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RTPDB, AGCSR (LEM/A)
AS-207/208

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APOLLO

LUNAR EXCURSION MODULE
ABORT GUIDANCE SYSTEM
SOFTWARE REQUIREMENTS

MISSION AS-207/208

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SECTION 1
INTRODUCTION

1.1 PURPOSE

This document specifies the Guidance Computer Software Requirements (GCSR) for the LEM Abort Guidance System Computer; the Abort Electronics Assembly (AEA) for the AS-207/208 mission.

1.2 SCOPE

The AEA flight program for this mission evolved from "Flight Program 1." Except for minor software changes, finalization of this program for this mission will essentially mean finalization for the AS-504 program. To satisfy the agreed upon documentation schedule, this document will serve as the preliminary GCSR document for AS-504A, subject to necessary scale and constant changes to allow lunar operations.

This is an official MSC document and is subject to approval by the Software Control Panel. The requirements will become better defined and understood through analysis, mission planning studies, and MSC/TRW/GAEC negotiations. As changes become imminent, they will be realized in revisions to this document.

SECTION 2
MISSION DESCRIPTION

2.1 NOMINAL MISSION

- a. The preliminary reference trajectory (see paragraph 10.1k) specifies the nominal mission sequences. The following briefly summarizes these sequences.
- b. The AS-207 configuration will be launched from the Cape Kennedy Launch Complex No. 34 on a true azimuth heading of about 82 degrees east of north. The CSM will be inserted into an 81/107 (apogee/perigee) nm elliptical orbit.
- c. The AS-208 configuration will consist of the 208 S-IV launch vehicle, LEM-2, and a boilerplate CSM, and will be launched from Pad 37B on a heading of about 78 degrees. The S-IVB/SLA combination will be inserted into a 120 nm circular orbit. The LEM will remain in the spacecraft-LEM adapter (SLA) until extraction later in the mission. The S-IVB will provide attitude control during the initial CSM rendezvous, docking, and the subsequent LEM extraction from the SLA.
- d. A total of four rendezvous exercises will be demonstrated. The CSM will initially rendezvous with the S-IVB/SLA combination utilizing the coelliptic rendezvous technique. Three re-rendezvous exercises will be performed with approximately 24 hours lapsing between each to allow sufficient tracking during the critical phases (coelliptic sequence and terminal phase initiate burns).
- e. After the initial CSM rendezvous, the CSM and LEM will be hard docked. A temporary crew transfer to the LEM will occur to allow power-up of

the systems necessary for auto attitude control. This attitude control will allow positioning of the LEM acquisition lights for the second CSM rendezvous. The primary guidance, navigation and control system (PGNCS) will provide this function.

- f. The second rendezvous will be CSM active under control of one crewman (navigator). The Commander and Systems Engineer will be present in the CSM but in a passive mode. The coelliptic rendezvous technique will again be employed. Upon completion of this rendezvous, the CSM/LEM will be in a 180 nm circular orbit. One crewman will demonstrate extra-vehicular transfer from the LEM to the CSM prior to beginning the third rendezvous exercise.
- g. The third rendezvous will be LEM active and will primarily provide a checkout of the AGS. The descent propulsion system (DPS) will be used for initial LEM separation from the CSM, under PGNCS control. Following this, the DPS will be started under PGNCS control. A guidance switchover to the AGS will be made. The DPS will remain on while the AGS guides to predetermined cutoff conditions using the orbit insertion routine. AGS will then utilize the coelliptic rendezvous technique to accomplish rendezvous with the CSM. The coelliptic sequence initiate (CSI), coelliptic maneuver, terminal phase initiate, midcourse correction maneuvers utilizing the rendezvous radar, and braking maneuvers will be performed (fixed range, range rate schedule).
- h. The fourth rendezvous will also be LEM active. The AGS will perform a fire-in-the-hole abort stage with the descent engine initially off. Another test will demonstrate switchover from PGNCS to AGS while the APS engine is burning. The AGS will provide correct insertion conditions for the subsequent PGNCS controlled rendezvous performed according to the coelliptic rendezvous technique.

