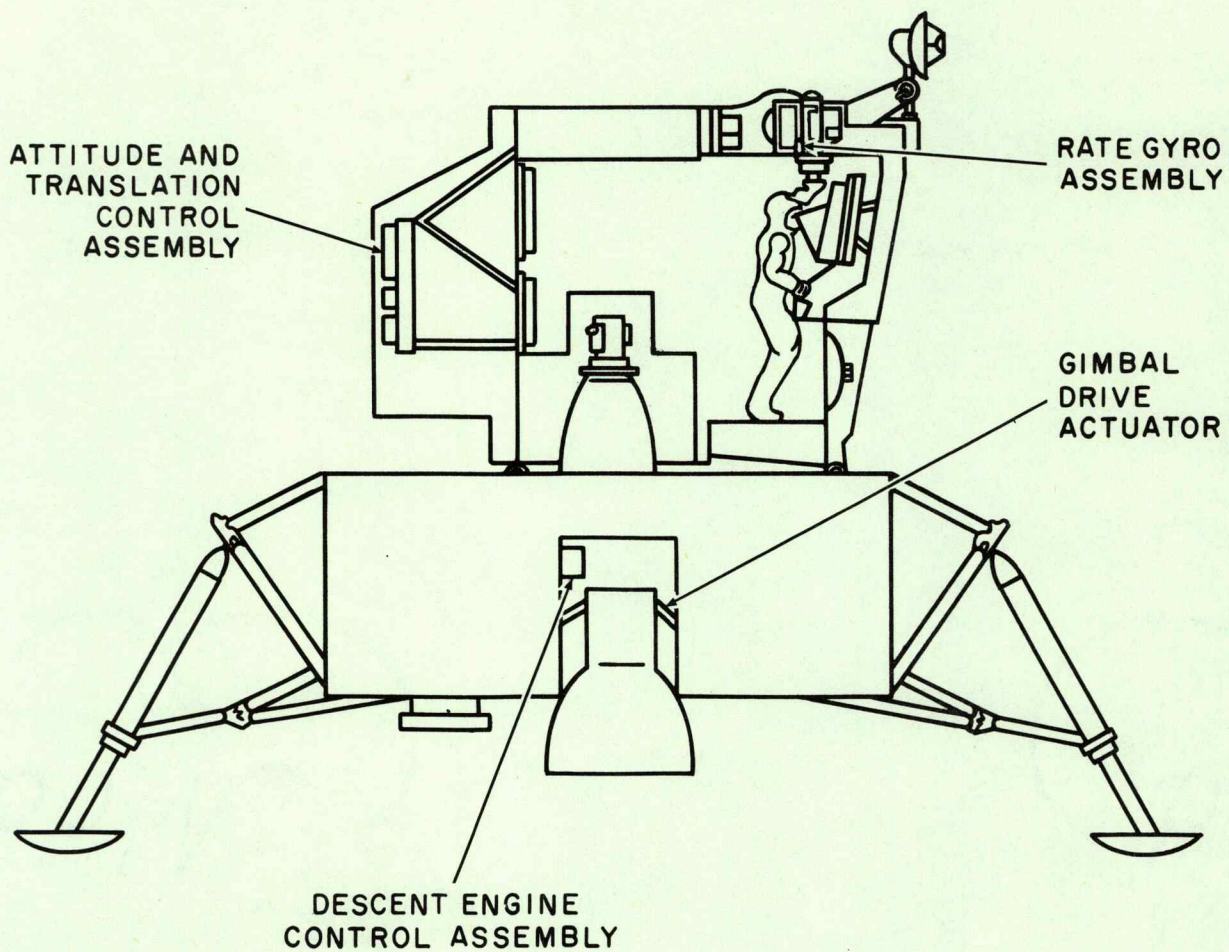


Figure 1-5



CES EQUIPMENT LOCATION

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II. CES ASSEMBLIES

1. Rate Gyro Assembly (RGA)

The rate gyro assembly consists of three sub-miniature single-degree of freedom rate gyros so mounted that they will sense vehicle roll, pitch, and yaw rates respectively. Each gyro is capable of measuring input rates up to ± 25 degrees per second and contains self test features consisting of a spin motor rotation detector and a self test torquer. Each rate gyro senses a rate of turn about its input axis, that is perpendicular to both the spin and output axis. In response to this input, the gyro precesses about its precession or output axis. Accordingly, the gimbal rotates against the torque restraint (torsion bar) until the input torque is equal to the restraining torque. Hence, the balanced gimbal position at this point is a measure of rate of turn. An electrical analog output (rate of turn) is obtained from the microsyn pickoff which is positioned by the precession of the gimbal.

Three phase 26 volt, 800 cps power, generated in the ATCA, is applied to the spin motor of each gyro. The flywheels run at synchronous speed of 24,000 rpm. Pickoff excitation of 28V 800 cps, generated in the ATCA, is applied to the primary of microsyn pickoff T1. The secondary of T1 will pickoff an 800 cps voltage proportional to the precession of the gyro and hence proportional to vehicle rate about the gyro input axis, .140 VRMS per degree per second. An in phase pickoff voltage indicates a positive rate and a 180° phase pickoff voltage indicates a negative rate. The pickoff voltage is sent to the rate meters for display and to the ATCA for rate damping in AGS guidance mode.

The gimbal torquer or self test torquer is used to apply a torque on the movable gimbal. When 28VDC is applied to winding L1 - L2 the secondary of T1 should pickoff a voltage equivalent to 5 degrees per second rotation. The direction of torquing is reversible by changing the polarity of the DC voltage.

Each gyro has two permanent magnets attached to the flywheel. These magnets induce pulses into winding L1 - L2. At synchronous speed the pulse frequency will be 1600 pulses per second. This signal can be monitored by ground support equipment.

2. 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 gimballed 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.

In PGNS operation, only the LGC preamplifiers are enabled by the guidance select 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. The balanced couple switch must be ON to enable all sixteen Abort Guidance preamplifiers. In the OFF position the four AGS preamplifiers controlling the upward firing jets are disabled.

In Abort Guidance operation 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 Attitude Controllers (ACA's) in detent. In narrow dead band 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 IM 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 gimballed descent engine. The deadband circuitry provides for either a wide deadband ($\pm 5^\circ$) or a narrow deadband ($\pm .3^\circ$ roll and pitch $\pm .4^\circ$ yaw). If a main engine is turned on, the deadband will automatically be switched to narrow. If the main engines are off the deadband depends on the position of the deadband switch on the control panel.

In automatic and attitude hold modes, the attitude error signals from the deadband circuits are applied to the summing amplifiers. In pulse mode, DC voltages from the Attitude Controller Assemblies (ACA's) are sent directly to the summing amplifiers. The eight summing amplifiers combine the attitude signals and translation commands from the Thrust Translation Controller Assemblies (TTCA's) and apply resultant signals to eight pulse ratio modulators. Logic circuitry determines whether 2 or 4 jets will fire for X-axis translation, pitch, and roll.

The 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 will fire one of a pair of opposing RCS jets depending on the sign of the input voltage.

3. S & C Control Assemblies

The displays and controls contain three S & C Control Assemblies which, among other functions, contain circuitry for processing automatic and manual main propulsion ON-OFF commands. Descent engine commands are processed and sent to the Descent Engine Control Assembly (DECA). These commands, consisting of descent engine arm, automatic and manual engine on and engine off, are further processed by the DECA for descent engine ignition and shutdown. The ascent engine commands are processed and engine ignition and shutdown commands are sent to the ascent engine and to pyrotechnics. The first time the ascent engine is started, pyrotechnics will use the engine ON command to start the staging sequence if the descent stage is still attached. The S & C control assemblies contain a memory circuit which will maintain the ascent engine on in the event of a loss of the automatic on signal until the receipt of an auto off or a manual stop. The DES.ENG. CMD. OVRD switch will apply a redundant feed to the descent engine through the S & C control assemblies. This command will keep the descent engine on in case of failure of the ON command from the Descent Engine Control Assembly. A manual stop will cause the S & C Control Assembly to remove this redundant feed.

4. 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 DECA receives auto engine ON, auto engine OFF, manual descent engine start, manual descent stop, and descent engine arm from the S & C control assemblies. If the descent engine arm is received, the DECA will turn on the descent engine if either an auto on or a manual start is received. If the engine was started by an auto on, either an auto off or a manual stop will shut it down. However, if the engine was started with a manual start, the DECA requires a manual stop or removal of the D.E. arm to shut it down. The DECA contains a memory circuit which will maintain the descent on if after receiving an automatic on, conflicting automatic commands are received. Either ON and OFF simultaneously or neither ON or OFF.

Manual throttle commands can be applied to the descent engine with the THR.CONT. 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 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 to a malfunction logic circuit and 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 and sends TRIM FAILED signals to the LGC and Instrumentation. The ENG. GIMBAL switch may be used to disable the two Gimbal Drive Actuators.

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 and power switching circuits. The rest of the operation is the same as in PGNS operation.

5. 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 axes. The GDA's move at a constant speed and rotate the descent engine at a rate of $.2^{\circ}$ per second.

The position transducer receives 115V 400 cps from the DECA on its primary winding. The secondary voltage is 400 cps, 7.5 volts per inch travel from mid-position; in phase when extended and 180° out of phase when retracted past the mid-position. The transducer output is sent to instrumentation for telemetry and to the DECA malfunction logic.

6. 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 counterclockwise 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.

28V 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 $.5^\circ$ 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 .28 volts per degree hand displacement from 1° to 11° displacement. Positive rotation commands will generate in phase voltage and negative commands 180° out of phase voltage.

When pulse operation is selected in PGNS operation, the LGC common, applied to a pair of ACA switches, is sent back to the LGC when the hand controller is displaced by more than $2-1/2^\circ$. When pulse operation is selected in AGS operation for an axis, plus and minus DC voltages are applied to a pair of ACA switches. When the hand grip is displaced 2.5° 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 acceleration.

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

The ACA's are also used in an incremental landing point designator (LPD) mode available to the crew during the final approach phase. In this mode the angular error between the current designated landing site and the desired landing site is nulled by repetitive manipulation of an Attitude Controller Assembly. The controller LPD signals are directed to the LGC, which will issue commands to incrementally shift the designated LM landing site along the Y and Z axes.

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

7. 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 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

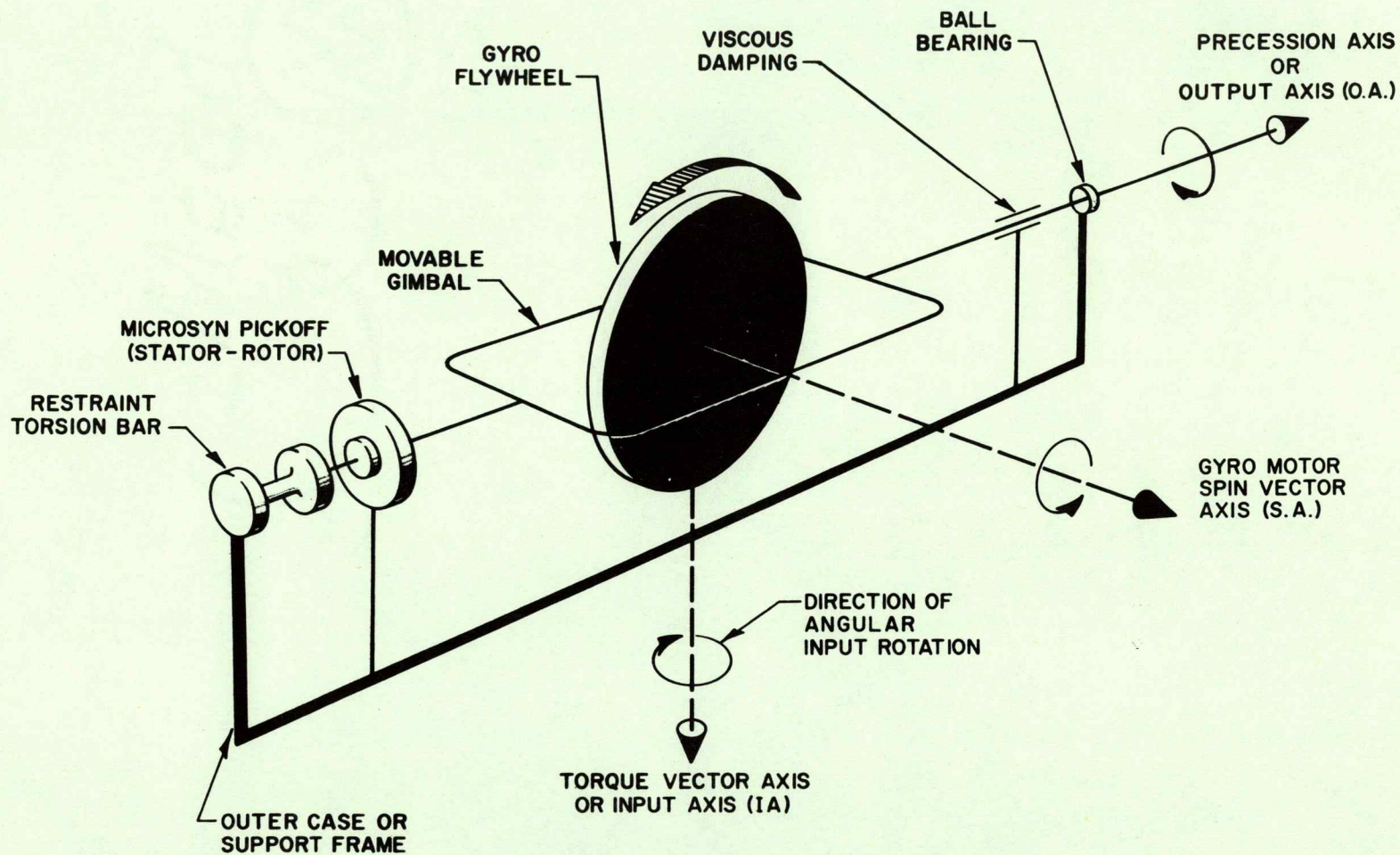
throttling capability of the descent engine. Two controllers are installed in the IM, one available for each astronaut. Due to the controller's mounting position, vehicle translations correspond approximately to astronaut hand motions. Motion of the controller to the left or right will command translations along the Y-axis, up and down movement will command translations along the X-axis, and movement of the controller forward or backward will result in translations along the Z-axis.

Each TTCA contains switches for commanding translation via RCS jets. One pair of switch contacts in each axis sends the desired command to the LGC when the hand grip is displaced approximately .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. Depending on the position of the Manual Throttle Switch either the Commander or Systems Engineer (IM pilot) will be able to generate manual throttle commands. The secondary winding of the transducer will pick up a voltage depending 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.

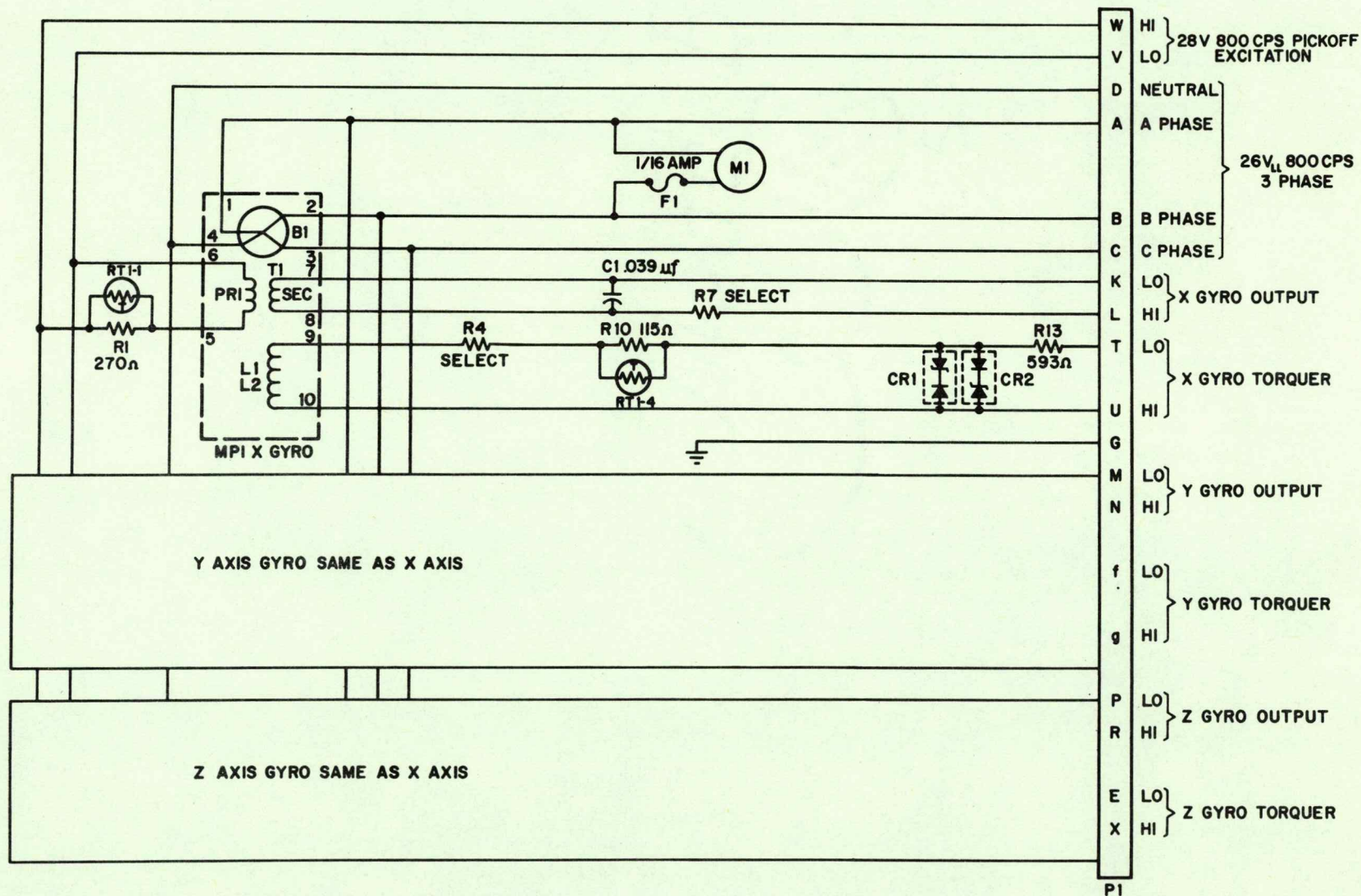
CES 800 CPS Synchronization

Since the CES uses analog 800 cps signals, it is necessary to synchronize the various assemblies. In PGNS operation the ACA's and TTCA's receive 28V 800 cps from the Power and Servo Assembly of the PGNS. The proportional attitude commands to the LGC will be either in phase or 180° out of phase with this 800 cps signal. In AGS operation, the ACA's and TTCA's receive 28V 800 cps from the ATCA. The proportional attitude commands back to the ATCA are now in synchronization with the ATCA power supply. The AGS and RGA receive 28V 800 cps from the ATCA and their outputs back to the ATCA will be in synchronization. The rate meters on the display panel also receive the 800 cps synchronization voltage in order to properly display the RGA signals.



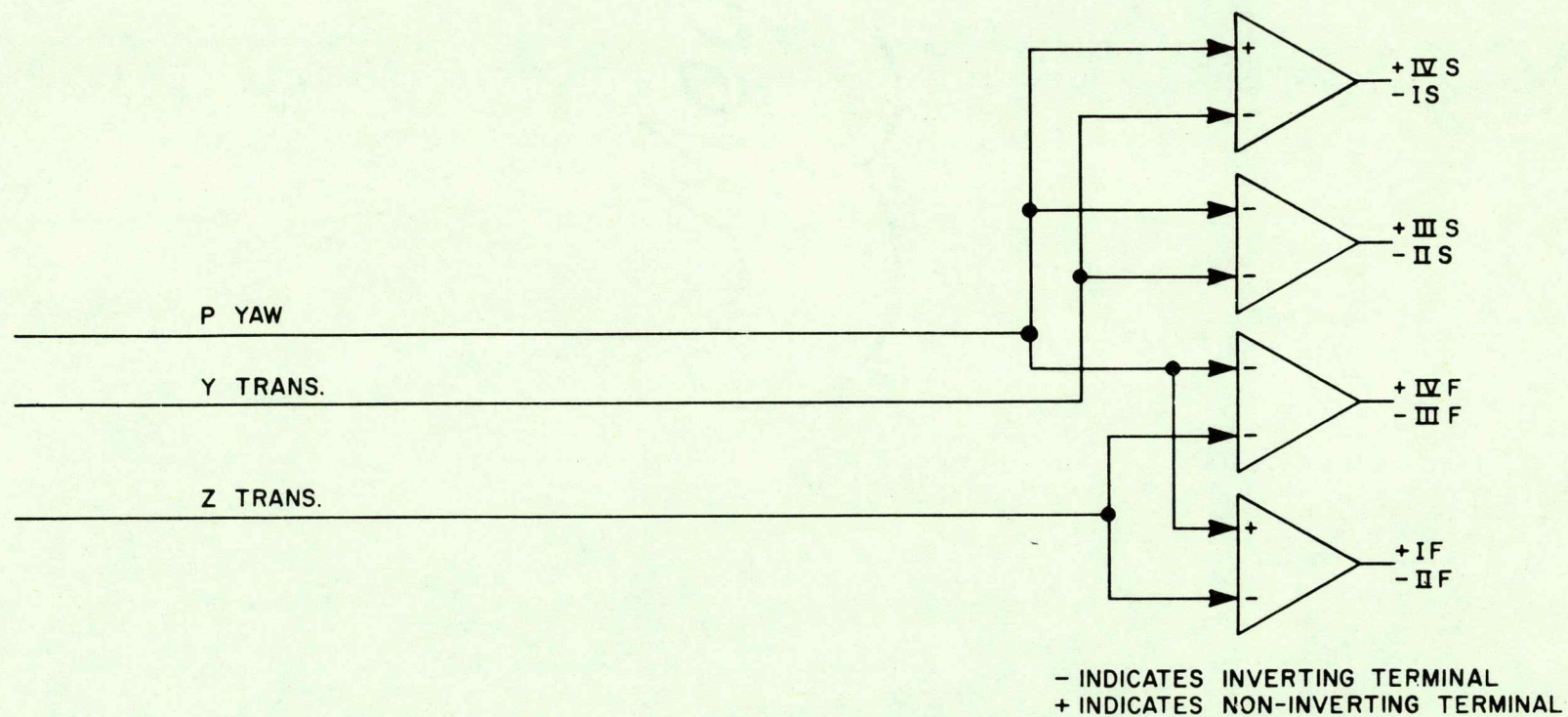
RATE GYRO-SIMPLIFIED DRAWING

T30312-29
FEB 66

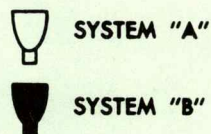
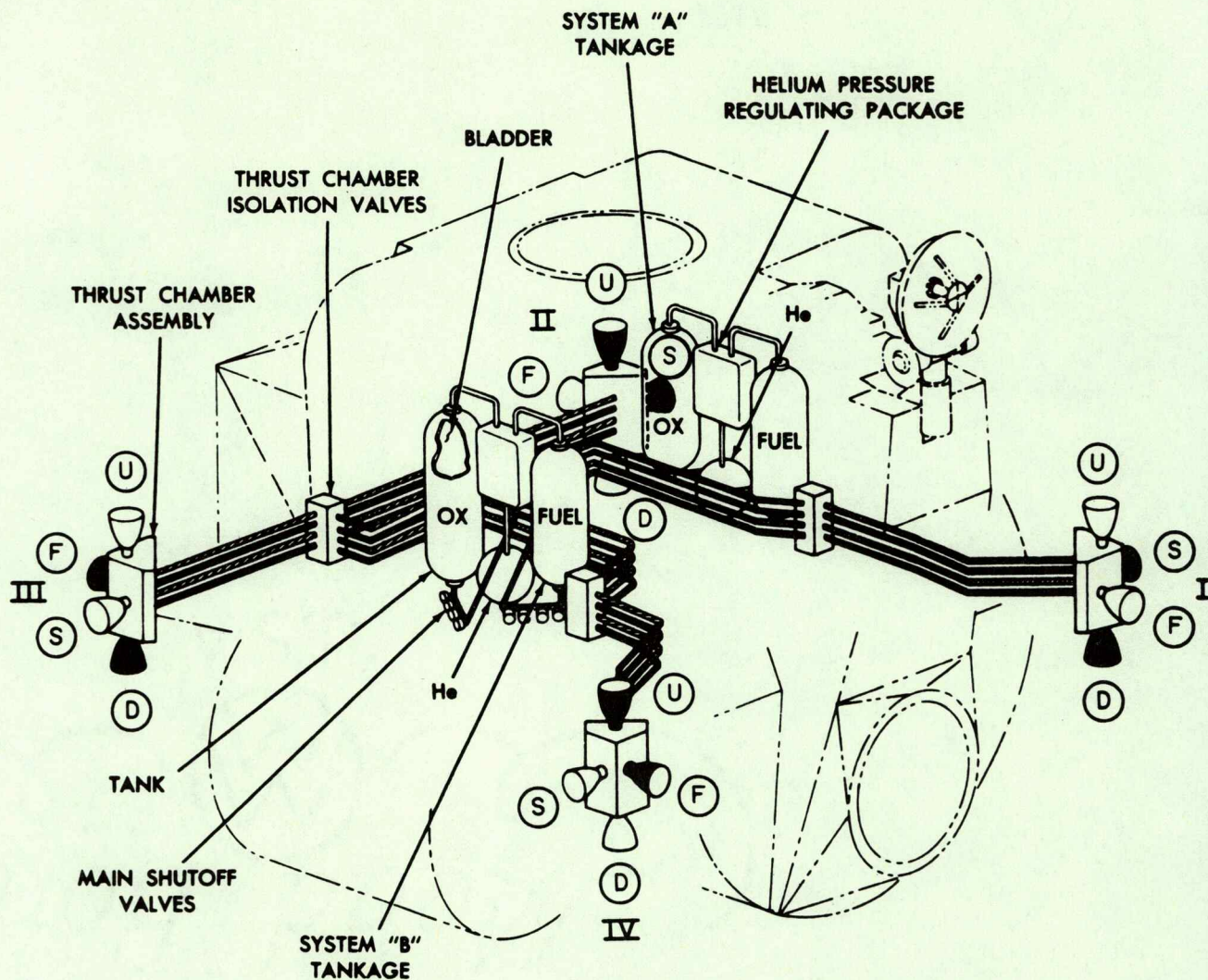


RATE GYRO ASSEMBLY SCHEMATIC



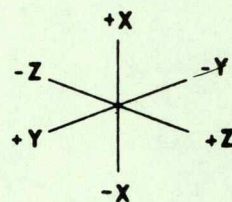


HORIZONTAL SUMMING AMPLIFIERS

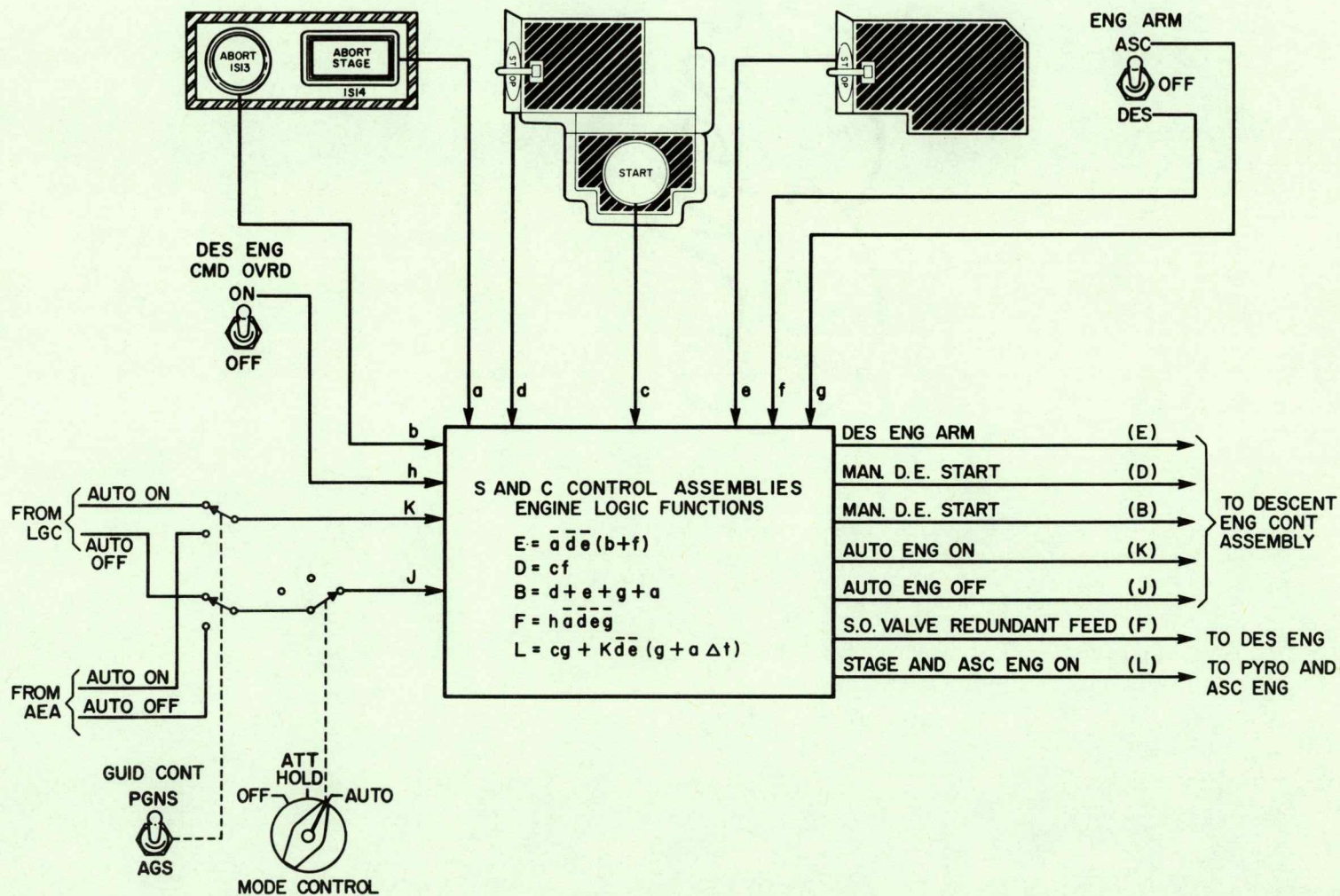


RCS INSTALLATION

AXES ORIENTATION

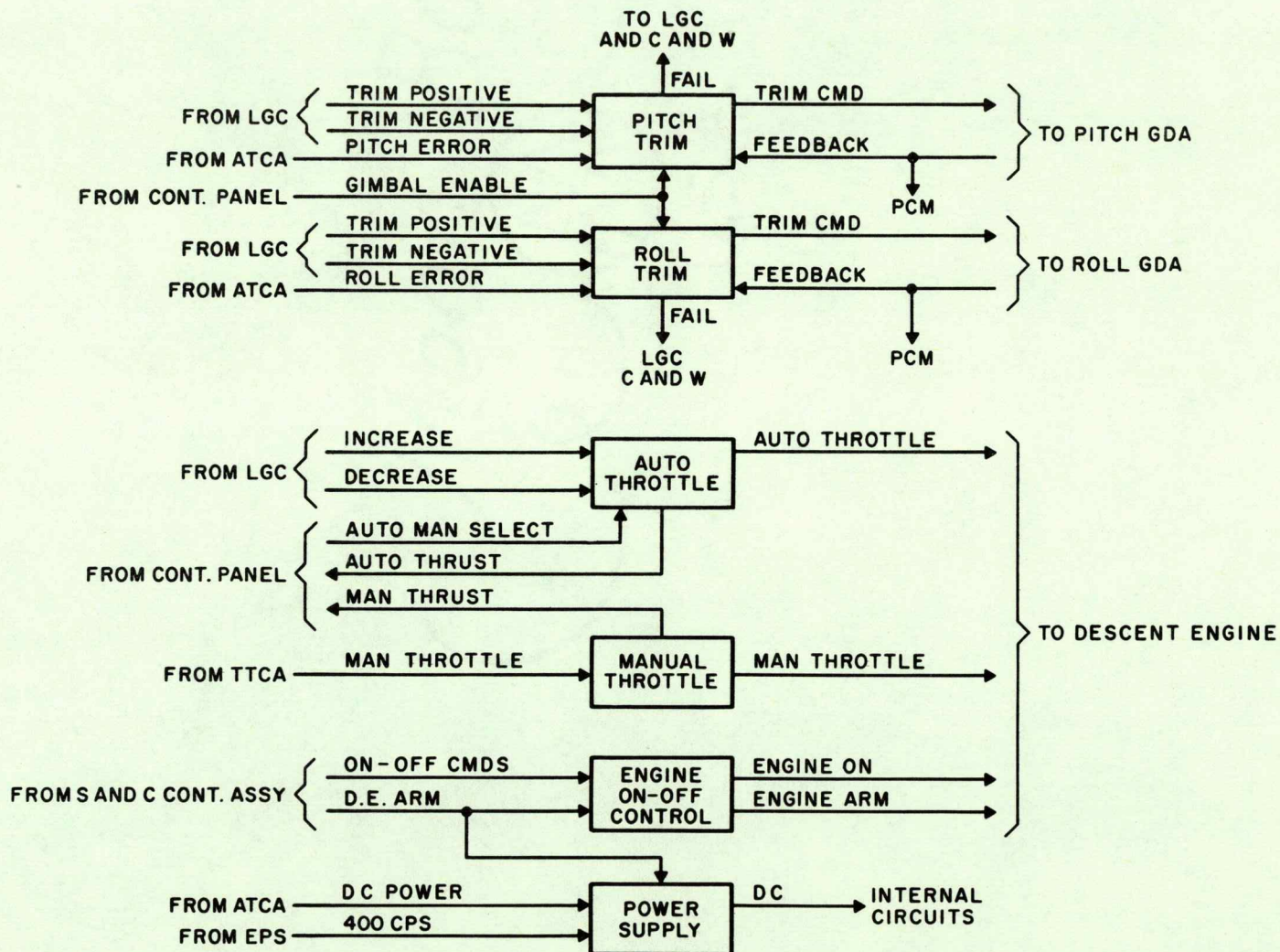


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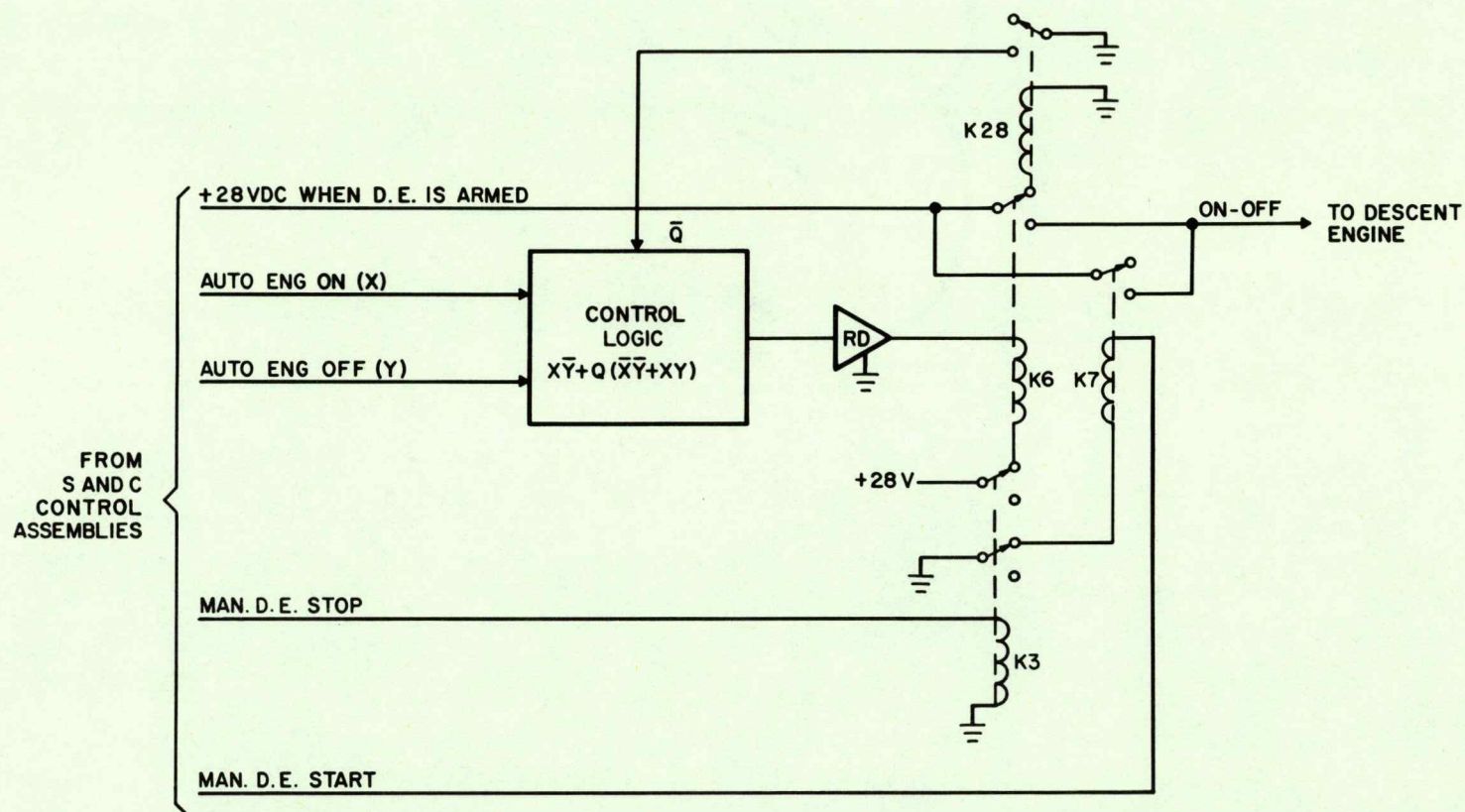
S AND C CONTROL ASSEMBLIES ENGINE LOGIC

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FEB 67



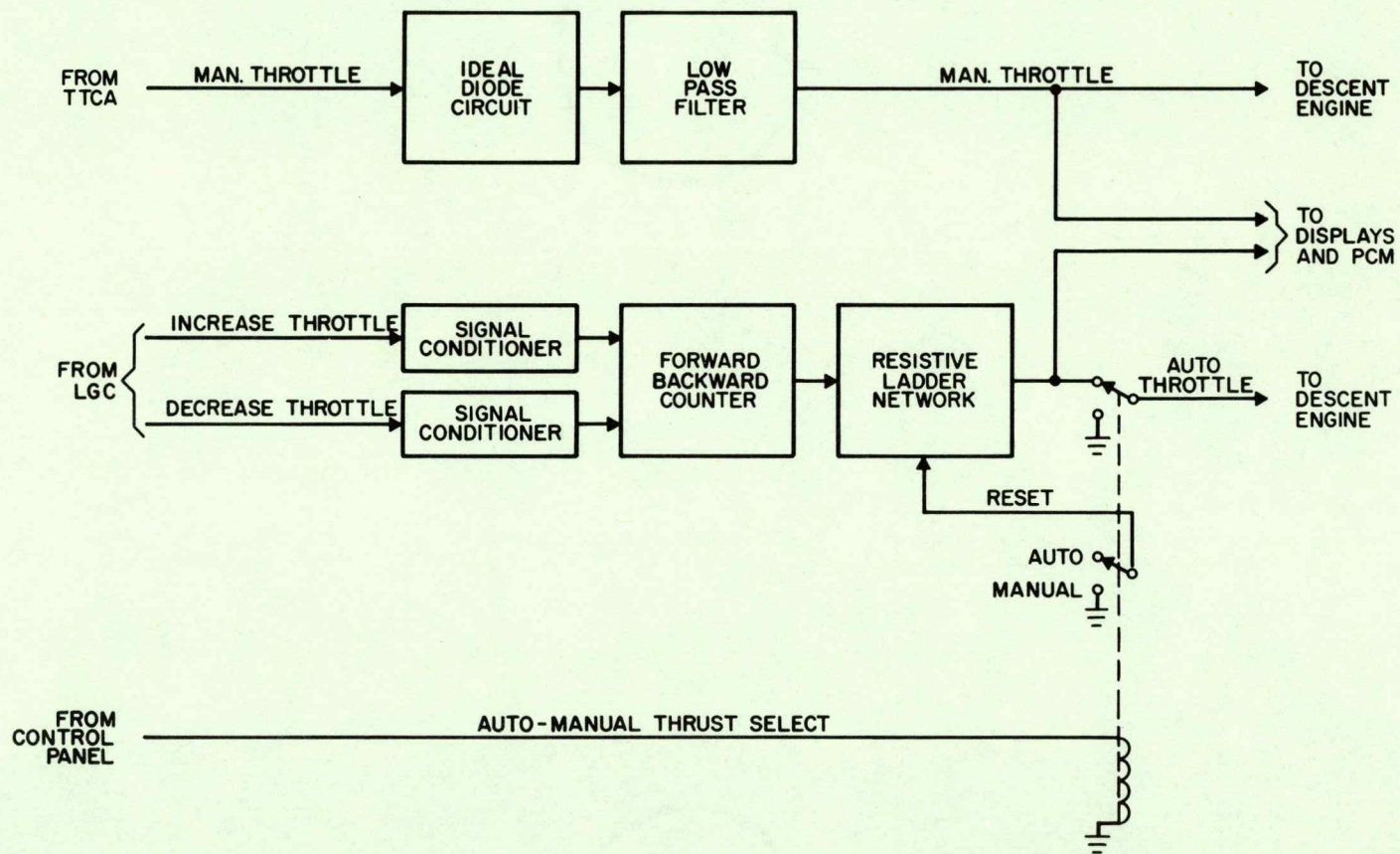
DESCENT ENGINE CONTROL ASSEMBLY BLOCK DIAGRAM

T30312-12
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DECA DESCENT ON-OFF CONTROL

