RTPDB, AGCSR(LEM)
AS-207/208(278)

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APOLLO

LUNAR EXCURSION MODULE
GUIDANCE COMPUTER
SOFTWARE REQUIREMENTS

MISSIONS AS-207/208(278)

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1. SUMMARY

This document defines the operational requirements on the LEM Spacecraft primary guidance and navigation system for Apollo Mission AS-207/208(278). The nominal mission requirements are listed according to the programs necessary to accomplish the mission. Crew interface requirements are also presented.

2. INTRODUCTION

The purpose of this report is to establish the operational requirements on the LEM primary guidance and navigation system in order to accomplish the flight test objectives of Mission 278 (ref. Par. 8a). These requirements are to be used along with the preliminary reference trajectory for Mission 278 to develop the flight software program in the LEM guidance computer (LGC). The nominal mission requirements are listed according to the programs necessary to accomplish the mission. Crew interface and uplink/downlink requirements are also presented.

This document is an in-line Apollo program document, and can be expected to change with time. Requirements will become better defined through additional analysis; mission planning studies will unearth new requirements; and MSC/MIT/IL negotiations in problem areas will define these requirements in greater detail. Such changes will be realized in the form of addendums and/or revisions to this document.

3. NOMINAL G&N REQUIREMENTS

3.1 Unmanned LEM

The G&N requirements for the unmanned phases of the LEM for flight 278 apply only to that unmanned phase subsequent to the CSM extraction of the LEM from the S-IVB. After CSM extraction of the LEM, the crew will enter the LEM and power up the G&N system and align the IMU to some preferred orientation (to be specified by MIT). The crew will then return to the CSM and during the following unmanned LEM phase the G&N requirements are as follows: The LGC will have a program to maintain an attitude profile commensurate with both the CSM acquisition of the LEM light (during CSM active rendezvous exercises), and DFI antenna requirements (to be specified by GAEC). In order to accomplish this, the LGC must accept CSM state vector updates and LEM state vector updates. The ground will provide the state vectors as needed.

3.2 Manned LEM

The requirements for the manned phases of the LEM are subsequent to the completion of the CSM active rendezvous phases. The crew will reenter the LEM and the G&N requirements are constituted by the following programs.

All of the burn programs should be capable of being implemented with the LEM RCS; APS, or DPS. The following G&N requirements apply to all burn programs:

a. The LGC should have a ΔV monitor program to compute and display ullage for all DPS and APS burns.

b. The LGC should display a countdown to t_{ign}, and the ΔV required for all burns.

c. The LGC should display V_g and T_{go} to completion of burn.

d. The LGC should display trim $\overline{\Delta V}$ in body axis after burn cutoff.

e. The LGC should supply the engine off signals to the RCS, APS, or DPS.

f. The DAP shall have jet select logic for all control modes to satisfactorily compensate for any RCS jet failure condition.

3.2.1 <u>AEA Initialization Program</u>

Purpose: To initialize the AEA with the LEM and CSM state vectors. Implementation: Upon a DSKY instruction from the astronaut, the LGC will initialize the AEA with the LEM and CSM state vectors divided by four (4), via the LGC downlink.

3.2.2 <u>External ΔV Program</u>

Purpose: To implement an externally computed maneuver. Implementation: The LGC will accept a t_{ign} and a $\overline{\Delta V}$ from the astronaut, via the DSKY. The $\overline{\Delta V}$ components will be as follows:

- +Z - Down along the local vertical at t_{ign}
- +X - Direction of motion normal to the local vertical at t_{ign}
- +Y - Forms a right-hand system at t_{ign}.

The LGC will orient the vehicle to the required burn attitude and perform the burn.

3.2.3 <u>Powered Ascent Program (Standard)</u>

Purpose: To implement a maneuver which simulates the standard powered ascent on the lunar mission. Implementation: The LGC will accept, via the DSKY and the uplink, the following target parameters:

- Launch window (the phase angles at the beginning and end of window)
- State vector of the target vehicle
- Desired horizontal velocity at cutoff
- Desired vertical velocity at cutoff
- Desired velocity normal to target orbit at cutoff
- Desired altitude at cutoff
- Desired distance normal to target orbit at cutoff.