2.2 AGS MISSION OBJECTIVES

Paragraph 10.1 h gives the AS-207/208 mission objectives; a brief summary of the AGS objectives is given below.

- a. Use the AGS to abort during powered descent. The guidance transfer from PGNCS to AGS must be demonstrated. With the DPS thrusting, verify AGS thrust vector control.
- b. While in coasting flight, perform a fire-in-the-hole abort stage.
- c. Use the AGS to abort from powered ascent. AGS takeover of PGNCS will be done while the APS engine is thrusting.
- d. Demonstrate AGS restart, inertial reference alignment, navigation updating, and self-checking.

2.3 CONTINGENCY MISSIONS

AEA functions during contingency missions will be identical to nominal mission requirements where appropriate.

SECTION 3
GENERAL GUIDANCE REQUIREMENTS

3.1 GENERAL

The AGS will incorporate the coelliptic rendezvous technique. A minimum of four AEA programs will be available for crew selection via the data entry and display assembly (DEDA). One or a combination of these programs will be used to accomplish rendezvous given CSM and LEM earth orbit initial conditions representative of any contingency lunar mission situation. These AEA programs are discussed separately below.

3.2 ORBIT INSERTION

a. The orbit insertion program will be used to obtain predetermined cutoff conditions, as given below.

- h_0 (ft): Altitude above the nominal earth insertion radius
- V_0 (fps): Magnitude of inertial velocity
- \dot{r}_0 (fps): Radial velocity (normally zero).

b. The AEA will generate powered flight steering signals that will allow automatic RCS control of the LEM X-axis such that, the LEM is yaw-steered into the CSM orbital plane by the time of attainment of the above cutoff conditions. AEA capability of steering out a wedge angle of 2 degrees should exist (assuming sufficient ΔV). TRW will determine the degree of compatibility of the AEA steering signals (attitude error signals, E_x, E_y, E_z) with the steering signals generated by the PGNC LGC Orbit Insertion Program.

c. When the velocity to go to cutoff (ΔV_g) reaches a predetermined threshold, updating of the steering signals will cease. The Attitude Hold Submode will then be entered. Engine cutoff will be commanded when ΔV_g equals the DPS or APS tailoff velocity threshold.

3.3 COELLIPTIC RENDEZVOUS

Coelliptic rendezvous will be initiated by the coelliptic sequence initiate burn (CSI) followed by the coelliptic maneuver (CDH-for constant differential altitude). The Direct Intercept Transfer Program, paragraph 3.4, will be used for the terminal phase initiate (TPI) burn, and subsequent midcourse corrections.

a. The CSI and CDH burns will be computed to satisfy the DEDA input targeting for the coelliptic rendezvous technique, as given below.

- (1) T_1 (sec): Time of CSI horizontal burn in AGS single precision absolute time. Single precision absolute time is quantized at 10 seconds. $T_1 = \text{time of insertion cutoff} + CT_1$. CT_1 will be chosen preflight.
- (2) T_2 (sec) : Desired TPI time in AGS single precision absolute time.
- (3) ϵ (deg): The angle that the LEM-CSM line of sight makes with the LEM local horizontal at the desired TPI time (T_2).

b. The CSI and CDH maneuvers will be computed in the orbital plane of the CSM. During the performance of these maneuvers, LEM attitude control will be such that the X-axis thrusting is parallel to the CSM orbit plane.

c. The coelliptic CDH burn will be performed at a particular time determined by the routine. This time will be displayed to the crew via DEDA, and will not be updated. It will be the predicted time (AGS absolute) of LEM arrival at the first apogee or perigee following the CSI burn. A crew input via DEDA will be required to specify CDH at perigee, if that is to be the case (as in the AS-207/208 second LEM rendezvous).