T30312 - 51
FEB 67



DECA THROTTLE CONTROL BLOCK DIAGRAM

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FEB 67

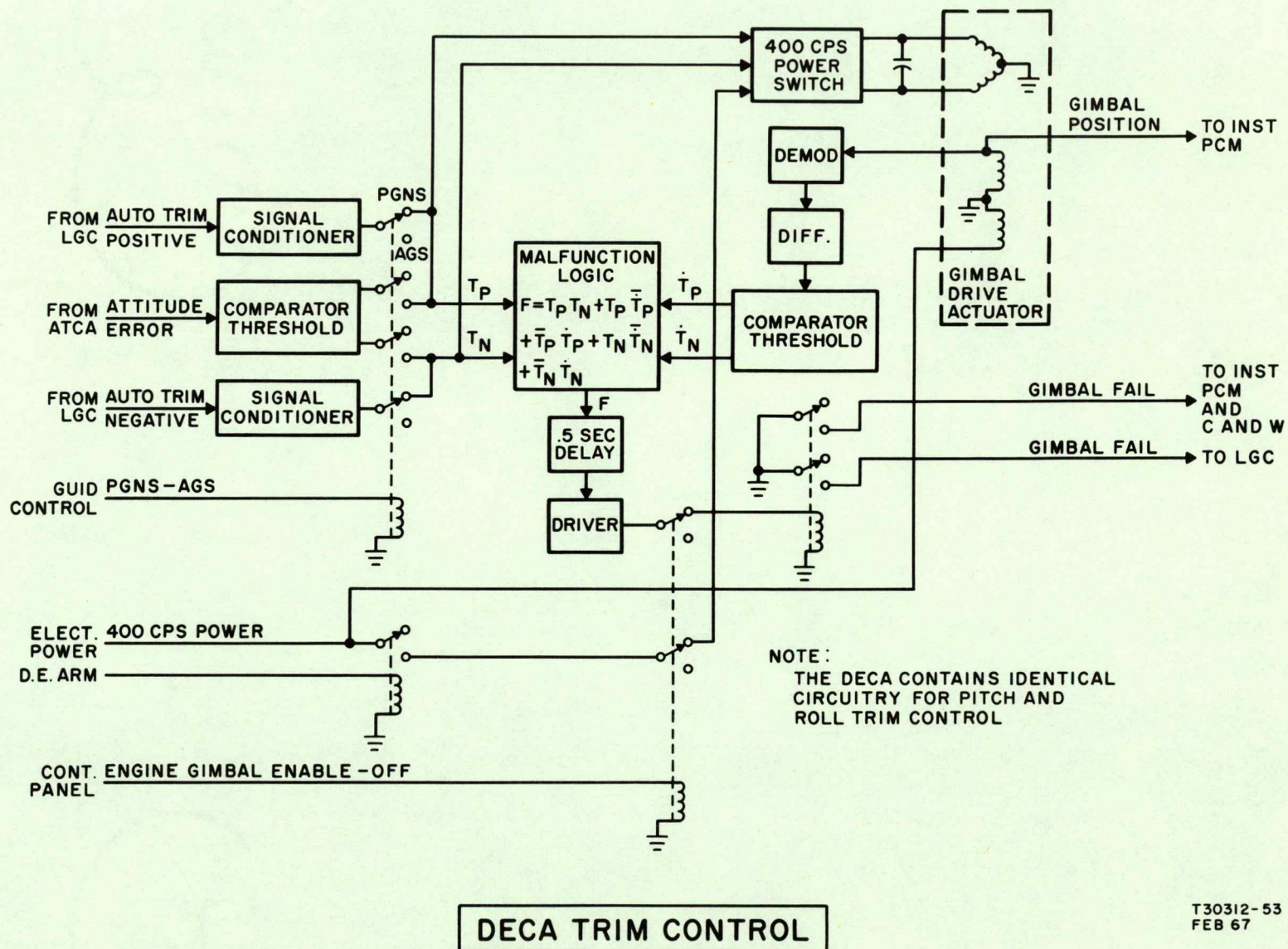
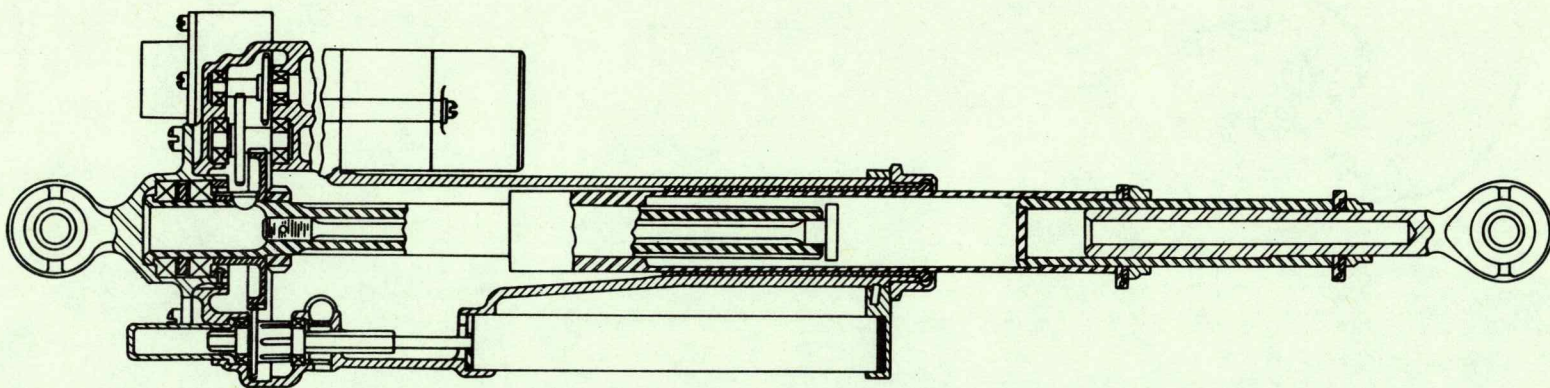
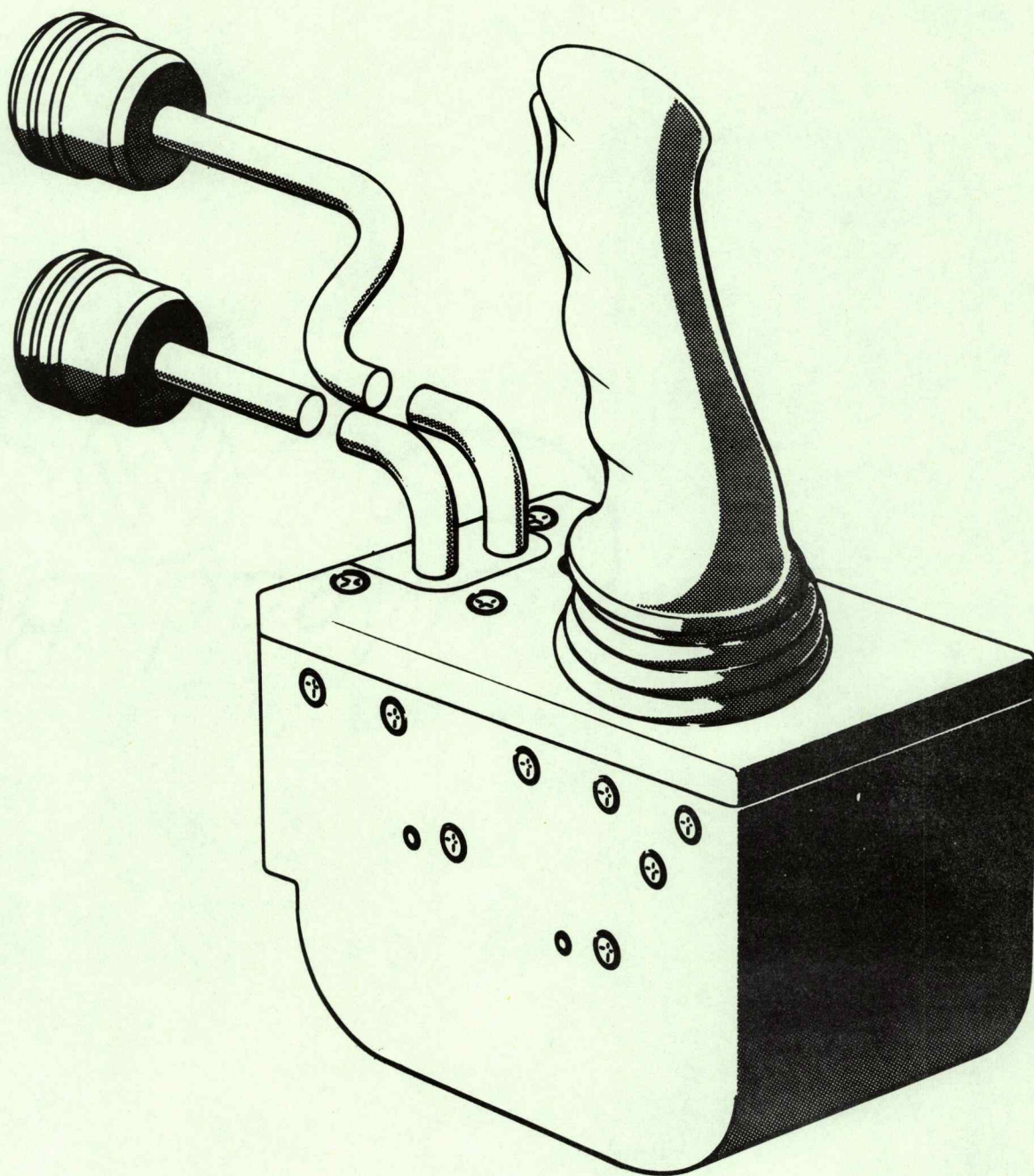


Figure 2-11

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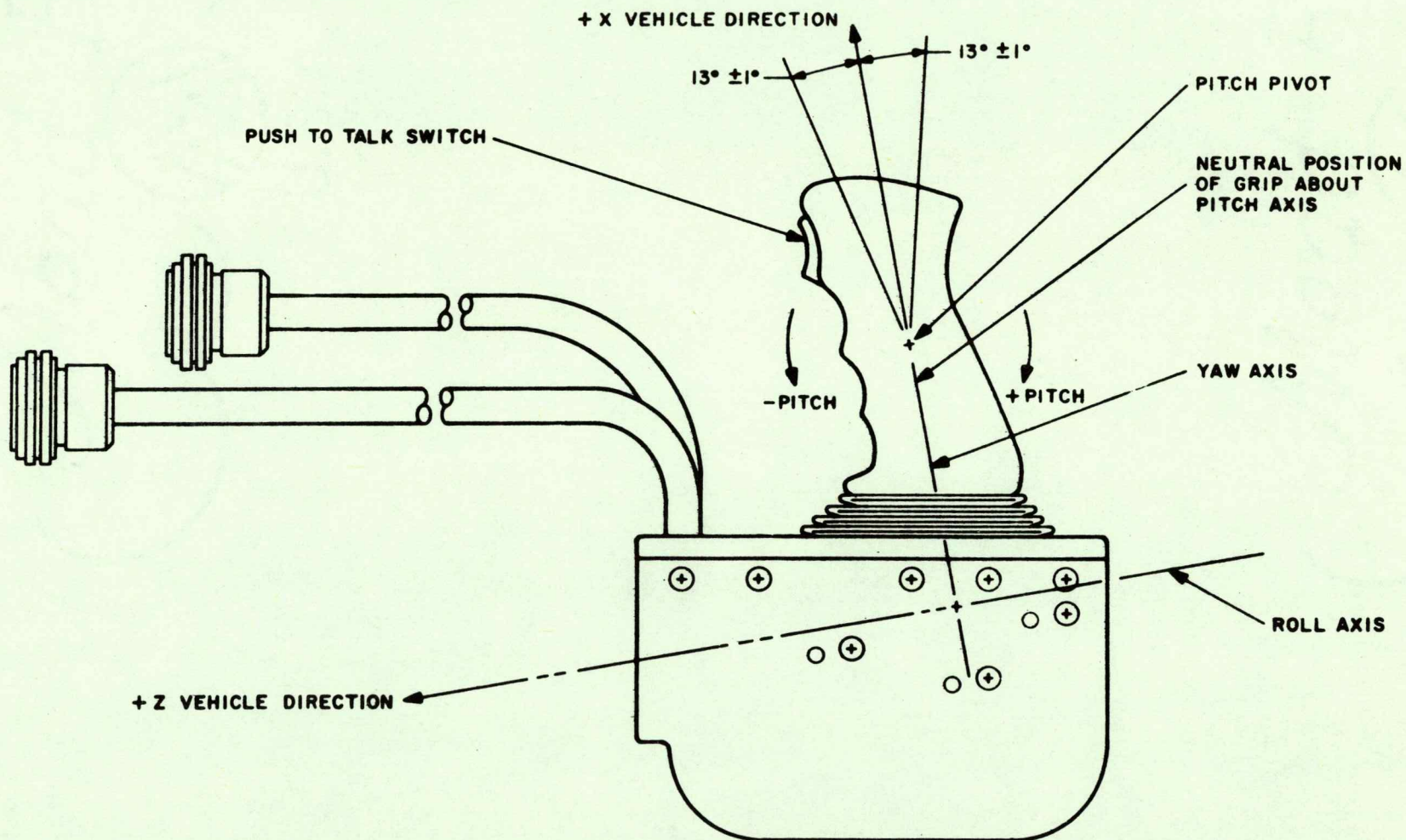


DESCENT ENGINE GIMBAL DRIVE ACTUATOR



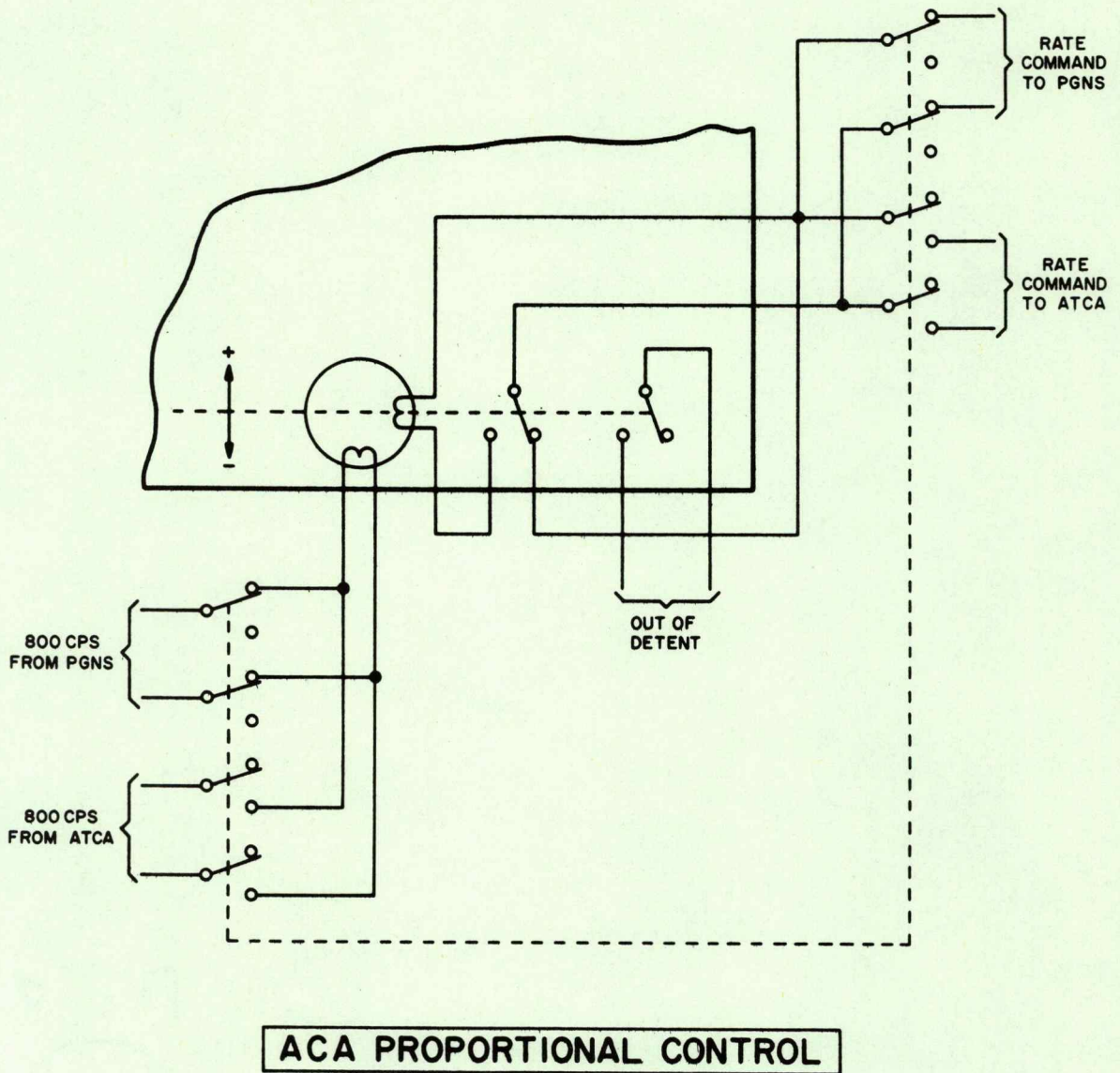
ATTITUDE CONTROLLER ASSEMBLY

T30900-15
JAN 66



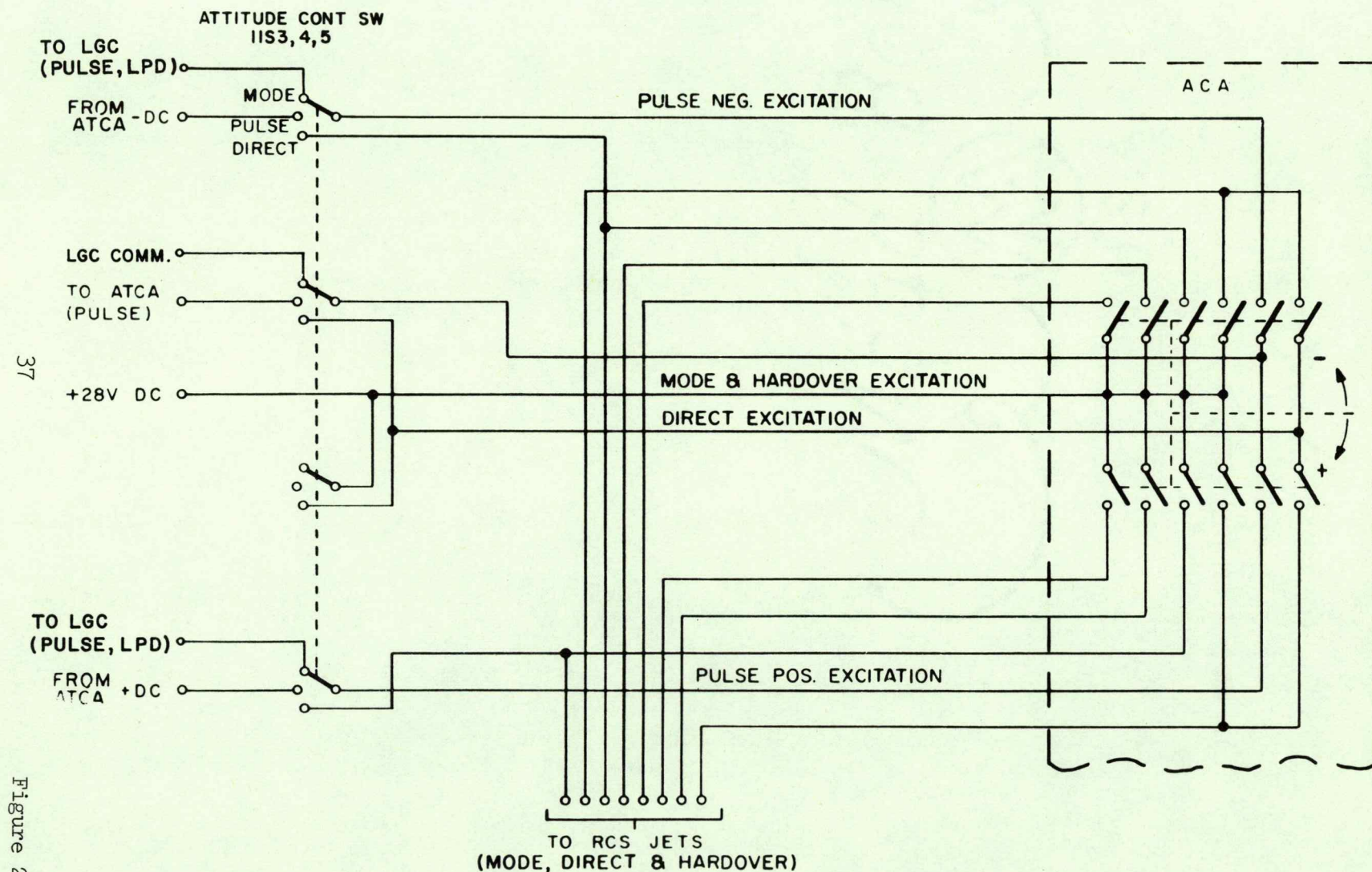
ACA MANIPULATION

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T30405-83
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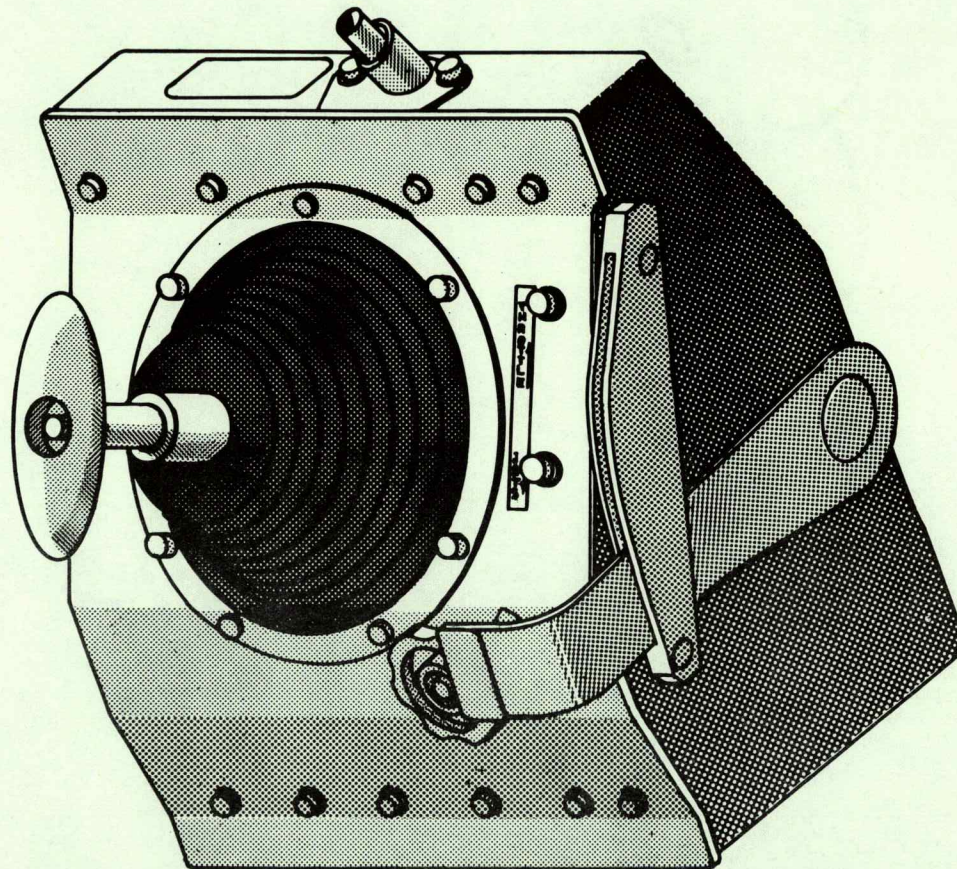
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TYPICAL DISCRETE ATTITUDE CONTROL SECTION

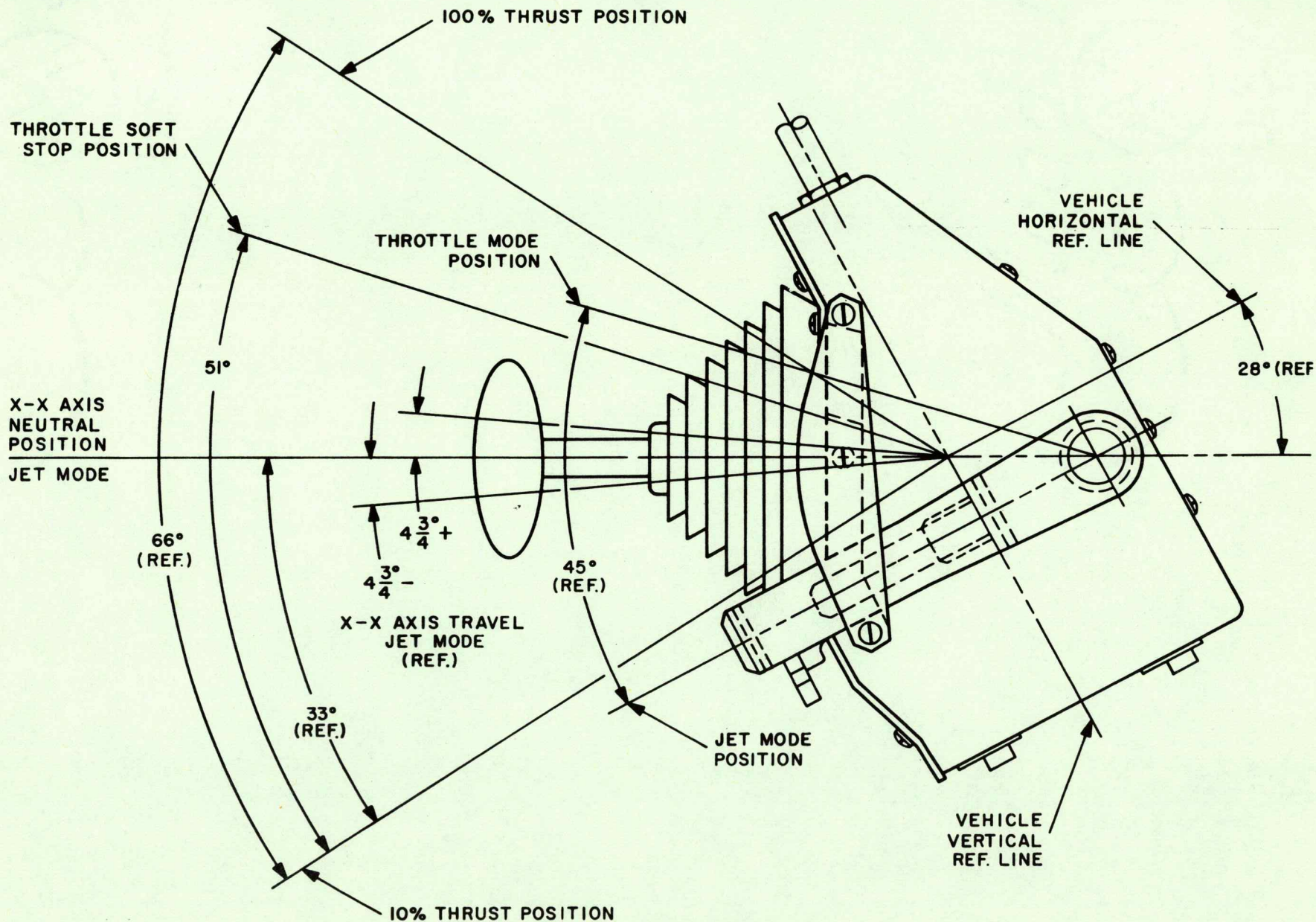
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Figure 2-16



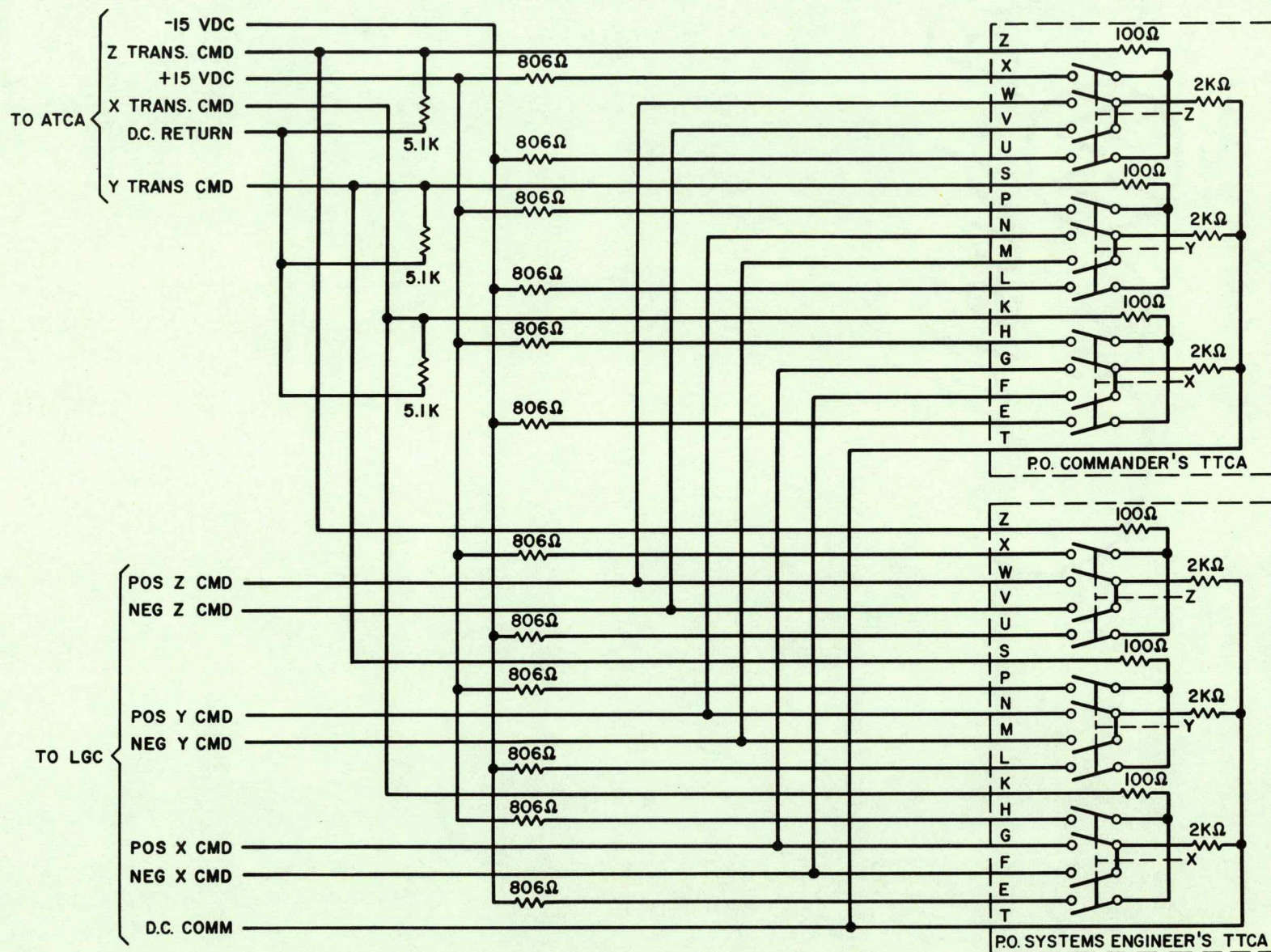
THRUST TRANSLATION CONTROLLER ASSEMBLY

T 30900-14
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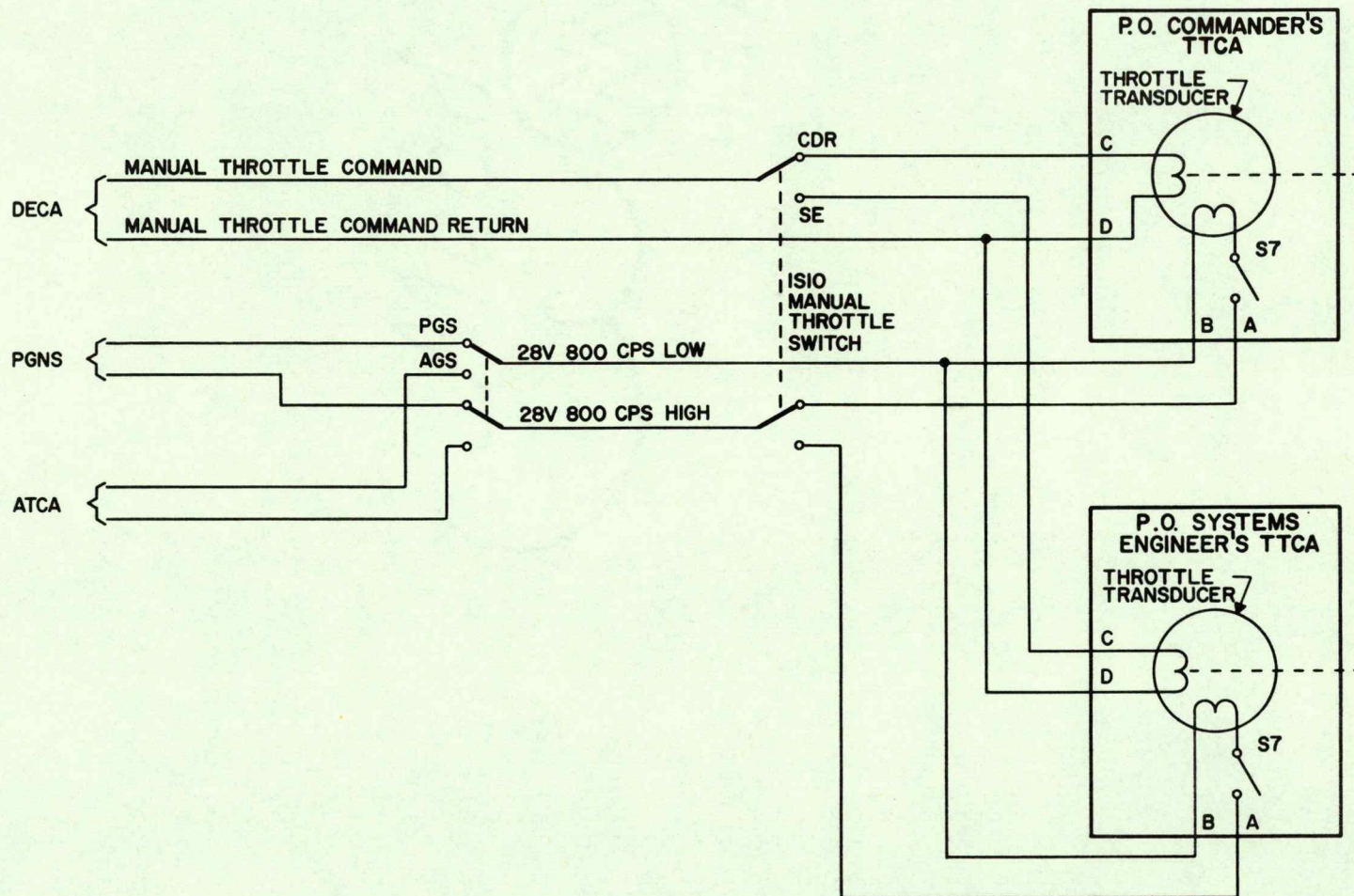
TTCA MANIPULATION

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JAN. 66



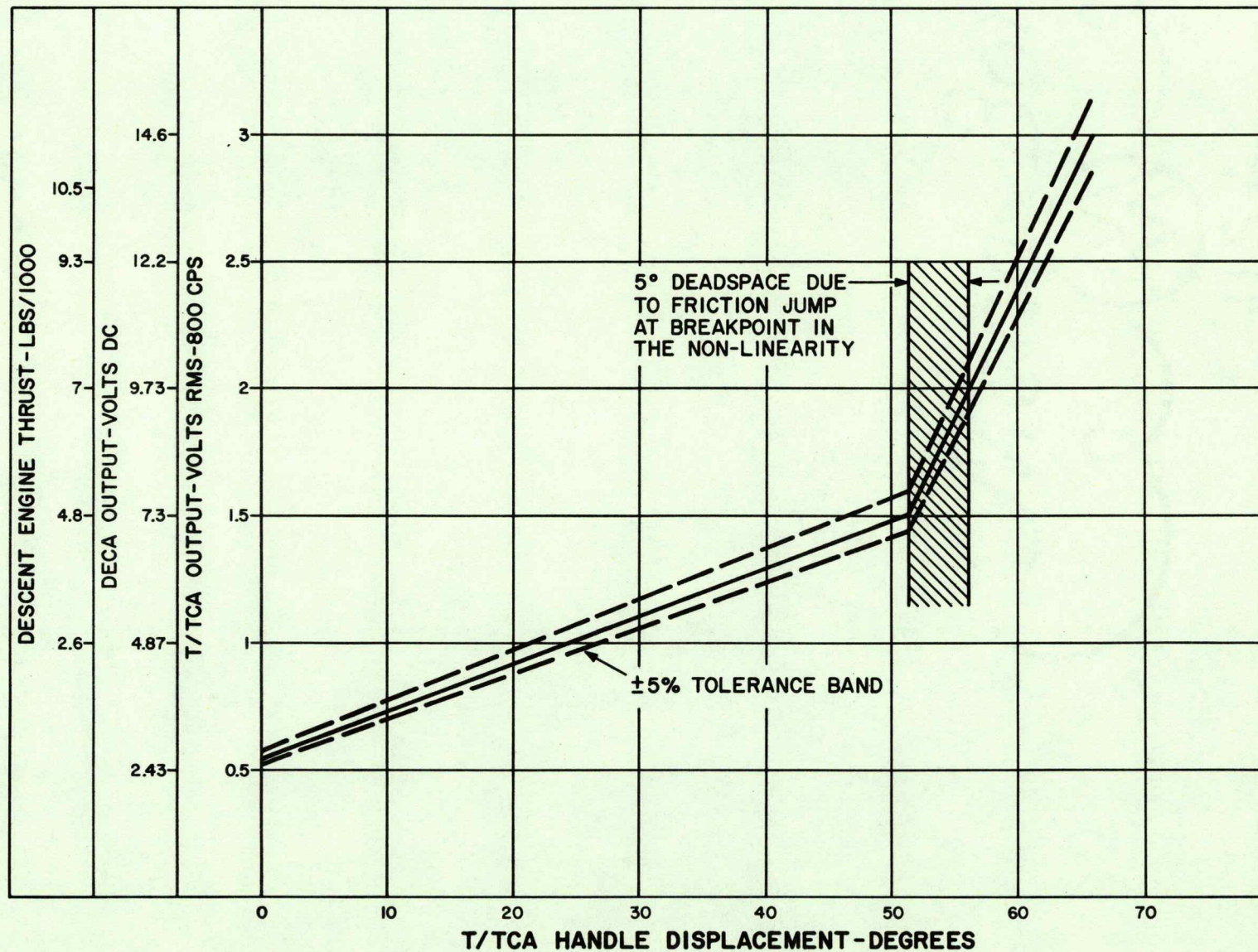
TTCA TRANSLATION INTERFACE

T 30312 - 32
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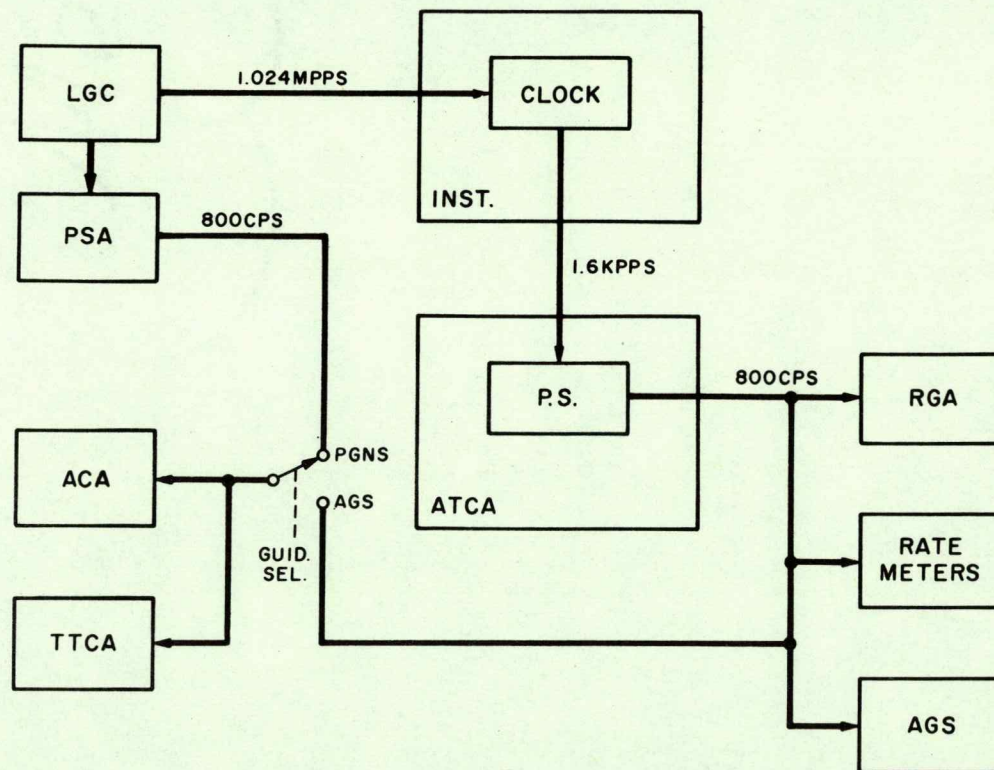


TTCA THROTTLE TRANSDUCER INTERFACE

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FEB 67



**THROTTLE CONTROL MODE
OUTPUT VS DISPLACEMENT**



CES 800CPS SYNCH

III. SUMMARY OF CES MODES OF OPERATION

PANEL SWITCHES

GUIDANCE CONTROL - 9S6 - PGNS

MODE CONTROL -11S6 - AUTO

ATTITUDE CONTROL - Normally in MODE
11S3 - 11S4 - 11S5 CONTROL

Must be in MODE
CONTROL for single
pulse and LPD modes

GUIDANCE SIGNALS

- Automatic steering and translation is accomplished by LGC commands to the jet drivers.

MANUAL ATTITUDE CONTROL

- X-axis override available for PGNS, whereby the crew commands X-axis rates proportional to controller displacement.

MANUAL TRANSLATION CONTROL

- The crew can command linear translation of the vehicle through on/off firing of the jets via the LGC by moving a TTCA out of detent.

ATTITUDE DAMPING

- Rate compensation is accomplished within the LGC.

ENGINE GIMBAL CONTROL

- Pitch and Roll Gimbal commands go directly to gimbal power control circuitry in the DECA from the LGC.

REMARKS

- All jet commands go to the jet drivers directly from the LGC. An override of the attitude control function is accomplished by moving the attitude controller to the hardover position, thereby commanding on/off four-jet operation through the secondary coils of the thruster solenoid valves. An override of +X translation is obtained by commanding four-jet operation direct to the RCS secondary coils by means of a control button on the panel.

PANEL SWITCHES:

GUIDANCE CONTROL - 9S6 - PGNS

MODE CONTROL - 11S6 - ATTITUDE HOLD

ATTITUDE CONTROL -
11S3 - 11S4 - 11S5 - Normally in MODE
CONTROL

Must be in MODE
CONTROL for single
pulse and LPD modes

GUIDANCE SIGNALS

- Vehicle stabilization is accomplished by LGC commands to the jet drivers.

MANUAL ATTITUDE
CONTROL

- The crew commands vehicle attitude rates proportional to controller displacement. Vehicle attitude is held when the controller is in detent.

MANUAL TRANSLATION
CONTROL

- The crew can command linear translation of the vehicle through on/off firing of the jets via the LGC by moving a TTCA out of detent.

ATTITUDE DAMPING

- Rate compensation is accomplished within the LGC.

ENGINE GIMBAL CONTROL

- Pitch and Roll Gimbal commands go directly to gimbal power control circuitry in the DECA from the LGC.

REMARKS

- All jet commands go to the jet drivers directly from the LGC. An override of the attitude control function is accomplished by moving the attitude controller to the hardover position, thereby commanding on/off four-jet operation through the secondary coils of the thruster solenoid valves. An override of +X translation is obtained by commanding four-jet operation direct to the RCS secondary coils by means of a control button on the panel.

A single pulse mode is available by entering a command in the DSKY. In this mode the LGC will command one RCS pulse each time the hand controller is displaced out of detent.

PANEL SWITCHES:

GUIDANCE CONTROL - 9S6 - AGS

MODE CONTROL - 11S6 - AUTO

ATTITUDE CONTROL - - MODE CONTROL
11S3 - 11S4 - 11S5

GUIDANCE SIGNALS

- Automatic steering signals from the AGS are sent to the Control Electronics Section to command changes in vehicle attitude.

MANUAL TRANSLATION
CONTROL

- The crew can command translation along the vehicle axes by ON/OFF firing of the jets when a TTCA is moved out of detent.

ATTITUDE DAMPING

- Rate gyro signals summed with steering signals.

ENGINE GIMBAL CONTROL

- Pitch and Roll Gimbal commands are derived from the ATCA attitude error channels.

REMARKS

- All jet commands go through the ATCA jet select logic and PRM. An override of the attitude control function is accomplished by moving the attitude controller to the hardover position thereby commanding ON/OFF 4-jet operation through the secondary coils of the thruster-solenoid valves bypassing the jet select logic, the PRM's and the jet drivers. An override of +X translation is obtained by commanding 4-jet operation direct to the RCS secondary coils by means of a control button panel.

PANEL SWITCHES:

GUIDANCE CONTROL - 9S6 - AGS

MODE CONTROL - 11S6 - ATTITUDE HOLD

ATTITUDE CONTROL - - MODE CONTROL
11S3 - 11S4 - 11S5

GUIDANCE SIGNALS

- Automatic stabilization signals sent to Control Electronics Section to maintain vehicle attitude commanded by the crew.

MANUAL ATTITUDE CONTROL

- The crew commands vehicle attitude rates proportional to controller displacement. Vehicle attitude is held when the controller is in the detent.

MANUAL TRANSLATION CONTROL

- The crew can command translation along the vehicle axes by ON/OFF firing of the jets when a TTCA is moved out of detent.

ATTITUDE DAMPING

- Rate gyro signals sum with stabilization signals.

ENGINE GIMBAL CONTROL

- Pitch and Roll Gimbal commands are derived from the ATCA attitude error channels.

REMARKS

- All jet commands go through the ATCA jet select logic and the PRM. An override of the attitude control function is accomplished by moving the attitude controller to the hardover position thereby commanding ON/OFF 4-jet operation through the secondary coils of the thruster solenoid valves bypassing the jet select logic, the PRM's and the jet drivers. An override of +X translation is obtained by commanding 4-jet operation direct to the RCS secondary coils by means of a control button.

PANEL SWITCHES:

- GUIDANCE CONTROL - 9S6 - AGS
- MODE CONTROL - 11S6 - AUTO/ATTITUDE HOLD
- ATTITUDE CONTROL - 11S3 - 11S4 - 11S5 - PULSE selectable on an individual axis basis

GUIDANCE SIGNALS

- Abort Guidance signals interrupted on an individual axis basis.

MANUAL ATTITUDE CONTROL

- The crew commands angular acceleration through low frequency pulsing of the RCS jets (2-jet operation).

MANUAL TRANSLATION CONTROL

- The crew can command translation along the vehicle axes by ON/OFF firing of the jets when a TTCA is moved out of detent.

ATTITUDE DAMPING

- No rate damping in axis selected for pulse operation.

ENGINE GIMBAL CONTROL

- Pitch and Roll Gimbal commands are derived from the ATCA attitude error channels.

REMARKS

- All jet commands go through the ATCA jet select logic and the PRM. An override of the attitude control function is accomplished by moving the attitude controller to the hard-over position thereby commanding ON/OFF 4-jet operation through the secondary coils of the thruster solenoid valves bypassing the jet select logic, the PRM's and the jet drivers. An override of +X translation is obtained by commanding 4-jet operation direct to the RCS secondary coils by means of a control button.

PANEL SWITCHES:

GUIDANCE CONTROL - 9S6 - AGS

MODE CONTROL - 11S6 - AUTO/ATTITUDE HOLD

ATTITUDE CONTROL - - DIRECT selectable
11S3 - 11S4 - 11S5 on an individual axis
basis

GUIDANCE SIGNALS

- Abort Guidance signals interrupted on an individual axis basis.

MANUAL ATTITUDE
CONTROL

- The crew commands angular acceleration through ON/OFF firing of the RCS jets. (2-jet operation direct to secondary coils).

MANUAL TRANSLATION
CONTROL

- The crew can command translation along the vehicle axes by ON/OFF firing of the jets when a TTCA is moved out of detent.

ATTITUDE DAMPING

- No rate damping in axis selected for direct operation.

ENGINE GIMBAL CONTROL

- Pitch and Roll Gimbal commands are derived from the ATCA attitude error channels.