As a function of the launch window and the target vehicle state vector, the LGC will compute and display a countdown to the t_{ign} associated with the earliest launch opportunity (beginning of launch window), and continue the countdown to the t_{ign} associated with the latest launch opportunity (end of launch window).

The steering for this program will be the same as that used for the lunar mission. (V required will be computed as a function of the desired orbit parameters.)

3.2.4 Coelliptic Sequence Initiation Prethrust Program (CSI) (See reference: Par. 8b)

a. Purpose. Calculate target and ΔV for CSI; ignition time, ΔV, and target for coelliptic burn; and ΔV for transfer phase initiation for the concentric rendezvous plan. Implementation: The LGC will accept, via the DSKY and uplink, the following target parameters:

(1) t_{ign} for CSI

(2) Time for the nominal transfer phase initiation (TPI) (GET)

(3) Elevation angle of LOS from active vehicle to target measured from active vehicle local horizontal at TPI (if the active vehicle is above at TPI then 180 degrees is added to this angle).

(4) Number of apses passings after CSI at which to execute the CDH maneuver (i.e., first apses, second apses etc. after CSI).

b. LEM Guidance Computer Display. The LGC will display the following:

(1) ΔV_{CSI} (sign of the dot product of $\overline{\Delta V}_{CSI}$ and $\overline{V}_{CSI}$ will be displayed also)

(2) t_{ign} for CDH

(3) Altitude at CDH

(4) Differential altitude at CDH (defined as the difference between the radius of the target vehicle at CDH and the radius of the active vehicle orbit along the same radius vector through CDH).

- o ΔV_{CDH}
- o t_{ign} for TPI
- o ΔV_{TPI}

The computations for the CSI prethrust program will be done in the target vehicle plane by rotating the active vehicle state vector into the target vehicle plane.

The CSI $\overline{\Delta V}$ for the prethrust program shall be along the active vehicle local horizontal at CSI.

The V-required for the CDH maneuver shall be determined as follows: The $\dot{r}$ (vertical velocity) of the active vehicle at the CDH radius vector shall be made equal to the $\dot{r}$ of the target vehicle along the same radius vector and the semi-major axis of the active vehicle orbit shall be equal to the semi-major of the target vehicle orbit $-\Delta h$.

3.2.5 CSI Thrust Program

Purpose: To implement ΔV_{CSI}. Implementation: The steering for this burn should be such that the thrust direction required is parallel to the target orbit plane. The thrust direction at the start of the burn should never be more than ± 3 degrees from the local horizontal.

3.2.6 CDH Thrust Program

Purpose: To implement ΔV_{CDH}. Implementation: The LGC will accept a t_{ign} (calculated from CSI prethrust program) for CDH. The steering will be such that the thrust direction is parallel to the target orbit plane.

3.2.7 TPI Prethrust Program

a. Purpose. Calculate maneuver to intercept the target vehicle. Implementation: The LGC will calculate the time associated with the desired LOS angle from the active vehicle to the target vehicle measured from the active vehicle local horizontal. The LGC will then display this time to the astronaut.

After calculating and displaying this time, the LGC will accept the following target parameters:

(1) t_{ign} (desired LOS angle time)
(2) The central angle of travel of the target vehicle from TPI time to the intercept time.

b. LEM Guidance Computer Display. The LGC will display the following:

(1) ΔV_{TPI}
(2) ΔV at intercept
(3) Time of intercept.

3.2.8 TPI Thrust Program

Purpose: To implement ΔV_{TPI}. Implementation: The steering should use the V required from Lambert Routine.

3.2.9 AEA Monitor Program

Purpose: To monitor AEA takeover or APS or DPS burn. Implementation: Simultaneous with AEA takeover of the APS or DPS burns, the LGC should switch over to the standard powered ascent guidance, which will be used by the AEA and compute steering signals in the same manner as if it were controlling the burn. The target parameter values should be the same as those being used by the AEA (Standard Powered Ascent Program). The LGC should display appropriate parameters for the astronaut to monitor the AEA. Some of the parameters which may be computed for possible display will be:

- Attitude errors on the FDAI
- T_{go} to cutoff
- V_g
- Altitude and altitude rate.

3.2.10 Orbital Navigation Program

Purpose: To compute LEM state vectors from observations made on the CSM. Implementation: Observations using either the rendezvous radar or the LORS will be made on the CSM. The program will have the capability to make necessary attitude maneuvers so that the sensor can acquire the CSM.

