RTPDB, AGCSR(CM)
AS-207/208

# MSC INTERNAL NOTE 66-FM-50

APOLLO

COMMAND MODULE
GUIDANCE COMPUTER
SOFTWARE REQUIREMENTS

MISSION AS-207/208

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TABLE OF CONTENTS

# 1. INTRODUCTION

## 1.1 Purpose

The purpose of this document is to specify the Apollo Command Module Guidance Computer Software Requirements in order to accomplish the flight test objectives of the AS-207/208 mission as outlined in reference (Par 7a). These requirements will be used in the development of the flight program in the Command Module Computer (CMC).

## 1.2 Scope

The Guidance and Navigation Subsystem (G&N) requirements are defined for the nominal and contingency missions, and are presented as a function of mission phase. The requirements were derived from the mission plans and requirements as outlined in references (Par 7a) and (b) and from the contingency situation as they are known to date.

It is intended that the CMC program developed for the AS-207/208 mission be an abbreviated version of the program that is to be developed for the lunar mission (with the exception of the stroking test). The basic logic that has been developed for the AS-204A program will be utilized where applicable, and additional software capabilities will be implemented for application to the AS-207/208 mission.

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/MIT negotiations. As changes become imminent, they will be realized in revisions to this document.

## 2. MISSION DESCRIPTION

### 2.1 Nominal Mission

The AS-207/208 mission planned to date is outlined in reference (Par 7b). However, there is strong consideration of changes in the mission as planned. The nominal mission outlined below is one version of a new mission and is presented for information only.

The AS-207 configuration (CSM) will be launched from Pad 34 on an azimuth of 82 degrees. The CSM will be inserted on a 100 nm circular orbit.

The AS-208 configuration (LEM) will be launched about one day later from Pad 37 on an azimuth of about 78 degrees. The S-IVB/LEM will be inserted into a 120 nm circular orbit and the S-IVB will provide attitude control until the first CSM/LEM rendezvous. Shortly after S-IVB/LEM insertion a phasing orbit will be initiated by the CSM to establish nominal phasing at the coelliptic maneuver (about 360 degrees later). For no insertion dispersions the CSM phasing orbit would be one with a period equal to that of the S-IVB/LEM with TPI occurring about 80 degrees after the coelliptic maneuvers.

After docking the CSM will extract the LEM from the S-IVB and then maneuver the docked configuration (CSM/LEM) to 180 nm circular orbit using the SPS.

At this point the LEM will be manned and the next two rendezvous will be under LEM control. The CSM will act as a target for LEM exercise of the Concentric Flight Plan (CFP).

The total CSM mission will last about 10 days and the recovery area will be in the Atlantic.

## 2.2 Contingency Mission

The G&N requirements for an abort or contingency situation are outlined below:

a. The G&N shall navigate over abort burns.

b. The G&N shall provide appropriate displays for manual control of aborts and contingency situations.

## 3. GUIDANCE AND NAVIGATION REQUIREMENTS

The guidance and navigation requirements are outlined below as a function of mission phase. The unknown time quantities ($\Delta t_i$) listed in the requirements will be furnished by MSC.

## 3.1 Prelaunch Phase

The prelaunch phase will start with the activation of the G&N and terminate with the receipt of the guidance reference release (GRR) discrete.

a. Accept erasable memory load from the Apollo checkout equipment (ACE).

b. Align the inertial measurement unit (IMU) to the following orientation:

(1) Z-axis down along the local vertical

(2) X-axis down range along a preselected azimuth (azimuth in erasable memory)

(3) Y-axis forms right-hand system

## 3.2 Pre-LET Monitor Phase

The pre-LET monitor phase will start with the receipt of the GRR discrete and terminate at $t_0 + \Delta t_1$.

a. Upon receipt of the GRR discrete the G&N shall perform the following functions:

(1) IMU to inertial mode

(2) G&N to an attitude control mode

(3) Initiate the powered flight navigation

b. Upon receipt of the liftoff discrete ($t_0$), the G&N shall perform the following functions:

(1) Zero the G&N clock

(2) Initiate the computation of the boost phase pitch and roll polynomials (coefficients in erasable memory and supplied by MSC). Generate vehicle attitude errors as a function of these polynomials and display on flight director attitude indicator (FDAI).

(3) Start monitor of CM/SM separation descrete for indication of LET abort.

c. At $t_0 + \Delta t_2$ the G&N shall terminate the calculation of the commanded gimbal angles from the boost polynomials and hold the commanded gimbal angles constant.

3.3 Abort During Pre-LET Monitor

If the G&N receives the CM/SM separation discrete during this time interval it shall force the attitude errors (FDAI) to zero.