REMARKS

- Attitude commands for the direct axis go to the RCS secondary coils. All other jet commands go through the ATCA jet select logic and the PRM. An override of the attitude control function is accomplished by moving the attitude controller to the hardover position thereby commanding ON/OFF 4-jet operation through the secondary coils of the thruster solenoid valves bypassing the jet select logic, the PRM's and the jet drivers. An override of +X translation is obtained by commanding 4-jet operation direct to the RCS secondary coils by means of a control button.

IV. CES Controls and Displays

Since the LM is manned, the crew must be furnished data relative to the status of the subsystems, be warned of malfunctions, be provided with guidance and navigational readouts, and once supplied this information, be able to take the required action.

Panels

Displays and Controls are mounted on panels. Each panel is identified by its location and by a Roman numeral designator.

Alpha Numeric Designators

Every display and control is assigned an alpha numeric designator. Below is an explanation of the system used.

FIRST DESIGNATOR

- 1 = ENGINE/THRUST CONTROLS
- 2 = EXPLOSIVE DEVICE (PYROTECHNICS)
- 3 = GUIDANCE AND NAVIGATION
- 4 = ELECTRICAL POWER
- 5 = TO BE DETERMINED
- 6 = CAUTION/WARNING
- 7 = ENVIRONMENTAL CONTROL
- 8 = REACTION CONTROL
- 9 = FLIGHT CONTROL
- 10 = PROPULSION
- 11 = STABILIZATION AND CONTROL
- 12 = ABORT GUIDANCE
- 13 = COMMUNICATIONS
- 14 = COMMUNICATIONS ANTENNAS
- 15 = AUDIO CONTROL

16 = LIGHTING CONTROLS

17 = RADAR CONTROLS

18 = HEATER CONTROLS

SECOND DESIGNATORS

S - SWITCH

M - DISPLAY (METER-DIGITAL DISPLAY-FLIGHT INDICATOR, ETC.)

DS - CAUTION/WARNING, COMPONENT CAUTION INDICATOR, OR LUNAR CONTACT LIGHT

R - THUMBWHEEL OR CONTINUOUS ROTARY SWITCH

CB - CIRCUIT BREAKER

FL - STATUS

T - AUDIBLE WARNING TONE

H - MANUAL CONTROL

COMMANDER'S L.H. CENTER PANEL

PANEL I

6-DS-6 CONTROL ELECTRONICS SECTION AC VOLTAGE FAILURE WARNING LIGHT

The (CES AC) warning light is illuminated if the AC voltage (single phase 28V 800 cps or three phase 26V 800 cps) in the Control Electronics Section is out of tolerance. The light is extinguished when the Gyro Test Control switch (11-S-1), is actuated to either the POS RT or NEG RT position.

6-DS-7 CONTROL ELECTRONICS SECTION DC VOLTAGE FAILURE WARNING LIGHT

The (CES DC) warning light is illuminated if the DC voltage of one or more of the DC power supplied (+15V, -15V, +4.3V, +6V, -6V), in the Control Electronics Section is out of tolerance. The light is extinguished when 11-S-1 is actuated to either the POS RT or NEG RT position.

9-M-1 FLIGHT DIRECTOR ATTITUDE INDICATOR COMMANDER

This indicator displays: (1) Vehicle Attitude, Attitude Rates, and Attitude Errors or (2) Vehicle Attitude, Attitude Rates and Rendezvous Radar Shaft and Trunnion angles, depending upon the position of 9-S-2. The position of 9-S-3 will select either PGNS or AGS as the source of displayed vehicle Attitude and Attitude errors for 9-M-1. The attitude rate information displayed on the three meters surrounding the ball is always obtained from the CES rate gyros. The shaft and trunnion angles are displayed respectively on the pitch and yaw error needles of 9-M-1 when 9-S-2 is in the "RNDZ RADAR" position.

9-M-7 THRUST INDICATOR

This indicator displays descent engine chamber pressure (left pointer), and manual throttle commands or LGC thrust commands (right pointer) as switched by 1-S-11. If the manual mode is selected by 1-S-11, then the right pointer will indicate either the Commander's or Systems Engineer's throttle commands depending on the position of the manual throttle select (1-S-10). The display range is 0-100% thrust. Under normal operation of LGC command authority both pointers will be aligned at the same scale reading. A divergence between needle settings will indicate malfunction or that the manual throttle authority is being introduced to enable a smooth transition to full manual control. If the latter is true, then the thrust control switch (1-S-11), will be switched to MAN when the LGC thrust command pointer reaches 10% thrust. After switching to MAN, both pointers should be aligned if the system responds correctly.

1-S-1 ENGINE ARM SWITCH THREE-POSITION TOGGLE LOCK-LOCK-LOCK

This three-position toggle (ASC - OFF - DES) provides arming signals to the engines. The "ASC" position provides an arming signal enabling firing of the ascent engine while simultaneously signaling the LGC that the engine is armed. In the "OFF" position the arming signals are removed from the engine valves and the LGC. In the "DES" position the descent engine is armed and the LGC is notified that the engine is armed. However, regardless of the position of this switch, the appropriate engine will be armed if 1-S-13 or 1-S-14 are actuated.

1-S-6 X TRANSLATION SWITCH
TWO-POSITION TOGGLE MAIN-MAIN

This two-position toggle (4 JETS - 2 JETS) selects the number of jets that will be utilized in X-axis translation maneuvers. This control can only be used with the AGS system.

1-S-9 BALANCED COUPLES SWITCH
TWO-POSITION TOGGLE-LOCK-LOCK

This two-position toggle (ON - OFF) selects either balanced pairs of RCS jets in a couple or unbalanced X-axis RCS jets for use in maintaining pitch and roll attitude during the ascent engine thrust phase when the AGS is in the guidance loop. This switch is normally in the "ON" position (balanced couples) during the initial phases of lunar ascent. This provides maximum stabilization and control over any center of gravity thrust vector misalignment. After some minimum burn time (to be determined), when the balanced couples operation is no longer required, the switch can be positioned to "OFF" to conserve fuel.

9-S-6 GUIDANCE CONTROL SWITCH
TWO-POSITION TOGGLE MAIN-MAIN-MAIN

This two-position toggle (PGNS - AGS) selects either PGNS or AGS for guidance control of the LM.

1-S-11 THRUST CONTROL SWITCH
TWO-POSITION TOGGLE LOCK-LOCK

This two-position toggle (AUTO-MAN) provides the capability of switching from automatic throttle control (LGC) to manual throttle control. In the "AUTO" position, LGC command signals are summed with the manual command signals of the throttle selected by 1-S-10 for descent engine throttle control. Only the LGC command signals are displayed on the Thrust Indicator (9-M-7). In the "MAN" position, LGC throttle command signals to the descent engine are interrupted. The display shows manual throttle commands; and the descent engine throttle is fed only by the manual throttle command signals.

1-S-10 MANUAL THROTTLE SWITCH
TWO-POSITION TOGGLE LOCK-LOCK

This two-position toggle (CDR - SE), selects the controller which will be used for manual descent engine thrust level adjustment if its corresponding select lever is in the "THROTTLE" position. Thus, in the "CDR" position only the Commander's Controller is enabled to adjust descent engine thrust level, and the "SE" position only the Systems Engineer's Controller is enabled.

FOR TRAINING PURPOSES ONLY

1-S-13 ABORT SWITCH
GUARDED PUSHBUTTON MAINTAIN

This pushbutton is activated to initiate an abort using the descent engine. Activation of this switch causes the following events to occur at the appropriate time: (a) a command signal is sent to arm the descent engine, (b) a signal is sent via instrumentation to telemetry indicating that the vehicle is preparing for an abort, and (c) a signal is sent to the LGC and AGS to compute and execute the abort trajectory by using the abort program.

1-S-14 ABORT STAGE SWITCH
GUARDED PUSHBUTTON MAINTAIN

This pushbutton is activated to initiate an abort using the ascent engine. Activation of this switch will cause the following events to occur at the appropriate times: (a) a command signal is sent to the electroexplosive devices to pressurize the ascent engine, (b) a signal is sent to the LGC and AGS to compute and execute the abort trajectory using the abort stage program, (c) a signal is sent via instrumentation to telemetry indicating that the vehicle is preparing to stage for an abort (d) the descent engine is shut down, and (e) the ascent engine is armed in preparation for an automatic ON from the LGC or the AEA. A time delay insures the descent engine has stopped thrusting before the ascent engine and the staging sequence is started. At some point in the Abort Stage sequence, electrical power is transferred automatically from descent batteries to ascent batteries.

PANEL II

6-DS-23 AUTOMATIC GIMBAL FAILURE CAUTION LIGHT (YELLOW)

The (ENG GIMBAL) Caution Light is illuminated if a difference between the gimbal drive signal and gimbal response from the Y or Z-axis trim function is sensed. This signal is enabled only if the Descent Engine is armed. Additionally, the signal is disabled if the ENGINE GIMBAL ENABLE switch (1-S-3) is in the OFF position or the vehicle is staged.

6-DS-30 PRE AMPS POWER FAILURE CAUTION LIGHT (YELLOW)

The (PRE AMPS) Caution Light is illuminated by an out-of-tolerance condition in either of two parallel redundant -4.7V regulated supplies which power the RCS jet pre-amplifiers. This light is extinguished either by the stage deadface switch or by actuation of the Abort pushbutton (1-S-13).

9-M-6 FLIGHT DIRECTOR ATTITUDE INDICATOR SYSTEMS ENGINEER

This indicator displays: (1) vehicle attitude, attitude rates and attitude errors or (2) vehicle attitude, attitude rates and rendezvous radar shaft and trunnion angles, depending upon the position of 9-S-2. The position of 9-S-3 will select either PGNS or AGS as the source of displayed vehicle attitude and attitude errors for 9-M-1. The attitude rate information displayed on the three meters surrounding the ball is always obtained from the CES rate gyros. The shaft and trunnion angles are displayed respectively on the pitch and yaw error needles of 9-M-1 when 9-S-2 is in the "RNDZ RADAR" position.

PANEL III

1-S-8 ENGINE GIMBAL ENABLE TWO-POSITION TOGGLE LOCK-LOCK

In the "ENABLE" position, gimbal trim signals are enabled to position the descent engine on both axes. In the "OFF" position, power is interrupted to the gimbal drive actuators thus disabling the gimbal drive capability.

1-S-19 DESCENT ENGINE COMMAND OVERRIDE SWITCH TWO-POSITION TOGGLE LOCK-LOCK

This two-position toggle (ON - OFF) in the "ON" position provides a 28V DC alternate power source to the descent engine shut-off valves to prevent engine shut-down should a loss of power occur in the DECA (4-CB-69). The "OFF" position interrupts the alternate power path.

11-S-2 DEADBAND SWITCH TWO-POSITION TOGGLE

This two-position toggle (MAX - MIN) selects either a large amplitude limit cycle (MAX) for the attitude control system to conserve RCS fuel during coasting flight, or a narrow deadband (MIN) for periods when accurate manual control is required. Regardless of this switch position the minimum deadband will operate during main engine thrusting. This switch is not functional when the PGNS is in use.

11-S-1 GYRO TEST CONTROL SWITCH
THREE-POSITION TOGGLE MOM-LOCK-MOM

This three-position toggle (POS RT - OFF - NEG RT) enables a test signal to be applied to the rate gyro selected by 11-S-7. It is maintained in the "OFF" position and momentarily held in the other two. When this switch is held in the "POS RT" position, a $+5^{\circ}/\text{sec}$ attitude rate will be indicated on the appropriate needles of the flight director attitude indicators (9-M-1 and 9-M-6). The "NEG RT" position produces the opposite effect. In "OFF", no test signal is produced.

11-S-7 GYRO TEST SELECT SWITCH
THREE-POSITION TOGGLE MAIN-MAIN-MAIN

This three-position toggle (ROLL - PITCH - YAW) associated with 11-S-1, selects the rate gyro which is to be tested. The test output is displayed as described for switch 11-S-1.

11-S-3 PITCH ATTITUDE
CONTROL SWITCH

11-S-4 ROLL ATTITUDE
CONTROL SWITCH

11-S-5 YAW ATTITUDE
CONTROL SWITCH
THREE THREE-POSITION TOGGLES
MAIN-MAIN-MAIN

These three Attitude Control Switches (MODE CONT - PULSE - DIR) are used, normally only with the AGS, in conjunction with switch 11-S-6 to establish vehicle attitude control. All three switches will normally be placed in the "MODE CONT" position. In this position, vehicle attitude control about the appropriate axis is determined by 11-S-6. If the AGS has been selected on the Guidance Control switch (9-S-6) and if one of the three Attitude Control switches is in the "PULSE" or "DIR" position, attitude about that axis can only be controlled manually. If the PGNS has been selected on 9-S-6, the "PULSE" position is inoperative (attitude commands are generated by the LGC and vehicle attitude control is automatic), but the "DIR" position will permit ACA operation of reaction jets. Under AGS control, the "PULSE" and "DIR" modes differ only in the way the reaction jets fire. When "PULSE" is selected, two jets in the appropriate axis are pulsed at a constant rate for as long as the attitude controller is displaced. When "DIR" is selected and the ACA's displaced, the two jets are activated continuously instead of being pulsed. When 11-S-6 is in the "OFF" position, only the "DIR" position is operative.

11-S-6 ATTITUDE MODE CONTROL SWITCH
THREE-POSITION ROTARY MAIN-MAIN-MAIN

This three-position rotary (OFF - ATT HOLD - AUTO) effects the outputs of the attitude controllers, the translation controllers, and the selected guidance computer. In the "OFF" position, the attitude controllers are only operative: (1) in the hardover position, and (2) when one or more of the attitude control switches is in the "DIR" position, which provides the crew with two-jet direct attitude control of that axis. The translation outputs of the T/TCA and the computer attitude commands are also disabled but the main engine throttle command outputs are not effected. However, with this switch in the "OFF" position, main-engine off signals from the LGC and the AGS are not enabled and the main engines can only be turned off manually. In the "ATT HOLD" position, the crew can command an angular rate proportional to the displacement of the ACA. This mode is implemented to operate with either PGNS or AGS. In the "AUTO" position, either the PGNS or the AGS will automatically control the attitude.

PANEL V

1-S-3 ENGINE STOP SWITCH
GUARDED PUSHBUTTON MAINTAIN

This pushbutton (1-S-3) sends a discrete stop signal to the descent and ascent engines independent of the position of 1-S-1. When actuated, the button illuminates red. It is reset by depressing it a second time.

1-S-2 ENGINE START SWITCH
GUARDED PUSHBUTTON MAINTAIN

This pushbutton provides a manual override capability for immediate firing of either the descent or ascent engine, depending upon the position of 1-S-1. Once actuated, the engine fire command continues and the button is illuminated red. Activation of 1-S-3 or 1-S-4 interrupts the override function and extinguishes the light.

1-S-12 +X AXIS TRANSLATION SWITCH
GUARDED PUSHBUTTON MOMENTARY

This pushbutton is located at the Commander's station. When it is held in the depressed position, it provides four jet translation in the +X direction by energizing the RCS secondary coils. Upon release of the button the signal is removed from the coils, terminating the jet firings.

PANEL VI

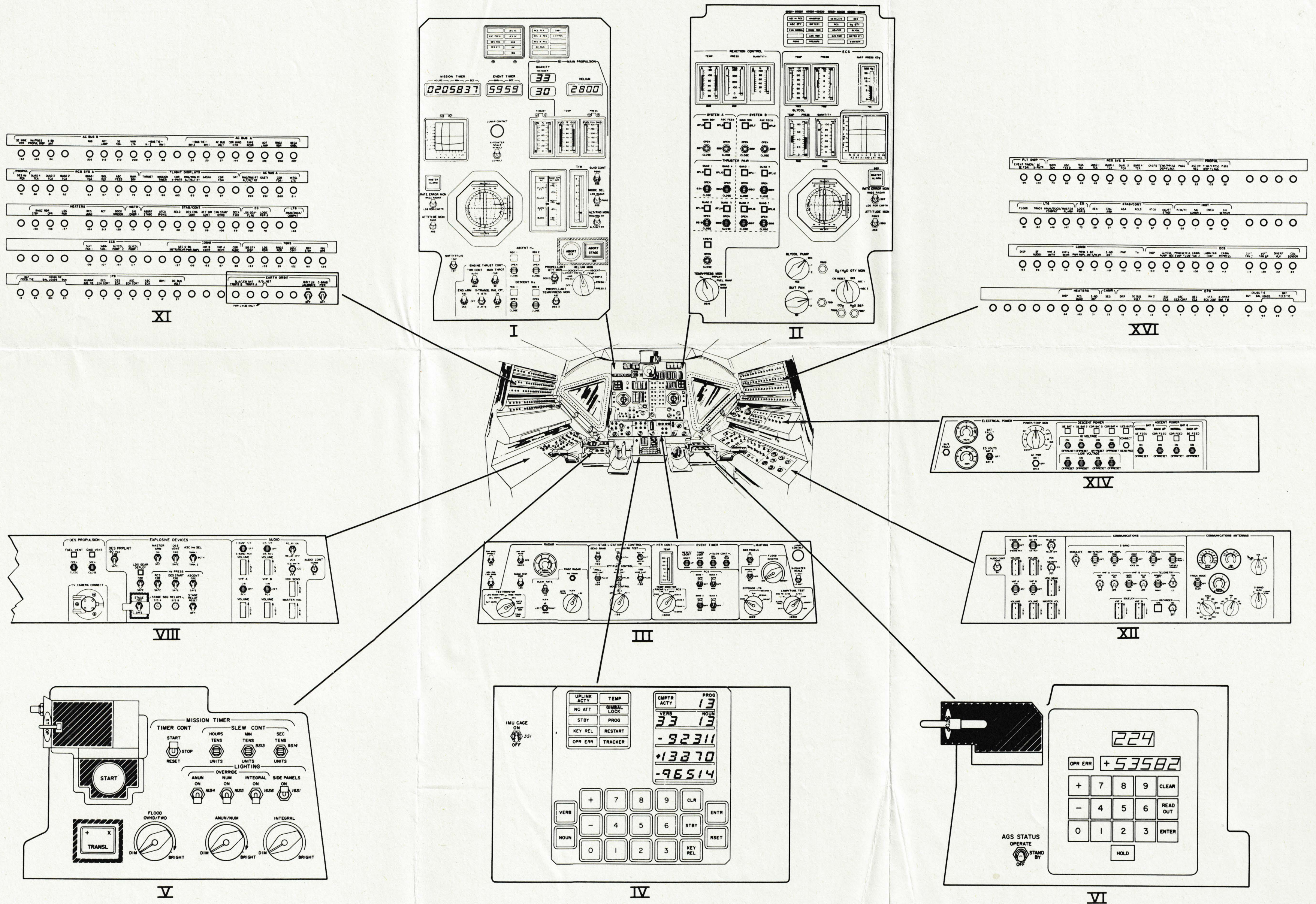
1-S-4 ENGINE STOP SWITCH
GUARDED PUSHBUTTON MAINTAIN

This pushbutton (1-S-4) sends a discrete stop signal to the descent and ascent engines independent of the position of 1-S-1. When actuated, the button is illuminated red. It is reset by depressing it a second time.

PANELS XI AND XVI - ELECTRICAL POWER SUBSYSTEM (CIRCUIT BREAKERS)

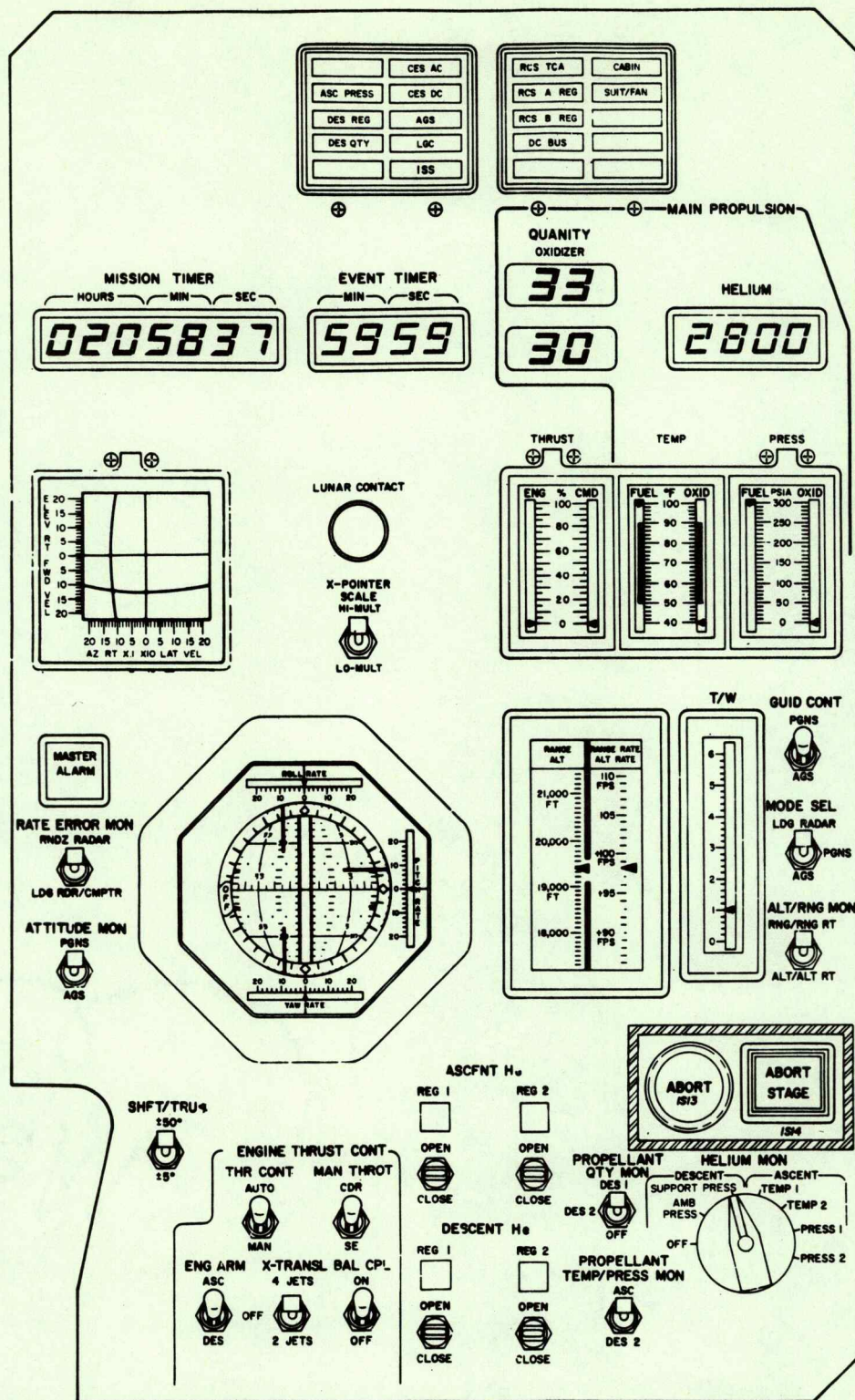
Breaker No.	Panel Nomenclature	Panel Location		Component(s) Served
		XI	XVI	
4-CB-2	ABORT STAGE		X	Abort staging electronics.
4-CB-3	ABORT STAGE	X		Abort staging electronics.
4-CB-37	ENG ARM		X	Powers engine arm switch.
4-CB-40	AELD	X		Ascent engine latching device.
4-CB-41	AELD		X	Ascent engine latching device.
4-CB-59	ATT DIR CONTR	X		Attitude controllers for direct firing of RCS.
4-CB-69	DECA POWER	X		Descent engine control assembly.
4-CB-80	DES ENG CONTR	X		(1) Lunar contact light (1-DS-2) and probe switches. (2) Auto switching from wide to narrow dead-band with engine "ON". (3) Auto switching from two to four jets with engine "ON". (4) CES analog control of GDA's when in AGS. (5) Disables auto thrust control. (6) Resets engine start switches. (7) Redundant power for stopping descent engine manually and when staging.

Breaker No.	Panel Nomenclature	Panel Location		Component(s) Served
		XI	XVI	
4-CB-81	ATCA (PGNS)	X		Certain attitude/translation control assembly circuits and jet drivers in ATCA which are used only by PGNS.
4-CB-82	ATCA		X	Attitude/translation control assembly, and lunar contact light (1-DS-1) and probe switches.
4-CB-106	ENGINE START OVRD	X		Engine start switch and redundant power for ascent engine arming circuit
4-CB-207	DECA GIMBAL	X		Descent engine GDA's within the DECA (AC).



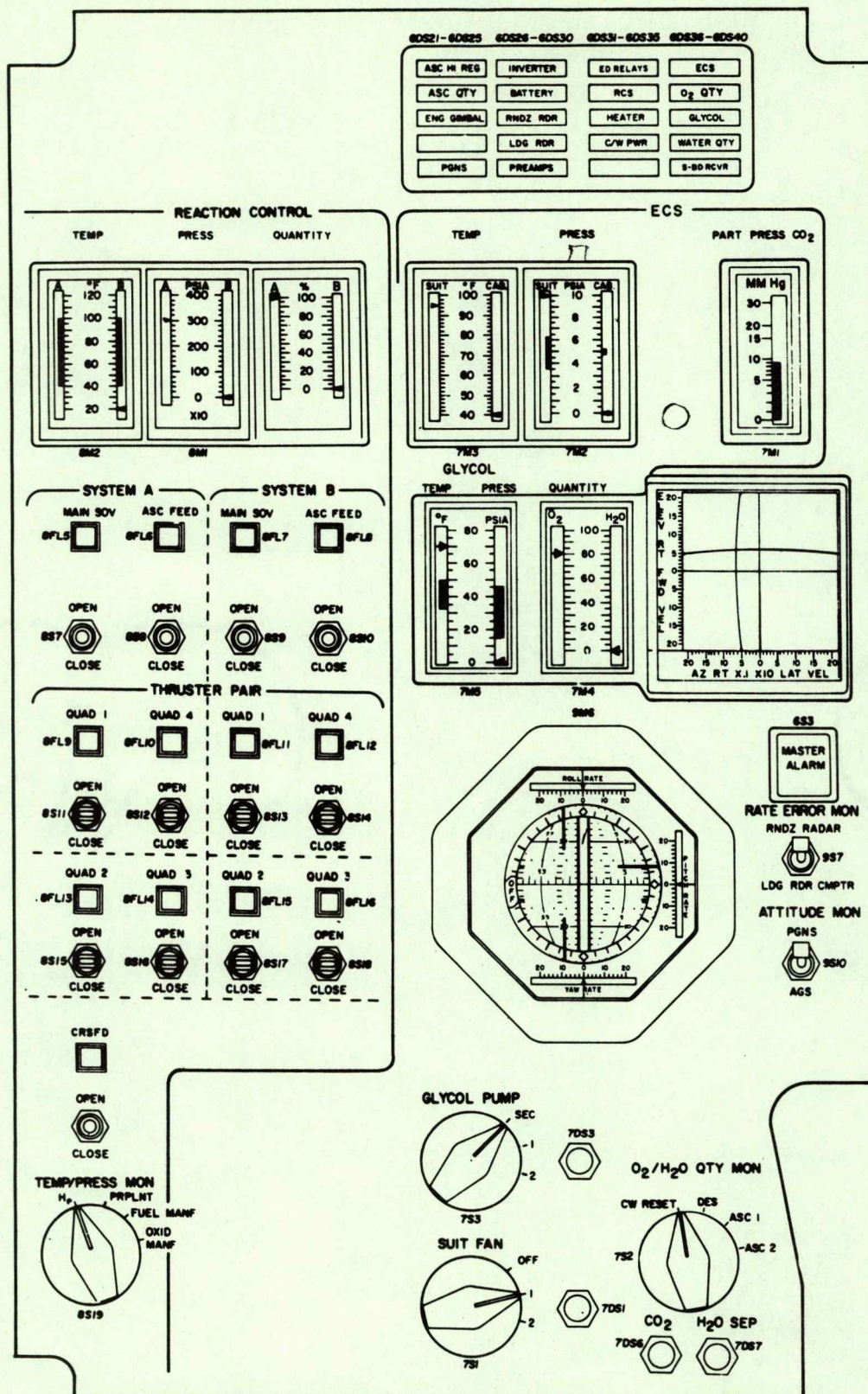
LM DISPLAYS AND CONTROLS

T30005-28
DEC 66



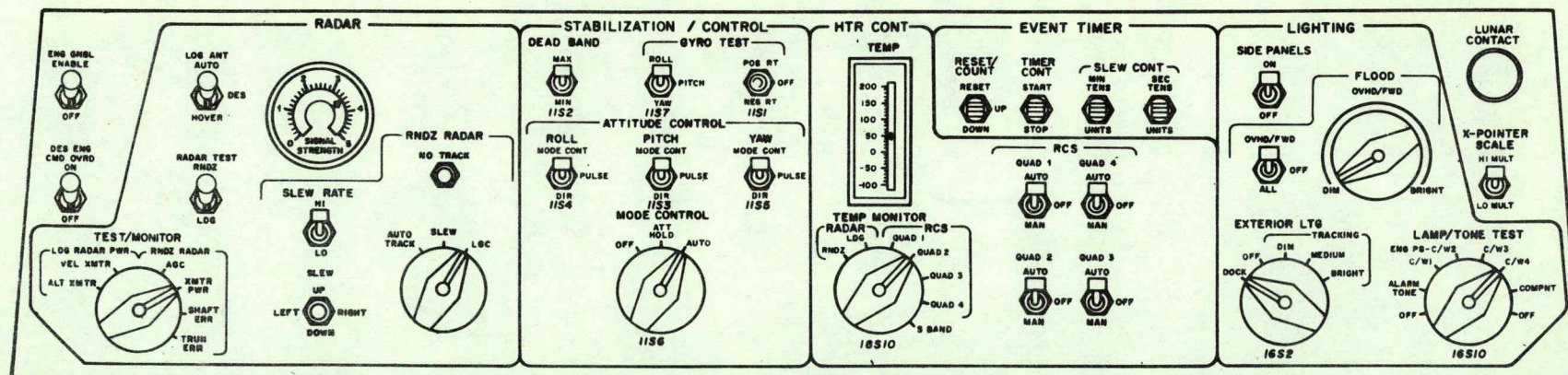
PANEL I

T30900-1
DEC 66

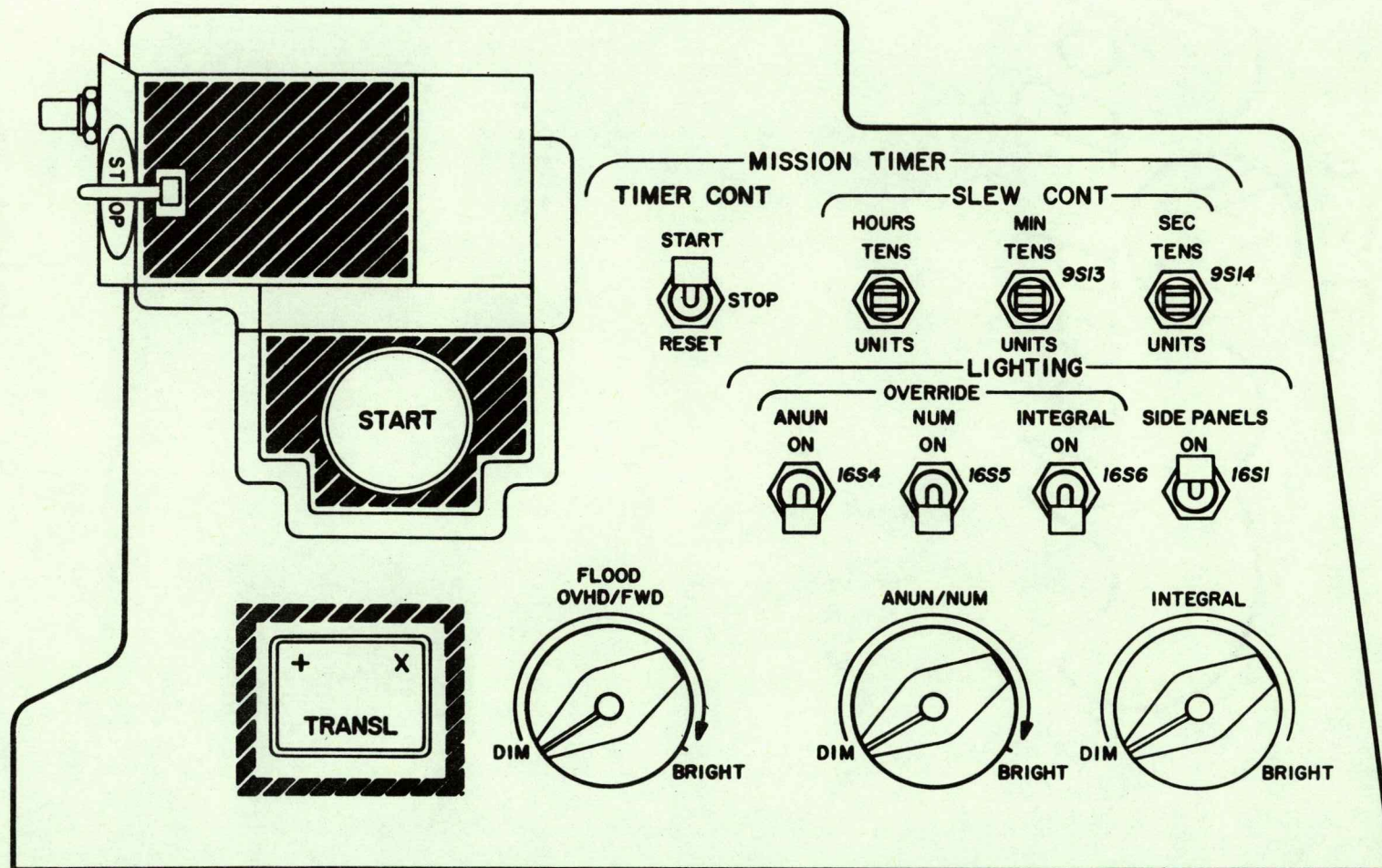


PANEL II

T30900-2
DEC 66



PANEL III

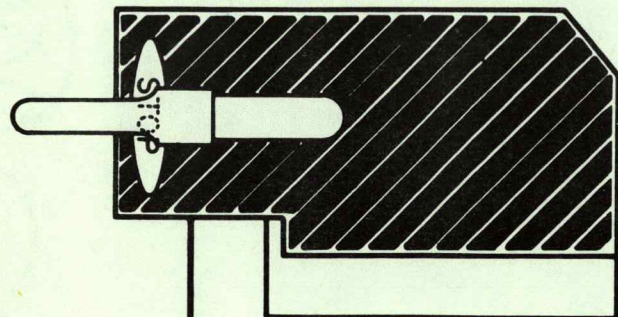


64

Figure 4-5

PANEL V

T30900-4
DEC 66



AGS STATUS

OPERATE



STAND
BY

OFF

224

OPR ERR

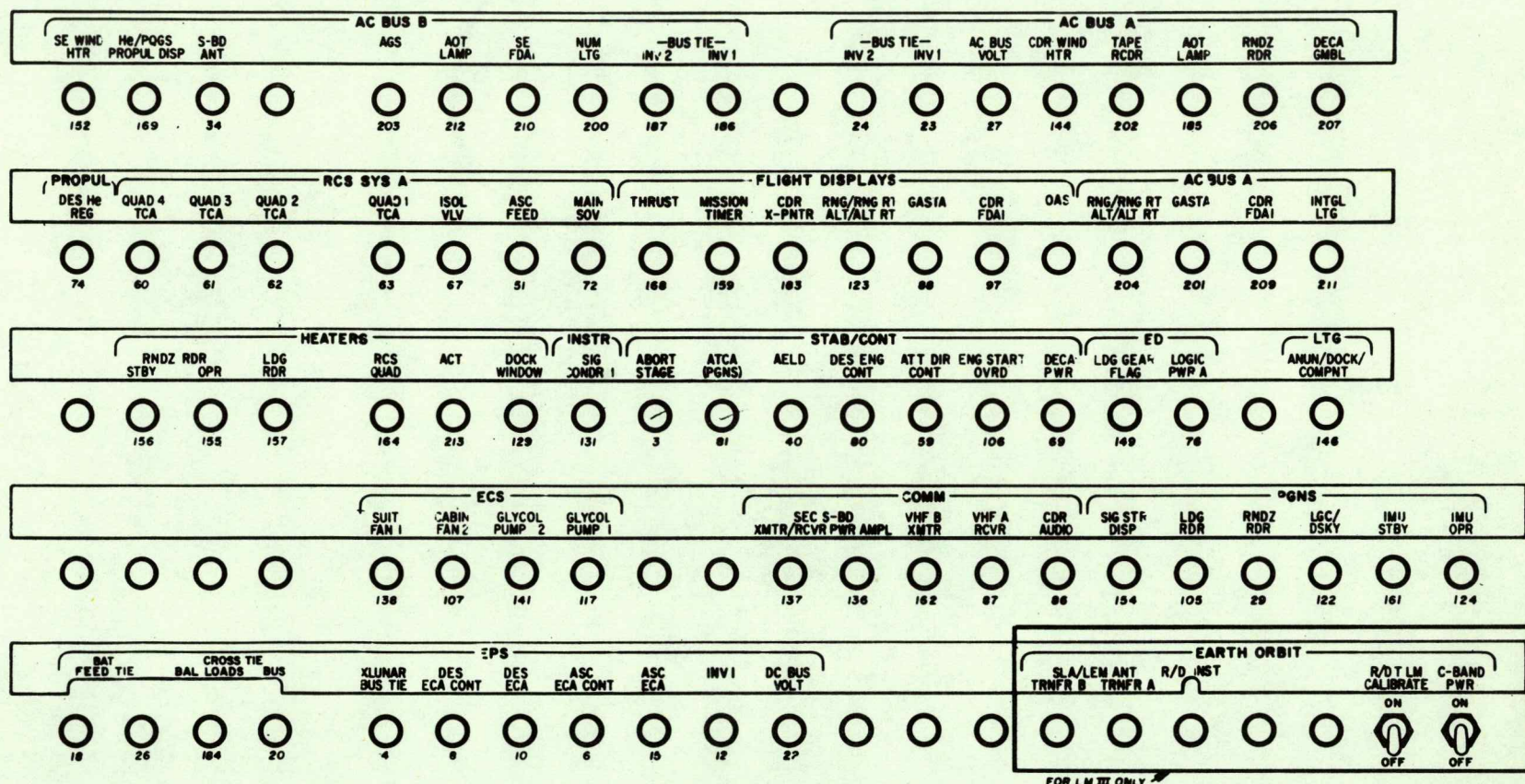
+ 53582

+	7	8	9	CLEAR
-	4	5	6	READ OUT
0	1	2	3	ENTER

HOLD

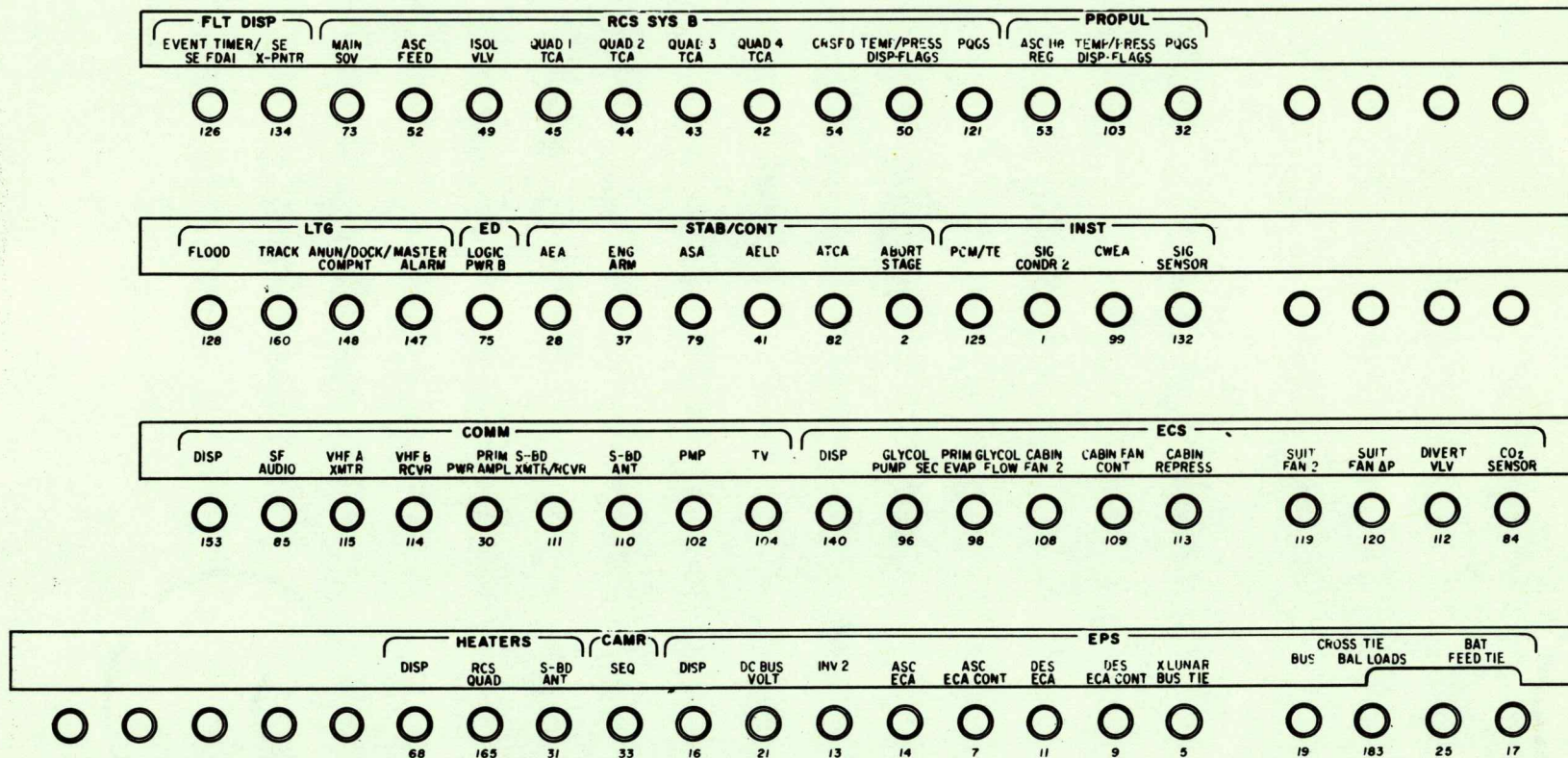
PANEL VI

T 30900-5
DEC 66



PANEL XI

T30900-20
NOV 66



PANEL XVI

T30900-21
NOV 66

V. CES TELEMETRY

The following is a list of CES telemetry measurements.

MEAS ID	MEASUREMENT DESCRIPTION	RANGE		
		LOW	NOM	HIGH
GH1204	X ACA OUT OF DETENT			CONTACT CLOSURE
GH1214	X AUTO ENG "ON" CMD			CONTACT CLOSURE
GH1217	X AUTO ENG "OFF" CMD			CONTACT CLOSURE
GH1230	X ASC ENG ARM (FROM PNL)	0	OR	28 VDC
GH1240	V VOLT, "X" TRANS CMD	-10	0 OR	+10 VDC
GH1241	V VOLT, "Y" TRANS CMD	-10	0 OR	+10 VDC
GH1242	V VOLT, "Z" TRANS CMD	-10	0 OR	+10 VDC
GH1247	V VOLT, YAW LOGIC INPUT ERROR	-13	+ .5	+13 VDC
GH1248	V VOLT, PITCH LOGIC INPUT ERROR	-13	+ .5	+13 VDC
GH1249	V VOLT, ROLL LOGIC INPUT ERROR	-13	+ .5	+13 VDC
GH1260	X A.E. ON/OFF TO PROP			CONTACT CLOSURE
GH1283	X ABORT STAGE COMMANDED			CONTACT CLOSURE
GH1286	X ENG FIRE OVERRIDE			CONTACT CLOSURE
GH1301	X DESC ENG -ON- TO PROP			CONTACT CLOSURE
GH1311	V VOLT, MANUAL THRUST CMD	2.6	15	VDC
GH1313	V VOLT, PITCH GDA POS (RET/EXT)	-15+	.05 +15	VRMS
GH1314	V VOLT, ROLL GDA POS (EXT/RET)	-15+	.05 +15	VRMS
GH1323	X PITCH TRIM FAIL			CONTACT CLOSURE
GH1330	X ROLL TRIM FAIL			CONTACT CLOSURE

MEAS ID	MEASUREMENT DESCRIPTION	RANGE		
		LOW	NOM	HIGH
GH1331	V VOLT, AUTO THRUST CMD	0.015	12	VDC
GH1348	X DESC ENG ARM (DECA OUT)	0	OR 28	VDC
GH1418	V VOLT, JET NO4U DRIVER OUTPUT, 28V	6PPS MAX,	10-400	MS
GH1419	V VOLT, JET NO4D DRIVER OUTPUT, 28V	6PPS MAX,	10-400	MS
GH1420	V VOLT, JET NO4F DRIVER OUTPUT, 28V	6PPS MAX,	10-400	MS
GH1421	V VOLT, JET NO4S DRIVER OUTPUT, 28V	6PPS MAX,	10-400	MS
GH1422	V VOLT, JET NO3U DRIVER OUTPUT, 28V	6PPS MAX,	10-400	MS
GH1423	V VOLT, JET NO3D DRIVER OUTPUT, 28V	6PPS MAX,	10-400	MS
GH1424	V VOLT, JET NO3F DRIVER OUTPUT, 28V	6PPS MAX,	10-400	MS
GH1425	V VOLT, JET NO3S DRIVER OUTPUT, 28V	6PPS MAX,	10-400	MS
GH1426	V VOLT, JET NO2U DRIVER OUTPUT, 28V	6PPS MAX,	10-400	MS
GH1427	V VOLT, JET NO2D DRIVER OUTPUT, 28V	6PPS MAX,	10-400	MS
GH1428	V VOLT, JET NO2F DRIVER OUTPUT, 28V	6PPS MAX,	10-400	MS
GH1429	V VOLT, JET NO2S DRIVER OUTPUT, 28V	6PPS MAX,	10-400	MS
GH1430	V VOLT, JET NO1U DRIVER OUTPUT, 28V	6PPS MAX,	10-400	MS
GH1431	V VOLT, JET NO1D DRIVER OUTPUT, 28V	6PPS MAX,	10-400	MS
GH1432	V VOLT, JET NO1F DRIVER OUTPUT, 28V	6PPS MAX,	10-400	MS
GH1433	V VOLT, JET NO1S DRIVER OUTPUT, 28V	6PPS MAX,	10-400	MS
GH1455	V VOLT, YAW ATT ERROR (.8KC)	-5		+5 VRMS
GH1456	V VOLT, PITCH ATT ERROR (.8KC)	-5		+5 VRMS
GH1457	V VOLT, ROLL ATT ERROR (.8KC)	-5		+5 VRMS
GH1461	V VOLT, YAW RG SIG (.8KC)	-3.5		+3.5 VRMS
GH1462	V VOLT, PITCH RG SIG (.8KC)	-3.5		+3.5 VRMS

FOR TRAINING PURPOSES ONLY

MEAS ID	MEASUREMENT DESCRIPTION	RANGE		
		LOW	NOM	HIGH
GH1463	V VOLT, ROLL RG SIG (.8KC)	-3.5		+3.5 VRMS
GH1603	X DEADBAND SELECT (WIDE)	0	OR	28 VDC
GH1608	X SCS MODE SELECT (AUTO)			CONTACT CLOSURE
GH1609	X SCS MODE SELECT (ATT HOLD)			CONTACT CLOSURE
GH1621	X GUIDANCE SELECT SWITCH (AGS)			CONTACT CLOSURE
GH1628	X ROLL ATT CON SEL(PULSED/DIRECT)			CONTACT CLOSURE
GH1629	X PITCH ATT CON SEL(PULSED/DIRECT)			CONTACT CLOSURE
GH1630	X YAW ATT CON SEL (PULSED/DIRECT)			CONTACT CLOSURE
GH1893	X "X" TRANS OVERRIDE	0	OR	28 VDC
GH1896	X UNBALANCED COUPLES			CONTACT CLOSURE

SECTION II

LM ABORT GUIDANCE SECTION (LM AGS)

I. GENERAL INTRODUCTION TO LM AGS

The purpose and design mission of the Abort Guidance Section (AGS) is to provide the necessary guidance and control commands for the LM during the flight mission such that a coelliptic rendezvous with the CSM can be achieved.