d. The CDH burn will make the LEM and CSM orbits coelliptical, as defined by making the product of LEM semi-major axis and eccentricity equal to the product of CSM semi-major axis and eccentricity. The desired LEM semi-major axis for the burn calculation will be equal to the CSM semi-major axis minus the differential altitude, Δh . Δh is the difference between

the CSM and LEM radial distances at the CDH burn location (CSM back-projected until relative phase angle equals zero). The radius rate of the LEM at CDH (\dot{r}_{LEM}) will be determined by:

$$\dot{r}_{LEM} = \dot{r}_{CSM} + K\Delta h$$

with the proviso that K can be set to zero preflight.

e. For the crew to ensure that the coelliptic rendezvous technique can be performed within the LEM ΔV capability, they will utilize DEDA readout of the CSI and CDH burn magnitudes, and the differential altitude, Δh . The TPI burn magnitude will be obtained from onboard charts which relate TPI ΔV with Δh .

f. After performing the CDH maneuver, the crew will use as a cue for TPI ignition the angle that the LEM-CSM line of sight makes with the local horizontal. This angle, in degrees, will be computed and displayed to the crew via DEDA. The manner of computation and display will be according to the requirements of paragraph 3.4.

g. Midcourse corrections will be performed by the crew according to a fixed time schedule. The Direct Intercept Program (paragraph 3.4a), will be used to compute the required burn magnitude, position the LEM to the proper attitude, and to provide a countdown of ΔV_g via the DEDA. Braking will be performed manually according to a predetermined range, range rate schedule. There is no requirement for AEA computation of the range rate maneuvers.

3.4 DIRECT INTERCEPT

a. The direct intercept transfer program will allow LEM/CSM rendezvous by calculating the necessary LEM velocity increment to place it on an intercept trajectory with the CSM. Necessary DEDA inputs to the program will be ignition time and desired LEM transfer time. Note that the LEM transfer time equals the CSM coast time from its location at ignition time to when LEM-CSM intercept occurs. For the general case of solving the direct intercept transfer for some fixed time in the future (abort from coasting descent, abort from insertion orbit, midcourse corrections), the DEDA inputs will be in AGS single precision absolute time.

b. Other modes of operation for this program will consist of solving for the intercept trajectory (corresponding to the desired transfer time) continuously in real-time, and continuously for some DT time increment ahead of real-time.

- (1) A time increment, DT, will be input via the DEDA to initiate computation of the LOS angle valid at the present time plus DT. That is, in real-time, the LOS angle valid DT minutes from the present time will be available for display via the DEDA.
- (2) When the desired angle is noted, the program will accept an input code via the DEDA that will freeze the calculation of the LOS angle.
- (3) When it is desired to orient to the proper burn attitude, commensurate with the frozen LOS angle, an ORIENT ENABLE instruction will be inserted via DEDA. The LOS angle computation will remain frozen until the TPI burn is initiated.
- (4) Upon manual application of the TPI burn, closed loop guidance and steering will resume; the LEM X-axis will continually be positioned in the correct direction.

3.5 EXTERNAL ΔV

a. The capability shall exist of inputting to the AEA via the DEDA an externally received ΔV . The event timer will be set to provide a countdown to ignition. The ΔV will be received in the form of three components, referenced to a LEM local vertical, local horizontal reference frame.

b. Attitude error signals will be generated for output to the control electronics section (CES) to maintain the X-axis toward the vector resultant of these components in real-time, independent of the required burn time. The components will be DEDA decimal inputs along the orthogonal body set of unit vectors defined below.

- (1) \hat{u} is through the LEM local vertical, along the geocentric radius line in the LEM orbital plane - positive away from the earth.
- (2) \hat{v} is in the local horizontal plane, positive in the direction of motion, and in the LEM orbital plane.
- (3) \hat{w} is out-of-plane, perpendicular to \hat{u} and \hat{v} , and positive in the sense that $\hat{u} \times \hat{w} = \hat{v}$.