3.4 Post-LET Monitor Phase

The post-LET monitor phase will start at $t_0 + \Delta t_1$ (nomial LET jettison) and terminate after S-IVB cutoff.

a. At $t_0 + \Delta t_1$ the G&N shall perform the following functions:

(1) Terminate the monitor of the CM/SM separation discrete for abort indication.

(2) Initiate monitor of the S-IVB/CSM separation discrete for indication of abort.

(3) Initiate a $\Delta$ V monitor for detection of S-IVB cutoff.

b. At $t_0 + \Delta t_3$ the G&N shall terminate its calculation of the vehicle attitude errors for FDAI display.

c. After the Δ V monitor routine detects S-IVB shutdown and at astronaut approval, the G&N shall perform the following functions:

(1) Terminate the powered flight navigation and save the present state vector.

(2) Terminate monitor of the S-IVB/CSM separation for abort indication.

(3) Terminate Δ V monitor for S-IVB shutdown indication.

(4) The G&N shall initiate its idling routine.

3.5 Abort During Post-LET Monitor

If the G&N receives the S-IVB/CSM separation discrete during this time interval it shall perform the following functions:

a. Initiate Δ V monitor routine to control powered flight navigation for abort burns.

3.6 Coast Phase

This phase will include all of the orbital functions except those associated with thrusting. Since this is a manned flight, the requirements are not necessarily defined in the sequence that they are expected to occur. The functions are outlined below and each may be called by either the astronaut or from another program.

a. The G&N shall have the capability of determining its state vector based on landmark and/or star sightings. The G&N shall display the magnitude of the difference between the last state vector and the present determination of the state vector before the sighting data is incorporated into the program. Provision for rejection of the present determination of the state vector shall be provided.

b. The G&N shall be capable of automatically positioning the optics to a preselected target.

c. The G&N shall have the capability of determining the state vector of the LEM based on its optical sightings.

d. The G&N shall be capable of displaying state vectors for initialization of the two LEM guidance computers (LGC and AGS). The initialization will be the LEM state vector in either the LGC or AGS coordinates as well as the CSM state vector in the LGC or AGS coordinates.

e. The G&N shall have the capability to align the IMU, CSM/LEM, and CSM with respect to the celestial reference system utilizing star sighting information.

f. The G&N shall have an orbital integration program for state vector projection.

g. The G&N shall have the capability to align the IMU to the prelaunch orientation with respect to the celestial reference system before CSM separation from S-IVB.

3.7 Prethrust Targeting Phase

The prethrust targeting programs will compute the preferred IMU orientation (FDAI attitude indicator shall read zero at ignition and IMU realignment on astronaut decision), desired CSM attitude at ignition (final gimbal angles displayed), and the targets for the thrusting programs. The astronaut will have the option of heads up or down at ignition and he will specify if the maneuver is to be performed with the RCS, or SPS. Also the astronaut shall have the capability of terminating the prethrust programs after the solution has been displayed on DSKY. The prethrust programs that will be required are outlined as follows:

a. The G&N shall have an "orbit change" prethrust program for changing the CSM orbit. The inputs to the program shall be:

(1) Time of ignition ($T_{IGN}$)

(2) Latitude of target point the new orbit must pass over (LAT)

(3) Longitude of the target point the new orbit must pass over (LONG)

(4) Altitude of new orbit over target point (ALT)

(5) Period of new orbit (PER)

(6) The number of orbits after the maneuver in which the spacecraft must pass over the LAT and LONG (N)

b. The G&N shall solve the orbit change problem and display the following information:

(1) Perigee altitude of resulting orbit ($h_p$)

(2) Apogee altitude of resulting orbit ($h_a$)

(3) Velocity change required for maneuver ($\Delta V$)

(4) Required plane change ($\Delta$ Ψ)

c. The G&N shall have a "Return-to-Earth" prethrust program to place the spacecraft on an orbit which will intersect the atmosphere at a satisfactory flight path angle and velocity. The inputs to the program shall be:

(1) Maximum allowable $\Delta V$ for maneuver ($\Delta V_{MAX}$)

(2) Earliest possible time of ignition ($T_{PIGN}$)

d. The G&N shall solve the return to earth problem and display the following information;

(1) Latitude of splash point ($LAT_{SP}$)

(2) Longitude of splash point ($LONG_{SP}$)

(3) $T_{IGN}$

(4) Inertial velocity predicted at 400 K feet ($V_0$)

(5) Inertial flight path angle predicted at 400 K feet ($\gamma_0$)