Even though it is possible for the astronaut to abort the mission using the primary guidance system (PGNCS), the AGS provides an immediate and direct guidance system for the return flight to the CSM. At any time during the LM flight the astronaut is free to use the AGS for control of the vehicle. The AGS provides the LM with a guidance system that may be started at any known point in the neighborhood of the moon. This is restricted, of course, to all points within the LM Design Reference Mission.

The AGS is a strapped down inertial system in which the inertial instruments are rigidly mounted with respect to the vehicle rather than mounted on a stabilized platform. The system utilizes outputs from the abort sensor assembly (ASA) in order to compute an equivalent inertial reference frame. The "heart" of the system is a high speed general purpose digital computer. The flight program, stored in the computer memory, solves the guidance equations. It provides commands for firing and shutting down engines, provides attitude information and drives attitude displays.

A strapped-down inertial approach was selected for this application because it offered sufficient accuracy for LM missions and significant weight savings.

The data entry and display assembly (DEDA) permits an operator to enter data into the system. By means of pushbuttons he can control the AGS or make midcourse corrections based on information secured by radar tracking of the command module from LM or by optical techniques. On command, the assembly displays position, velocity, altitude, altitude rate, as well as other important parameters.

An important feature of the system is that it makes widespread use throughout its three assemblies of semiconductor and hybrid microcircuits. About 1,900 semiconductor microcircuits appear in the complete system, almost 1,600 of them in the computer, abort electronics assembly (AEA). The DEDA uses about 250, the ASA another 100.

ASA

The ASA contains six inertial instruments housed in a beryllium block which is bolted to the spacecraft. The six consist of three orthogonally oriented single-degree-of-freedom integrating gyros aligned with the three reference axes of the LM spacecraft and a triad of force balance accelerometers, also orthogonally situated. Pulse torquers and other circuitry, including temperature control amplifiers and power supply, are mounted with the instruments. A beryllium block offers high strength with little weight and good heat transmitting properties.

The ASA senses the spacecraft's angular displacements and velocity increments and generates output signals to update the computer. Electromagnetic torquers balance the gyroscopic input torque, the average current in the torquers corresponding to angular rate. Pulses, or time-modulated increments of current, are equivalent to and are used to indicate angular increments sensed by the gyroscope. These signals are used by the computer in the same manner that torquers would balance gimballed gyros.

In the accelerometers a current is generated to produce a torque that opposes the torque caused by the force of acceleration on a pendulum mass. The average current is proportional to the acceleration, and pulses are generated for use by the computer to measure velocity increments.

Six pulse torquing servo amplifiers, one associated with each of the six inertial instruments, employ quantized, time-modulated feedback to torque balance each of their respective inertial sensors. Each of the servo amplifiers is composed of an amplifier, quantizer bridge and driver, and a current regulator.

Only a small number of semiconductor microcircuits are used in the sensor assembly, since so much of its circuitry is analog in nature. The analog circuits consist primarily of discrete components packaged in cordwood style, some thin films and a single type of analog semiconductor microcircuit amplifier.

AEA

The abort guidance section's computer is a high speed general purpose parallel machine. Its master clock is 1.024 mc and it has a DRO core memory capacity of 4,096 18-bit words. Half of its memory is hardwired as a non-destructive readout memory, the remainder is electrically alterable. The memory is made up of 30-mil-diameter cores in preassembled core stacks.

Read-write drivers and switches for the memory are located about the core in small packages which TRW calls functional electronic

blocks (FEB). Essentially these are hybrid circuits in which the insulating substrates for thin-film resistors become the mounting substrates for flat packs containing diodes or transistors. The entire FEB circuit is then sealed in a 28-lead macro-flat pack. Other memory circuits are located on multilayered boards that make up the memory assembly. The remaining memory circuits consist of discrete components and semiconductor microcircuit sense amplifiers.

The arithmetic portion of the computer is implemented in microcircuitry, using nine types of DTL integrated circuits packaged in flat packs and soldered to 10-layer laminate boards.

The computer power supply is a DC to DC converter which is of modular construction. The modules are uniquely located within the unit to provide optimum power distribution.

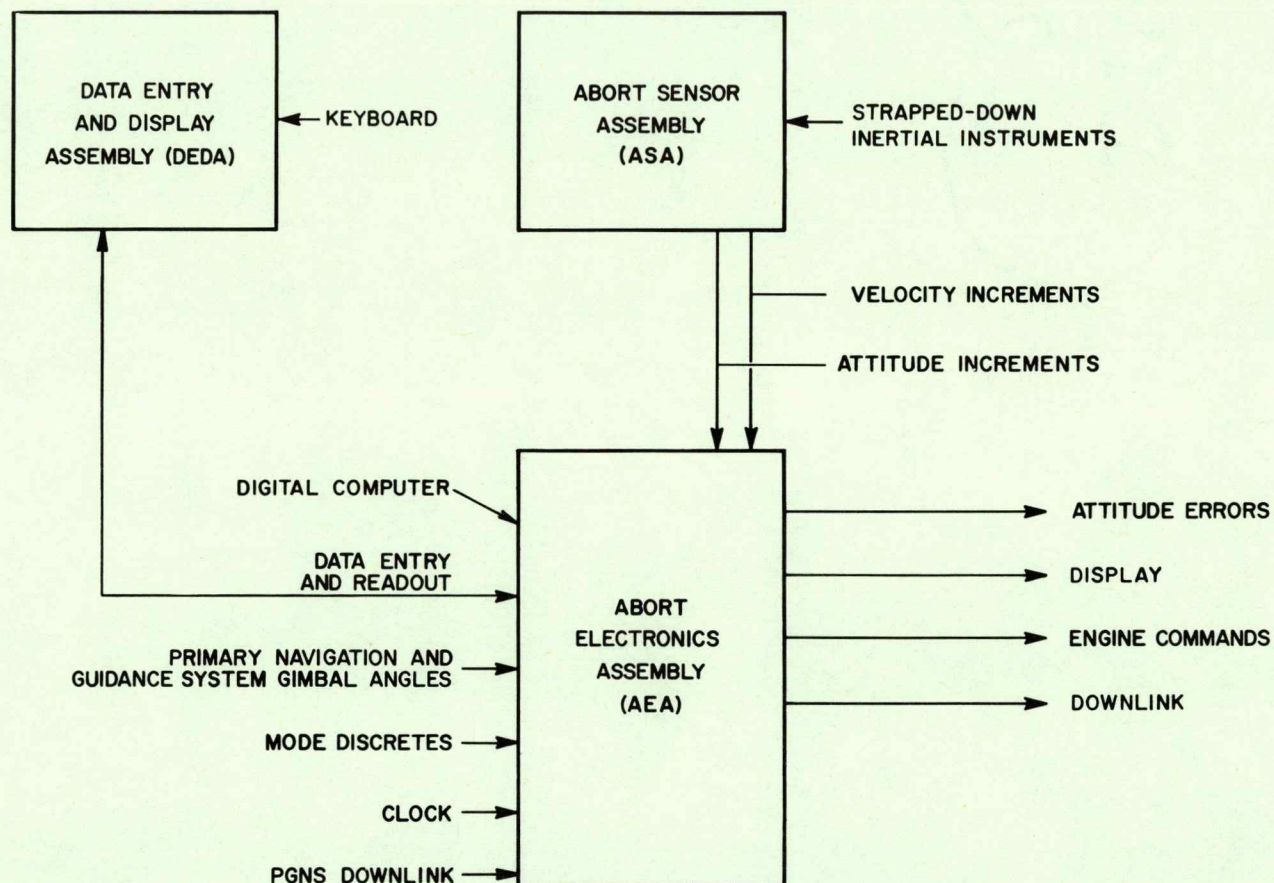
The special input-output section of the computer includes both D/A converters for driving the LM control subsystems and serial registers for accumulating input data.

DEDA

The data entry and display provides a numeric readout panel which is lighted by electroluminescent elements and a pushbutton keyboard. Nine multilayered circuit boards contain interface and power supply electronics of which the logic uses semiconductor microcircuits of the type employed in the abort electronics assembly.

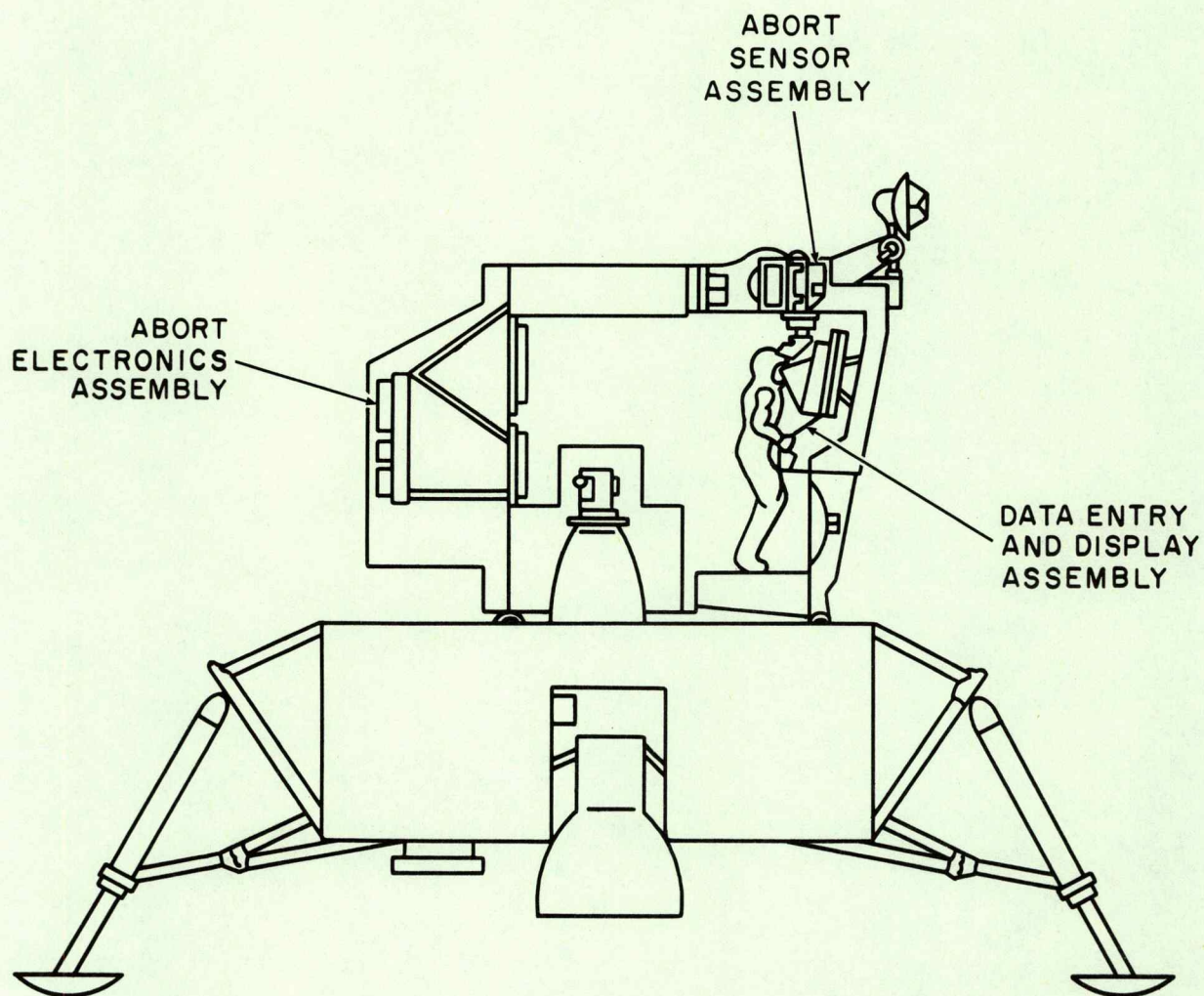
The abort system will be aligned in position and velocity with the primary system before separation of LM from the command module and it can abort the mission at any time after separation. The astronaut can depress an abort button and the vehicle will go into direct ascent. On the lunar surface, the abort section will be realigned with the primary system.

The functional relationship of the three components (ASA, AEA, and DEDA) comprising the LM AGS is illustrated in figure 1-1.



ABORT GUIDANCE SECTION BLOCK DIAGRAM

T30312-9
FEB 67



AGS EQUIPMENT LOCATION

T30312-54
FEB 67

II. AGS PERFORMANCE

The AGS will be capable of performing the following functions during the LM mission:

- a) Provide guidance functions which will result in a LM-CSM rendezvous from any point in the LM mission with the following conditions:
 - 1) The AGS shall steer LM into a direct transfer trajectory using the Explicit Guidance with a minimum pericynthion of 25,000 feet above the mean lunar radius, after the first powered burn. All subsequent thrust maneuvers shall also result in a minimum clear pericynthion of 25,000 feet.
 - 2) After midcourse corrections have been commanded by the AGS, the AGS shall guide the LM to intercept a sphere having a radius of 5 nautical miles (three sigma) with its center at the CSM. At the point of intersection of LM and the sphere defined above, the actual relative velocity of LM with respect to the CSM and the AGS computed desired relative velocity shall be within ± 30 fps of the actual relative velocity of LM with respect to CSM. These capabilities require Rendezvous Radar data during periods of free flight for the purpose of improving navigation accuracy.
- b) Provide an inertial reference frame which can be used as an attitude reference for vehicle stabilization during the coasting phases of the LM mission and for stabilization and control during the powered phases of the LM mission.
- c) Provide mode and submode selection by utilizing DEDA inputs, Control Electronics Section inputs and AGS mode switch inputs.
- d) Absolute time will be initialized through the DEDA.
- e) Provide the necessary decoding of the PGNS downlink data to extract LM and CSM position, velocity and their associated time of computation. This information will be used to initialize or update the AGS navigation computations upon command from the DEDA during non-powered flight phases of the mission.
- f) Provide the capability of outputting digital data via the telemetry data output channel.

- g) Provide the capability of outputting analog signals to the instrumentation subsystem to verify AGS performance.
- h) Provide the capability of orienting the LM Z axis toward the CSM and of accepting range and range rate data via the DEDA and using this data for midcourse correction computations.
- (i) Provide sensor compensation permitting the AGS automatically to compensate for fixed non-g gyro drift terms during the coasting phases of the LM mission.
- j) Provide the capability of accepting an external ΔV vector input via the DEDA. The AGS will issue attitude commands to maintain the X-axis in the direction of this vector.
- k) Provide the capability of aligning the AGS reference frame to one of three sources.
- l) Provide an inflight self-test to verify that the computer's memory and logic are functioning properly.

III. CLASSES OF AGS OPERATION

A. GENERAL

External control of AGS condition, mode, submode, and operation is achieved via the AGS STATUS switch on panel VI, the DEDA, and CES input discretes. The classes of AGS operation are as follows:

1. Condition

- a. OFF - AGS STATUS switch in the OFF position and the circuit breaker (4CB79) supplying +28V DC to the Abort Sensory Assembly pulled.
- b. WARMUP - AGS STATUS switch in the OFF position and 4CB79 pushed in.
- c. STANDBY - AGS STATUS switch in the STANDBY position and 4CB79 pushed in.
- d. OPERATE - AGS STATUS switch in the OPERATE position and 4CB79 pushed in.

2. Mode - The OPERATE condition is divided into the following modes:

ALIGNMENT Mode

INERTIAL REFERENCE Mode

3. Submode - These modes are further subdivided into the following:

IMU ALIGN Submode

LUNAR ALIGN Submode

BODY AXES ALIGN Submode

Submodes of ALIGN

ATTITUDE HOLD Submode

FOLLOW-UP Submode

AUTOMATIC Submode

SEMI-AUTOMATIC Submode

CSM Acquisition Submode

Submodes of INERTIAL
REFERENCE

Please note that the AUTOMATIC and SEMI-AUTOMATIC submodes are further referred to as the RENDEZVOUS submode.

B. INERTIAL REFERENCE MODE

When the AGS is in the INERTIAL REFERENCE mode, it shall provide attitude error information and engine on-off commands which will be used for vehicle stabilization and/or for directing vehicle abort. The INERTIAL REFERENCE mode shall consist of and shall always be in one of the following submodes.

1. FOLLOW-UP

2. AUTOMATIC

3. SEMI-AUTOMATIC

4. ATTITUDE HOLD

5. CSM ACQUISITION

RENDEZVOUS

FOLLOW-UP Submode - With AGS in the INERTIAL REFERENCE mode and the "Follow-up" signal present, the AGS shall be in the FOLLOW-UP submode. While in the FOLLOW-UP submode the AGS shall be capable of performing the following functions:

- a. Maintain an inertial reference frame and output total attitude signals for display.
- b. Maintain the attitude error signals to the CES at zero.
- c. Utilize accelerometer inputs from the ASA to calculate LM vehicle present position and velocity in the inertial reference frame.

- d. Solve the LM abort guidance problem using an explicit guidance scheme.
- e. Accept initializing information either from the PGNS down-link or the DEDA.
- f. Command Engine-ON if either the Ascent Engine-ON signal or the Descent Engine-ON signal are present and command Engine-OFF otherwise.

AUTOMATIC Submode - When the AGS is in the AUTOMATIC Submode, it will output attitude error signals and engine commands which are necessary to guide the vehicle to a rendezvous with the CSM. During this submode the AGS will also perform functions a, c, and d as outlined for the FOLLOW-UP submode.

SEMI-AUTOMATIC Submode - In this submode the AGS shall generate attitude error signals to orient LM to the desired thrust direction. An Engine-On COMMAND will be generated on completion of this maneuver provided the Engine-On signal is present. In addition the AGS will perform functions a, c, d, and f. The basic difference between AUTOMATIC and SEMI-AUTOMATIC is that the ullage condition must be satisfied for entry into AUTOMATIC. The ullage condition will be satisfied when the accumulated velocity increments along the vehicle X-axis exceed 0.2 ft/sec each two second computer cycle for three consecutive cycles (six seconds).

ATTITUDE HOLD Submode - The ATTITUDE HOLD submode is provided to maintain any selected attitude; i.e., the AGS will issue attitude error signals which will maintain (within the deadband selected by the DEADBAND switch on panel III) the attitude existing at entry into the ATTITUDE HOLD submode.

The attitude errors are determined by the following equations:

$$E_x = -\underline{Y}_b \cdot \underline{Z}_D \text{ (Dot Product)}$$

$$E_y = -\underline{Z}_b \cdot \underline{X}_D$$

$$E_z = \underline{Y}_b \cdot \underline{X}_D$$

Where \underline{X}_b , \underline{Y}_b , and \underline{Z}_b are unit vectors defining the current vehicle attitude, and \underline{X}_D and \underline{Z}_D are unit vectors defining the vehicle attitudes at entry into the submode. The unit

vectors correspond to the rows of the transformation matrix, A. (See Section IV.)

ATTITUDE HOLD shall be entered in the absence of the other INERTIAL REFERENCE submodes and at the following times during an abort operation:

- (1) During staging as signaled by the ABORT STAGE signal and thereafter for one second after receipt of the ASCENT ENGINE-ON signal.
- (2) At liftoff from the lunar surface and thereafter for one second after receipt of the ASCENT ENGINE-ON signal.
- (3) At termination of guidance during an abort or midcourse correction.

During the ATTITUDE HOLD submode the AGS will perform functions a, c, d, e, and f as listed for the FOLLOW-UP submode.

CSM ACQUISITION Submode - In this submode the AGS will orient the LM vehicle Z body axis toward the AGS computed line-of-sight to the CSM. The X body axis will be oriented such that it lies in the X-Z inertial plane. During this submode the AGS will also perform functions a, c, and d as listed for the FOLLOW-UP submode. The CSM ACQUISITION submode is entered by setting DEDA Address 400_g to +20000.

The CSM ACQUISITION submode is provided in order to accommodate updating of AGS navigation with Rendezvous Radar inputs. Radar updating consists of accepting and processing rendezvous radar data input via the DEDA and updating LM navigation. The radar data will consist of range and range rate data and a code entered at the time when radar pointing error with respect to the vehicle Z-axis is nulled. A minimum of six data points will be used, spaced no more than 4 minutes apart.

C. ALIGNMENT

Alignment consists of initializing the elements of the transformation matrix [A] see Section IV, to obtain attitude reference to a desired inertial reference frame. Given an alignment submode instruction (a DEDA entry), the inertial reference frame will be aligned to one of the three reference frames described below.

The three alignment submodes are IMU Align, Lunar Align and Body Axis Align. IMU Align aligns the AGS direction cosines to the

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attitude reference determined by the PGNS Euler angles Θ , Ψ , and Φ . Lunar Align uses the local vertical as sensed by the Y and Z accelerometers and a previously stored azimuth angle δ_L , which is updated for lunar stay by the correction factor $\Delta\delta$ for a reference attitude. Body Axis Align, previously designated Orbital Align, uses the present vehicle attitude as the reference attitude.

The AGS causes the attitude error signals to the CES to be reduced to zero during the alignment submode.

IMU ALIGN

When the AGS alignment is to be accomplished using PGNS Euler angles, the IMU ALIGN submode shall be utilized. This submode shall be initiated by entering +30000 into memory location 400_g (Function Selector Soo) via the DEDA keyboard. One must remove AGS from the IMU ALIGN submode by changing the Function Selector to something other than +30000 ----- nominally to +00000, attitude hold after completion of the operation.

The transformation matrix is initialized to align the computational inertial reference frame to the coordinate system defined by the PGNS IMU. The PGNS reference frame is defined as follows:

a) Before Lunar Landing

A selenocentric coordinate frame with the X-axis through the intended landing site at the nominal time of landing, positive outward from the lunar center, is obtained by crossing the angular momentum vector of the CSM orbit with a unit vector along the X-axis. This defines the Z-axis direction. The Y-axis direction completes the right handed x, y, z coordinate system.

b) After Lunar Landing

A selenocentric coordinate frame with the inertial X-axis through the intended launch site at the nominal time of launch, positive outward from the lunar center, is obtained by crossing the angular momentum vector of the CSM orbit with a unit vector along the X-axis. This defines the Z-axis direction.

PGNS Euler angles, Θ_p , Ψ_p , Φ_p , which are the IMU gimbal angles of the PGNS, are used by the equations for IMU alignment. Θ_p corresponds to pitch (IMU INNER GIMBAL), Ψ_p to roll (IMU MIDDLE GIMBAL), and Φ_p to yaw (IMU OUTER GIMBAL). See figure 3-1 for the generation of

these Euler angles. The relations of the Euler angles to the nine elements of the transformation matrix are given below.

$$[A] = \begin{bmatrix} C\psi_p C\theta_p & S\psi_p & -C\psi_p S\theta_p \\ -C\phi_p S\psi_p C\theta_p + S\phi_p S\theta_p & C\phi_p C\psi_p & C\phi_p S\psi_p S\theta_p + S\phi_p C\theta_p \\ S\phi_p S\psi_p C\theta_p + C\phi_p S\theta_p & -S\phi_p C\psi_p & -S\phi_p S\psi_p S\theta_p + C\phi_p C\theta_p \end{bmatrix} =$$

or \updownarrow

$$\begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

where

$$C\theta_p = \cos\theta_p, S\theta_p = \sin\theta_p, \text{ etc.}$$

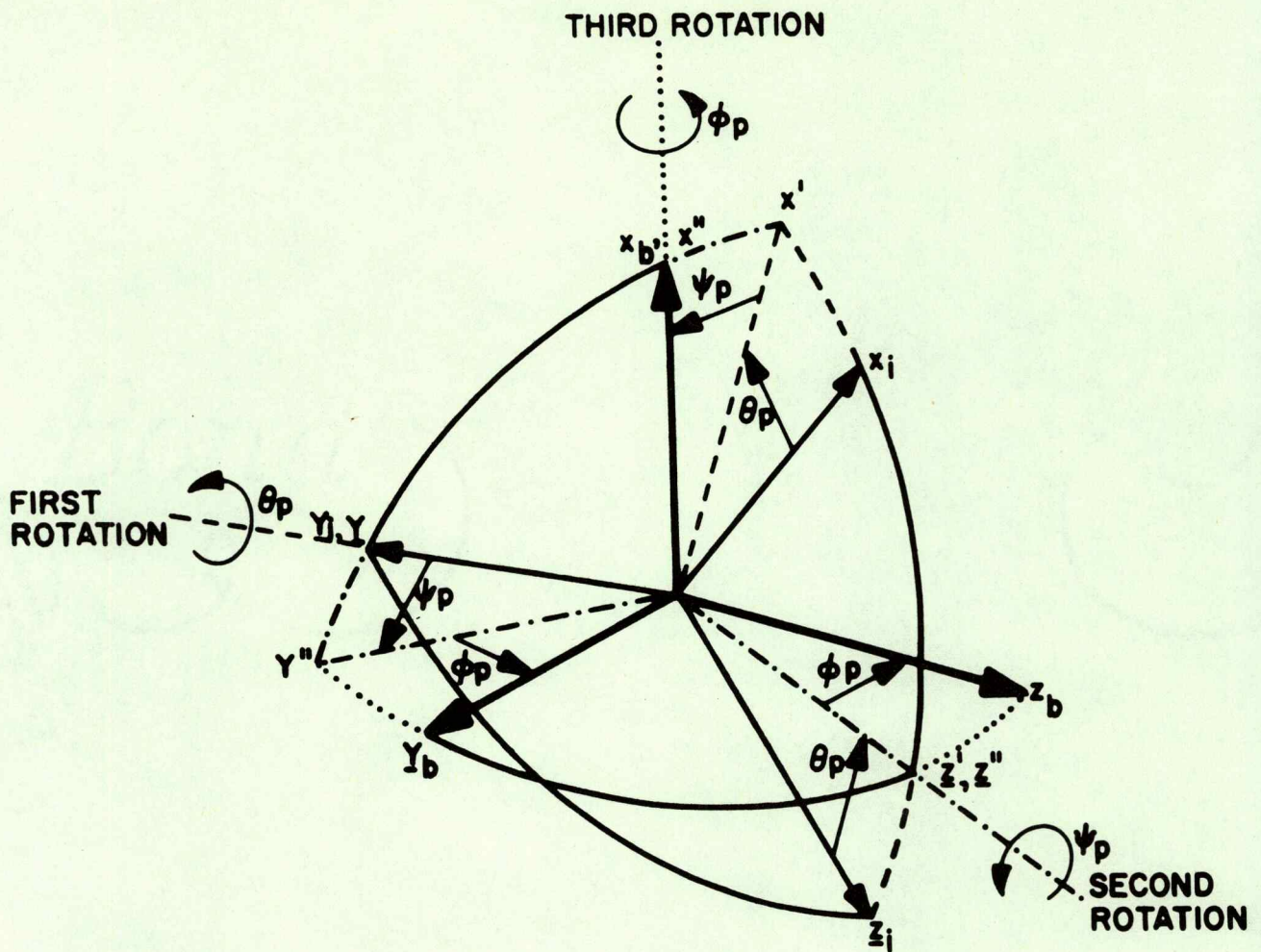
The limits on these gimbal angles are as follows:

$$\theta_p \text{ and } \phi_p, \pm 180^\circ; \psi_p, \pm 60^\circ$$

LUNAR ALIGN

The transformation matrix [A] is aligned so that the computational inertial reference x, y, z axes coincide with the axes of a selenocentric coordinate frame with the x-axis along the lunar local vertical positive outward from the lunar center, and the z-axis direction conceptually obtained by crossing the unit angular momentum vector of the CSM orbit with a unit vector along the x-axis. Compensated velocity increments from the Y and Z accelerometers are used to determine local vertical.

The vehicle azimuth angle with respect to the CSM orbit plane at lunar touchdown is determined by storing, upon command of the DEDA, the AGS azimuth reference as defined by appropriate elements of the



1st rotation Θ_p about y_i ----, Inner Gimbal

2nd rotation Ψ_p about z' -.-.-., Middle Gimbal

3rd rotation Φ_p about x'' , Outer Gimbal

Euler angles (Θ_p, Ψ_p, Φ_p) are used to specify the vehicle reference frame (x_b, y_b, z_b) with respect to the PGNCS inertial reference frame (x_i, y_i, z_i).

Figure 3-1 IMU Euler Angles

transformation matrix. An azimuth correction angle is subtracted from the stored reference to compensate for the effects of lunar rotation during lunar stay time and for any CSM plane changes. The azimuth correction angle $\Delta\delta$, which updates the inertial Z-axis direction, is inserted via the DEDA prior to commencing lunar alignment.

The stored azimuth angle, δ_L , the azimuth correction angle $\Delta\delta$, and the combination $\delta_A = \delta_L - \Delta\delta$ are defined as follows: δ_L and δ_A are each the angle between the y inertial axis and the projection of the Z body axis on the yz inertial plane, measured positive in a counterclockwise direction from the y inertial axis when viewed from above the landing site. The δ_A is the updated value of δ_L .

Just after lunar touchdown the crew should perform a "STORE LANDING AZIMUTH" operation. This operation will store the landing azimuth, δ_L , which will later be used for LUNAR ALIGN. Keying +10000 into memory location 413 (S13) via the DEDA keyboard will implement this requirement.

The correction factor $\Delta\delta$ will be input via the DEDA into memory location 547. It is presently anticipated that this factor will be made available to the crew via voice link with the CSM or earth ground stations.

Before actually entering the LUNAR ALIGN submode, one should verify that δ_{21} , the lunar surface flag, has a negative value when read out from memory location 604 via the DEDA. This confirms that "STORE LANDING AZIMUTH" was previously performed.

Entering the LUNAR ALIGN submode is accomplished by setting Soo, memory location 400, equal to +40000 by entering it via the DEDA.

One may monitor for completion of the lunar alignment by monitoring the Lunar Align complete flag, $\Delta\gamma_I$, via DEDA readout from memory location 606. Alignment is completed when $\Delta\gamma_I$ is consistently displayed as a negative number. Consistently may be defined as $\Delta\gamma_I < 0$ for 10 seconds or longer.

The compensated velocity increments from the ASA y and z accelerometers shall be used by the equations to determine local vertical with respect to the instantaneous vehicle coordinators.

BODY AXIS ALIGN (Orbital Align)

The transformation matrix shall be set to a unit matrix. Thus, the inertial reference frame shall be aligned to the vehicle reference frame at the time of alignment completion.

Body axis align is achieved by setting the function selector Soo (memory location 400) to +50000. Exit from this alignment mode must be manually achieved by setting Soo to something other than +50000, nominally to +00000.

Table I. AGS Operations Performed in Submodes

Operation	IMU Align	Lunar Align	Body Axes Align	Followup	Attitude Hold	Semi Automatic	Automatic	Acquisition	Calibration	Notes
PGNS Downlink Processing	2	2	2	2	2	0	0	0	2	(1) Zero attitude errors are output
Initialize	2	2	2	2	2	0	0	0	2	(2) Performed only on lunar surface if lunar surface signal is present
Gyro Data Processing and Compensation		1		1	1	1	1	1	1	(3) Not performed when lunar surface signal is present (input via DEDA)
Accelerometer Data Processing and Compensation	1	1	1	1	1	1	1	1	1	(4) Engine OFF command is output
Update Direction Cosines	1	1		1	1	1	1	1	1	(5) Not performed for 2 seconds when initialize via downlink or LM initialize via DEDA is commanded
IMU Align ⁽⁶⁾	1								1 ⁽³⁾	(6) PGNS Euler Angles processed only when IMU align operation is performed
Lunar Align		1								
Body Axes Align			1							

Table I. (Continued)

Operation	IMU Align	Lunar Align	Body Axes Align	Followup	Attitude Hold	Semi Automatic	Automatic	Acquisition	Calibration	Notes
Compute Attitude Errors	1 ⁽¹⁾	1 ⁽¹⁾	1 ⁽¹⁾	1 ⁽¹⁾	1	1	1	1	1 ⁽¹⁾	
Telemetry	1	1	1	1	1	1	1	1	1	
RR Data Processing	0	0	0	2	2	0	0	2	0	
DEDA Processing	1	1	1	1	1	1	1	1	1	
FDAI	1	1	1	1	1	1	1	1	1	
LM Navigation	1 ⁽⁵⁾	1 ⁽⁵⁾	1 ⁽⁵⁾	1 ⁽⁵⁾	1 ⁽⁵⁾	1	1	1	1 ⁽⁵⁾	
CSM Navigation	1 ⁽⁵⁾	1 ⁽⁵⁾	1 ⁽⁵⁾	1 ⁽⁵⁾	1 ⁽⁵⁾	1	1	1	1 ⁽⁵⁾	
Guidance and Steering	1 ⁽⁵⁾	1 ⁽⁵⁾	1 ⁽⁵⁾	1 ⁽⁵⁾	1 ⁽⁵⁾	1	1	1	1 ⁽⁵⁾	
Inflight Self Test	1	1	1	1	1	1	1	1	1	
Inflight Gyro Drift Calibration									1 ⁽³⁾	

Legend:

1 - These operations are always performed in the submodes indicated

2 - These operations are performed on command via DEDA in the submodes indicated

Table I. (Continued)

Operation	IMU Align	Lunar Align	Body Axes Align	Followup	Attitude Hold	Semi Automatic	Automatic	Acquisition	Calibration	Notes
Lunar Surface Gyro Drift Calibration									1 ⁽²⁾	Legend:
Inflight Accelerometer Bias Calibration									1 ⁽³⁾	0 - These operations should not be commanded in the submodes indicated
Navigation Display	1	1	1	1	1	1	1	1	1	
Engine ON/OFF Commands	1 ⁽⁴⁾	1 ⁽⁴⁾	1 ⁽⁴⁾	1	1	1	1	1	1 ⁽⁴⁾	
Store Lunar Azimuth	2	0	0	2	2	0	0	0	0	

IV. ATTITUDE REFERENCE

The inertial attitude reference is maintained in a 3 x 3 orthonormal transformation matrix $[A]$ which relates vehicle coordinates X_b, Y_b, Z_b to the inertial coordinates X_i, Y_i, Z_i with the following relations:

Let

$$\underline{X}_b = \begin{bmatrix} a_{11} \\ a_{12} \\ a_{13} \end{bmatrix}$$

be the attitude of the X-body axis, where a_{1j} is the direction cosine between \underline{X}_b and j^{th} inertial axis.

$$\underline{Y}_b = \begin{bmatrix} a_{21} \\ a_{22} \\ a_{23} \end{bmatrix}$$

be the attitude of the Y-body axis, where a_{2j} is the direction cosine between \underline{Y}_b and the j^{th} inertial axis.

$$\underline{Z}_b = \begin{bmatrix} a_{31} \\ a_{32} \\ a_{33} \end{bmatrix}$$

be the attitude of the Z-body axis, where a_{3j} is the direction cosine between \underline{Z}_b and the j^{th} inertial axis.

Then A is given by the relation

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}$$

The matrix $[A]$ is not constant but varies with time as the IM body axes rotate about the inertial axes. The gyros are body mounted. Their outputs after compensation for drift and scale factor errors, measure each 20 msec the incremental change in the angles between the body axes and the inertial axes. These incremental angles $\Delta\gamma_x, \Delta\gamma_y, \Delta\gamma_z$ are used to update the direction cosine matrix each 20 msec.

V. INITIALIZATION

A. NAVIGATION INITIALIZATION

The AGS accepts initialization inputs either automatically from the PGNCs Downlink or manually from the DEDA. Data will be accepted whenever an initialize instruction has been entered through the DEDA during a non-powered flight-phase of the mission. Data is not to be inserted during LM powered flight. Initialization is referenced to the AGS absolute time base and the AGS inertial reference frame at the time of initialization. Upon completion of initialization, an initialization complete indication is generated and may be displayed via the DEDA upon request.

Both LM and CSM ephemeris data are input for initialization. Both may be initialized automatically by setting S14 (memory location 414) to +10000. Completion of automatic initialize is indicated by S14 being automatically set back to +00000.

Manual initialization of LM ephemeris data is affected by use of DEDA. Enter the three components of LM position into 1J1, 1J2, and 1J3 via the DEDA. Enter the three components of the LM velocity vector into 1J4, 1J5, and 1J6.

Enter the LM epoch time, a multiple of 6 seconds, into 1J7 via the DEDA. Initialization is now completed by entering +20000 into S14 via the DEDA. When initialization is complete, S14 will be automatically set back to +00000.

Manual initialization of CSM ephemeris data is affected by entry via the DEDA. Enter the three components of the CSM position vector into 2J1, 2J2, and 2J3, the three components of CSM velocity into 2J4, 2J5, and 2J6, and the CSM epoch time, a multiple of 6 seconds, into 2J7 via the DEDA. Initialization is completed by entering +30000 into S14 via the DEDA. Initialization is completed when S14, displayed on the DEDA returns to +00000.

The memory locations involved are:

1J1	-	240	2J1	-	244
1J2	-	241	2J2	-	245
1J3	-	242	2J3	-	246
1J4	-	260	2J4	-	264
1J5	-	261	2J5	-	265
1J6	-	262	2J6	-	266
1J7	-	254	2J7	-	272
S14	-	414			

B. TIME INITIALIZATION

Initialization of AGS absolute time consists of entering an absolute time of zero into memory locations 377.

A "time tag" is associated with each state vector and is referred to as epoch time. Primary system time is referenced to the time of lift-off and is referred to as Ground Elapsed Time (GET). Therefore, the epoch times are the values of GET at which the state vectors were determined. The Primary System clocks - LCG and CMC - have a capacity of approximately 2.7 million seconds each while the AEA's clock is only about 0.26 million seconds. This disparity requires a procedure for modifying the epoch times transmitted from the LGC to the AEA at Initialization. Since the AEA does not need to know when launch occurred, it is possible to modify the epoch times with a subtractive "time bias." This bias is the GET at which the AEA clock was started.

The procedure calls for setting a verb on the DSKY and setting an absolute time of zero on the DEDA. At the desired initialize time the two ENTER pushbuttons are depressed simultaneously. The absolute time in the PGNS at the initialize time becomes the AGS time bias and may be read out in hours, minutes, and seconds via the DSKY. This time bias must then be subtracted from all subsequent times entered into the AGS.

C. PGNS DOWNLINK DATA (AGS INITIALIZE FORMAT)

The PGNS downlink provides LM and CSM position, velocity, and epoch time which are used to initialize LM navigation and CSM orbit parameters. The data is provided in the AGS inertial coordinate frame. The LM and CSM epoch times are in the same time base as the AGS absolute time.

The initialization data will be contained in the PGNS downlink in closed sequence as shown in Table II. The sequence of 17 sequential words will occur at a basic rate of 50 words per second. No interrupts will occur to the sequence shown. The word formats of the 17 bit downlink words are shown in Table III. The scaling of the data words and the identification (ID) word value are given in Table IV.

A STOP pulse discrete, which is set after a new downlink word has been inputted to the downlink input register, will be available to the program. The STOP pulse discrete will be reset upon reading the downlink input register. The time interval between STOP pulses is 20 ms. The program shall interrogate the STOP pulse discrete twice per 20 ms cycle, with at least 1 ms separation and read

the input register only if the STOP pulse discrete is set to ensure that the input register is not read while data is being shifted into the input register.

Table II. PGNCs Downlink Word Sequence

- 1) ID Word
- 2) LM x Position
- 3) LM y Position
- 4) LM z Position
- 5) LM Epoch Time Most Significant
- 6) LM x Velocity
- 7) LM y Velocity
- 8) LM z Velocity
- 9) LM Epoch Time Least Significant
- 10) CSM x Position
- 11) CSM y Position
- 12) CSM z Position
- 13) CSM Epoch Time Most Significant
- 14) CSM x Velocity
- 15) CSM y Velocity
- 16) CSM z Velocity
- 17) CSM Epoch Time Least Significant
- 18-50) Not Applicable

Table III. PGNCS Downlink Word Format

Bit No.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
ID Word	0	0	0	0	0	0	X	X	X	X	X	X	X	X	X	X	Y	Y
Data Word	1	S	X	X	X	X	X	X	X	X	X	X	X	X	X	X	Y	Y

X = 0 or 1

Y = Not Applicable

S = Sign bit, (0 or 1)

Table IV. PGNCS Downlink Data Characteristics

- 1) Data will be in a 2's complement binary form
- 2) Position Scaling: Most significant bit = 2^{22} ft.
- 3) Velocity Scaling: Most significant bit = 2^{12} ft/sec.
- 4) Timing Scaling: Most significant bit of most
significant word = 2^{17} sec.
- 5) ID Word Code: 000 000 000 1

VI. ASA INPUTS

The ASA provides the computer with incremental angular information about the vehicle x, y, and z axes and incremental velocity changes along the vehicle x, y, and z axes. The incremental data in the form of pulses are accumulated in six 11-bit input registers of the AEA. During any one-millisecond period, the presence of 32 pulses represents a zero signal; the presence of 61 pulses represents the maximum positive signal; the presence of 3 pulses represents the maximum negative signal.

The bias of 32,000 pulses per second is removed by the program after sampling the input register. The input register sampled every 20 msec and cleared under program control upon sampling.

The nominal pulse weight of the incremental angular information is 2^{-16} radians/pulse, 0.00087042642 deg/pulse, $\approx 3^\circ$ sec.

The nominal pulse weight of the velocity increments is (0.1/32) ft/second/pulse, 0.003125 ft/sec.

VII. SENSOR COMPENSATION

A. GYRO COMPENSATION

Angular inputs in the form of gyro output pulses are available to the equations. The equations compensate these inputs for fixed gyro drift, X-gyro spin axis mass unbalance, and gyro scale factor errors.

1. Fixed Gyro Drift

The fixed gyro drift compensation constants K_1^1 , K_6^1 , and K_{11}^1 will be inserted into the computer prior to the mission. They can be modified by Inflight or Lunar Surface Calibration. A positive gyro drift results from a gyro output of more than 32 pulses/msec (640 pulses/20 msec) for no ASA rotation. The pulse rate bias of 640 is removed by a constant K_7^1 . A positive gyro drift is compensated in the AEA by a negative fixed drift compensation constant. Gyro fixed drift compensation is provided over a range of ± 10 deg/hr.

2. X-Gyro Spin Axis Mass Unbalance Drift

The X-gyro spin axis mass unbalance compensation coefficient K_{14}^1 will be inserted into the computer prior to the mission. For a positive X-gyro spin axis mass unbalance, a positive ASA acceleration in the direction of the X-gyro input results in a negative X-gyro output (less than 32 pulses/msec with no ASA rotation). A positive (negative) X-gyro spin axis mass unbalance is compensated in the AEA by a positive (negative) X-gyro spin axis mass unbalance compensation coefficient which multiplies the velocity sensed along the LM X body axis during the 20 msec computer cycle. Compensation is provided over a range of ± 10 deg/hr/g.

3. Gyro Scale Factors Errors

The scale factor constant K_2^1 and the scale factor error compensation constants K_3^1 , K_8^1 , and K_{13}^1 will be inserted into the computer prior to the mission. A positive scale factor error exists when a gyro's scale factor is greater than 2^{-16} rad/pulse. A positive gyro scale factor is compensated in the AEA by a positive gyro scale factor compensation constant. Scale factor error compensation is provided over a range of ± 0.2 percent.