Note that an external ΔV defined by the components $(\hat{u}, \hat{v}, \hat{w}) = (0, n, 0)$ would essentially maintain the LEM X-axis along the local horizontal, in the direction of travel (equivalent to orbit rate torquing).

SECTION 4
GENERAL NAVIGATION REQUIREMENTS

4.1 GENERAL

- a. Vector updating must occur in the AGS inertial computation coordinate frame. Reference (page 68), paragraph 10.1j, defines this system for the lunar mission. For AS-207/208, the inertial X and Z axes will be in the CSM orbital plane.
- b. The following vector update capability shall exist:
 - (1) LEM and CSM state vector components and time tag will be extracted from the PGNCSS downlink. This is a hardline transmission of data words in a 2's complement binary format. The AEA will avoid overflow of its input registers by working internally in units of 4 feet rather than 1 foot. Thus, the vector position and velocity components will be divided by 4 in the LGC prior to supplying them via the downlink. Acceptance of these vector components will require both DEDA and DSKY input operations.
 - (2) The LEM vector components and time tag, in decimal form, shall be inserted via the DEDA. These components will not have been divided by 4 since the AEA DEDA logic will perform this division.
 - (3) The CSM vector components shall be insertable via DEDA, as above.
- c. The DEDA insertable vector components will be received, via voice link from the ground (MSFN) or from the CSM.

SECTION 5
SPECIFIC GUIDANCE AND NAVIGATION REQUIREMENTS

5.1 GENERAL

In addition to requirements defined in following paragraphs, all appropriate functions specified in paragraph 10.1a will be incorporated. Any conflict existing between requirements specified herein and the provisions of paragraph 10.1j will be brought to the attention of MSC.

5.2 SECOND CSM RENDEZVOUS

The AEA shall function normally in the attitude hold submode upon PGNCS failure (PGNCS prime), and shall perform all functions as commanded via the LMP. The LMP command functions are identical to those of AS-206A.

5.3 FIRST LEM RENDEZVOUS

5.3.1 Coast Prior to First DPS Sep Burn

- a. The AEA shall accept an initialization of time, in seconds, which will be the absolute time frame for AGS calculations and display. This initialization will be via, the DEDA only.
- b. Accept LEM and CSM state vectors for navigation updating, as specified in paragraph 4.1.
- c. Align the AEA inertial reference frame to that of the PGNCS IMU. CDU inputed Euler angle pulses (representing IMU gimbal angles with respect to the IMU stable member) are processed (scaled) and used to set the body-to-inertial coordinates transformation matrix direction cosines.
- d. Upon DEDA command, perform an automatic inflight calibration and compensation of the integrating rate gyro output angles (determine alignment error signals and compensate the incoming angular data).

5.3.2 First DPS Burn After Separation

Necessary targeting for this PGNCS burn will be input via the DEDA prior to its initiation. Detail AEA functions during this burn will depend on whether the external ΔV or orbit insertion guidance program is used. MSC will provide these targeting parameters.

5.3.3 PGNCS/AGS DPS Takeover

During PGNCS controlled DPS thrusting, the AEA function shall be rendezvous guidance in the orbit insertion guidance mode and in the follow-up submode.

- a. At crew option, attitude errors, E_x , E_y , and E_z shall be output to the CES and FDAI.
- b. ΔV_g shall be computed and available for display via DEDA.
- c. When the crew places the guidance control switch to AGS, AGS enters attitude hold submode, whereby the LEM attitude at the time of guidance switchover is maintained by automatic RCS thrusting.
- d. AEA shall continue to command engine ON.
- e. Upon receipt of the abort discrete (crew pushes Abort button), AGS shall enter the automatic submode whereby the AEA generated attitude error signals (E_x , E_y , E_z) are used for powered steering to the targeted cutoff conditions. Note here the benefit of compatible PGNCS-AGS steering signals.
- f. Calculate ΔV_g for DEDA display.
- g. Calculate and output h , h , V_y to their respective displays. V_y is the y-body axis component of the LEM inertial velocity,

5.3.4 CSI Burn with RCS

During the coast period prior to this burn:

- a. Accept LEM-CSM state vectors per paragraph 4c.
- b. Accept T_1 via DEDA; the time of the CSI burn, and the necessary concentric rendezvous technique targeting per paragraph 3.3.