If the splash is not satisfactory, a lower $\Delta V_{MAX}$ may be selected and input for a new solution to the problem This iteration can be continued until a satisfactory longitude at splash is achieved.

e. The G&N shall have an "External $\Delta V$" prethrust program as a general purpose routine for miscellaneous maneuvers. The inputs to the program shall be:

(1) $\overline{\Delta V_B}$ thrust velocity changes at ignition along the following coordinates:

(a) $\Delta V_z$ - down along the radius vector ($\overline{R}$)

(b) $\Delta V_x$ - in $\overline{R}$-$\overline{V}$ plane but perpendicular to $\overline{R}$

(c) $\Delta V_y$ - forms right-hand system

(2) $T_{(IGN)}$ (optional)

(a) If $T_{IGN}$ is input the burn will be a standard burn

(b) If $T_{(IGN)}$ is not input the G&N will assume that the burn is to be performed manually and it will continously orient the CSM to the burn attitude. In this case $\overline{V}_g$ will be displayed for manual steering.

For both options (a) and (b) above, the required velocity at cutoff ($\overline{V}_R$) shall be:

$$\overline{V}_R = \overline{V}_{(IGN)} + \overline{\Delta V} + \overline{g}(\Delta t)$$

when:

$\overline{V_{(IGN)}}$ is inertial velocity at ignition. For case (b) above $\overline{V_{(IGN)}}$ can be determined when $\Delta V$ monitor sets thrust on flag.

$\overline{\Delta V}$ are the components of the $\overline{\Delta V_B}$ in IMU coordinates.

After the inputs have been entered and prior to CSM orientation to the burn attitude the CMC shall display the gimbal angle changes required to orient to the burn attitude. The CSM orientation will occur after astronaut approval.

f. The G&N shall have a "Terminal Phase Initiate" (TPI) prethrust program for a transfer maneuver to intersect with the target vehicle. The inputs shall be:

(1) (a) $T_{IGN}$ (optional)
or

(b) Elevation angle (E)

Angle between line of sight from CSM to LEM and local CSM horizontal.

(2) Central angle of travel of the target vehicle from TPI to intercept time ($\Phi_{TR}$)

g. The G&N shall solve the TPI problem and display the following information:
   (1) (a) E if $T_{IGN}$ is input
   or
   (b) $T_{IGN}$ if E is input
   (2) $\Delta V$
   (3) Closing speed at intercept of target vehicle ($\Delta V_{INT}$)
   (4) Time of intercept of target vehicle ($T_{INT}$)

h. The G&N shall have a "Midcourse Correction" prethrust program to be used during the terminal phase of rendezvous
   (1) $T_{IGN}$
   (2) $T_{INT}$

i. The G&N shall solve the problem and display the following:
   (1) $\Delta V$
   (2) $\Delta V_{INT}$

j. The G&N shall have a "Terminal Rendezvous" prethrust program to achieve desired terminal range and range rate gate conditions. There are no inputs required for this maneuver. The G&N shall solve the problem based on the stored range and range rate gates and display the following information:
   (1) $T_{IGN}$
   (2) Range from CSM to LEM (R)
   (3) Range Rate from CSM to LEM after burn ($\dot{R}$)
   (4) $\Delta V$

   To achieve terminal rendezvous this program will be called prior to each braking maneuver.

## 3.8 Thrusting Phase

The thrusting phase is made up of the thrusting programs that were initialized in the prethrust phase. The functions required for the thrusting programs are outlined below:

a. The G&N shall measure and display the ULLAGE applied prior to engine ignition. The $\overline{Vg}$ shall also be displayed prior to engine ignition. The G&N shall then countdown, initiate, control, monitor and terminate the thrusting maneuvers outlined below:
   (1) Orbit change
   (2) Return to earth
   (3) External $\Delta V$
   (4) Terminal phase initiate
   (5) Midcourse correction
   (6) Terminal rendezvous.

b. The G&N shall calculate $\overline{V_g}$ residuals in body axes for velocity trim determination. The $\overline{V_g}$ shall be displayed automatically after each burn and shall be displayed anytime at astronaut request. The residuals shall be updated every two seconds.

c. For CSM maneuvers that are not G&N controlled, the G&N shall have a monitor program to navigate and compute the $\overline{\Delta V}$ applied along the CSM body axis. The $\overline{\Delta V}$ shall be displayed and updated every two seconds.

d. The G&N shall be capable of performing the "Stroking Test" as outlined in reference (Par 7c). The test shall be performed during SPS thrusting when the CSM/LEM is in the docked configuration.

e. The digital autopilot (DAP) shall have jet select logic for all control modes to satisfactorily conpensate for any RCS jet failure conditions.

f. The DAP input constants shall be in erasable memory.

g. The attitude and rate command deadband of the DAP shall be selectable by the astronaut.

h. The DAP shall be programmed such that all ULLAGE maneuvers will use two RCS jets.