Crew activity is not required for inputting the above terms (K_1^1 , K_6^1 , K_{11}^1 , K_7^1 , K_{14}^1 , K_2^1 , K_3^1 , K_8^1 , and K_{13}^1); i.e., they are input by checkout crews prior to launch or they are updated in flight by gyro calibration.

B. ACCELEROMETER COMPENSATION

The equations compensate the accelerometer inputs for accelerometer static bias and accelerometer scale factor errors. This compensation is performed as corrections to the accelerometer inputs.

a) Accelerometer Static Bias

The accelerometer static bias compensation constants K_{19}^1 , K_{21}^1 , and K_{23}^1 will be inserted into the computer prior to the mission. They can be modified by Inflight Calibration. A positive accelerometer bias error results from an accelerometer output of more than 32 pulses/msec with no acceleration (the pulse rate bias is removed by the constant K_7^1). A positive acceleration bias error is compen-

sated in the AEA by a negative accelerometer bias compensation constant. Accelerometer static bias compensation is provided over a range of $\pm 1000 \mu\text{g}$.

b) Accelerometer Scale Factor Errors

The X, Y, and Z accelerometer scale factors, K_{18}^1 , K_{20}^1 , and K_{22}^1 , respectively, will be inserted into the computer prior to the mission. Each of these scale factors has the nominal value of $1/320 \text{ fps/pulse}$. A positive (negative) accelerometer scale factor error exists when an accelerometer's scale factor is greater than (less than) $1/320 \text{ fps/pulse}$ and is compensated in the AEA by increasing (decreasing) the value of the accelerometer scale factor constant above (below) the nominal value of $1/320 \text{ fps/pulse}$. Scale factor error compensation is provided over a range of ± 0.2 percent.

Crew activity is not required for inputting the terms K_{19}^1 , K_{21}^1 , K_{23}^1 , K_7^1 , K_{18}^1 , K_{20}^1 , and K_{22}^1 , because they are input by checkout crews prior to launch or they are updated by accelerometer calibration.

VIII. CALIBRATION

One of the calibration submodes, Inflight Calibration or Lunar Surface Calibration, is automatically selected by the flight program when Calibration is commanded via the DEDA. The status of the Lunar Surface flag (δ_{21}) determines which calibration is selected. Both gyro bias and accelerometer bias are calibrated and compensated by inflight calibration, whereas only gyro bias calibration and compensation is accomplished by lunar surface calibration.

A. Gyro Calibration

1. In-flight Gyro Calibration

The program provides Inflight Calibration to automatically update gyro fixed drift compensation. This calibration takes place during freefall with the program in the Calibrate Submode, lunar surface flag absent, and the LM in the Attitude Hold steering mode. The gyro drift calibration uses the PGNCs IMU Euler angles as reference. The program automatically selects IMU align during the first two second cycle to provide initial alignment of the AGS to the PGNCs IMU. For the remainder of the calibrate period the program computes the angular errors of the AGS indicated body axes (as defined by the transformation matrix) with respect to the PGNCs indicated body axes (as defined by the PGNCs IMU Euler angles). The angular errors, multiplied by an appropriate gain factor, are added to the AGS compensated angular increments, causing the AGS attitude reference (transformation matrix) to remain aligned to the PGNCs IMU reference. At the same time, the accumulated error signals, multiplied by another gain factor, are added to the gyro drift compensation such that in steady state the compensation is equal to the gyro drift.

2. Lunar Surface Calibration

The AGS program also provides for gyro calibration to automatically update gyro fixed drift compensation while the LM is resting on the lunar surface. The Lunar Surface Calibration requires that a Lunar Alignment or IMU Alignment has immediately preceded. The program then stores the existing transformation matrix to provide a reference attitude. The input angular increment is compensated by the calibration equations to remove the lunar rotation rate. As in the Inflight Calibration, angular errors of the AGS indicated attitude (as defined by the transformation matrix) with respect to the reference attitude are computed and used to maintain the AGS attitude alignment with the stored reference attitude, and also to correct the gyro drift compensation. The end result of the gyro calibration routine is to provide updated values of K_1^1 , K_6^1 , and K_{11}^1 .

B. Accelerometer Calibration

In a period when the LM is in free-fall, the AGS program, when in the Calibrate submode, provides for inflight calibration of the accelerometer static bias compensation to take place concurrently with the Inflight Gyro Calibration. The accelerometer velocity increments accumulated during the period of free-fall are multiplied by an appropriate gain factor and added at the end of the measurement period to the accelerometer bias compensation such that the compensation is equal to the accelerometer bias.

The accelerometer calibration provides updated values of K_{19}^1 , K_{21}^1 , K_{23}^1 .

C. Crew Activity for Calibration

1. Inflight Calibration

Display the Lunar Surface flag (821) on the DEDA by readout from memory location 604. If 821 is not a positive number, enter +10000 into 821 via the DEDA and verify this entry by again displaying it on the DEDA. Inflight gyro bias and accelerometer bias calibration is now initiated by entering +60000 into memory location 400 (Soo) via the DEDA. An inflight calibration complete indication is obtained by displaying Soo on the DEDA. Calibration is complete when Soo returns to +00000.

2. Lunar Surface Calibration

Display the Lunar Surface flag (821) on the DEDA by readout from memory location 604. If 821 is not a negative number, enter -10000 into 821 via the DEDA and verify this by again displaying it on the DEDA.

Next one performs an IMU or LUNAR ALIGN.

After alignment is completed, lunar surface gyro bias calibration is initiated by entering +60000 into memory location 400 (Soo) via the DEDA. A calibration complete indication is obtained by displaying Soo on the DEDA. Calibration is complete when Soo returns to +00000.

IX. DEDA INPUTS AND OUTPUTS

A list of required DEDA inputs and outputs and their quantization is given in Tables V and VI. Decimal inputs and outputs have a range of plus or minus 10^5 times their quantization.

A. DEDA PROCESSING

The DEDA Processing Routine provides for read-in, decoding and storage of instructions and data, and processing and read-out of stored flags and data through the DEDA Data Register. All transfer of information is initiated under control of the DEDA discretes.

Data is processed in two forms, octal or decimal. Octal words consist of a sign and 5 octal characters. Decimal data consist of a sign and 5 BCD characters. Decimal parameters have an associated scale factor stored in the computer's memory.

All data transfer is initiated by the Clear discrete. Upon sensing the Clear, the routine sets up the Clear Mode during which it awaits either an Enter or a Read-out discrete.

Upon sensing an Enter discrete, the routine inputs and process the data contained in the DEDA Shift Register.

Upon sensing a Readout discrete, the routine reads in the address of the requested data from the DEDA Shift Register. Thereafter, the requested data is output twice per second until either a Hold or a Clear Discrete is sensed. Hold causes the last output data to be held until the Readout discrete is again sensed. Depression of Readout will reinitiate output.

B. DEDA INPUT AND OUTPUT PARAMETERS

DEDA constants and variables are entered and/or read out in decimal or octal via the DEDA. Input processing converts them to and/or from binary. Five decimal or octal digits can be entered via the DEDA. In both Table V and Table VI below, these quantities are entered or read out in decimal unless otherwise indicated.

Table V is a list of the constants which the astronaut might wish to input via the DEDA together with a description, the values or range in values, and the quantization. The range and quantization reflect the limit on the input to the DEDA. All of these input quantities can also be read out and displayed by the astronaut.

Table VI is a list of the quantities which the astronaut might wish to monitor via the DEDA. Again the description, the value or range of values, and the quantization is given for each parameter.

Table V. DEDA Input Parameters

Constants	Definition	Value	Range	Quantization*
S ₀₀	AGS Function Selector	0,1,2,3,4,5,6		0
S ₀₇	External ΔV Reference and Sensed Velocity Increment Accumulation	0,1		0
S ₁₀	Guidance Mode Selector	0,1,2,3,4,5		0
S ₁₁	Engine Select	0,1		0
S ₁₂	Inflight Self-Test Control	0,1,3,4,7		0
S ₁₃	Store Landing Azimuth	0,1		0
S ₁₄	Navigation Initialize (Ephemeris Input)	0,1,2,3		0
S ₁₅	Store Z-axis Direction Cosines	0,1		0
S ₁₆	CDH Apisidal Crossing Selection	0,1		0

* A zero stands for non-decimal input.

Table V. (Continued)

Constants	Definition	Value	Range	Quantization*
S_{17}	Select CSI Elliptical or Circular Orbit Logic	0,1		0
S_{55}	Select altitude rate output for moon or earth mission	0,1		0
J_1^1, J_2^1, J_3^1	LM Ephemeris Position Vector (ft)		$\pm 8,388,600$	10^2
J_4^1, J_5^1, J_6^1	LM Ephemeris Velocity Vector (fps)		± 8191	10^{-1}
J_7^1	LM Epoch Time (min)		± 4369	10^{-1}
J_1^2, J_2^2, J_3^2	CSM Ephemeris Position Vector (ft)		$\pm 8,388,600$	10^2
J_4^2, J_5^2, J_6^2	CSM Ephemeris Velocity Vector (fps)		± 8191	10^{-1}
J_7^2	CSM Epoch Time (min)		0 to 4369	10^{-1}
t	Absolute Time (min)		0 to 4369	10^{-1}
J_1^{28}	Component of External ΔV in local horizontal plane, positive in direction of motion and parallel to the CSM plane (fps)		± 8191	10^{-1}
J_2^{28}	Component of External ΔV perpendicular to LM orbit plane, positive in the direction of the AGS y inertial axis (fps)		± 8191	10^{-1}

* A zero stands for nondecimal input.

Table V. (Continued)

Constants	Definition	Value	Range	Quantization*
J_3^{28}	Component of External ΔV along the LM local vertical, positive toward the moon (fps)		± 8191	10^{-1}
J^1	Absolute Time of Desired TPI Maneuver (used for CSI Computation) (min)		0 to 4369	10^{-1}
J^2	Desired LOS Angle at TPI Time for CSI Computation (deg)	26.6	20 to 75	10^{-2}
J^3	Target Offset Time for Direct Transfer Mode (min)	0	± 136	10^{-2}
J^4	Desired Angle through which Vehicle is rotated about its X-axis during APS Operation (deg)	0	± 30	10^{-1}
J^5	Landing Site Radius	5,702,400	5×10^6 to 6×10^6	10^2
J^6	Desired LM Transfer Time for Direct Intercept Transfer Routine (min)	48	0 to 136	10^{-2}
J^{16}	Desired Altitude above the Landing Site at Orbit Insertion (ft)	60,000	0 to 10^5	10^2
J^{18}	Radar Range (nmi)		0 to 600	10^{-1}
J^{21}	Altitude at which Orbit Injection Steering Profile is changed (ft)	25,000	0 to 10^5	10^2

* A zero stands for nondecimal input.

Table V. (Continued)

Constants	Definition	Value	Range	Quantization*
J^{22}	Vertical Pitch Steering Altitude Rate Threshold (fps)	50	± 1000	10^{-1}
J^{23}	Desired Radial Rate at Orbit Insertion (fps)	0	± 1000	10^{-1}
J^{24}	Desired Horizontal Velocity at Orbit Insertion (fps)	5510	0 to 8191	10^{-1}
$T \Delta$	Fixed Time Increment from Present to TPI Maneuver (min)		0 to 136	10^{-2}
t_{igA}	Absolute Time of CSI Maneuver (min)		0 to 4369	10^{-1}
t_{igC}	Absolute Time of TPI Maneuver (min)		0 to 4369	10^{-1}
K_1^1, K_6^1, K_{11}^1	Gyro Drift Compensation Constants (deg/hr). The DEDA converts these constants to rad/20 msec for use in the program		± 10	10^{-1}
$\Delta \delta$	Correction for Lunar Ro- tation (rad) (used in Lunar Align Computations)**		± 1	2^{-14}

* A zero stands for nondecimal input.

** Input in octal

Table VI. DEDA Output Parameters

Quantity	Definition	Range	Quantization
r_x, r_y, r_z	Components of LM inertial position vector (ft)	$\pm 8,388,600$	10^2
V_x, V_y, V_z	Components of LM inertial velocity vector (fps)	± 8191	10^{-1}
V	Components of LM velocity magnitude (fps)	0 to 8191	10^{-1}
r_{cx}, r_{cy}, r_{cz}	CSM inertial position vector (ft)	$\pm 8,388,600$	10^2
V_{cx}, V_{cy}, V_{cz}	CSM inertial velocity vector (fps)	± 8191	10^{-1}
t	Absolute time (min)	0 to 4369	10^{-1}
q	Pericyynthion Altitude of Present LM Trajectory (nmi)	± 1380	10^{-1}
q_1	Pericyynthion Altitude of LM Transfer Orbit (nmi)	± 1380	10^{-1}
V_{gX}, V_{gY}, V_{gZ}	Body Axis Components of Vector of Velocity-yet-to-be-gained to Burnout (fps)	± 8191	10^{-1}
V_{dX}	Accumulated Sensed Velocity along Body Axis (fps)	0 to 8191	10^{-1}
C'_0	"Best" Value of Cost Function (deg)	0 to 360	10^{-2}
V_0	"Best" Value of Horizontal Velocity Increment Added in CSI Burn (fps)	± 8191	10^{-1}

Table VI. (Continued)

Quantity	Definition	Range	Quantization
V_{p0}	"Best" Value of Velocity Increment Added in CDH Maneuver (fps)	0 to 4369	10^{-1}
T_{c0}	"Best" Value of Predicted Time from CDH Burn to TPI (min)	± 8191	10^{-1}
Δr_0	Differential Altitude of Coelliptic Orbits (ft)	$\pm 10^6$	10^2
T_{AO}	"Best" Value of Coast Time from CSI to CDH (min)	0 to 136	10^{-2}
R	Range from LM to CSM (nmi)	0 to 1380	10^{-1}
\dot{R}	Range Rate between CSM and LM (fps)	0 to 4095	10^{-1}
\dot{h}	LM Radial Velocity (fps)	± 8191	10^{-1}
ξ	Angle Between the LM Z Body Axis and the Local Horizontal (deg)	± 90	10^{-2}
h	LM Altitude above Landing Site Radius (ft)	0 to 76,677	10^2
V_G	Magnitude of LM Velocity-yet-to-be-gained to Burn-out (fps)	0 to 8191	10^{-1}
t_{igB}	Predicted Absolute Time of CDH Maneuver (min)	0 to 436.8	10^{-1}
θ LOS	Predicted LOS Angle at t_{igC} (deg)	0 to 360	10^{-2}
δ 21	Lunar Surface Flag		0

Table VI. (Continued)

Quantity	Definition	Range	Quantization
$\Delta \alpha_I$	Lunar Align Status (rad)**	± 0.0625	0.4768
r_f	Predicted LM Burnout Altitude at TPI (ft)	0 to 8,388,600	10^2
V	Component of LM Inertial Position Vector Perpendicular to CSM Orbit Plane for Orbit Insertion* (ft)	$\pm 8,388,600$	10^2
V_y	LM Velocity Perpendicular to CSM Orbit Plane for Orbit Insertion or Perpendicular to Transfer Orbit for Direct Transfer (fps)	± 8191	10^{+1}
V_T	A Constant times the Sum of the Transfer and Braking Velocity Impulses Required for Rendezvous (fps)	$+8191$	10^{-1}

* A zero means nondecimal output

** Binary scaled quantity

X. CES DISCRETES

The Control Electronics Section (CES) provides the following discretetes to the AGS:

1. ABORT
2. ABORT STAGE
3. AUTOMATIC
4. ASCENT ENGINE ON
5. DESCENT ENGINE ON
6. FOLLOW-UP

These discretetes are used by the AGS to define the submodes of the Inertial Reference Mode and to aid in the engine logic. These discretetes are sampled every 40 ms.

The ABORT discrete is received by direct contact closure resulting from depressing the ABORT pushbutton. (see Panel I)

The ABORT STAGE discrete is received by the AGS nine ms after the ABORT STAGE pushbutton (see Panel I.) is depressed. The nine millisecond delay is because of relay closure time in the CES.

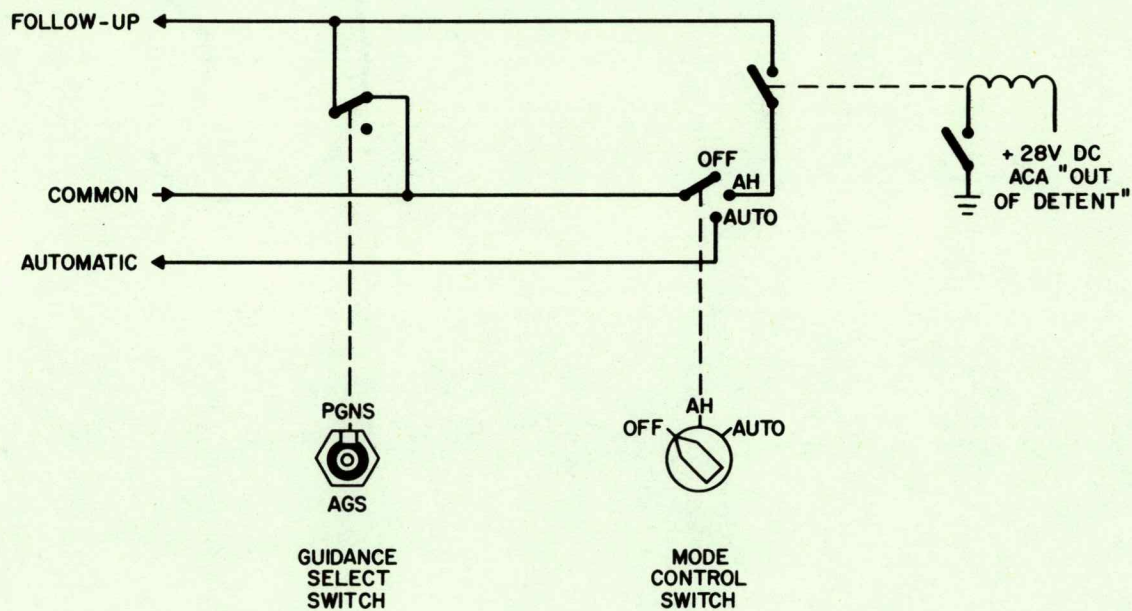
Refer to "AUTOMATIC and FOLLOW-UP DISCRETE GENERATION" fig. 10-1. As the drawing points out, the FOLLOW-UP discrete is issued to the AGS under two conditions:

1. When the PGNS/AGS Guidance Select switch (see Panel I) is in the PGNS position.
2. When the MODE CONTROL switch on Panel III is in AH (ATTITUDE HOLD) position and one or both of the ATTITUDE CONTROLLER ASSEMBLIES (ACA) are out of detent by one degree or more.

The AUTOMATIC discrete is generated by having the MODE CONTROL switch in the AUTO position. See fig. 10-1 for the mechanization.

When the CES issues the ASCENT ENGINE-ON command to the Ascent Engine, it also closes a relay, the contacts of which provide the ASCENT ENGINE ON discrete to the AGS.

When the CES issues the DESCENT ENGINE-ON command to the Descent Engine, it also closes a relay, whose contacts provide the DESCENT ENGINE-ON discrete to the AGS.



"AUTOMATIC" AND "FOLLOW-UP" DISCRETE GENERATION

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XI. ENGINE COMMANDS

a. Engine ON

The program generates an Engine ON command every 40 ms under the following conditions:

1. When the AGS is in the Semi-Automatic Submode and when ullage has been detected.
2. When the AGS is in the Automatic Submode until thrust termination is desired, or until loss of ullage is detected.
3. When the AGS is in the Attitude Hold submode because the Staging condition is set to one.
4. When the AGS is in the Attitude Hold submode because the Lunar Surface flag is set to one.
5. When the AGS is in the Follow-up submode or the Attitude Hold submode (except for cases 3 and 4 above) and if the Ascent Engine ON or the Descent Engine ON signal is present.

b. Engine OFF

The program generates an Engine OFF command every 40 ms under the following conditions:

1. When the AGS is in the Automatic submode and when thrust termination is desired ($\Delta V < \text{threshold}$) or when loss of ullage is detected.
2. When the AGS is in the Semi-Automatic submode unless ullage is detected.
3. When the AGS is in the Alignment mode or the Acquisition mode.
4. When the AGS is in the Follow-up submode or the Attitude Hold submode (except for cases a3 and a4 above) and if the Ascent Engine ON and the Descent Engine ON signals are absent.

XII. IN-FLIGHT SELF TEST

The in-flight self test checks on a continuous basis that the computer's logic and memory are functioning properly. A DEDA switch, S5 (also called S12) memory location 412, is used in conjunction with the test to indicate test results.

The logic test checks the operation of all computer instructions except those associated with input/output operations. The memory test performs a check sum of all hardwired memory plus a portion of the softwired memory which contains fixed data.

The S5 switch may have the following states:

<u>State</u>	<u>Function</u>
+00000	Reset error indicators
+10000	Test successfully completed
+30000	Logic test failure
+40000	Memory test failure
+70000	Logic and memory test failure

XIII. IN-FLIGHT MONITORING

A. Total Attitude Display

γ The sines and cosines of the Euler angles, α , β , and γ shall be computed from the transformation matrix to provide outputs for total attitude display. This total attitude information shall be computed every 40 milliseconds for all vehicle attitudes. The computed data shall be limited to the maximum value specified under range before outputting. The output data shall have the following characteristics:

- a. Output Rate - 25 times per second
- b. Range - 9 bits plus sign.
- c. Scale Factor - Most significant bit equals $1/2$.

B. Attitude Error Display

The attitude error information shall be computed and output for controlling vehicle attitude and for display. The computed data shall be limited to the maximum value specified under range before outputting. The output data shall have the following characteristics:

- a. Output Rate - 25 times per second.
- b. Computation Delay - The maximum computation delay between sampling of the gyro inputs and the subsequent output of the attitude errors shall not exceed 15 milliseconds.
- c. Range - 9 bits plus sign.
- d. Scale Factor - Least significant bit equals $0.15113269 \times 10^{-5}$ rad.

C. Altitude

- a. Output Rate - 5 times per second.
- b. Range - 15 bits.
- c. Scale Factor - Least significant bit equals 2.34 feet.
- d. Format - Magnitude.

D. Altitude Rate

- a. Output Rate - 5 times per second.
- b. Range - 14 bits plus sign.
- c. Scale Factor - Least bit equals 0.5 ft/sec.
- d. Format - Sign and magnitude. Sign shall be represented as a "one" for plus and a "zero" for minus.

E. Lateral Velocity (Y-Body Axis)

- a. Output Rate - 5 times per second.
- b. Range - 8 bits plus sign.
- c. Scale Factor - Most significant bit equals 100 ft/sec.
- d. Format - Sign and magnitude in the last 8 bits. Sign shall be represented as a "zero" for plus and a "one" for minus.

F. Special Computations for DEDA Display

1. Total Velocity - The LM vehicle total velocity in the AGS selenocentric coordinate system shall be computed and made available for output via the DEDA. This quantity is available from memory location 433.
2. Range to CSM - The magnitude of the relative position vector of the CSM with respect to the LM shall be computed and made available for output via the DEDA. This may be read from memory location 210.
3. Range Rate - The range rate along the LM line of sight to the CSM shall be computed and made available for display via the DEDA. This quantity may be read from memory location 440.
4. Differential Altitude - The difference between the radial distances to the LM and CSM orbits at the predicted CDH maneuver location, LM altitude minus CSM altitude. (Memory location 405)
5. CSI Velocity Increment - The ΔV required for the CSI maneuver. (Memory location 507)
6. CDH Velocity Increment - The ΔV required for the CDH maneuver. (Memory location 371)

G. Test Mode Failure Discrete

This discrete output is used to indicate the existence of a computer program or hardware failure. The discrete shall be turned ON, under program control, whenever the inflight test routine detects an error. The discrete is turned OFF, under program control, after completion of the Program Initialization sequence when the AGS is set to operate. The discrete also is turned OFF at the beginning of Self Test routine and remains off if the test does not fail.

The TEST MODE FAILURE discrete output feeds into the CAUTION and WARNING subsystem. When the discrete is set, the AGS WARNING LIGHT and the MASTER ALARM light will come on, (Panel I). Setting S₁₂ to +00000 will cause the self test to be run again.

Refer to the discussions on In-Flight Self Test and DEDA Utilization.

H. AGS WARNING LIGHT

The AGS WARNING LIGHT is inhibited from being operational until the AGS STATUS switch (Panel VI) is placed in STANDBY or OPERATE. Under these conditions this caution and warning light monitors the ASA +28V DC, ASA +12V DC, ASA 28 V/400 CPS, and the TEST MODE FAILURE discrete.

XIV. AGS OUTPUT TELEMETRY

The AGS supplies one digital output telemetry word every 20 milliseconds, provided a telemetry stop pulse from the instrumentation section has been sensed. The program shall interrogate the telemetry control discrete twice per 20 ms cycle, with at least 1 ms separation and load the output register only if the control discrete is set to ensure that the output register is not loaded while data is being shifted from the output register.

Each output word shall contain 24 bits, the most significant 6 bits being an identification (ID) code and the least significant 18 bits comprising one AGS computer word. The ID code ranges sequentially from Octal 01 to Octal 62 with Octal 01 being downlink word 1.

The output data shall be comprised of a fifty word block of computer memory, the output of which shall be repeated every second. At the end of each second, the program shall be initialized such that the next word output will be the first word of the block. At the same time, six current direction cosines shall be stored in the block for later output.

The words contained in the telemetry data block shall be as defined in Table VII.

Table VII. Telemetry Data Format

<u>Number</u>	<u>Word</u>	<u>Description</u>
1	Readout Mode Flag	DEDA readout mode gives negative value
2	DEDA Data Word	Last word of DEDA data entered or readout
3	Clear Mode Flag	DEDA clear mode gives negative value
4	a_{11}	Row one direction cosine
5	a_{12}	Row one direction cosine
6	a_{13}	Row one direction cosine

Table VII. (Continued)

<u>Number</u>	<u>Word</u>	<u>Description</u>
7	DEDA Address	DEDA data word address
8	a_{31}	Row three direction cosine
9	a_{32}	Row three direction cosine
10	a_{33}	Row three direction cosine
11	LM Altitude	
12	r_x	LM inertial position component
13	r_y	LM inertial position component
14	r_z	LM inertial position component
15	q	Pericynthion of present LM orbit
16	r_{xc}	CSM inertial position component
17	r_{yc}	CSM inertial position component
18	r_{zc}	CSM inertial position component
19	r_f	Predicted burnout altitude
20	Δv_x	Compensated 20 ms velocity increment input
21	Δv_y	Compensated 20 ms velocity increment input
22	Δv_z	Compensated 20 ms velocity increment input
23	Absolute Time	Least significant word
24	Δa_x	Compensated 20 ms angular increment input
25	Δa_y	Compensated 20 ms angular increment input
26	Δa_z	Compensated 20 ms angular increment input
27	T_B	Time to burnout
28	v_x	Component of LM inertial velocity
29	v_y	Component of LM inertial velocity
30	v_z	Component of LM inertial velocity

Table VII. (Continued)

<u>Number</u>	<u>Word</u>	<u>Description</u>
31	V_{yb}	LM y-body velocity component
32	V_{xc}	CSM inertial velocity component
33	V_{yc}	CSM inertial velocity component
34	V_{zc}	CSM inertial velocity component
35	\dot{h}	Altitude rate
36	V_G	Required velocity impulse
37	V_{po}	Predicted CDH ΔV
38	V_{dx}	X-axis accumulated sensed velocity
39	T_{Ao}	CSI to CDH coast time
40	X_{D1}	Unit vector component of desired x-axis attitude
41	X_{D2}	Unit vector component of desired x-axis attitude
42	X_{D3}	Unit vector component of desired x-axis attitude
43	Absolute time	Most significant word
44	S_3 (400)	Function selector
45	Discrete Input Word Number One	Discretes: Downlink STOP, Output Telemetry Stop, Followup, Auto- matic, D/E On, A/E On, Abort, Abort Stage
46	S_5 (412)	Self Test control
47	Engine ON Command	Engine ON command gives negative value
48	μ_8	Ullage counter
49	Δr_o	Differential altitude
50	y_f	Predicted out-of-plane-CSM-orbit plane displacement at orbit injection burnout

Note: DEDA accessible parameters of telemetry may be read out of memory starting at address 325₈.

XV. ABORT GUIDANCE ROUTINES

The AGS program shall contain the following five guidance routines:

Orbit Insertion Routine
Coelliptic Sequence Initiate (CSI) Routine
Coelliptic Maneuver (CDH) Routine
Direct Intercept Transfer Routine
External ΔV Routine

These routines shall be available for selection via the DEDA using the Guidance Selector Switch, S_{10} .

A. Orbit Insertion Routine

The orbit insertion routine shall provide attitude commands and engine off command to obtain predetermined cutoff conditions. These conditions shall be defined by the following targeting parameters input via the DEDA:

- h_o - Insertion altitude above the nominal lunar radius
- V_o - Magnitude of the horizontal component of inertial velocity
- \dot{r}_o - Radial velocity (normally zero)

The attitude commands shall also be generated to provide yaw steering of LM into the CSM orbital plane by the time of attainment of the above cutoff conditions. The capability of steering out a wedge angle of up to 2 degrees shall be provided (assuming sufficient ΔV).

When the velocity to go to cutoff (ΔV_g) reaches a preselected threshold, updating of the commanded attitude shall be terminated. Engine OFF shall be commanded when ΔV_g reaches the nominal ascent engine tail-off velocity threshold.

B. Coelliptic Sequence Initiate Routine

The coelliptic rendezvous will be initiated by the coelliptic sequence initiate (CSI) burn followed by the coelliptic maneuver (CDH - for constant differential altitude).

The coelliptic sequence initiate routine shall compute the magnitude of the horizontal velocity increment, parallel to the CSM orbit plane, required to satisfy the following targeting conditions, input via the DEDA.

- T_1 - Absolute time of CSI burn (t_{igA})
- T_2 - Absolute time of transfer phase initiate (TPI) burn, executed using direct intercept transfer routine (J_1)
- ϵ - The angle that projection of the LM-CSM line of sight (LOS) on the X-Z inertial plane makes with the LM local horizontal at the desired TPI time, positive measured clockwise from the local horizontal forward of the LM when looking in the +y inertial axis direction. (J_2)

The magnitude of the CSI burn shall be computed such that, after the CSI and CDH maneuvers, the LM shall arrive at the desired TPI time with the desired LOS angle to the CSM. The CSI and CDH maneuvers shall be computed in the AGS X-Z inertial plane.

The CDH burn will be performed at the time determined by the CSI routine. This time shall be the predicted time of LM arrival at the first or second crossing of the LM orbit line of apsides following the CSI burn. A DEDA input shall specify if CDH will be performed at the second crossing. Otherwise it will be assumed that the CDH will be performed at the first crossing. The CSI routine shall compute the required velocity increment to make the LM and CSM orbits coelliptical, as defined by making the product of the LM semi-major axis and eccentricity. The desired LM semi-major axis for the calculation shall be equal to the CSM semi-major axis plus the differential altitude, Δh . Δh is the difference between the LM and CSM orbits at the predicted CDH maneuver location. The desired radius rate of the LM (\dot{r}_{LM}) at CDH shall be determined by

$$\dot{r}_{LM} = \dot{r}_{CSM} \left(\frac{N_{LM}}{N_{CSM}} \right)$$

The N_{LM} and N_{CSM} are the mean orbital angular rates of the LM and CSM respectively.

The CSI routine shall provide commanded attitude such that the vehicle X-axis lies along the required velocity increment.

The CSI routine shall compute and make available for output via the DEDA the following parameters:

- a. Differential Altitude - the difference between the radial distances to the LM and CSM orbits at the predicted CDH maneuver location, LM altitude minus CSM altitude.
- b. CSI Velocity Increment - the ΔV required for the CSI maneuver.
- c. CDH Velocity Increment - the ΔV required for the CDH maneuver.
- d. CDH Time - the AGS computed time of the CDH maneuver.

C. Coelliptic Maneuver Routine

The coelliptic maneuver (CDH - for constant delta h) routine shall compute in real time, attitude commands and velocity increment required to make the LM and CSM orbits coelliptical. The CDH routine shall provide commanded attitude such that the horizontal component of vehicle X-axis thrusting shall be parallel to the CSM orbit plane.

D. Direct Intercept Transfer Routine

The direct intercept transfer routine shall calculate the necessary LM velocity increment to place LM on an intercept trajectory with the CSM. A DEDA input of the desired LM transfer time will be available. Direct intercept transfer trajectories whose apocynthion is greater than 180 n.mi., or whose eccentricity is greater than 0.1, are not required. Transfer trajectories in a 25 degree neighborhood of the 180 degree or the 360 degree singular points are not required.

The direct intercept transfer routine is not required to compute transfer trajectories which result in intercept with the CSM more than 2^{13} seconds in the future.

This routine will have two options, both selected by the Guidance Selector Switch, S_1 . The first option will be used for pre-thrust calculations only. The second option will be used for pre-thrust calculations and to execute the transfer maneuver.

- a. Transfer Time in Real Time + DT - This option shall consist of solving for the intercept trajectory continuously corresponding to a transfer initiation time which is some time increment ahead of real time. The time increment, DT, will be input via the DEDA.
- b. Transfer Time at a Fixed Absolute Time - This option shall consist of solving for the intercept trajectory corresponding to a transfer phase initiation (TPI) time at some fixed absolute time. This fixed absolute time shall correspond to the transfer initiation time existing at switchover from the real time option to the fixed absolute time option or may be modified via DEDA input. The routine shall limit the input TPI time to be no less than real time.

The direct intercept transfer routine may be used to execute direct transfer abort trajectories, the TPI maneuver in a coelliptic rendezvous, or midcourse correction maneuvers during a transfer trajectory.

The direct intercept transfer routine shall provide attitude commands to orient the LM X-axis along the desired thrust direction.

E. External Delta V Routine

The external ΔV routine shall accept the components of a ΔV vector input via the DEDA. A commanded attitude shall be generated to maintain the X-axis toward the vector resultant of these components in real time, independent of the required burn time.

The ΔV components will be referenced to the following set of unit vectors.

\bar{u}_1 is along the LM local vertical, positive toward the moon

\bar{v}_1 is in the local horizontal plane, positive in the direction of motion, and parallel to the CSM plane.

\bar{w}_1 is defined by $\bar{v}_1 \times \bar{w}_1 = \bar{u}_1$

XVI. ABORT ELECTRONICS ASSEMBLY (AEA)

COMPUTER DESCRIPTION

The AEA is a small, high speed, general purpose computer with a substantial amount of special purpose input/output electronics. It employs a fractional two's complement, parallel arithmetic section and parallel data transfer. Instruction words are 18 bits in length, consisting of a 5 bit order code, an index bit, and a single 12 bit operand address. Data words are 18 bits in length including sign. The ferrite core memory system is partially hardwired, partially scratchpad and has a five microsecond cycle time. For purposes of explanation, the computer may be separated into the Memory, the Central Computer, and the Input/Output Section.

CENTRAL COMPUTER

In the Central Computer are eight data and control registers, an 18 bit parallel adder, two timing registers, and associated logic. The data and control registers are interconnected by a parallel data bus. Computer operations are executed by appropriately timed transfers of information between these registers, between the Memory and the M Register, and between the Accumulator and input/output registers. The Adder and three registers, the M Register, the Q Register and the Accumulator, form the basis for execution of arithmetic operations.

Adder

The arithmetic section is designed around an 18 bit three microsecond parallel adder. Two 18 bit registers, the Accumulator and the M Register furnish the inputs to the Adder. The sum generated by the Adder is loaded into the Accumulator. Shifting operations are implemented by displacing the sum generated by the Adder one bit right or left when loading it into the Accumulator.

Accumulator (A Register)

This 18 bit register communicates in parallel with the Adder and the Data-Bus. In addition, it communicates serially with the Q Register for shifting operations such as multiplication, division, and double length shifts. The Accumulator holds the results of most arithmetic operations and is the register which is used to communicate with input/output registers.

Memory Register (M Register)

The M Register is an 18 bit register which is loaded from the Memory or from the Data Bus. It holds data which is being transferred between the Central Computer and the Memory via the Data Bus. Data transferred from the Memory is held by the M Register as it is placed on the Data Bus. During this time, the data is also written back into the Memory from the M Register if the transfer of data is a read and restore operation. Data transferred to the Memory from the Central Computer is held by the M Register as it is written into the Memory. The M Register holds the multiplicand during multiplication, the divisor during division, the addend during addition, and the subtrahend during subtraction. Load Accumulator operations are accomplished by clearing the Accumulator and then adding the contents of the M Register to the Accumulator.

Multiplier-Quotient Register (Q Register)

The Q Register is an 18 bit register which communicates in parallel with the Data-Bus and serially with the Accumulator. The Q Register holds the least significant half of the double length product after multiplication, and initially holds the least significant half of the double length dividend for division. After division, it holds the unrounded quotient. For double length shifting operations, the Q Register is logically attached to the low-order end of the Accumulator. After execution of a TSQ instruction, the Q Register holds a transfer instruction with an address field set to one greater than the location of the TSQ instruction. If the Q Register is then stored by the routine which has been transferred into, a convenient means of returning to the main program is provided. For divide operations, an extra bit, Q18, is attached to the Q Register.

Index Register

The Index Register is a three bit counter which is used for operand address modification. When an indexed instruction is executed, the effective operand address is computed by a logical OR operation between the Index Register and the three least significant bits of the operand address. When a TIX instruction is executed, the Index Register is decremented by one if it is greater than zero, and the next instruction is taken from the location specified by the address field of the TIX instruction. If the Index Register is zero, it is not decremented, and the next instruction is taken in sequence. The Index Register is loaded under program control from the least significant three bits of the data bus.

Address Register

The Address Register is a 12 bit register which is loaded under computer control from the least significant 12 bits of the Data Bus. It holds the address of the memory location to which access has been requested by the Central Computer.

Operation Code Register

The Operation Code Register is a 5 bit register which is loaded under computer control from the 5 most significant bits of the data bus. It holds the 5 bit order code during its execution.

Program Counter

The Program Counter is a 12 bit counter which is loaded from the least significant 12 bits of the data bus by execution of a transfer instruction. It holds and generates instruction addresses in sequence.

Cycle Counter

The Cycle Counter is a five bit counter which is used to control shift instructions and certain long orders.

Timing

Timing is controlled by two registers, one eight bits in length, and the other three bits in length. These registers produce the timing signals required to control all operations of the Central Computer.

INPUT-OUTPUT SECTION

There are four basic types of registers in the input-output section. These registers operate independently of the central computer except when they are accessed during execution of an input or output instruction. All transfers of data between the central computer and the input-output registers are in parallel. The PGNS Euler Angles are accumulated in three 15 bit integrator registers. The integrator registers shift 15 bits positions upon receipt of each input pulse, serially adding or subtracting one from the previous count. The integrator registers are set to zero by an external signal. ASA gyro and accelerometer pulses are accumulated in six 11 bit counters which are set to zero when accessed by the central computer. The four bit DEDA Register, the 18 bit Input Telemetry Register, the 24 bit Output Telemetry Register, and the 15 bit output register time shared for altitude and altitude rate

Memory

Each core in the temporary storage memory is threaded by an X selection winding, a Y selection winding, a sense winding, and an inhibit winding. In the permanent storage memory, the inhibit winding is omitted, and the X selection winding passes only through cores which represent zeros.

The cycle time of the memory is five usec.

COMPUTER INSTRUCTIONS

The AEA instruction word consists of a five bit operation code, an index bit, and a single 12 bit address field. Instruction and data formats are shown in Figure 1.

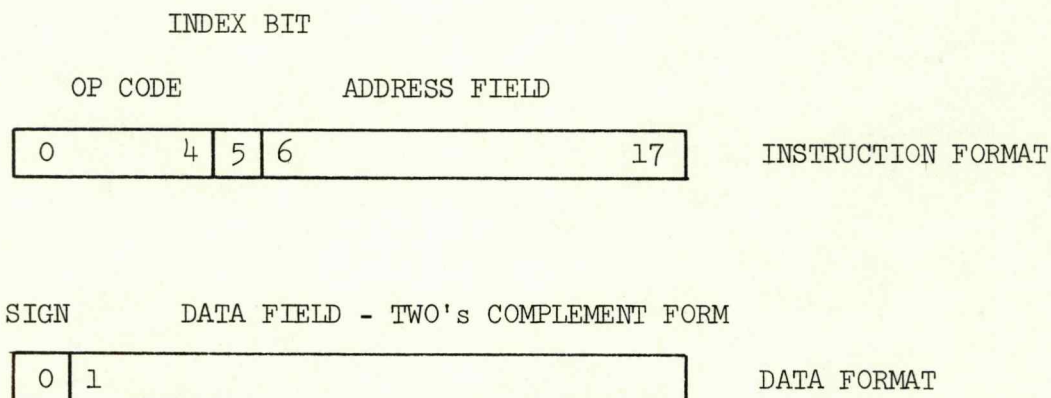


FIGURE 1. AEA INSTRUCTION AND DATA FORMATS.

If the index bit is a one, the address field of any instruction which accesses the Memory is modified by the Index Register. The effective operand address is computed by a logical OR operation between the three bits of the Index Register and the three least significant bits of the operand address.

The AEA executes 27 basic instructions. Four of these instructions, CLZ, ADZ, SUZ, and MPZ, do not include a memory restore cycle after data is read, leaving the addressed memory cell contents equal to zero. These instructions require less power than the corresponding instructions CIA, ADD, SUB, and MPR, and should be used whenever the contents of the addressed memory location need not be retained.

In the subsequent function definition of AEA program instructions, each description is headed by the following information: A three letter mnemonic code used in symbolic programs to represent the five bit operation code; the letter Y or N to represent the address field in the description of the instruction; a two digit octal number which corresponds to the five bit operation code of the instruction word; and the time, in microseconds, required to execute the instruction. The letter Y, as used in the definitions, represents both the address field of the instruction and the memory location of the operand. This is only the case when no indexing is present. If indexing is present, the memory location which is actually addressed is Y modified by the Index Register. The execution times listed are nominal times. The actual times are obtained by dividing the nominal times by 1.024. Individual bit positions of a register are referred to by the letter which represents the register, followed by the bit position.

ARITHMETIC INSTRUCTIONS

Add

ADD Y 22 10 μ sec

The contents of Y are algebraically added to the contents of the Accumulator. If overflow occurs, the overflow indicator is set. The contents of Y are unchanged.

Add and Zero

ADZ Y 32 10 μ sec

The contents of Y are algebraically added to the contents of the Accumulator. If overflow occurs, the overflow indicator is set. The contents of Y are set to zero.

Subtract

SUB Y 24 10 μ sec

The contents of Y are algebraically subtracted from the contents of the Accumulator. The contents of Y are unchanged. If overflow occurs, the overflow indicator is set.

Subtract and Zero

SUZ Y 34 10 μ sec

The contents of Y are algebraically subtracted from the contents of the Accumulator. The contents of Y are set to zero. If overflow occurs, the overflow indicator is set.

Multiply

MPY Y 06 70 μ sec

The contents of the Accumulator are multiplied by the contents of Y. The most significant half of the double length product is placed in the Accumulator and the least significant half in the Q Register.

A special condition exists when the contents of Y are equal to minus one ($Y_0 = 1$, Y_1 thru $Y_{18} = 0$). In this case, the contents of the Accumulator will remain unchanged for all initial values of the Accumulator including minus one. The Q Register will contain zeros. If the Accumulator initially contains minus one and Y contains some value other than minus one, multiplication proceeds normally. In this case, the product will be represented by the two's complement of the contents of Y in the Accumulator, and zeros in the Q Register.

Multiply and Round

MPR Y 26 70 μ sec

This instruction is identical to the MPY instruction with the exception that the most significant half of the double length product, held in the Accumulator, is rounded. Rounding is implemented as follows: If, after obtaining the double length unrounded product, bit Q1 is a one, a one is added into the least significant bit of the Accumulator. If bit Q1 is a zero, both the Q Register and the Accumulator remain unchanged.

Multiply and Zero

MPZ Y 36 70 μ sec

This instruction is identical to the MPR instruction with the exception that the contents of Y are set to zero.

Divide

DVP Y 04 73 μ sec

The contents of the double length dividend, the most significant half of which is contained in the Accumulator and the least significant half in the Q Register, is divided by the contents of Y. The sign of the Q Register is disregarded. The rounded quotient is held by the Accumulator and the unrounded quotient by the Q Register.

To prevent greater than fractional quotient, the dividend and divisor must be scaled such that the absolute magnitude of the dividend is less than that of the divisor when represented in the machine. When initial conditions which result in greater than fractional quotients are detected, the overflow indicator is set and the divide operation proceeds normally. One exception to this occurs when the contents of Y are positive and the Accumulator contains an equal negative value. The overflow indicator is not set and the quotient which results is minus one (A0 = 1, A1 thru A17 = 0). If the contents of Y are negative and the Accumulator contains an equal positive value, the overflow indicator is set. The result, however, is also minus one.

The last step of the division process is placing the quotient in the Accumulator and rounding it. Rounding is based upon a determination of the next bit of the quotient. If the additional bit is a one, a one in the least significant bit position is added to the quotient in the Accumulator. If the additional bit is a zero, the Accumulator remains unchanged and equal to the unrounded quotient retained in the Q Register. Rounding is inhibited when it causes overflow in the Accumulator. This condition exists when the Accumulator contains the maximum positive value (A0 = 0, A1 thru A17 = 1). It results from division of a quantity by a quantity of equal sign and only slightly larger magnitude.