- c. Compute and have available for DEDA output display the following (see paragraph 9.3):
- ΔV_{CSI}
 - ΔV_{CDH}
 - Δh
 - Txfer
 - T_{CDH}
- d. Upon resetting the AEA to the CRT guidance mode (CSI code), compute and display the required quantities for monitoring and performing the burn (see paragraph 9.3):

$$\Delta V_g, E_x, E_y, E_z, r, \dot{r}$$

- e. The attitude error signals (on FDAI) will be used to monitor the auto orientation of the LEM for manual RCS performance of the burn.

AEA shall support the performance of the CSI burn using the RCS.

- f. Inhibit APS or DPS engine ON signals when crew pushes engine STOP button (these are issued upon sensing ullage, as below).
- g. Issue engine ON signal when ullage is sensed. Ullage condition is satisfied when the sensed X-axis acceleration is greater than A_x (normally 0.1 ft/sec^2) for three 2-second computing intervals. A_x will be determined.
- h. Continue to orient the LEM in the required direction during RCS + X translation thrusting.
- i. When thrusting is terminated, the AEA shall enter the attitude hold submode (discussed in par. 5.3.3c). Crew manually terminates thrusting when DEDA display of ΔV_g reaches zero. Crew will reset engine STOP button.

5.3.5 CDH Burn with DPS

Prior to this burn, accept LEM-CSM state vectors per paragraph 4. Event timer will be set to countdown T_{CDH} . CDH guidance mode computation will be selected via DEDA. The AEA shall be in the attitude hold submode prior to receiving the abort discrete (crew initiates). After receiving the discrete, the semi-automatic submode will be entered whereby auto control of LEM attitude occurs such that the X-axis is pointed in the required direction for performing the burn (closed-loop steering performed prior to and during the burn).

- Detect manual ullage
- Issue engine ON signal
- Continue closed-loop steering during DPS thrusting
- Enter A/H submode upon sensing first ΔV_g threshold
- Command engine OFF upon sensing second ΔV_g threshold.

5.3.6 TPI Burn with DPS

Same requirements as 5.3.5 where appropriate.

AEA shall perform in accordance with requirements in paragraph 3.4a.

5.3.7 Midcourse Correction Phase

- a. For a rendezvous radar (RR) capability, the AEA shall develop steering signals to orient the Z-axis along the LOS to the CSM to support radar lock-on procedures. RR range measurements (from tape meter) shall be accepted via DEDA, to accomplish updating of the LEM ephemeris.
- b. r , \dot{r} shall be calculated and displayed for RR comparison and for use with backup rendezvous procedures.

5.3.8 Docked DPS PGNCS Burn

The AGS will provide monitor and takeover capability for this burn. The necessary guidance mode and targeting will be input via the DEDA. MSC will determine these parameters.

5.3.9 AGS FITH

AEA will satisfy previous requirements where appropriate.

- a. Accept orbit insertion routine targeting.
- b. Upon receipt of abort stage discrete:
 - Arm APS engine
 - Enter semi-automatic submode
 - Auto-steer to burn attitude
 - Sense ullage
 - Issue engine ON signal to initiate staging (if ascent engine has been manually armed)
 - Enter A/H submode upon receiving ascent engine ON verification signal for a time determined by a DEDA insertable constant
 - Enter automatic submode (determined by above constant)
 - Continue commanding engine ON
 - Continue closed-loop steering
 - Enter A/H submode at first ΔV_g threshold
 - Command engine OFF at second ΔV_g threshold.