3.9 Preentry Phase

a. The G&N shall orient the CSM to the proper attitude for CM/SM separation.

b. After separation the G&N shall orient and hold the CM to the correct entry attitude.

c. The G&N shall initialize the entry equations with the following information:
   (1) Calculate initial roll angle as a function of inertial velocity and flight path angle
   (2) Calculate desired spacecraft pitch and yaw attitude as determined by the CM state vector with respect to the atmosphere
   (3) Select landing site

d. When the G&N senses the occurrence of .05g, it shall transfer to the entry phase and indicate event on DSKY.

3.10 Entry Phase

a. The G&N shall control the CM lift vector to attain a desired splash point. If the splash point is outside the footprint, the G&N shall maneuver the CM to the extreme of the footprint closest to the target.

## 4. CREW INTERFACE

The requirements as outlined below are a function of the G&N inputs to the astronaut displays, as well as the astronaut control of the G&N and the spacecraft using the G&N. The requirements are presented in a general mission phase outline.

### 4.1 Launch Phase

a. During the total launch phase (including aborts) the G&N shall display the following parameters:
   (1) Total inertial velocity (V)
   (2) Vehicle altitude above the launch pad (h)
   (3) Vehicle altitude rate of change above launch pad ($\dot{h}$)

b. After the $\Delta$ V monitor senses S-IVB cutoff and on astronaut approval, the G&N shall display the following parameters:
   (1) Altitude of apogee above mean equatorial radius ($h_a$)
   (2) Altitude of perigee above mean equatorial radius ($h_p$)
   (3) Time of free fall to 300,000 ft ($T_{ff}$)

### 4.2 Orbital Phase

a. A visual indication shall be provided the crew when a thrusting program selected is not compatible with the prethrusting program previously accomplished. The G&N should allow reselection of the thrusting program by DSKY entry without re-accomplishing the prethrust program.

b. Display on DSKY the desired final IMU gimbal angles prior to start of a course alignment of the IMU.

c. Following an "Op Error" detection, the "Enter" pushbutton shall be inhibited until the conditon causing the operator error has been cleared.

d. CMC programs will not be terminated by changing the position of the CMC Mode Switch.

e. At astronaut request during rendezvous, the G&N shall display the present range (R) and range rate ($\dot{R}$) to the target. The range will be in feet from zero to 60,000 ft and in nautical miles (to nearest 0.01nm) from 60,000 feet up.

f. The gimbal angles shall be displayed on DSKY at astronaut request.

g. For all burns that are computed by the G&N the total attitude and attitude errors shall be indicated on the FDAI.

4.3 Entry Phase

a. During the entry initialization program, the G&N shall display the following parameters:
   (1) Inertial velocity ($V_0$) predicted at an altitude (h to be defined)
   (2) Predicted range to go from h to chute deploy ($R_{OTG}$)
   (3) Inertial flight path angle predicted at h ($\gamma_0$)

b. The G&N shall continuously display from 0.05g to shute deploy the following parameters:
   (1) Commanded bank angle (B)
   (2) Total inertial velogity (V)
   (3) Range to go to chute deploy ($R_{TG}$)

5. UPLINK REQUIREMENTS

The G&N shall be capable of accepting the following ground inputs, via the digital uplink.

a. CMC Clock Alignment

b. Liftoff Discrete

c. State Vector of CSM in Earth Centered Inertial (ECI) Coordinate

d. State Vector of LEM in ECI Coordinate

e. Prethrust "Orbit Change" Targeting Data

f. Prethrust "Return to Earth" Targeting Data

g. Prethrust "External V" Targeting Data

h. Prethrust "Terminal Phase Initiate" Targeting Data

i. Prethrust "Midcourse Correction" Targeting Data

j. Prethrust "Terminal Rendezvous" Targeting Data

k. CMC Clock and DTEPOCH Update

## 6. DOWNLINK REQUIREMENTS

To be provided.

## 7. REFERENCES

a. "Mission Requirements for Apollo Spacecraft Development Mission, AS-207/208A", 7 March 1966.

b. "Apollo Mission As-207/208A Preliminary Spacecraft Reference Trajectory", 30 April 1966.

c. Memorandum, "Proposed Stroking Test Format for Mission 207", EG 23-37-66-330, 22 March 1966.