3.2.11 IMU Alignment Program

Purpose: To perform an inflight alignment. Implementation: The capability for inflight alignment must be available to the astronaut, by use of any of the methods being planned for the lunar mission with either the AOT or the LORS.

3.2.12 Additional Crew Interface Requirements

a. When the PGNS is in control of the LEM, LGC mission programs in progress will not be terminated by switching the mode control switch from AUTO to ATT HOLD or vice versa.

b. DSKY displays will be continued as a function of the LGC mission program regardless of the position of the mode control switch.

c. When OPR ERR (operator error) on the DSKY illuminates, the ENTR button should be inhibited until the condition causing illumination is corrected.

d. DSKY inputs/outputs of flight data must be in decimal form.

e. The LGC shall display at astronaut request, the FDAI angles on the DSKY that would exist if the spacecraft was pointed at the target and display also the rate at which these angles would be changing. These displays would be for a given time input by the astronaut and are not to be updated.

f. The LGC shall display, via the DSKY at astronaut request the total inertial velocity (fps), altitude (ft), and altitude rate (fps). This display should be updated every ten seconds.

g. The LGC shall display at astronaut request, via the DSKY, the present range and range rate (fps) relative to the CSM. The display will be updated every ten seconds. The range will be in feet for ranges from zero feet to 60,000 and in nautical miles for ranges over 60,000 feet (to nearest 0.01 nm).

h. The LGC shall display at astronaut request the FDAI angles on the DSKY that would esist if the LEM had the following orientation:

- o +X body - up along local vertical
- o +Z body - along local horizontal in the direction of motion
- o +Y body - forms right-hand system

This display would be for a given time input by the astronaut and is not to be updated.

i. The LGC shall compute and display the time of arrival at TPI in ground elapsed time at astronaut request.

j. The LGC must compute and display the angle between the LEM local horizontal plane and the relative position vector vetween the two vehicles at crew request, through the DSKY.

4. UPLINK REQUIREMENTS

As much as possible of the LGC uplink quantities of Mission 206A should be retained. As much as possible should be done to retain the philosophy of addressing programs, times of programs, times within these programs, etc.

5. DOWNLINK REQUIREMENTS

(To be specified at a later date by MSC.)

6. DAP REQUIREMENTS

It is required that the constants in the digital auto pilot equations be stored in erasable memory.

7. LGC-CSM CFP CAPABILITY

The LGC shall have the capability of solving the concentric flight plan for CSM active rendzvous (i.e., the LGC will supply the CSM with a t_{ign} and $\overline{\Delta V}$ for the CSI and the CDH maneuvers.

8. REFERENCES

a. "Mission Requirements for Apollo Spacecraft Development, Mission AS-207/208", TRW Systems Report No. 2132-H008-R8-000

b. Letter of Direction to MIT, EG22-2-66-38 LGC Guidance Specifications for the Concentric Flight Plan

APPENDIX A

PRELIMINARY MISSION PROFILE SUMMARY

A tabular summary of the 278 preliminary mission profile is given below. The LGC programs necessary for each mission phase are listed along with the corresponding mission phase. The LGC programs are those listed in the preceding text. Only those LEM active phases under LGC control or those phases requiring LGC programs are listed.

It should be understood that this profile is under no circumstances fixed. The Orbital Navigation Program, IMU Alignment Program, and the AEA Initialization Program would be called in each mission phase as needed.

MISSION PHASE	LGC PROGRAMS
1. CSM active rendezvous (unmanned LEM)	Unmanned LEM programs
2. First DPS Burn (Manned LEM)	External ΔV Program
3. Second DPS Burn	External ΔV Program AEA Monitor Program
4. Third DPS Burn (LEM/CSM Docked Configuration)	External $\overline{\Delta V}$ Program
5. AGS controlled FITH	AEA Monitor Program
6. PNGS/AGS controlled APS Burn	Powered Ascent Program (Standard) AEA Monitor Program
7. PNGS Controlled Concentric Flight Plan	Coelliptic Sequence Initiation Prethrust Program CSI Thrust Program CDH Thrust Program TPI Prethrust Program TPI Thrust Program