5.3.10 PGNCS/AGS APS Takeover

After AGS cutoff, guidance will be switched to PGNCS. AEA shall accept LEM and CSM vector updates. Targeting for the orbit insertion routine will be accepted via the DEDA. During the PGNCS controlled APS burn (for time ≥ 10 sec), the AEA will output the normal monitoring quantities. Upon guidance switchover to AGS:

- a. Enter A/H submode

- b. Continue to command engine ON

- c. Upon receiving the abort discrete (crew action):
 - (1) Enter automatic submode.
 - (2) Output attitude error signals to FDAI and CES to maintain attitude.
 - (3) Compute ΔV_g for DEDA display.
 - (4) Enter A/H submode at first ΔV_g threshold.
 - (5) Command engine OFF at second ΔV_g threshold.

5.4 SECOND LEM RENDEZVOUS

Rendezvous with the CSM will occur under PGNCS control, utilizing the coelliptic rendezvous technique. The detailed maneuvers are given in reference (page 77) cited in paragraph 10.1k.

The AGS will be targeted to fly the same plan, and must have the capability to complete the rendezvous in the event of a PGNCS failure.

AGS parameters necessary to effect this rendezvous shall be compatible with corresponding LGC parameters, and be available for display to the crew.

SECTION 6
UPLINK REQUIREMENTS

6.1 GENERAL

There are no uplink requirements for the AEA. There is a hardware interface with the LEM mission programmer (LMP) through which ground control of AGS can be accomplished.

SECTION 7
DOWNLINK REQUIREMENTS

7.1 GENERAL

Details for these requirements (digital format, down sequencing, etc.) will be provided at a later date.

The output telemetry word list (Table 7.1-1) that is presently fixed in hardware is provided from reference data cited in paragraph 10.1a. A total of nine words remains to be defined by MSC.

TABLE 7.1-1

OUTPUT TELEMETRY WORD LIST

NO.	WORD	DIMENSIONS	DESCRIPTION
1	DEDA data word	-	Last word of DEDA data entered or read out
2	Readout Mode Flag	-	DEDA readout mode gives negative value
3	Clear Mode Flag	-	DEDA clear mode gives negative value
4	a_{13}	-	Row one direction cosine
5	a_{12}	-	Row one direction cosine
6	a_{11}	-	Row one direction cosine
7	DEDA address	-	DEDA data word address
8	a_{33}	-	Row three direction cosine
9	a_{32}	-	Row three direction cosine
10	a_{31}	-	Row three direction cosine
11	LEM altitude	-	
12	r_x	ft	LEM inertial position component
13	r_y	ft	LEM inertial position component
14	r_z	ft	LEM inertial position component
15	g	ft	Pericynthian of present orbit
16	r_x	ft	CSM inertial position component
17	r_y	ft	CSM inertial position component
18	r_z	ft	CSM inertial position component
19	r_f	ft	Predicted burnout altitude
20	ΔV_x	fps	Compensated accelerometer input
21	ΔV_y	fps	Compensated accelerometer input

TABLE 7.1-1 (CONT'D)

NO.	WORD	DIMENSIONS	DESCRIPTION
22	ΔV_z	fps	Compensated accelerometer input
23	Absolute time		Least significant word
24	Δa_x	radians	Compensated gyro input
25	Δa_y	radians	Compensated gyro input
26	Δa_z	radians	Compensated gyro input
27	T _B	sec	Time to burnout
28	V_{xL}	fps	LEM inertial velocity component
29	V_{yL}	fps	LEM inertial velocity component
30	V_{zL}	fps	LEM inertial velocity component
31	To be specified by MSC.		
32	V_{xE}	fps	CSM inertial velocity component
33	V_{yE}	fps	CSM inertial velocity component
34	V_{zE}	fps	CSM inertial velocity component
35	\dot{h}	fps	Altitude rate
36	V_G	fps	Required velocity impulse
37	To be specified by MSC.		
38	To be specified by MSC.		
39	To be specified by MSC.		
40	X_{Di}	-	Unit vector component of desired X-axis attitude
41	X_{Dj}	-	Unit vector component of desired X-axis attitude

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TABLE 7.1-1 (CONT'D)

NO.	WORD	DIMENSIONS	DESCRIPTION
42	X_{Dk}	-	Unit vector component of desired X-axis attitude
43	Discrete input Word Number one		
44	S_3	-	Modeword
45	Absolute time	sec	Most significant word
46	To be specified by MSC.		
47	To be specified by MSC.		
48 thru 50	To be specified by MSC.		