Complement Accumulator

COM 60 16 μ sec

The contents of the Accumulator are replaced by their two's complement. If the contents of the Accumulator are minus one (A0 = 1, A1 thru A17 = 0) or zero, the Accumulator remains unchanged.

Absolute Value of Accumulator

ABS 62 16 μ sec

If the contents of the Accumulator are negative, they are replaced by their two's complement. If the contents of the Accumulator are positive, zero, or equal to minus one (A0 = 1, A1 thru A17 = 0), the Accumulator remains unchanged.

LOAD AND STORE INSTRUCTIONS

Clear and Add

CIA Y 20 10 μ sec

The Accumulator is loaded from Y. The contents of Y remain unchanged.

Clear, Add and Zero

CLZ Y 30 10 μ sec

The Accumulator is loaded from Y. The contents of Y are set to zero.

Load Q Register

LDQ Y 14 13 μ sec

The Q Register is loaded from Y. The contents of Y remain unchanged.

Store Accumulator

STO Y 10 13 μ sec

The contents of the Accumulator are stored in Y. The Accumulator remains unchanged.

Store Q Register

STQ Y 12 13 μ sec

The contents of the Q Register are stored in Y. The Q Register remains unchanged.

SHIFT INSTRUCTIONS

Accumulator Left Shift

ALS N 56 $3N + 13 \mu\text{sec}$

The contents of the Accumulator are shifted left N places. N is specified by bits 13 thru 17 of the instruction word. If any bit shifted from A1 changes A0, the overflow indicator is set. Zeros are shifted into A17, and bits shifted from A0 are lost.

Long Left Shift

LLS N 52 $3N + 13 \mu\text{sec}$

The contents of the Accumulator and bits one thru seventeen of the Q Register are left shifted as one register N places. N is specified by bits 13 thru 17 of the instruction word. The sign of the Q Register is made to agree with the sign of the Accumulator. If any bit shifted from A1 changes A0, the overflow indicator is set. Zeros are shifted into Q17, and bits shifted from A0 are lost.

Long Right Shift

LRS N 54 $3N + 13 \mu\text{sec}$

The contents of the Accumulator and bits one thru seventeen of the Q Register are right shifted as one register N places. N is specified by bits 13 thru 17 of the instruction word. The sign of the Q Register is made to agree with the sign of the Accumulator. Bits shifted into A0 are the same as A0, and bits shifted from Q17 are lost.

TRANSFER INSTRUCTIONS

Transfer

TRA Y 40 $10 \mu\text{sec}$

The next instruction is taken from Y.

Transfer and Set Q

TSQ Y 72 $16 \mu\text{sec}$

The contents of the Q Register are replaced by a transfer instruction with an address field set to one greater than the location of the TSQ instruction, and one in the index bit position.

The next instruction is taken from Y. If the Q Register is stored by the routine to which control has been transferred a convenient means of returning to the main program is provided. The one in the index bit position of the transfer instruction is disregarded when the instruction is executed.

Transfer on Minus Accumulator

TMI Y 46 10 μ sec

The next instruction is taken from Y if the contents of the Accumulator are negative. If the contents of the Accumulator are positive or zero, the next instruction is taken in sequence.

Transfer on Overflow

TOV Y 44 10 μ sec

If the overflow indicator is set, the next instruction is taken from Y, and the overflow indicator is reset. If the overflow indicator is reset, the next instruction is taken in sequence.

INDEX INSTRUCTIONS

Address to Index

AXT N 50 13 μ sec

The index register is set to N. N is specified by bits 14 thru 17 of the instruction word.

Text Index and Transfer

TIX Y 42 10 μ sec

If the index register is greater than zero, it is decremented by one and the next instruction is taken from Y. If the index register is zero, it remains unchanged and the next instruction is taken in sequence.

TIMING INSTRUCTION

Delay

DLY Y 70

Execution is halted until a timing signal, which is generated at 20 millisecond intervals, is received. The next instruction is taken from Y. If the computer is not in the halt mode when the timing signal is generated, the Test Mode Failure Discrete is set.

Execution of this instruction at the completion of each computational cycle provides a means of equalizing the time duration of computational cycles.

INPUT-OUTPUT INSTRUCTIONS

There are two operation codes for this set of instructions, one to address input registers and one to address output registers. The individual registers are addressed by variations in the address field of the input or output instruction word. Section 2.0 defines the format for AEA instructions. The following is a definition of the two input-output instructions:

Input

INP Y 64 16 or 67 μ sec

The contents of the input register specified by Y are loaded into the Accumulator and the register is set to zero or remains unchanged depending upon the register which is selected. To facilitate resetting registers, the addresses of certain registers may be combined. When this is done, each of the input registers involved will be reset or will remain unchanged depending upon the registers which are addressed. When more than one input register is addressed simultaneously, the Accumulator will contain the logical OR of the contents of all of the registers which are addressed. Only addresses which have the same most significant octal character can be combined. To combine the addresses of two or more input registers, add their addresses together algebraically, excluding the most significant character. For example, combining the addresses of all six of the eleven bit counters results in an address of 6176. Execution time is 67 usec if a PGNS Angle Register is addressed, and 16 usec for all other input registers.

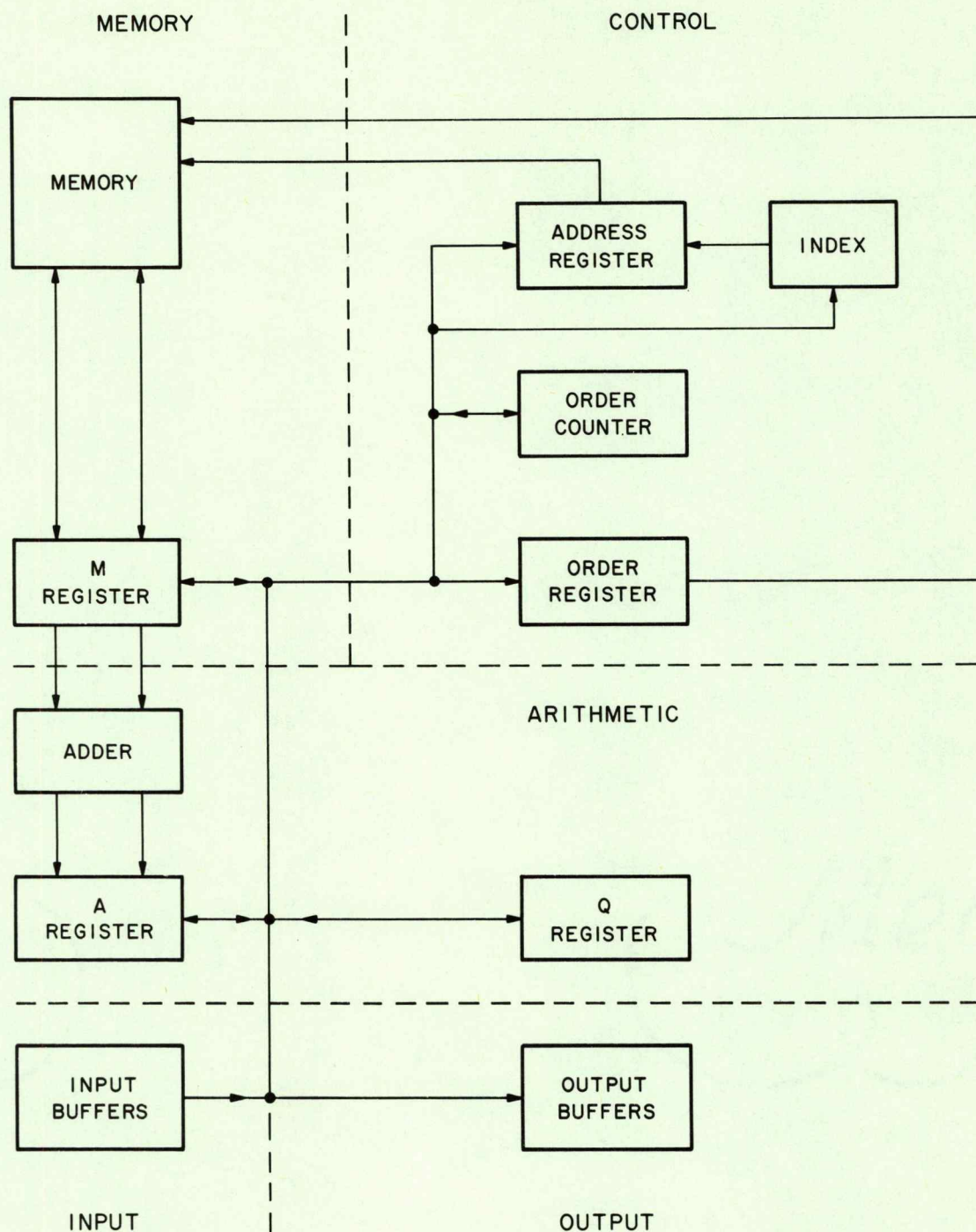
The addresses of the individual input registers and input discrete bit positions are given in Table C and D of Appendix B.

Output

OUT Y 66 13 μ sec

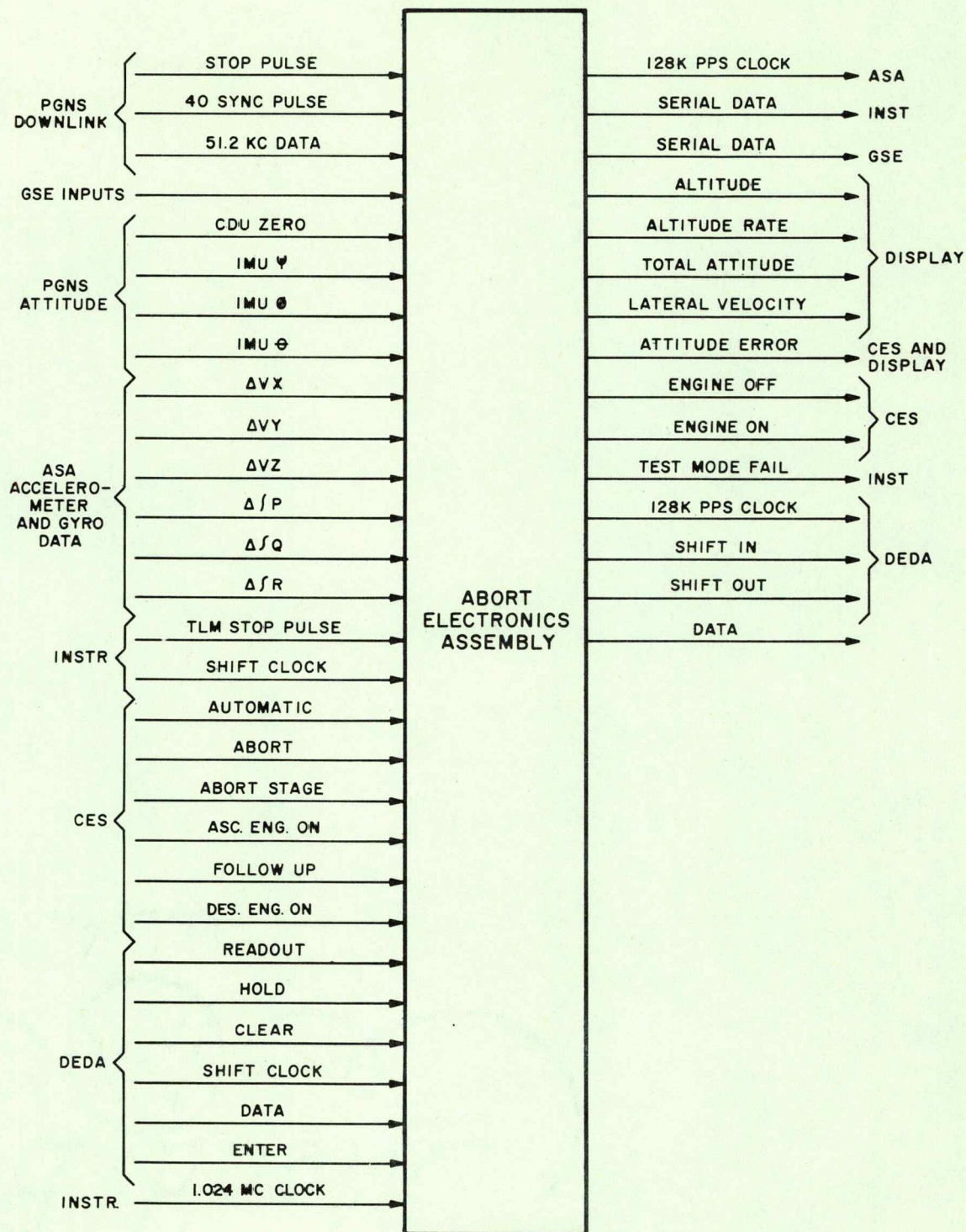
The contents of the Accumulator are transferred to the output register specified by Y unless Y is the address of a discrete output. If Y is the address of a discrete output, the discrete is set or reset as specified by Y. The addresses of certain groups of output registers and output discretelys may be combined. Only addresses with the same most significant octal character may be combined. To combine the addresses of two or more output registers,

add their addresses together algebraically excluding the most significant octal digit. When combining the address of two or more discrete outputs, this procedure cannot be followed for the set addresses. When adding the set addresses together, the most significant four binary bits are excluded. For example, combining the addresses of the first four discrete set outputs results in an address of 2760. When more than one output register is addressed simultaneously, each register is loaded from the bit positions of the Accumulator which normally load the specific register. Combinations of output discrete addresses cause each of the discrettes involved to be set or reset depending upon the four most significant binary bits of the combination.



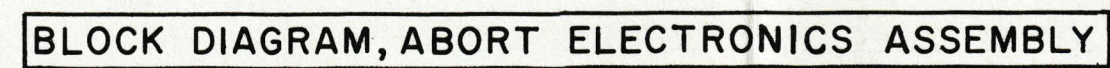
SIMPLIFIED COMPUTER BLOCK DIAGRAM

T30405-107
MAY 66



AEA INTERFACE

T30405-108
MAY 66



XVII. DATA ENTRY AND DISPLAY ASSEMBLY (DEDA)

Introduction

The Data Entry and Display Assembly (DEDA) enables manual insertion of information into the AEA computer and manual display of information within the AEA computer. Manual control is accomplished by depression of pushbuttons on the DEDA front panel in a prescribed sequence.

Operation (Figure 17-1)

The DEDA operation is initiated by depression of the CLEAR pushbutton which enables entry from the digit pushbuttons. As each digit pushbutton is depressed, its code is placed in the register for display in the order that it is depressed (most significant digit first). When the appropriate number of digits have been entered, the ENTER or READOUT pushbutton can be depressed without generating an operator error. When entering information, nine digit pushbuttons must be depressed prior to depression of the ENTER pushbutton. When requesting a READOUT, three pushbuttons must be depressed prior to depression of the READOUT pushbutton.

The AEA computer recognizes the ENTER or READOUT signal and sends the DEDA a SHIFT-IN discrete. The DEDA then provides a serial sequence of a data pulse and a shift pulse that is repeated four times and results in the transferral of a digit code to the AEA computer. The computer issues further SHIFT-IN discrettes and the process is repeated until all digits have been transferred. If the READOUT pushbutton had been depressed, following the entering process, the DEDA will receive a SHIFT-OUT discrete from the computer. The DEDA will then provide a sequence of four-shift pulses and receive four-bits of data from the computer in return. The computer issues further SHIFT-OUT discrettes and the process is repeated until the entire word is received. The information is displayed until the AEA computer updates the word or the CLEAR pushbutton is depressed, which terminates the readout operation. Upon depressing the HOLD pushbutton, the AEA computer will stop sending SHIFT-OUT discrettes after the next complete word has been received. Depression of the READOUT pushbutton in this mode will cause the AEA computer to resume updating the displayed data.

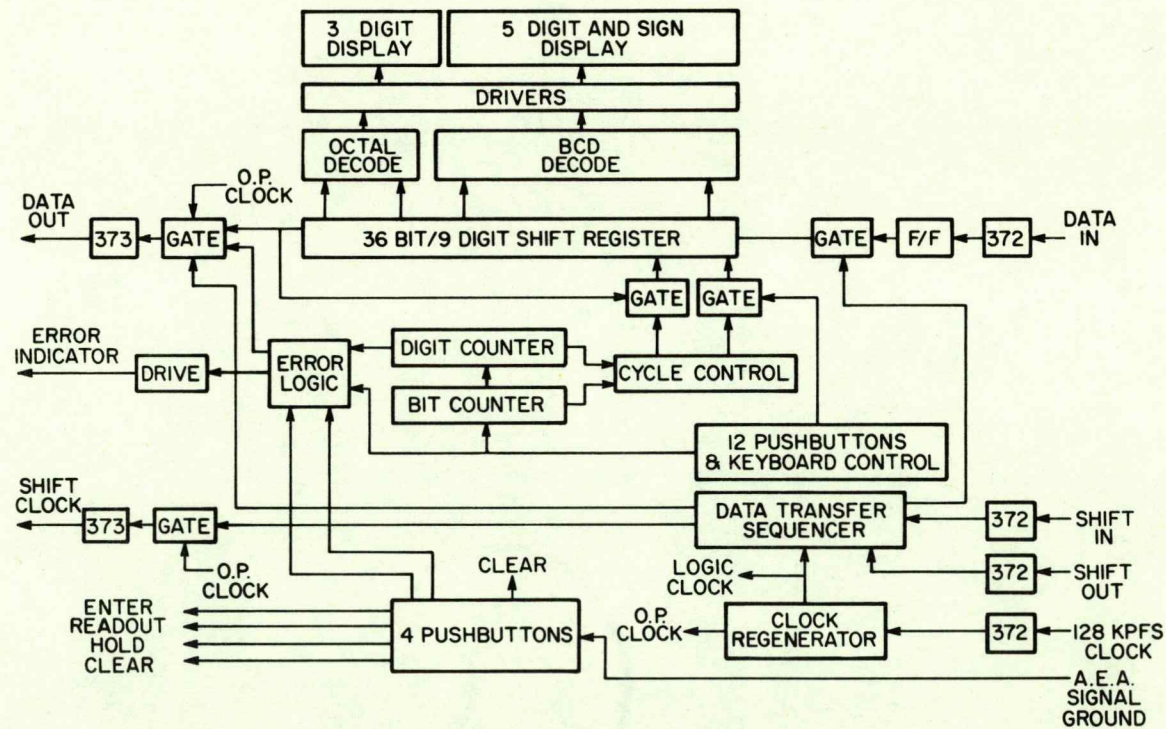
Front Panel (Figure 17-2)

The DEDA front panel contains ten digit and two sign pushbuttons. Four additional pushbuttons labeled CLEAR, READOUT, ENTER,

and HOLD provide functional control of the DEDA and data transfer operation. Each pushbutton controls two sets of contacts.

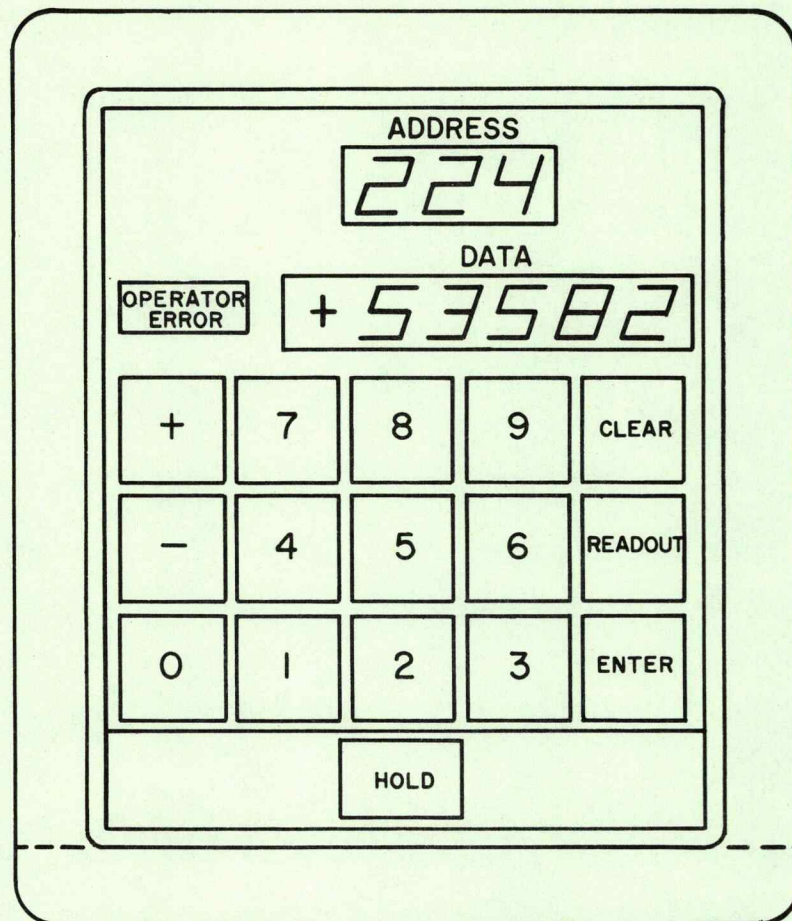
The error indicator is illuminated whenever an Operator Error condition exists. It remains illuminated until the CLEAR pushbutton is depressed. The operator error indicator is illuminated by setting a flip-flop under the following conditions:

1. Nine pushbuttons not depressed and the ENTER pushbutton depressed.
2. Three pushbuttons not depressed and the READOUT pushbutton depressed.
3. More than nine pushbuttons depressed.
4. The 8 or 9 digit pushbuttons depressed when loading the address portion of the word.
5. A digit pushbutton depressed in the fourth position.
6. The plus (+) or minus (-) pushbuttons depressed in other than the fourth position.



DEDA LOGIC BLOCK DIAGRAM

T30312-39
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DEDA FRONT PANEL

T30312-38
FEB 67

XVIII. ABORT SENSOR ASSEMBLY

General Introduction (See Figure 18-1)

The Abort Sensor Assembly (ASA) of the Lunar Module LM Abort Guidance System will be used to sense incremental angular displacement about the LM vehicle axes and velocity increments along the vehicle orthogonal axes. The ASA is required to produce output signals that are measurements of the angular and velocity quantities and transmit these signals in the form of discrete pulses to the Abort Electronics Assembly for further processing.

The ASA contains six inertial sensors consisting of three integrating gyros and three accelerometers that sense motions of the Lunar Excursion Module about the vehicle roll, pitch, and yaw axes and accelerations along these axes. Along with these sensors, is a group of analog and digital circuitry. Associated with each sensor is a Pulse Torque Servo Assembly (PTSA) which provides a means of accurately controlling the torquing currents sent to the sensors. The PTSA's also feed a digital pulse train to the AEA to indicate a change in velocity in the case of the accelerometers and a change in angle in the case of the gyros.

The Frequency Countdown Assembly within the ASA package provides all internal timing and control signals. The FCD works in conjunction with the ASA power supply to generate a portion of the voltages used for excitation of the gyros and accelerometers.

A Fine Temperature Control unit and a Fast Warmup Unit provide for proper temperature control of the ASA package which utilizes a block heating concept.

The ASA contains an Interface Electronics unit which conditions input or output signals to the appropriate voltage levels and/or pulse widths.

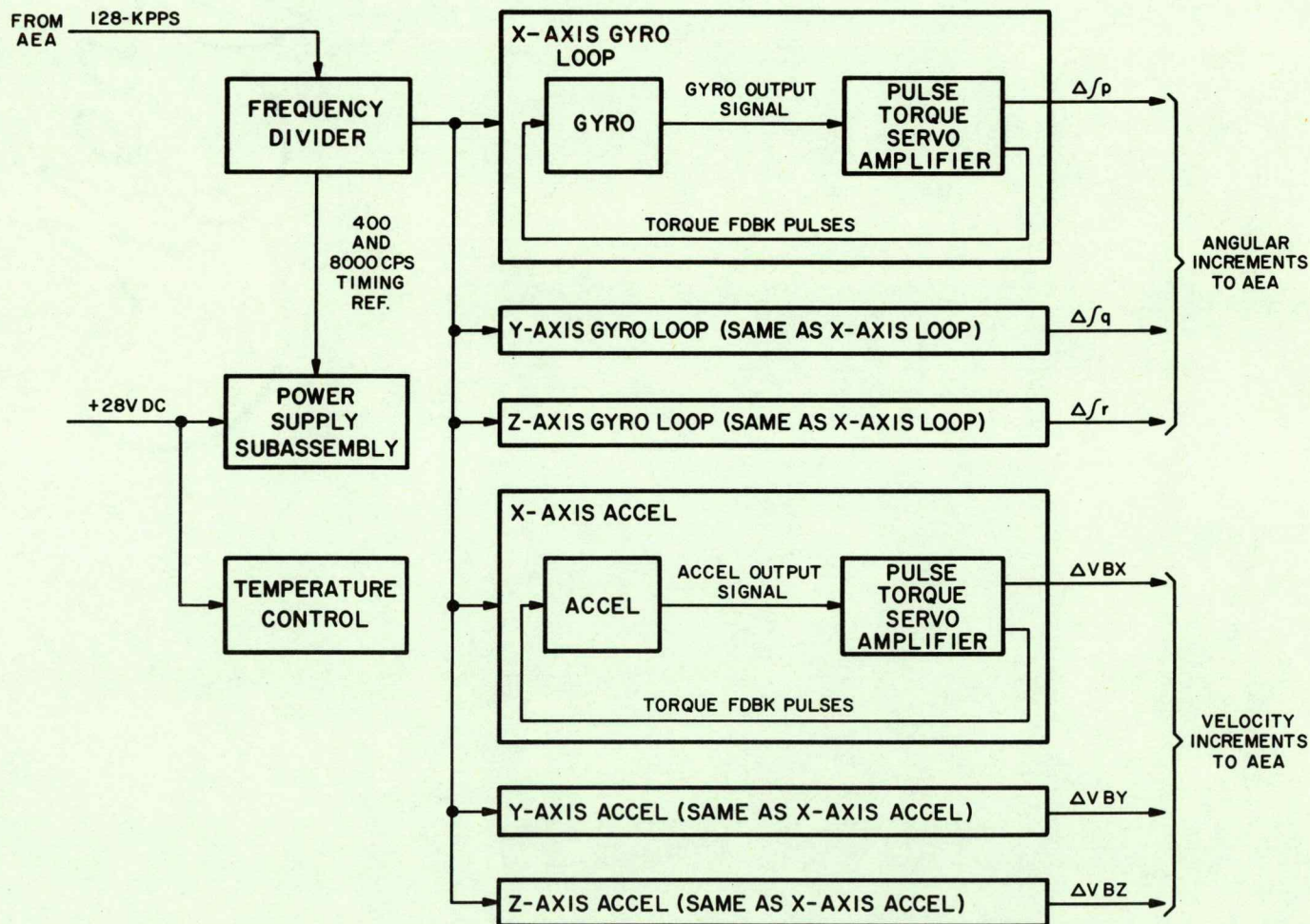
The following are the highlights of ASA characteristics:

<u>Requirement</u>	<u>Production Model</u>
1. General	
Exterior Dimensions	11.5" x 9.0" x 5.06"
Weight	20.4 lbs.

	<u>Requirement</u>	<u>Production Model</u>
1.	General (Cont)	
	Steady State Power (Vacuum)	73 w
	Mission Reliability	0.991
2.	Angular Measurements	
	Maximum Angular Rate	25°/sec
	Gyro Drift Rate (30 days)	0.8°/hr (max)
	Angular Scaling (per pulse)	2 ⁻¹⁶ rad (3 sec)
3.	Linear Measurements	
	Maximum Acceleration Range	100 ft/sec ²
	Accelerometer Bias (30 days)	70 ug's (max)
	Velocity Scaling (per pulse)	0.10/32 ft/sec (0.003 ft/sec)

The ASA is a strapped-down (gimballess) inertial system as opposed to the more conventional (gimballed) stabilized platform. The strapped-down system has the advantage of substantial size and weight reduction compared with the conventional inertial system, but has the disadvantage of error buildup. Error buildup is neutralized by the continuous updating technique.

Outputs are provided to the computer of the AGS, the Abort Electronics Assembly (AEA), to indicate ASA measurements of angular displacement and velocity increments. Angular measurements for an axis are indicated by pulses representing small angular displacements (approximately 3 arc-seconds) generated by the particular PTSA associated with the gyro whose input axis is aligned within 2 arc-minutes of the designated LM ASA reference axis. Similarly, the three accelerometer channels comprise one accelerometer and one PTSA each. The accelerometer channels' output pulses represent small increments of linear velocity. The input axes of the three accelerometers and of the three gyros are orthogonally related to each other and aligned with the ASA X, Y, and Z reference axes.



ASA BLOCK DIAGRAM

XIX. CONTROLS AND SWITCHES ASSOCIATED WITH THE LM AGS

AGS STATUS SWITCH (PANEL VI)

Switch Positions:

- OFF - Applies "warmup" discrete to the ASA and applies the "standby" discrete to the AES.
- STANDBY - Removes "warmup" discrete to the ASA.
- OPERATE - Removes "warmup" and "standby" discrettes.

GUIDANCE CONTROL SWITCH (PANEL I)

Switch Position:

- PGNS - Applies "Followup" discrete to the AEA.
- AGS - Removes "Followup" discrete from AEA.

MODE CONTROL SWITCH (PANEL III)

Switch Positions:

- AUTO - Applies "Automatic" discrete to the AEA.
- ATTITUDE HOLD - Remove Automatic Discrete and applies "Followup" discrete to the AEA if an attitude control stick (ACA) is out of detent.
- OFF - Removes "Automatic" discrete, and prevents generation of the "Followup" discrete regardless of position of the ACA.

ABORT BUTTON (PANEL I)

(Guarded Pushbutton)

When depressed it applies the ABORT discrete to the AEA. If the Descent Engine has not been previously armed, depression of this switch will arm the Descent Engine.

ABORT STAGE BUTTON (PANEL I)

(Guarded Pushbutton)

Applies ABORT STAGE signal to AEA, and pressurizes the Ascent Engine. Initiates staging if the Engine On command is present.

MODE SELECT SWITCH (PANEL I)

This three-position toggle switch (LDG RADAR - PGMS - AGS) selects radar or computer data for display on the two Cross-Pointer indicators and the ALTITUDE/RANGE indicator.

Switch Positions:

- | | | |
|--------------|---|--|
| LDG
RADAR | - | Altitude, altitude rate, forward velocity, and lateral velocity from the LDG RADAR are enabled for display. |
| PGNS | - | In the PGNS position LGC computed altitude, altitude rate, forward and lateral velocities are enabled for display. |
| AGS | - | In the AGS position AGS computed altitude, altitude rate, and lateral velocity are enabled for display. |

The data from the source selected by the MODE SELECT Switch are displayed on the X-Pointers (Cross-Pointers) only when the RATE ERROR MONITOR switches (panels I and II) are in the LDG RADAR/COMPUTER position. When the RATE ERROR switches are in the RNDZ RADAR position, no inputs from the MODE SELECT switch are presented to the X-Pointers.

Data from the source selected by the RATE ERROR MONITOR switch is displayed on the ALTITUDE/RANGE Indicator only when the ALT/RNG MONITOR switch is in the ALT/ALT RT position. When the ALT/RNG MONITOR switch is in the RNG/RNG RT position, no inputs from the MODE SELECT switch are presented to the ALTITUDE/RANGE indicator for display.

ALTITUDE/RANGE MONITOR SWITCH

This two position toggle (RNG/RNG RT - ALT/ALT RT) selects Rendezvous Radar range and range rate data or landing altitude and altitude rate data to be displayed on the ALTITUDE/RANGE indicator. In the RNG/RNG RT position Rendezvous Radar range and range rate data are presented to the ALTITUDE/RANGE display. In the ALT/ALT RT position data from whatever source is selected by the MODE SELECT switch will be presented to the ALTITUDE/RANGE display.

ATTITUDE MONITOR SWITCHES (PANEL I & PANEL II)

These two-position toggles (PGNS - AGS) select the source of Attitude data to be displayed on the FDAI's. In the PGNS position, vehicle Total Attitude signals (after conditioning by GASTA) are sent to the FDAI balls and LGC Attitude error signals are sent to the FDAI pitch roll and yaw error needles. In the AGS position, the AGS total vehicle attitude signals are sent to the FDAI balls and AGS attitude error signals are sent to the FDAI pitch, yaw and roll error needles.

The ATTITUDE MONITOR switches select TOTAL ATTITUDE signals from the AGS or from the PGNS for display on the FDAI's.

In addition they enable ATTITUDE ERROR signals from either AGS or PGNS to be fed to the RATE ERROR MONITOR switches which control their application to the FDAI's.

RATE ERROR MONITOR SWITCHES (PANELS I & II)

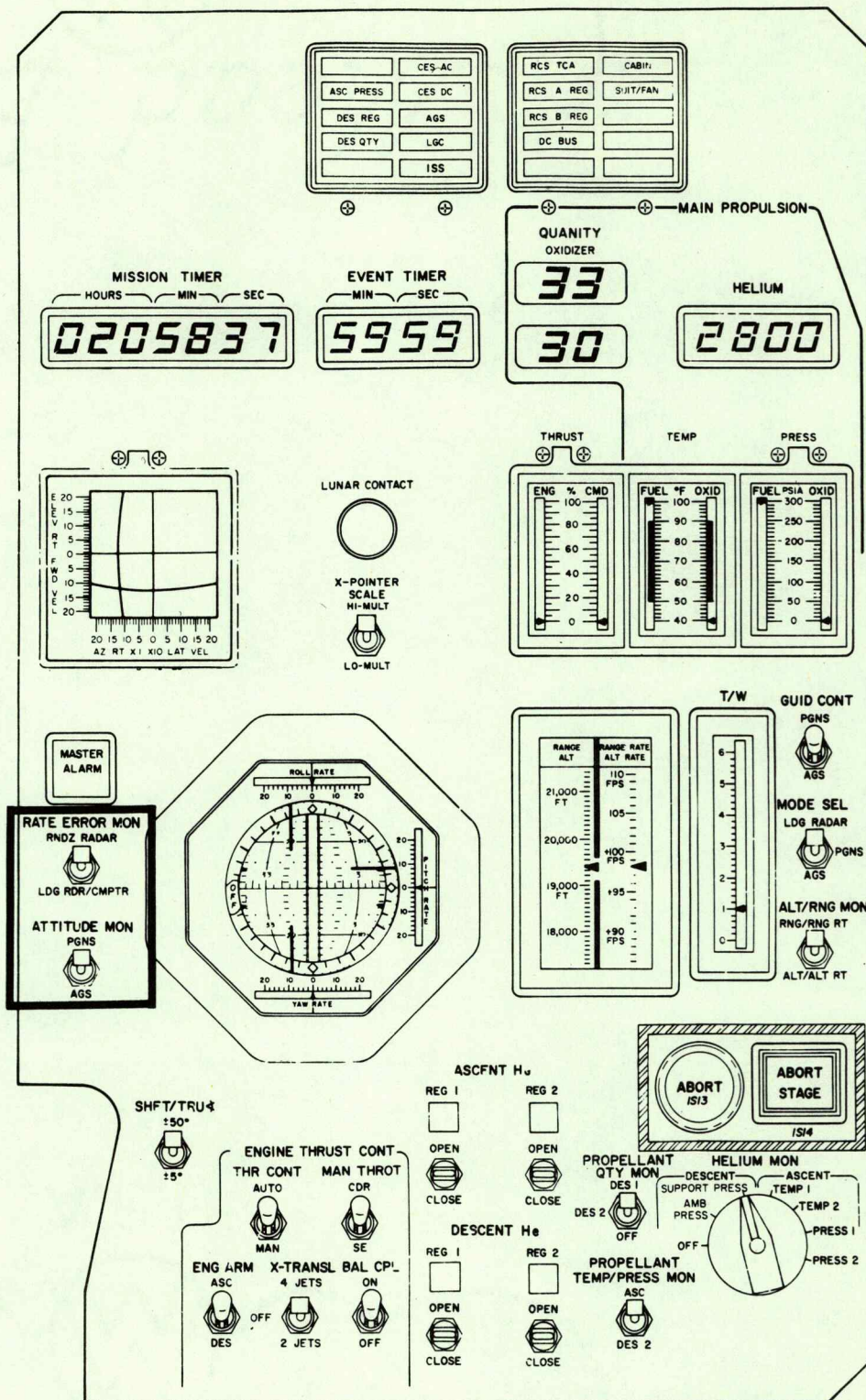
These two-position toggles (RNDZ RADAR - LDG RDR/COMPTR) enables signal inputs to the FDAI's and the X-Pointer displays. In the

RNDZ RADAR position, shaft and trunnion angles from the Rendezvous Radar are displayed on the pitch and yaw error needles of the FDAI, and LOS Azimuth and Elevation rates are displayed on the X-Pointer display, (illuminating LOS AZ and LOS ELEV). In the LDG RDR/COMPTR position, vehicle attitude errors are displayed on the FDAI error needles and forward and lateral velocities are displayed on the X-Pointer display, (illuminating LAT VEL and FWD VEL).

The RATE ERROR MONITOR Switches present inputs to the ATTITUDE ERROR needles on the FDAI's.

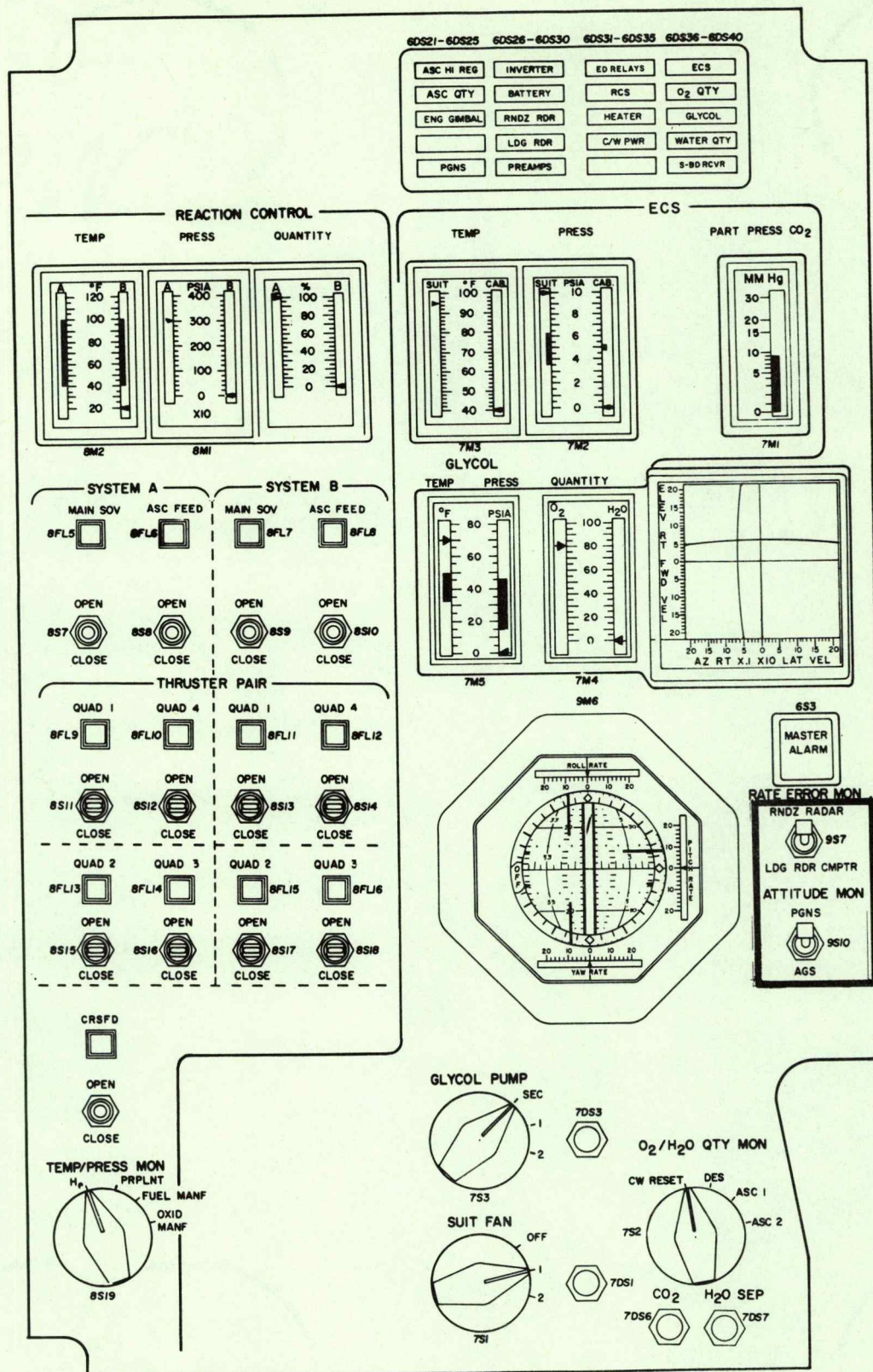
ATTITUDE CONTROL SWITCHES (PANEL III)

There are three of these switches - one each for ROLL, PITCH, and YAW. Each of these three switches has three positions - MODE CONT, PULSE, and DIR. If the ROLL ATTITUDE CONTROL switch, for example, is in a position other than MODE CONT, the roll attitude error output from the AGS will be disabled. The same applies to the PITCH and YAW ATTITUDE CONTROL SWITCHES.



