RTPDB, AGCSR(CM)
AS-502

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APOLLO

COMMAND MODULE

GUIDANCE COMPUTER SOFTWARE

REQUIREMENTS

MISSION AS-502

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1. INTRODUCTION

The intent of this document is to enumerate a set of guidance software functions which, when programed, will enable the AGC to support the mission objectives for AS-502. This set will constitute the minimum requirements on the AGC, pending properly authorized adjustments.

It should be noted that the AS-502 program is largely dependent on the AS-501 program (Ref: Par. 7c); thus, most of the requirements will be repetitive (see AS-501 requirements, Ref: Par. 7b). Abort Mode III is slightly different from AS-501, and an additional SPS burn is scheduled, but other changes are primarily numerical. It should also be noted that any appreciable AS-501 program modifications must almost certainly apply to AS-502.

2. MISSION DESCRIPTION

2.1 Nominal Mission

Mission AS-502 will be launched on a 72-degree launch azimuth from Pad A, Complex 39, of the Merritt Island launch area.

The major phases and events are as follows.*

2.1.1 Launch. S-IC, S-II, and partial S-IVB burn into a 100-nm circular orbit.

2.1.2 Earth Parking Orbit. Coast for approximately two revolutions.

2.1.3 Second S-IVB Burn. In the vicinity of Cape Kennedy, S-IVB restarts to inject the S-IVB CSM configuration on a 72-hour lunar transfer ellipse.

2.1.4 CSM/S-IVB Separation and First SPS Burn. Following the burn described in paragraph 2.1.3, the S-IVB performs an attitude maneuver to the spacecraft first-burn orientation, followed by CSM/S-IVB separation, a short (about 1 min) coast, and then SPS ignition at S-IVB cutoff plus 4 minutes. The SPS burn should achieve a desired apogee (presently 9000 nm), entry flightpath angle at 400,000 feet (presently γ_{EI} = -9 deg) and splash point (presently Φ = 32 deg N, λ = 165 deg W) should the second SPS burn not occur. The burn will last about 305 seconds in the "retrograde" direction.

2.1.5 Second SPS Burn. Occurring about 4 hours and 26 minutes after first burn cutoff, the posigrade second SPS burn is intended to achieve specified entry conditions (presently specified as V_{EI} = 36,337 fps and γ_{EI} = -7.13 deg) and splash point (presently Φ = 30.5 deg N, λ = 144.8 deg W).

*All trajectory figures assume a 36,600-lb SPS propellant loading.

2.1.6 Preentry Sequence. Following the second SPS burn, there will be about 4 minutes of coast in which to orient to the separation attitude, separate, and orient the CM for entry.

2.1.7 Entry. Entry will nominally occur about 8 hours from liftoff, and will simulate a lunar mission entry. About 2500 miles will be traversed from first entry to touchdown.

2.2 Contingency Missions

A contingency mission is defined here as that part of a flight following an abort, and is predesigned to salvage some of the mission objectives. Aborts in AS-502 may be initiated by the ground (MCC), the S-IVB, or the AGC. In any event, the abort sequence is enabled by the CSM/S-IVB SEP signal from the MCP.

On receipt of the SEP signal, the AGC must determine whether the signal resulted from the normal separation discrete, "commanded" abort, or tumbling abort. If a "tumble flag" is set, the SPS should ignite to reduce the rates; if (or when) it is not, the AGC should check for a commanded abort mode (an uplink key code is defined for each mode). If no abort flag is set, a normal (RCS only) separation is allowed; if one is set, the SPS should perform a constant-attitude 3-second separation burn to reduce recontact probability.

The abort mode requirements for AS-502 are as follows.

2.2.1 Abort Mode I. For aborts from early (time to be defined) post-LET boost, the AGC must:

(a) Command a maneuver to obtain adequate separation from the S-IVB.

(b) Arrest tumbling if necessary.

(c) Enable T_{ff} (to 300,000 ft) interrupt. When T_{ff} first falls below a predefined time (to be defined), the preentry sequence is initiated.

(d) Perform a 4 deg/sec RCS maneuver to the SPS burn attitude (with the S/C +X-axis 35 deg from the visible horizon) as defined for AS-501.

(e) Perform an SPS burn at the attitude defined in (d) above, designed to achieve impact at a discrete Atlantic recovery area (to be defined).

(f) Perform normal preentry sequence.

(g) Perform lift vector control to target.