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SECTION 8
INTERFACE REQUIREMENTS

8.1 HARDWARE INTERFACES

All normal interface wiring such as PCMTEA, LGC downlink, CDU, etc. will exist in LEM-2.

8.1.1 LEM Mission Programmer

a. The following discretes will be received from, or effected by, the LMP:

- (1) Auto.
- (2) Follow-up. When "PGNCS Guidance" is selected by LMP, follow-up is always present. If AGS is in the attitude hold submode, an attitude command by LMP will cause an "out-of-detent" signal which puts the follow-up discrete to the AEA.
- (3) Abort stage.
- (4) CES reference (common) - LMP can open.
- (5) Ascent engine ON.
- (6) Descent engine ON.
- (7) +28 V DC B+ for AEA power when CB 4CB28 is energized.
- (8) Attitude hold.

b. AGS status switch functions of warm-up, standby, and operate are available via LMP.

8.1.2 Control Electronics Section (CES)

- E_x , E_y , E_z attitude error signals
 - Auto engine ON
 - Auto engine OFF.
- { AGS selected and in automatic submode

8.1.3 FDAI

Sines and cosines of Euler angles α , θ , γ .

8.1.4 Control Panel Displays

- h - altitude to 9M9B tape meter
- \dot{h} - altitude rate to 9M9A meter
- V_y - lateral velocity to 9M2 meter

8.1.5 PCM Timing Electronics Assembly (PCMTEA)

- Test mode fail signal
- Sync pulse
- Clock pulse
- Downlink data, 50 words/sec.

8.1.6 PGNCS

- CDU zero, +28V, when present to zero AEA counters
- Input Euler angle pulses, $\pm \Delta \theta$, $\pm \Delta \psi$, $\pm \Delta \phi$, the IMU inner, middle, and outer gimbal angles. These gimbal angles are referenced to the platform x, y, z axes which are parallel to the three accelerometers.

8.1.7 ASA

- Input pulses from x, y, and z rate integrating gyros.
- Input x, y, and z accelerometer pulses.

8.2 PREFLIGHT GROUND CHECKOUT REQUIREMENTS

Same as for AS-206A; the AGS ground checkout procedures shall be demonstrated to the fullest extent in satisfying the lunar mission requirements.

SECTION 9
CREW INTERFACE

9.1 GENERAL

All cockpit display parameters and DEDA input/output parameters shall be identical with corresponding LGC/DSKY parameters with respect to dimensions, scaling, and decimal format.

9.2 DEDA INPUTS

- a. DT (sec): Time increment used in the direct intercept routine for calculation of the LOS angle.
- b. h_0 (ft): Altitude above the nominal earth insertion radius.
- c. V_0 (fps): Inertial cutoff velocity (orbit insertion routine).
- d. \dot{r} (fps): Radius rate (orbit insertion routine).
- e. T_1 (sec): Time to start CSI horizontal burn.
- f. T_2 (sec): Desired TPI time in AGS single precision absolute time.
- g. ϵ (deg): LEM elevation angle at TPI time. (See paragraph 3.3).
- h. Instruction to calculate attitude error signals whenever the follow-up and auto discretetes are present in AEA.
- i. Instruction to zero attitude error signals whenever follow-up and auto discretetes are present in AEA.
- j. Instruction specifying CDH maneuver to occur at perigee.
- k. Orient enable code. Allows X-axis orientation commensurate with the frozen LOS angle.

These inputs are to be considered additions to the inputs as specified in references, paragraphs 10.1a and 10.1j.