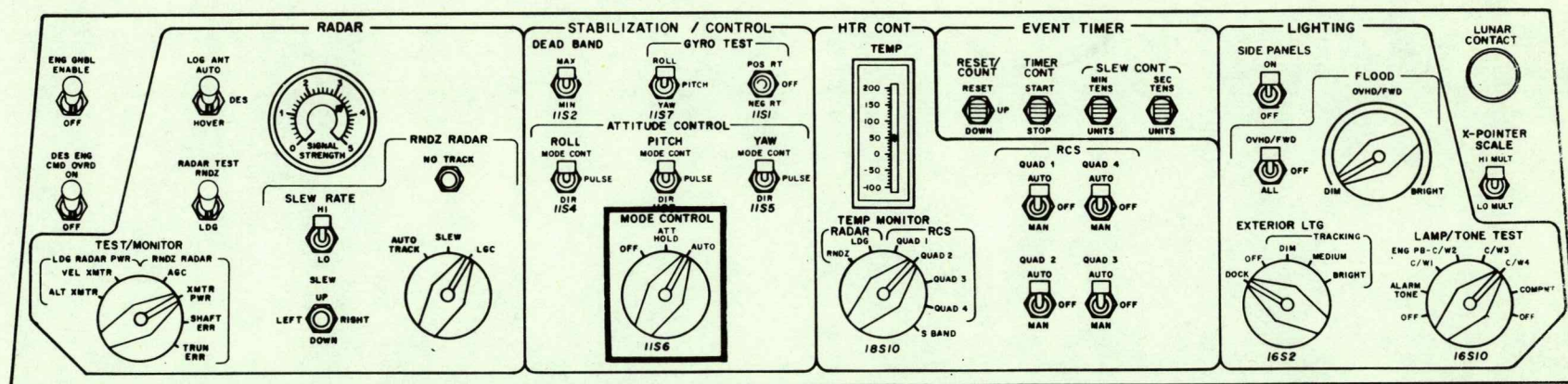
PANEL I

T30900-1
DEC 66



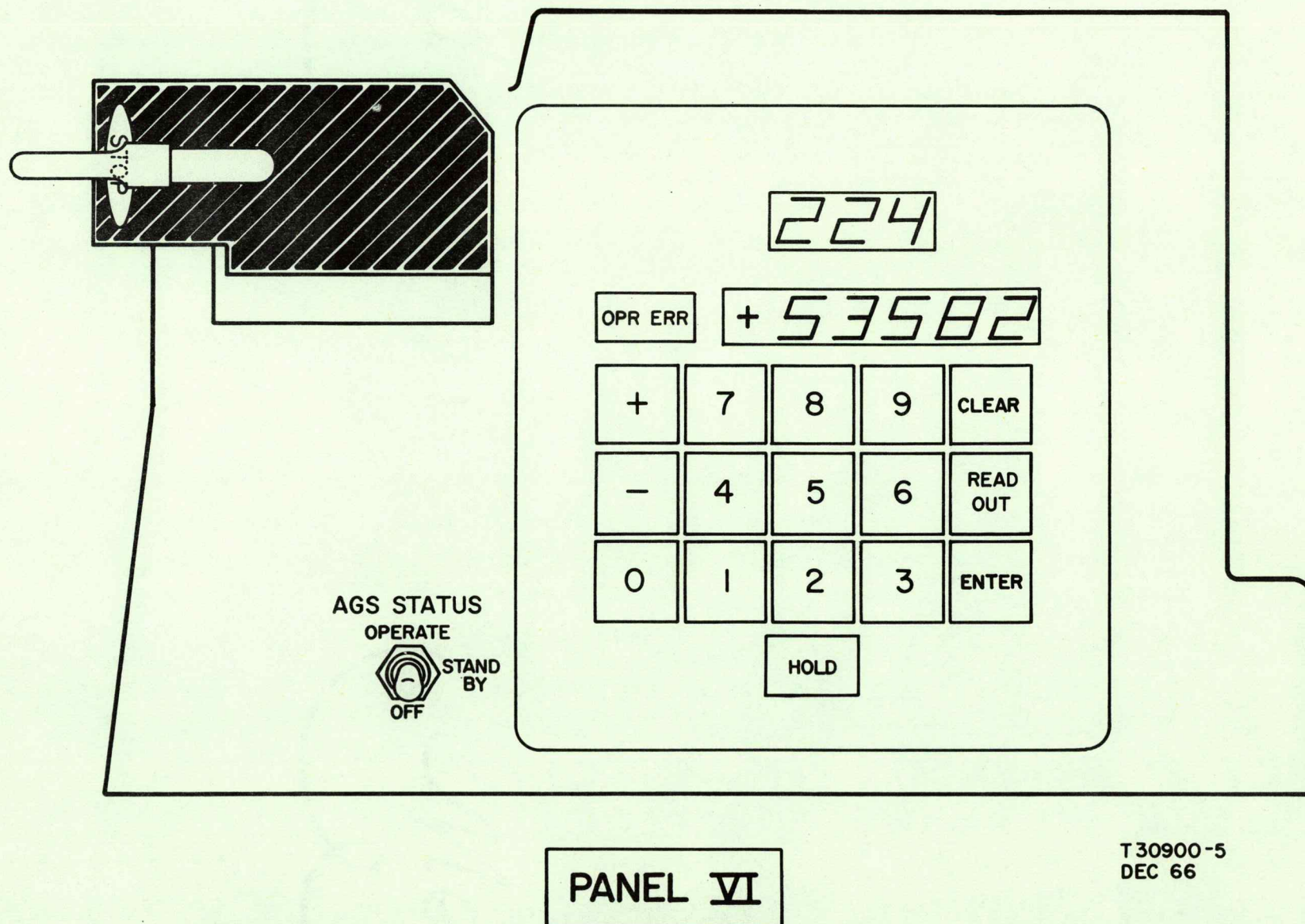
PANEL II

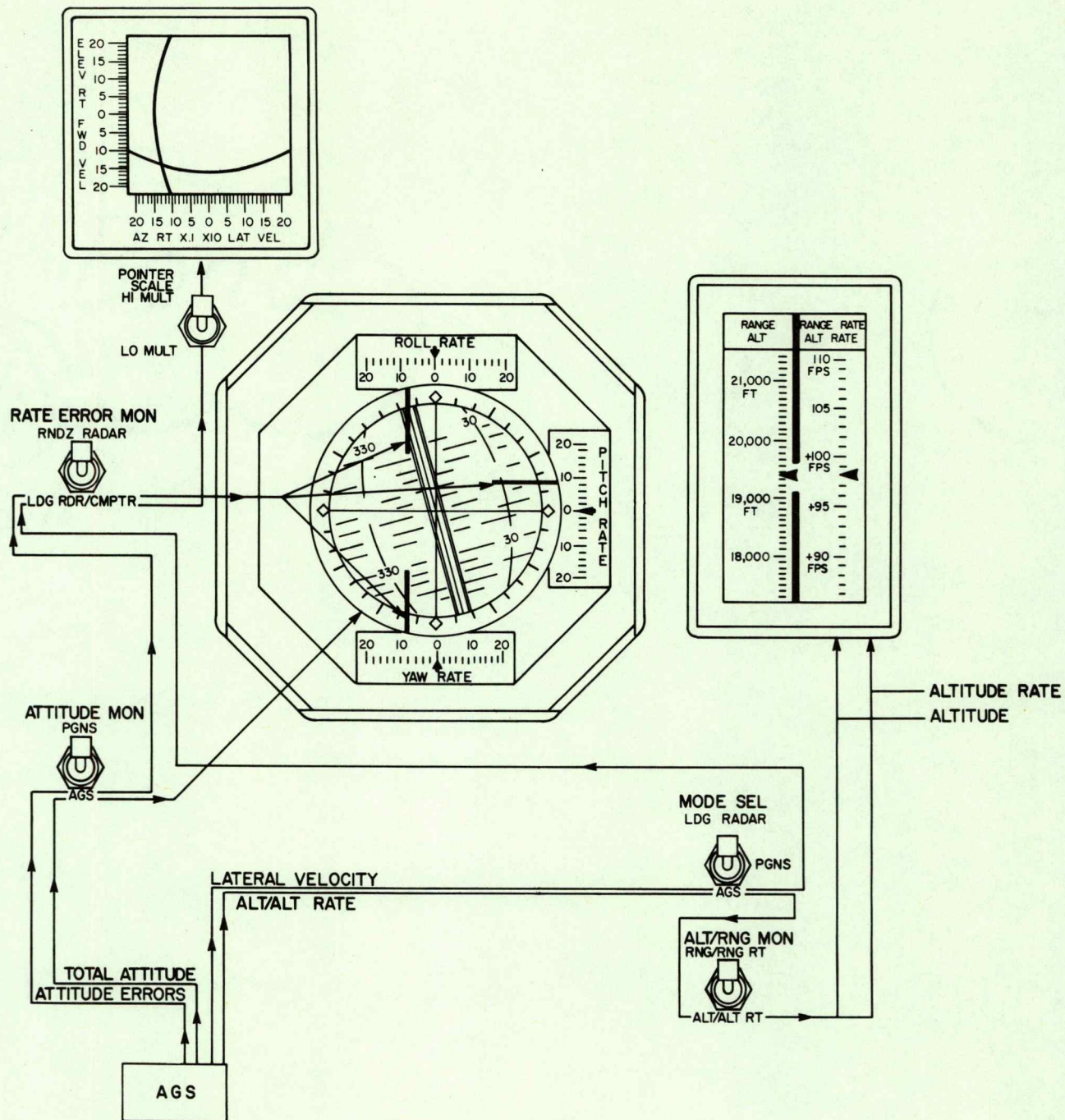
T30900-2
DEC 66



PANEL III

Figure 19-3





AGS DISPLAYS

T30312-18
FEB 67

XX. MISSION PROFILE

1. Nominal Mission

The sequence of AGS operations during a nominal mission (PGNS operating) will be as follows:

a. Prior to Separation

Operate

Re-initiate Self Test

IMU Alignment

Initialize Absolute Time

Initialize LM and CSM via PGNS Downlink

b. Post Separation - Pre-Insertion

Initialize LM and CSM via PGNS Downlink 30 minutes prior to insertion.

Inflight Calibration (includes IMU alignment)

c. Insertion

Follow-up Submode (Direct Transfer Guidance Routine)

d. Coasting Descent

Follow-up Submode (Direct Transfer Guidance Routine)

Initialize LM and CSM via PGNS Downlink 20 minutes prior to start of powered descent.

IMU Alignment 5 minutes prior to powered descent

e. Powered Descent

Follow-up Submode (Orbit Insertion Guidance Routine)

f. Lunar Surface After Touchdown

IMU Alignment immediately after touchdown

Store Lunar Azimuth

Shutdown

g. Lunar Surface Before Liftoff

Operate

Re-initiate Self Test

Initialize Absolute Time

Initialize LM and CSM via PGNS Downlink 20 minutes prior to liftoff.

IMU Alignment 4 minutes prior to liftoff.

h. Orbit Insertion

Follow-up Submode (Orbit Insertion Guidance Routine)

i. Coast from Orbit Insertion Burnout to CSI

Initialize LM and CSM via PGNS Downlink 10 minutes prior to CSI.

IMU Alignment 5 minutes prior to CSI

Follow-up Submode (CSI Maneuver Guidance Routine)

j. CSI Maneuver

Follow-up Submode (CSI Maneuver Guidance Routine)

k. Coast from CSI to CDH

IMU Alignment 5 minutes prior to CDH.

Follow-up Submode (CDH Maneuver Guidance Routine)

l. CDH Maneuver

Follow-up Submode (CDH Maneuver Guidance Routine)

m. Coast from CDH to TPI

Initialize LM and CSM via PGNS Downlink 10 minutes prior to TPI.

IMU Alignment 5 minutes prior to TPI.

Follow-up Submode (Direct Transfer Guidance Routine).

n. TPI Maneuver

Follow-up Submode (Direct Transfer Guidance Routine)

o. Subsequent to TPI

Initialize LM and CSM via PGNS Downlink 10 minutes prior to PGNS midcourse corrections.

Follow-up Submode (Direct Transfer Guidance Routine).

2. Abort Missions

The sequence of AGS operations during abort missions (PGNS not operating) starting from various phases of the mission will be as follows:

2.1 Abort from Coasting Descent

Attitude Hold Submode

- * Semi Automatic/Automatic Submodes (Direct Transfer Guidance Routine)

Remainder of operations same as 2.3.f.

2.2 Abort from Powered Descent

Attitude Hold Submode

Automatic Submode (Orbit Insertion Guidance Routine)

Remainder of operations same as Abort from Lunar Surface, starting at 2.3.c.

2.3 Abort from Lunar Surface

a. Prior to Liftoff

Operate

Re-Initiate Self Test

Initialize Absolute Time

Initialize LM and CSM Navigation via DEDA 20 minutes prior to liftoff.

Lunar Alignment

Orbit Insertion Guidance Routine

b. Orbit Insertion

Attitude Hold Submode During Staging

Automatic Submode

c. Coast from Orbit Insertion Burnout thru CSI Maneuver

Attitude Hold Submode at Orbit Insertion Burnout

CSI Maneuver Guidance Routine

Initialize LM and CSM via DEDA 10 minutes prior to CSI

Semi Automatic Submode

Automatic Submode During Burn

d. CSI Burnout thru CDH Maneuver

Attitude Hold Submode at CSI Burnout

CDH Maneuver Guidance Routine

Semi Automatic Submode

Automatic Submode During Burn

e. CDH Burnout thru TPI Maneuver

Attitude Hold Submode at CDH Burnout

Direct Transfer (Real Time plus DT) Guidance Routine

Initialize LM and CSM via DEDA 10 minutes prior to TPI

Direct Transfer (Fixed Absolute Time) Guidance Routine at desired value of Θ_{LOS}

Semi Automatic Submode

Automatic Submode During Burn

f. Subsequent to TPI Maneuver

Attitude Hold Submode at TPI Burnout

Update LM Navigation via DEDA using Radar Data (S_{12} and Range) approximately every 4 minutes.

Midcourse Corrections using Direct Transfer (Fixed Absolute Time) Guidance Routine

2.4 Aborts During Ascent

Attitude Hold at Abort Initiation

Remainder of operations same as Abort from Lunar Surface, 2.3, starting at appropriate Mission Phase.

LSG 770-430-25 - LTA-8

ABORT GUIDANCE SYSTEM

STUDY GUIDE

LUNAR MODULE

LTA-8

CONTRACT NAS 9-1100

EXHIBIT E; PARAGRAPH 3.7.4

TYPE III DOCUMENT

FOR TRAINING PURPOSES ONLY; IN
SUPPORT OF LTA-8 SUBSYSTEM BRIEFINGS

REFERENCE CF22/T21-67-T471

LM TRAINING SECTION
PRODUCT SUPPORT DEPARTMENT
GRUMMAN AIRCRAFT ENGINEERING CORPORATION
BETHPAGE, NEW YORK

SEPTEMBER 1967

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Section 6

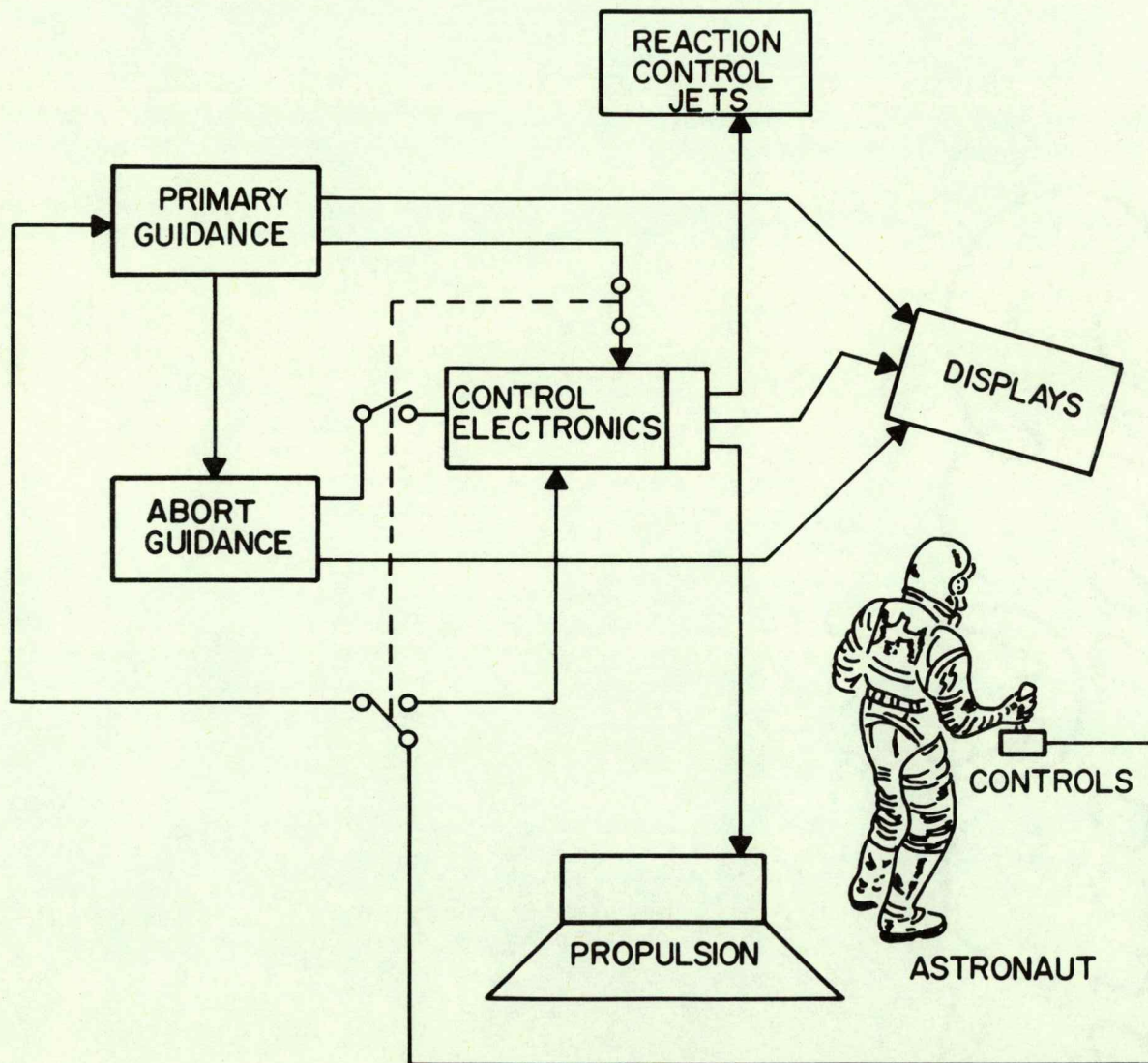
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Panel 1	23
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Section 7

ASA - Portable Temperature Maintenance Unit Interface	30
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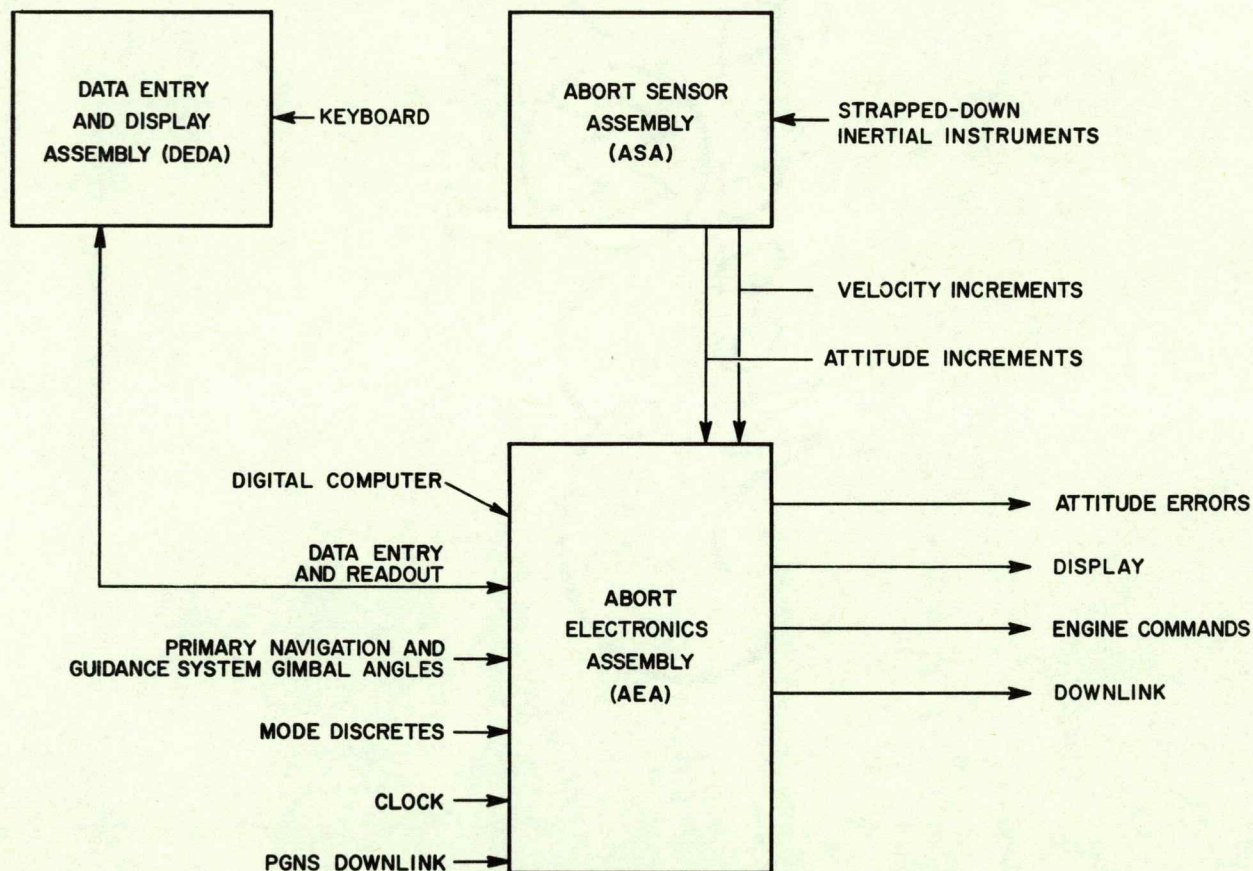
Page 3



INTEGRATED FLIGHT CONTROL SUBSYSTEM

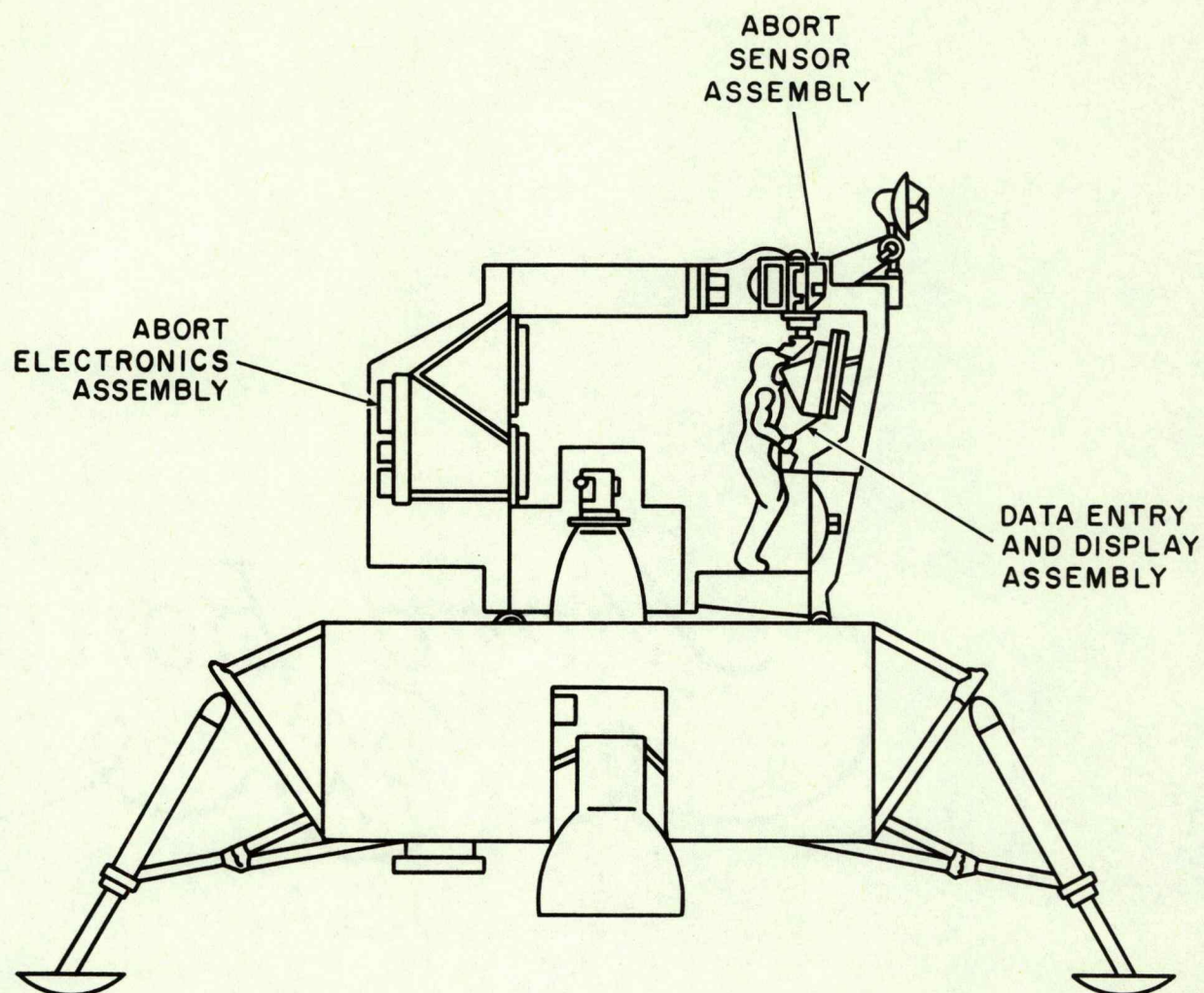
T30312-17.1

LTA-8



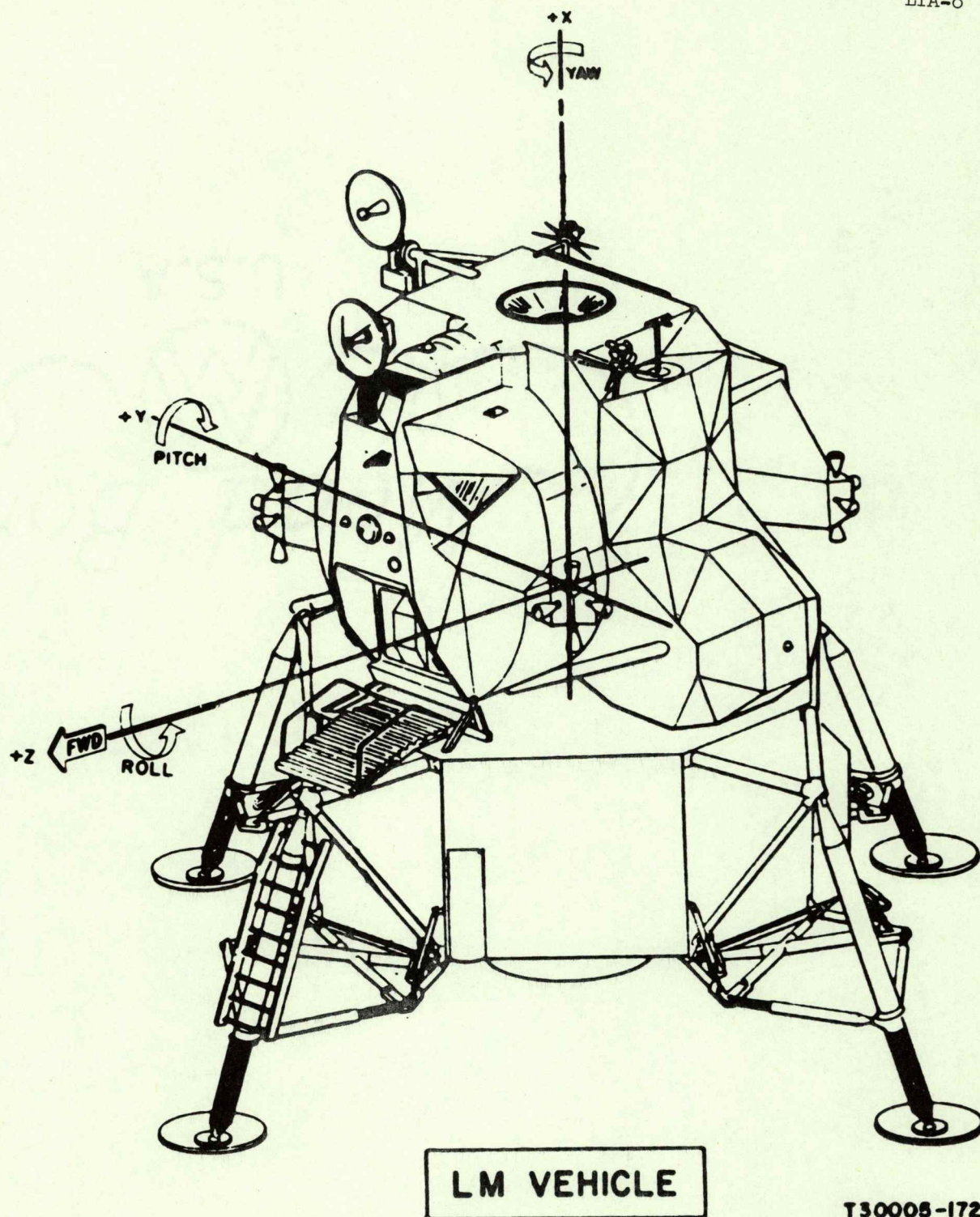
ABORT GUIDANCE SECTION BLOCK DIAGRAM

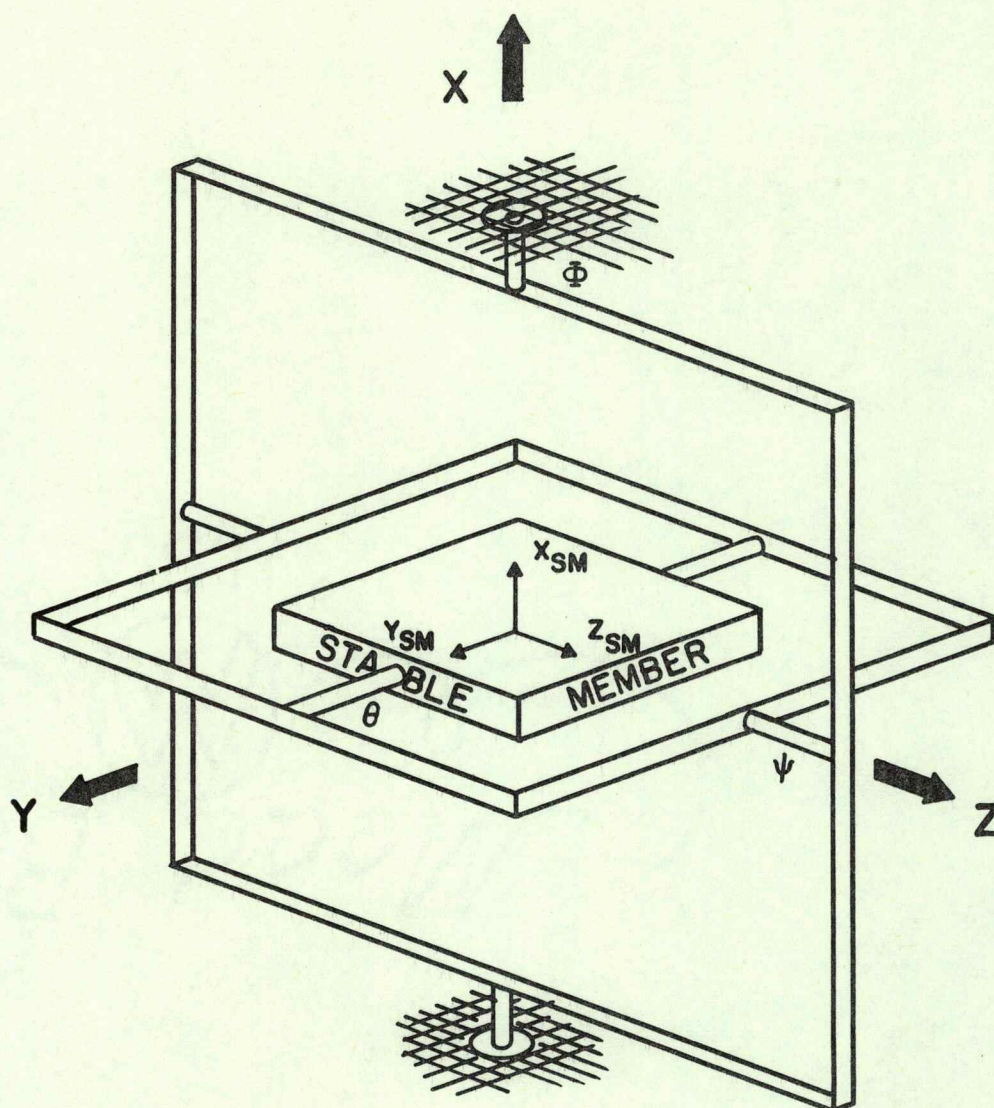
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AGS EQUIPMENT LOCATION

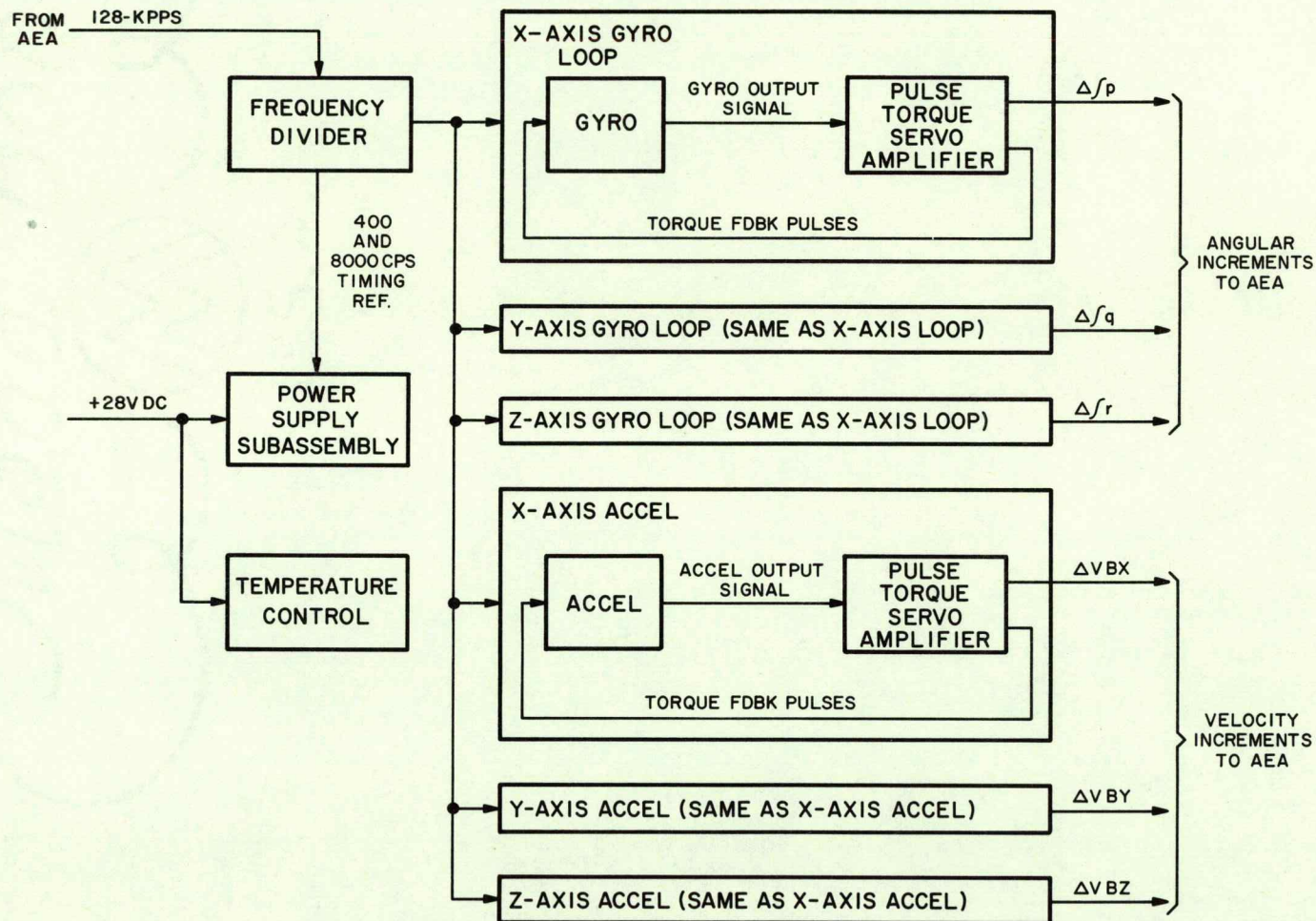
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STABLE PLATFORM

T30900-47.1



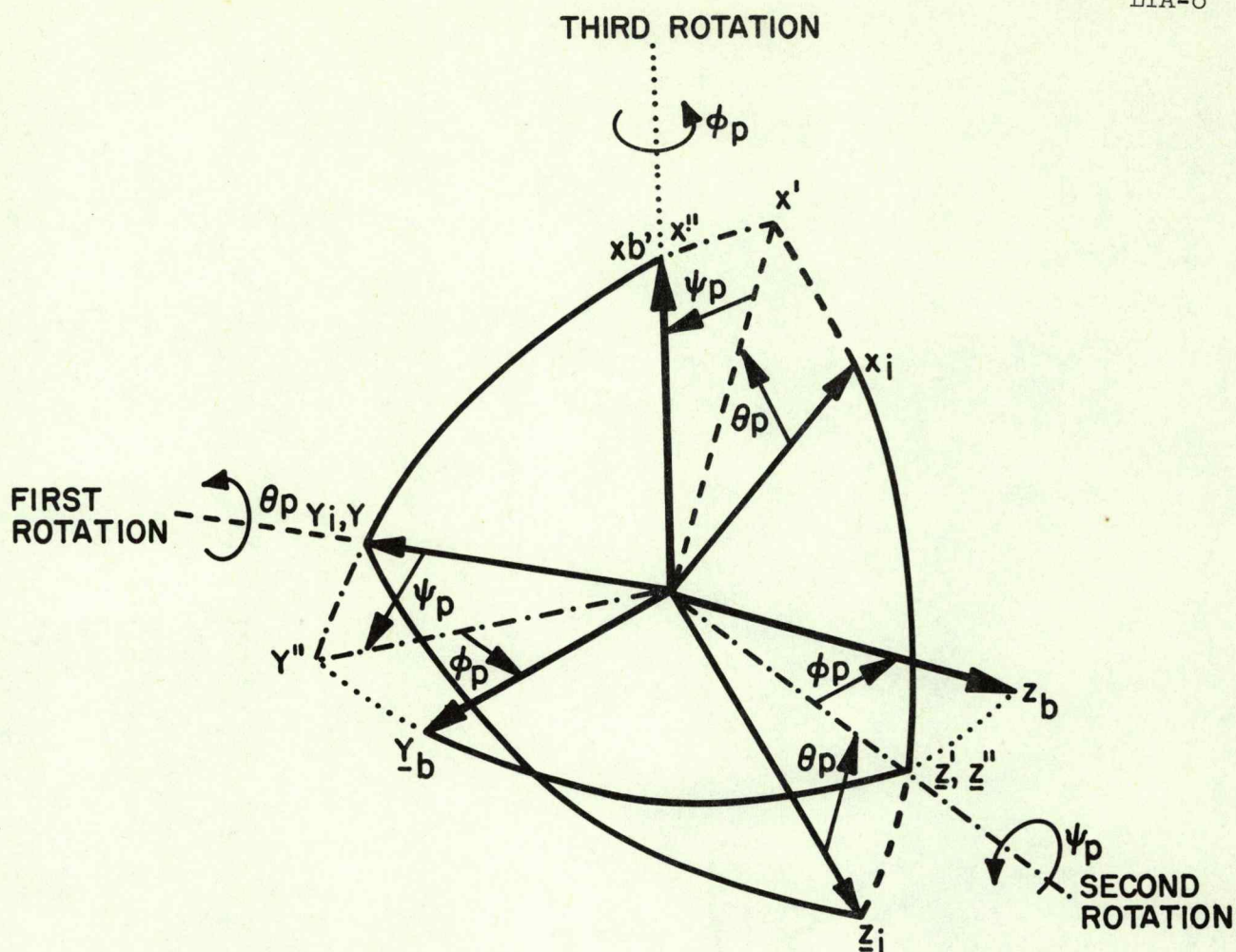
ASA BLOCK DIAGRAM

T30405-109.1

$$= \begin{bmatrix} C\psi C\theta & S\psi & -C\psi S\theta \\ -C\phi S\psi C\theta + S\phi S\theta & C\phi C\psi & C\phi S\psi S\theta + S\phi C\theta \\ S\phi S\psi C\theta + C\phi S\theta & -S\phi C\psi & -S\phi S\psi S\theta + C\phi C\theta \end{bmatrix}$$

TRANSFORMATION MATRIX

T30405-168.1



1ST ROTATION θ ABOUT \underline{y}_i -----, INNER GIMBAL

2ND ROTATION ψ ABOUT \underline{z}'' -----, MIDDLE GIMBAL

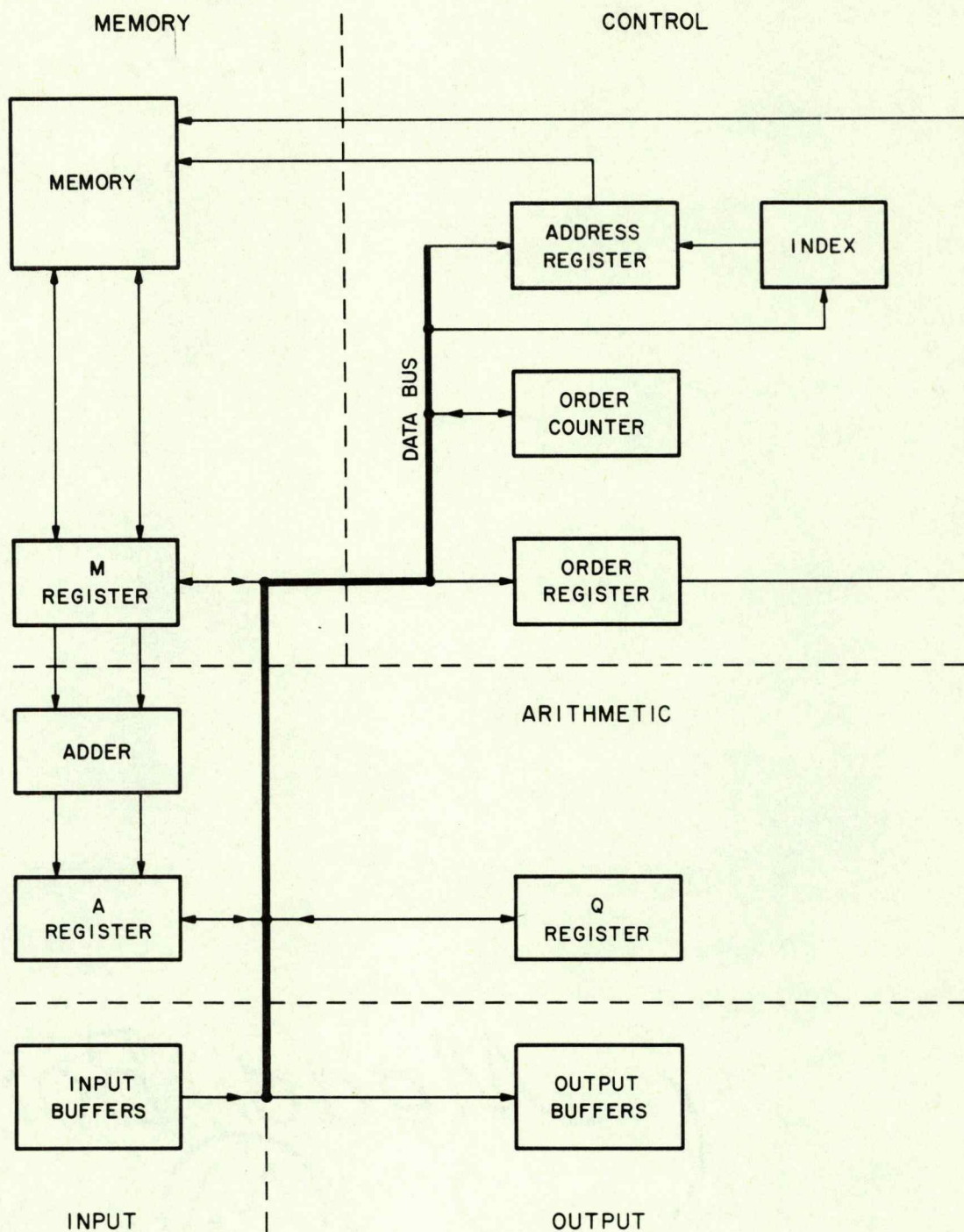
3RD ROTATION ϕ ABOUT \underline{x}'' , OUTER GIMBAL

EULER ANGLES (θ, ψ, ϕ) ARE USED TO SPECIFY THE

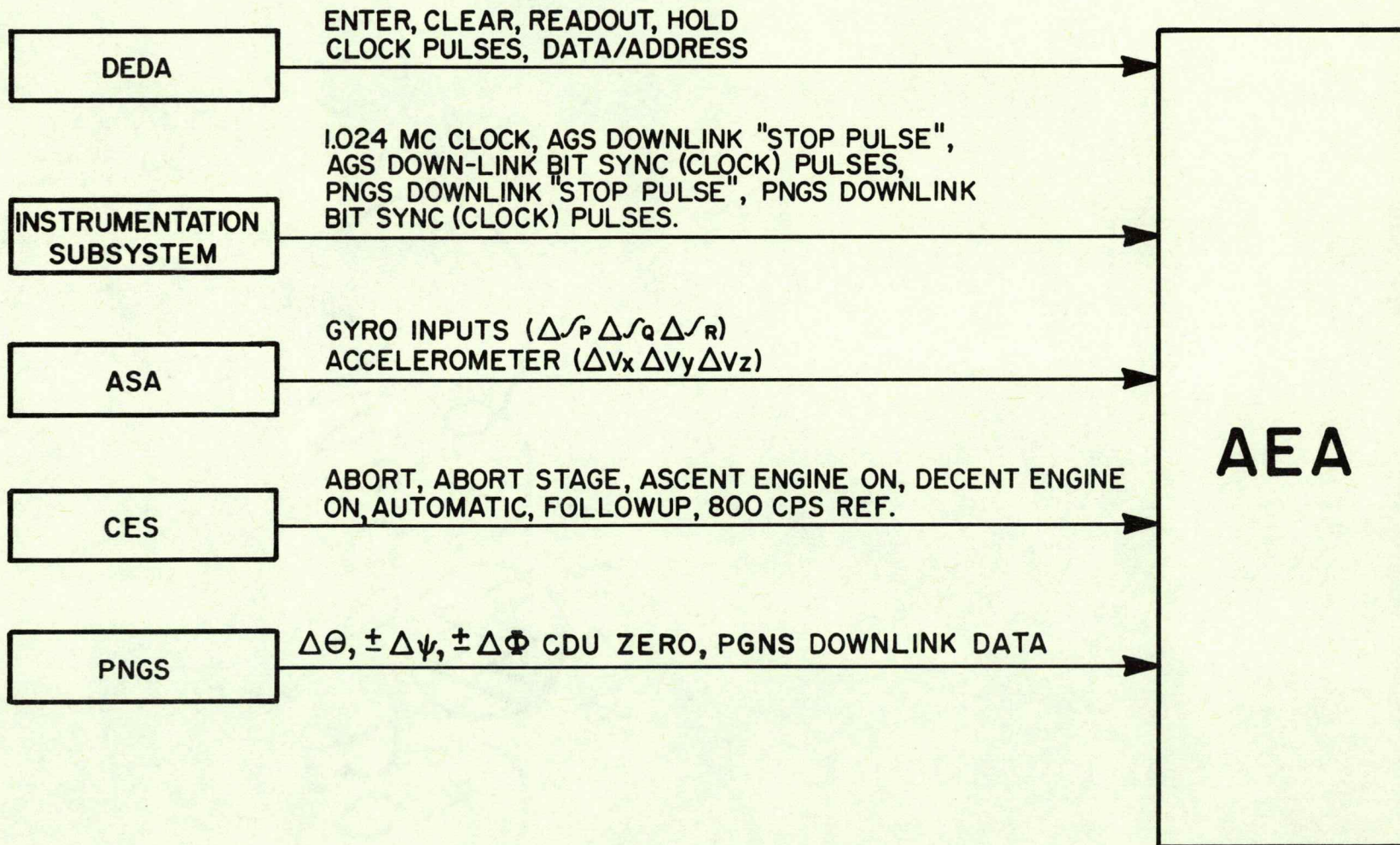
VEHICLE REFERENCE FRAME ($\underline{x}_b, \underline{y}_b, \underline{z}_b$) WITH RESPECT TO
THE PGNCS INERTIAL REFERENCE FRAME ($\underline{x}_i, \underline{y}_i, \underline{z}_i$).