9.3 DEDA OUTPUTS

- a. ΔV_g (fps): Thrust velocity to be gained per guidance loop solutions.
- b. Δh (ft): Differential altitude resulting from coelliptic rendezvous solution.
- c. Txfer (sec): The time of initiation of the TPI maneuver; not updated after CSI burn.
- d. T_{CDH} (sec): Time of apocynthion (or pericynthian if crew selected pericynthian CDH).
- e. ΔV_{CSI} (fps): Required CSI delta velocity magnitude.
- f. ΔV_{CDH} (fps): Required CDH delta velocity magnitude.
- g. ΔV_{gx} (fps): The component of $\overrightarrow{\Delta V_g}$ as resolved along the local LEM X-axis. $\overrightarrow{\Delta V_g}$, as determined by guidance loop solutions, will be resolved along the LEM local X, Y, Z axes, regardless of LEM attitude. These components will be available for DEDA readout during individual axis thrusting maneuvers (including residual trimming), and will "countup or countdown" sensed ΔV along these axes.
- h. ΔV_{gy} (fps): Local body Y-axis component of $\overrightarrow{\Delta V_g}$.
- i. ΔV_{gz} (fps): Local body Z-axis component of $\overrightarrow{\Delta V_g}$.
- j. \dot{r} (fps): Range rate along the LEM line of sight to the CSM.
- k. Line of sight angle (deg): This is the angle the LEM-CSM line of sight makes with the LEM local horizontal.

9.4 DISPLAY MONITORING REQUIREMENTS

- a. DEDA. One-word monitoring; address required per readout.

- b. FDAI
 - (1) Attitude errors, E_x , E_y , and E_z .
 - (2) Display of total attitude (orientation of body axes with respect to the inertial reference frame).

- c. 9M9B and 9M9A Tape Meters (see control panel displays)

Unless meter scale and labeling changes are made, the display of lateral velocity, altitude, and altitude rate (V_y , h , \dot{h}) will not be usable for earth orbit missions.

SECTION 10
REFERENCES

10.1 GENERAL

- a. "Preliminary LEM AGS Flight Equations Document - Revision A," December 10, 1965, TRW Report 4250-6048-T0000.
- b. U. S. Government Memorandum from FM1/Assistant Chief, Mission Planning and Analysis Division, "AS-207/208 Re-rendezvous Mission Planning," March 17, 1966, by Howard W. Tindall, Jr.
- c. U. S. Government Memorandum from FM/Technical Assistant, Mission Planning and Analysis Division, "Minutes of AS-207/208 Software Requirements Meeting No. 2, February 25, 1966, "March 20, 1966, by Morris V. Jenkins.
- d. P. J. Stull, "LGC Guidance Specification for the Concentric Flight Plan," January 12, 1966, MSC Internal Note No. 66-EG-5.
- e. D. E. Steele, "AGS Guidance Specification for the Concentric Flight Plan," February 24, 1966, MSC Internal Note No. 66-EG-9.
- f. K. A. Young, J. W. Kahanek, and R. E. Simms, "Proposed Rendezvous Profile for Apollo 207/208 Mission," March 16, 1966, MSC Internal Note No. 66-FM-30.
- g. J. D. Alexander and R. P. Kehl, "LEM Nominal Concentric Accent Technique for Lunar Landing Mission," January 24, 1966, MSC Internal Note No. 65-FM-170.
- h. "Mission Requirements for Apollo Spacecraft Development Missions AS-206/207 and AS-207/208B", April 1, 1966; TRW Report 2132-H009-R8-000.

i. "Non-interpretive Simulation Results for Hardwired AGS Guidance Computations," November 16, 1965, TRW interoffice correspondence memo 9321.4-1039.

j. "LEM Abort Guidance Section Guidance, Navigation and Control Subsystem Equipment Performance and Interface Specification", Preliminary, April 7, 1966, GAEC Spec. No. LSP-500-1.

k. "Apollo Mission AS-207/208A Preliminary Spacecraft Reference Trajectory", April 30, 1966, TRW report 3902-H015-R0-000.