IMU EULER ANGLES

T30405-169.1

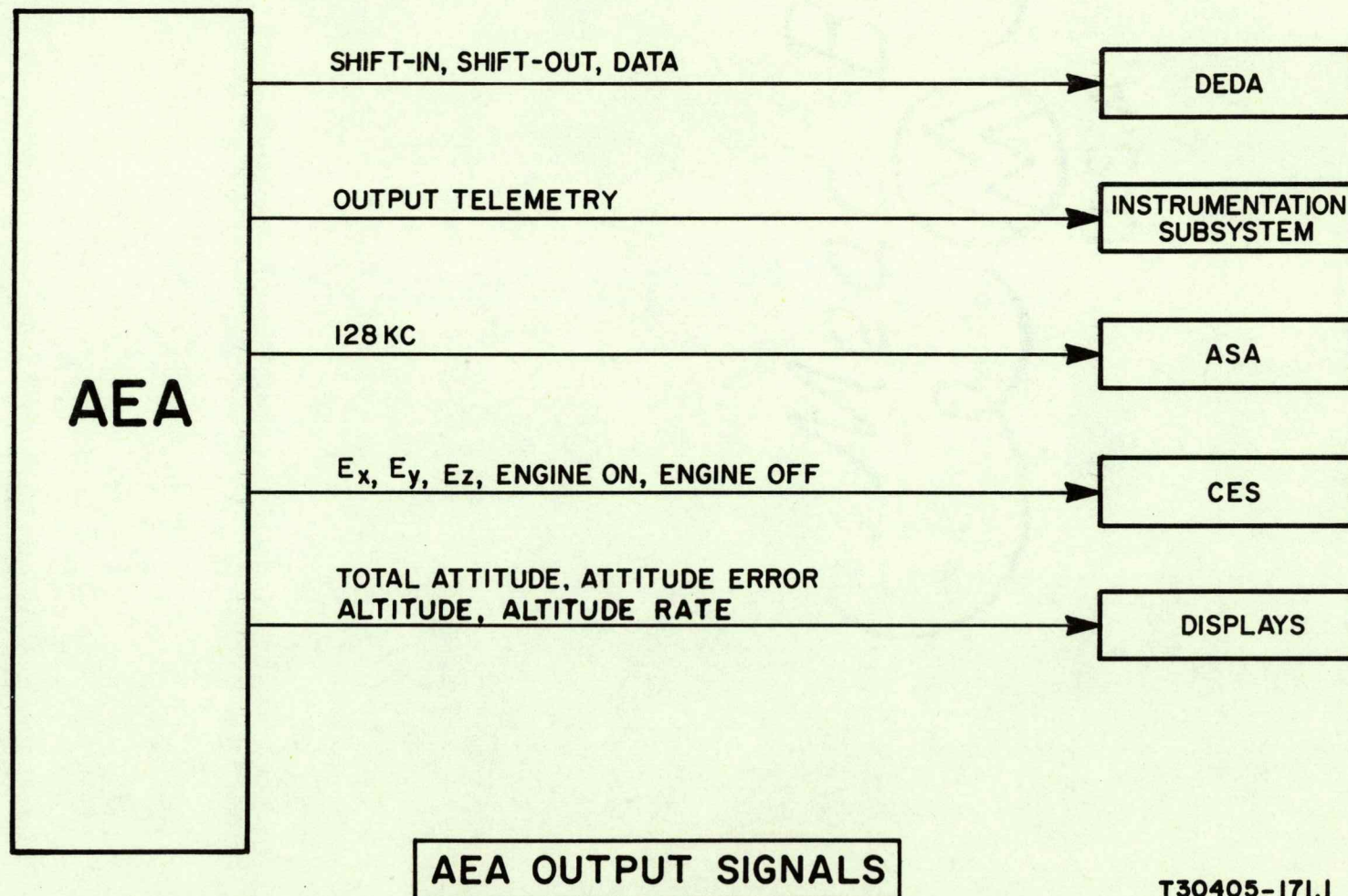
**SIMPLIFIED COMPUTER BLOCK DIAGRAM**

T30405-107.1



AEA INPUT SIGNALS

T30405-170.1



AEA COMPUTER DATA SHEET

High speed, digital, general purpose, parallel machine.

Central Processor

Parallel 2's complement arithmetic.
 18 Bit data and instruction word.
 One index register, 3 bits, address modification.
 Add 10 u sec. Multiply 70 u sec.
 Single instruction.
 Clock 1.024 megacycle.
 27 Basic instructions.

Memory

Coincident current, parallel, random access ferrite core. 18 bit word.
 4096 total words.
 2048 DRO 2048 Hardwired.
 Cycle time 5 usec.

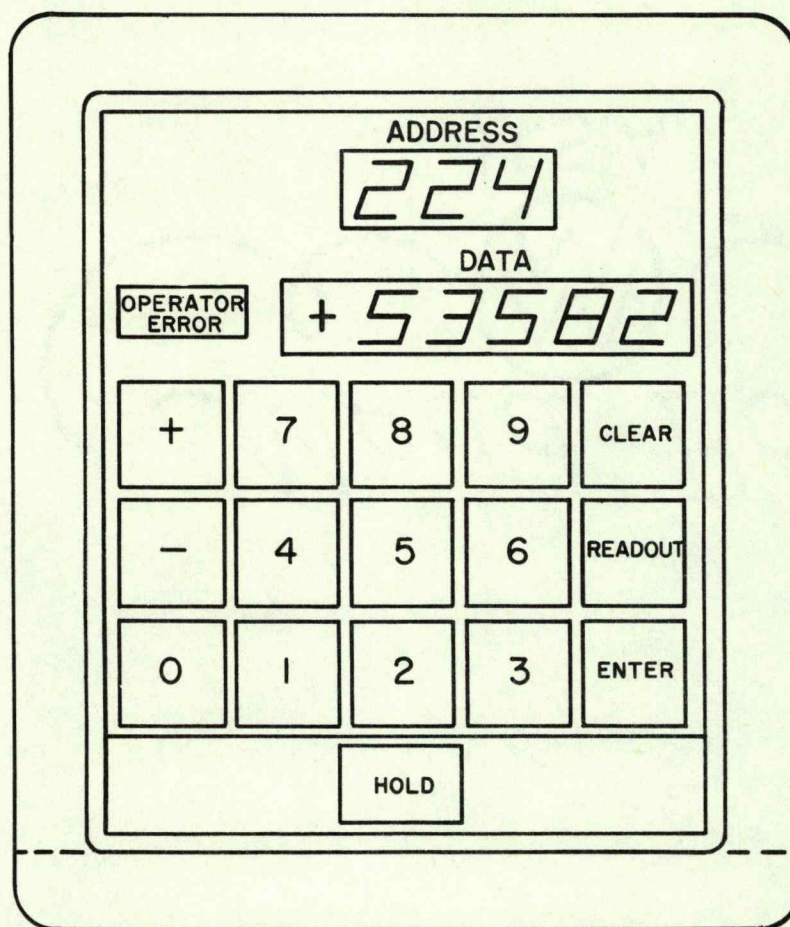
Input/Output

Serial input registers, 18 bits and 4 bits.	
Counter input registers, 3-15 bit, 6-11 bit.	
Discrete inputs	15
Serial output registers	24 bit, 4 bit, and 15 bit.
Analog outputs 400 cycle	6-9 bits + sign.
800 cycle	3-9 bits + sign.
DC	8 bits + sign.
Discrete outputs	10

Power Supply

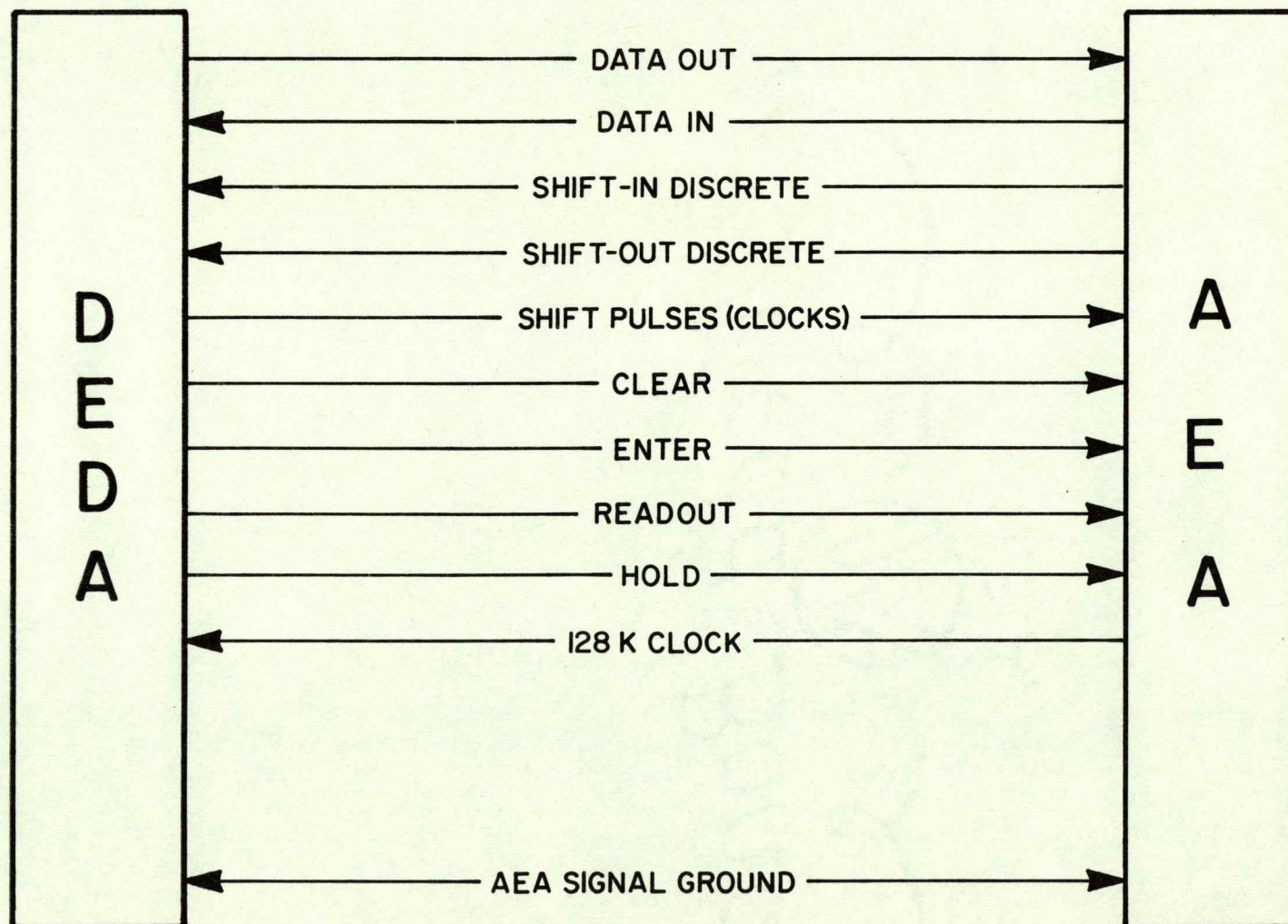
DC to DC converter + 28V input	+4 -2, +12, +6, +14, -18 output.
Analog reference	AC regulator.
Power	90 watts maximum.

T100-50

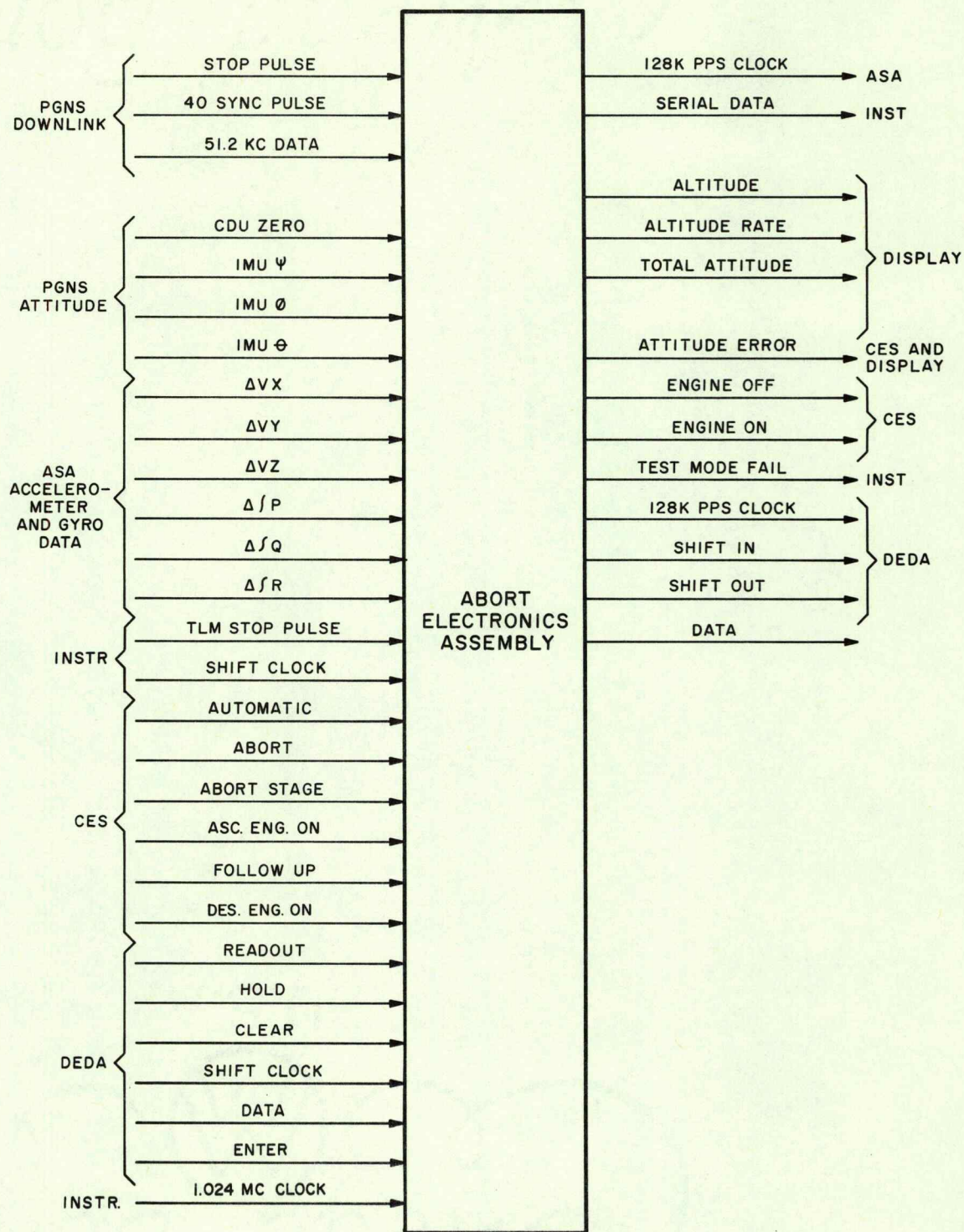


DEDA FRONT PANEL

DEDA-AEA INTERFACE

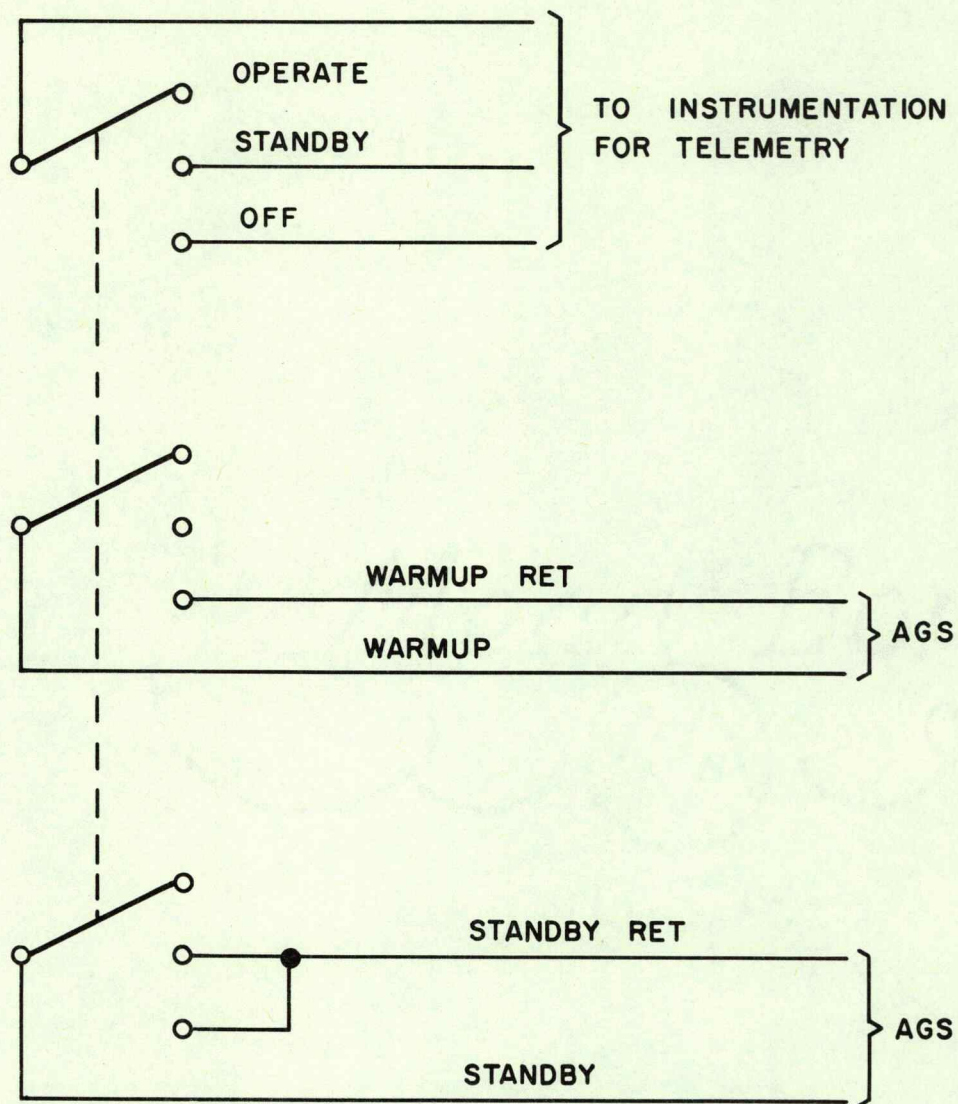


T30405-172.1



AEA INTERFACE

T30405-108.1



AGS STATUS SWITCH

T30405-173.1

1. ALIGNMENT MODE

a) SUBMODES OF THE ALIGNMENT MODE:

IMU ALIGN SUBMODE

LUNAR ALIGN SUBMODE

ORBITAL ALIGN SUBMODE

2. INERTIAL REFERENCE MODE

a) SUBMODES OF THE INERTIAL REFERENCE MODE:

FOLLOW-UP SUBMODE

ATTITUDE HOLD SUBMODE

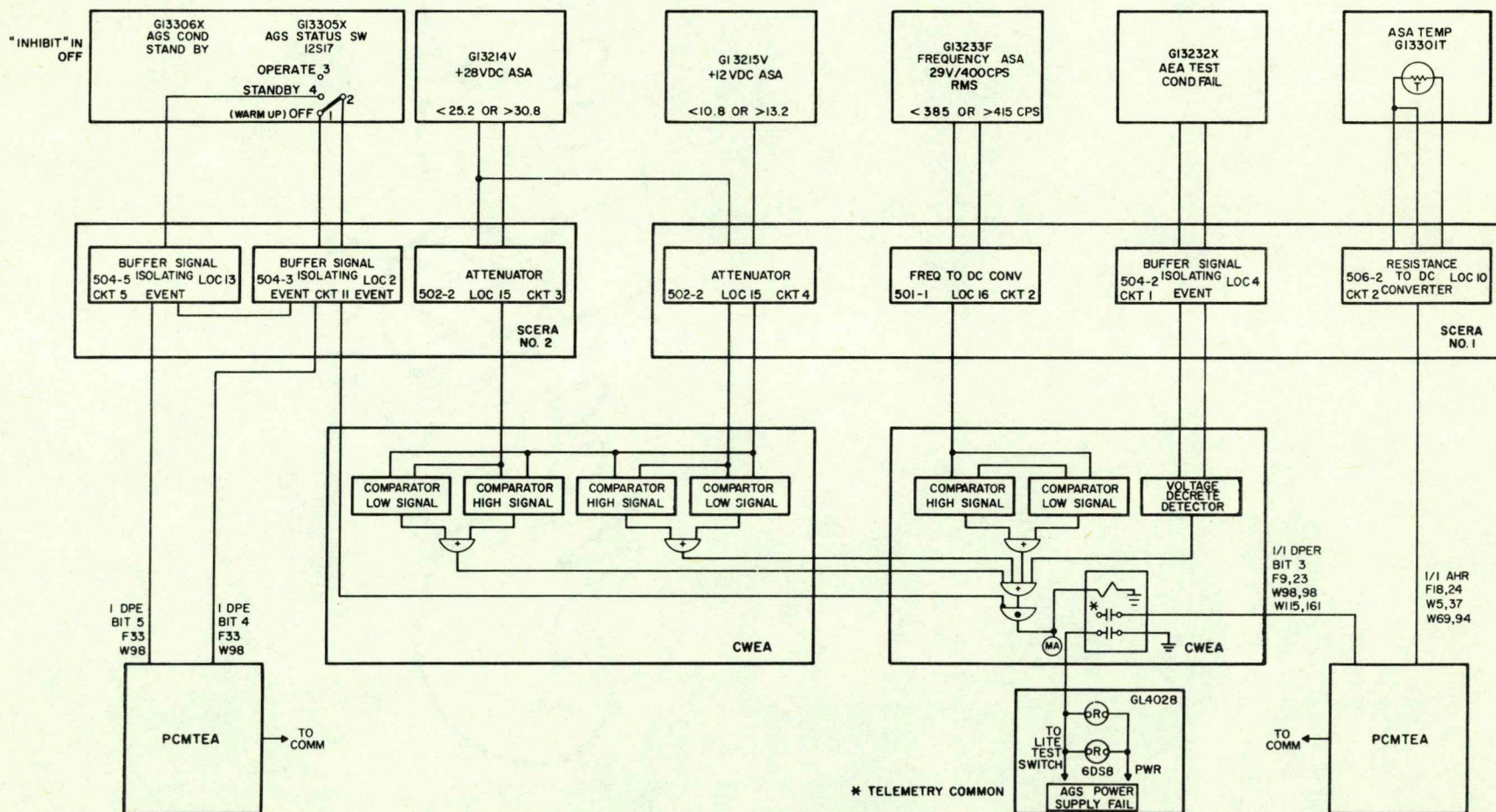
SEMI-AUTOMATIC SUBMODE

AUTOMATIC SUBMODE

ACQUISITION SUBMODE

AGS OPERATING MODES

T30405-105.1



ABORT GUIDANCE SYSTEM/INST INTERFACE

T30609-180 2

A TYPICAL TEST PERFORMED ON LTA-8

AEA SELF-TEST

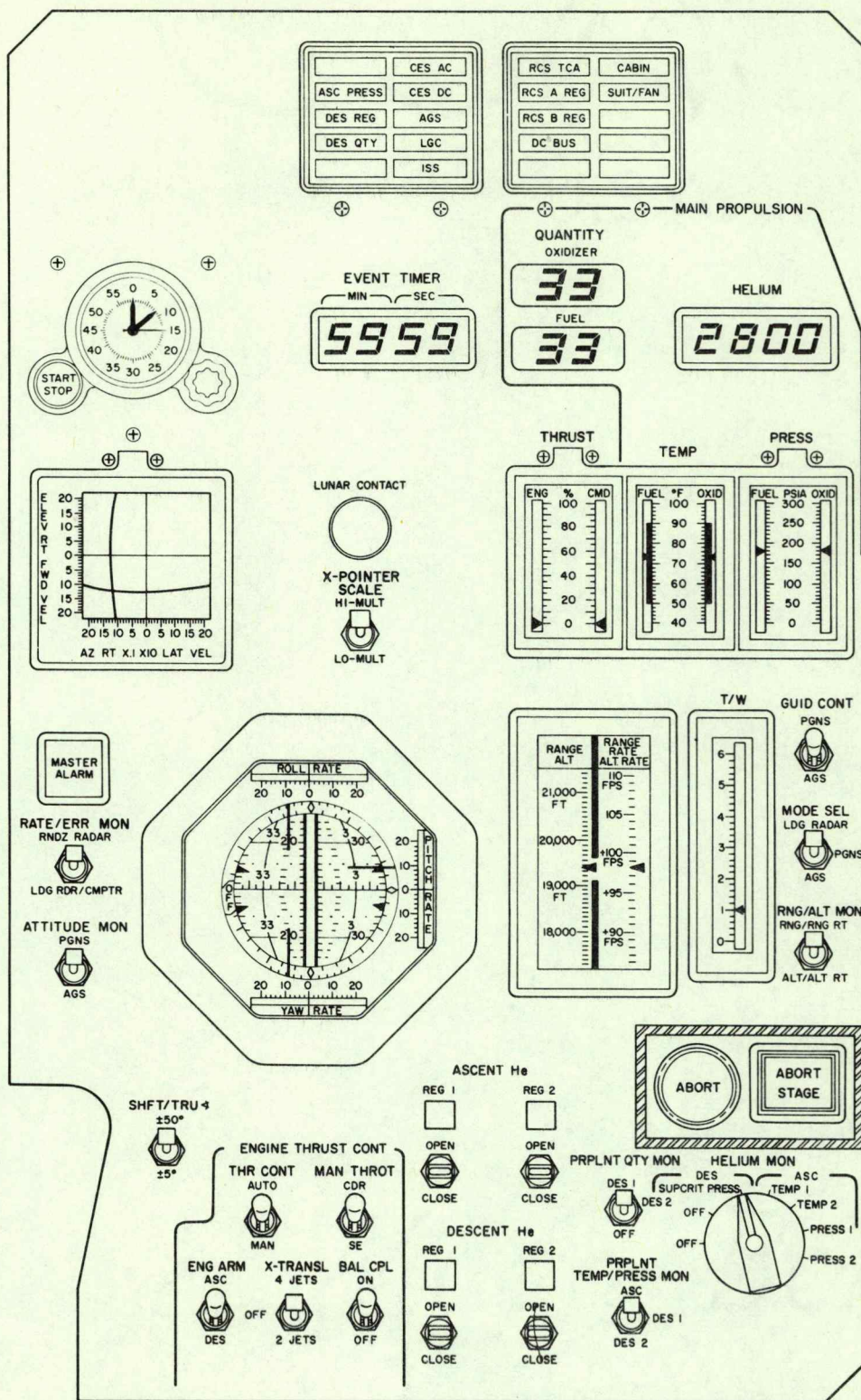
Verify that all circuit breakers are pushed in and the AGS STATUS SWITCH on Panel 6 is in the operate position.

NOTE: During a normal turn-on the AGS warning light on Panel 1 will come on temporarily. At the same time a tone will be present in the headset and the master alarm lights on Panels 1 and 2 will come on. The computer program will automatically reset the warning light, but it will be necessary for a manual reset of the master alarm. If you don't get a warning light along with the master alarm at power turn-on, the warning system is not functioning properly. This can be construed as an AGS caution and warning self-test.

To initialize the self-test, use the DEDA on Panel 6. Press the clear pushbutton on the DEDA panel. This notifies the computer to look for an enter or readout from the DEDA. Via the DEDA, insert 333 + 00000. Verify that these numbers appear on the DEDA display; then press the enter pushbutton. This initializes the self-test in the AEA. It takes the computer approximately 30 seconds to go through the complete self-test routine. When the self-test is completed, (approximately 30 seconds), location 333 will return to +10000. This can be verified by pressing 333, then the readout pushbutton on the DEDA. The complete status of the self-test can be verified as follows:

Location 333 + 00000	Initiate AEA Self-Test
+ 10000	Test Successfully Completed
+ 30000	Logic Test Failure
+ 40000	Memory Test Failure
+ 70000	Logic and Memory Test Failure

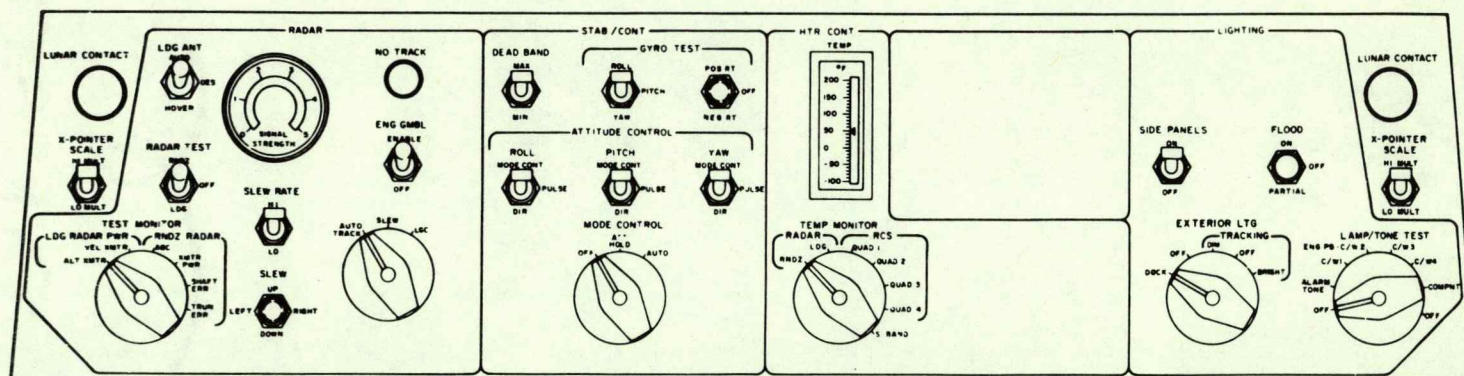
If the self-test fails the AEA will send out a self-test fail to caution and warning. The AGS warning light on Panel 1 will come on along with the master alarm lights on Panels 1 and 2. If the AEA doesn't pass the self-test, it is not capable of doing proper calculation, therefore, it should not be used.



PANEL I
LTA 8

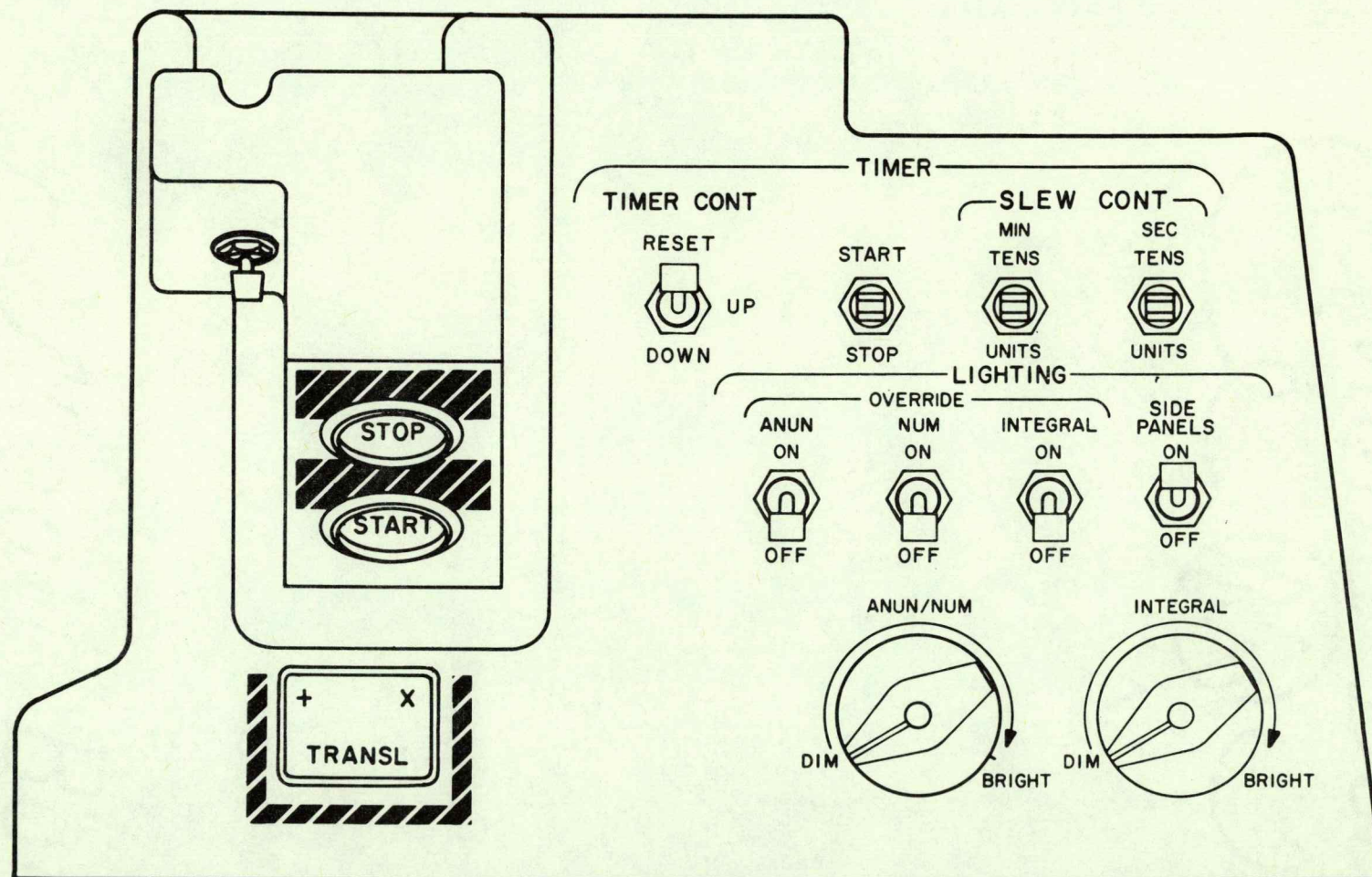
T30900-108.1

Date: September 1967



PANEL III
LTA 8

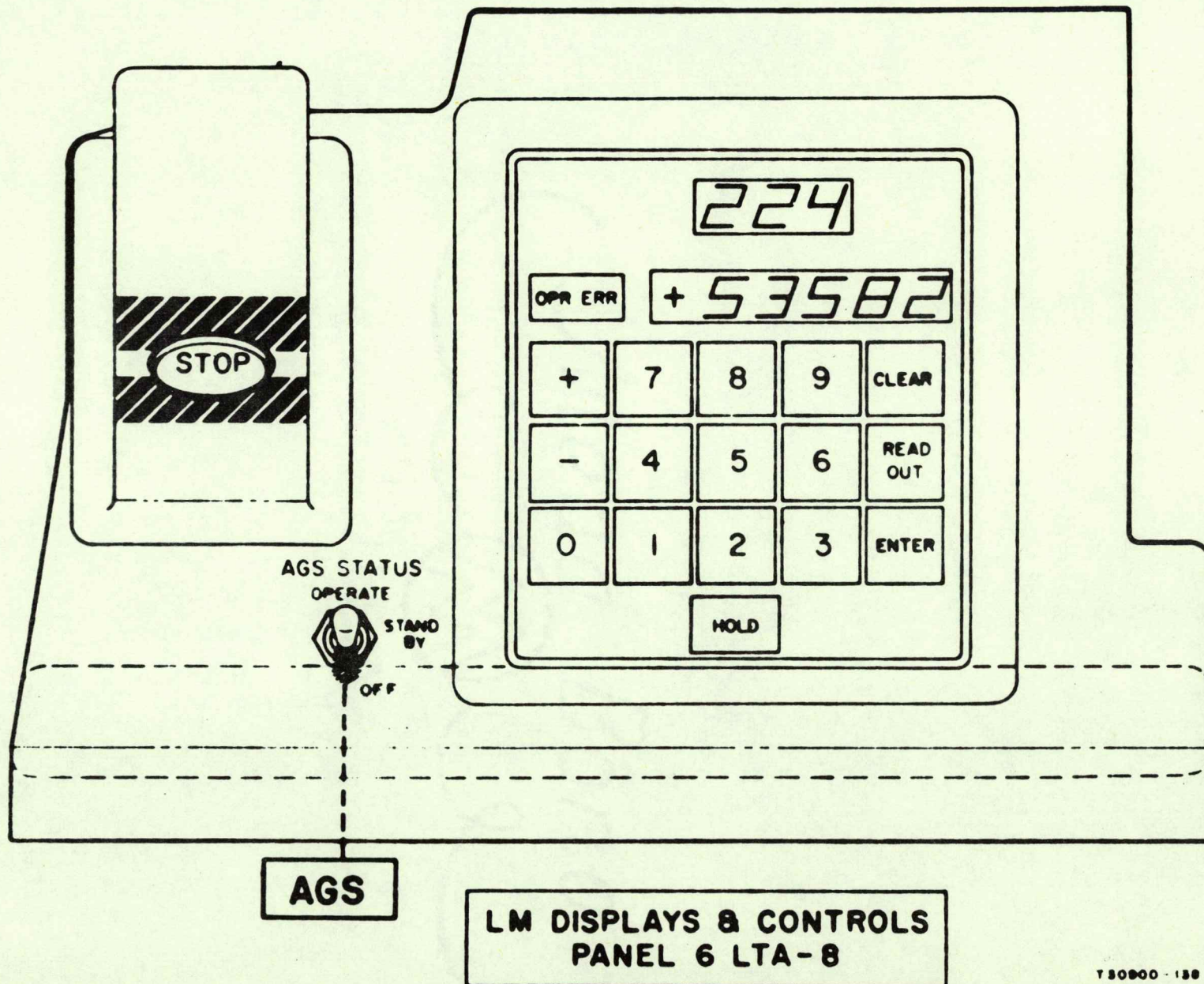
T30900-109.1

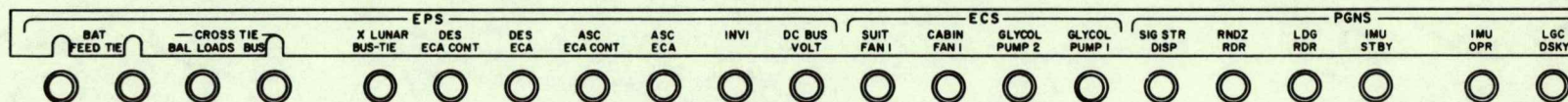
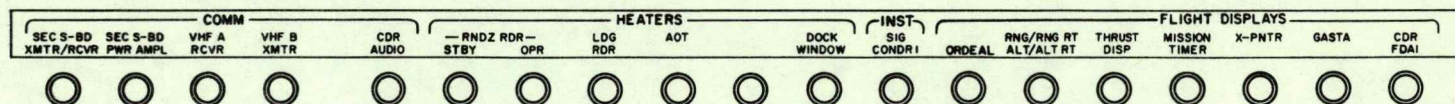
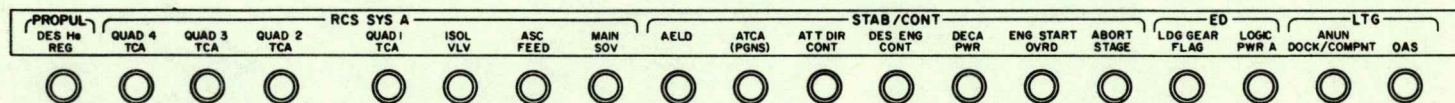
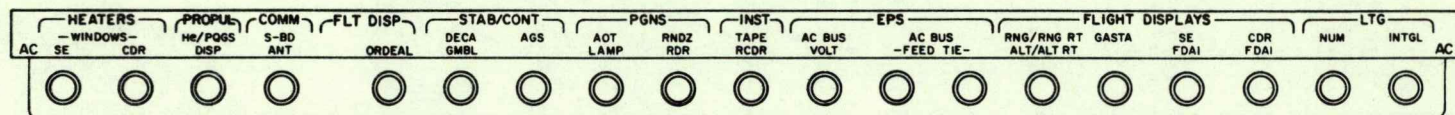


PANEL V
LTA-8

T 30900 - 107.1

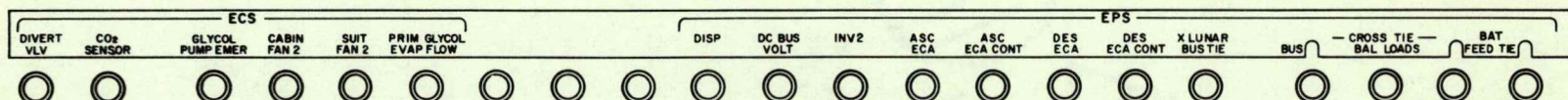
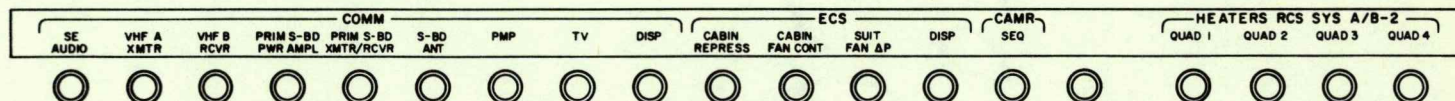
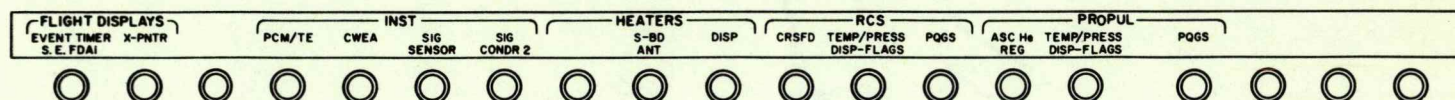
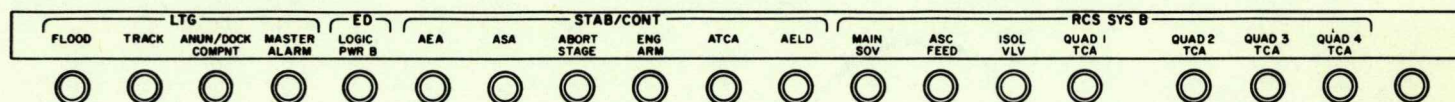
LTA-8





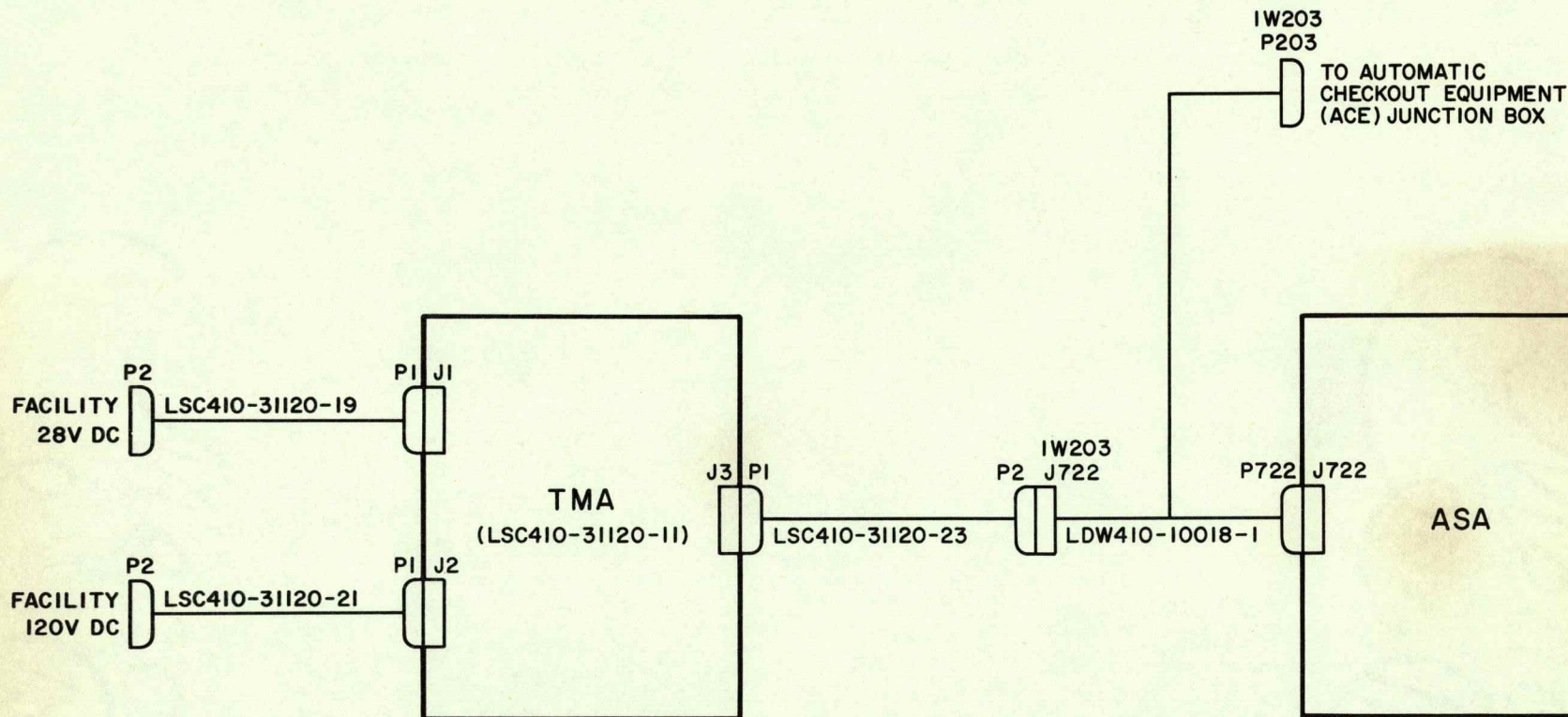
PANEL XI
LTA-8

T 30900 - 133.1



PANEL XVI
LTA-8

T30900-132.1



NOTE:
P2 MATES DIRECTLY TO ASA J722
WHEN ACE IS NOT USED.

**AGS-TEMPERATURE MAINTENANCE
ASSEMBLY INTERFACE**

T30312-57.1



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