2.2.2 Abort Mode II. For aborts from "near-insertion" (time limit to be defined) S-IVB boost, the AGC must:

(a) Command a maneuver to obtain adequate separation from the S-IVB.

(b) Arrest tumbling if necessary.

(c) Change T_{ff} altitude reference to 400,000 ft, and enable T_{ff} interrupt.

(d) Command an attitude maneuver to the desired SPS thrust attitude (defined for ignition).

(e) Perform an SPS burn targeted to an earth-intersecting ellipse of specified p, e, and landing point (targets to be supplied) designed to optimize entry test conditions.

(f) Command CSO (cold-soak orientation) defined in Reference e, Par. 7.

(g) Accept an update for additional SPS burn target parameters and ignition time, command burn attitude maneuver, and perform an "uplinked" SPS second burn.

(h) Perform preentry sequence.

(i) Perform entry.

2.2.3 Abort Mode III. For aborts that occur during the second S-IVB burn, the AGC must:

(a) Command a maneuver to achieve adequate separation from the S-IVB.

(b) Arrest tumbling if necessary.

(c) Compute parameters, based on the nominal first SPS burn target, necessary to perform a steered SPS maneuver.

(d) Command a 4 deg/sec attitude maneuver to the initial SPS burn attitude computed in (c) above.

(e) Perform SPS ignition at SEP plus 4 minutes, and steer the burn to achieve targets stored for the nominal first SPS burn.

3. GUIDANCE AND NAVIGATION REQUIREMENTS

The AGC program requirements related to guidance and navigation are shown as specific tasks to be accomplished for a given mission phase. It is assumed that the complete G&N system will be in the "operate" mode continuously from prelaunch through touchdown.

3.1 Prelaunch Phase

(a) Interface with the ACE (see the proper ICD) and accept a full erasable memory load from it (also see Sections 4 and 5, Telemetry Requirements).

(b) Establish a zero time reference known to the ground control complex and adjustable by it.

(c) Establish an earth-fixed stable member reference aligned as accurately as possible to the following axis definitions:

- X_{SM} Along the flight azimuth (72 deg E of N)
- Z_{SM} Down along the local gravity vector
- Y_{SM} Completing a right orthogonal triad.

3.2 Launch Phase

(a) On receipt of the GRR (guidance reference release) signal

- Release the IMU stable member
- Initiate navigation
- Initiate T_{ff} (to 300K ft) calculation.

(b) On receipt of liftoff from the Saturn IU (or backup liftoff signal from uplink), provide backup GRR signal in case of nonreceipt.

(c) At liftoff receipt time plus Δt_1 seconds (to be defined), initiate control of CDU's with commands generated by the pitch and roll polynomials (to be supplied by NASA).

(d) At liftoff discrete plus Δt_2 seconds (to be defined)

- Terminate CDU control
- Start side-force parameter displays on DSKY (equations to be supplied by NASA).

(e) At liftoff plus Δt_3 (to be defined), terminate side-force calculations.

(f) At liftoff plus Δt_4, initiate monitoring for tumble and receipt of uplink abort signal. T (liftoff) plus Δt_4 should coincide with nominal LET jettison. Tumbling is constituted by spacecraft attitude rates of 5 deg/sec, or greater, about any axis.

3.3 Parking Orbit Phase (From First S-IVB Cutoff to Second S-IVB Ignition)

(a) Accept a state vector update.

(b) At liftoff plus Δt_5 (to be defined), change the entry interface altitude reference to 400,000 ft.

3.4 Second S-IVB Burn and 4-Minute Coast

(a) Monitor CSM/S-IVB separation discrete.

(b) Perform appropriate separation sequence.

(c) Orient CSM for first SPS burn. Nominally, the S-IVB will have achieved the correct attitude.

3.5 First SPS Burn

Perform steering to desired burnout vector to satisfy the target conditions (to be specified by NASA).

3.6 Earth Intersecting Coast Phase (From First SPS Cutoff to Nominal Ignition Time of Second SPS Burn)

(a) Orient the CSM to the cold-soak orientation. This is the same as it is for AS-501 (see MIT Document R-537). Hold CSO (may use coarse dead-band) until the orientation maneuver for second SPS burn.

(b) Accept a state vector update.

(c) Perform 0.5 deg/sec maneuver to ignition attitude for the second SPS burn.

(d) Enable T_{ff} (to 400K ft) interrupt and begin T_{ff} calculation.

(e) Perform second burn ignition sequence. Ignition should be timed so cutoff occurs about 4 minutes prior to entry.

3.7 Second SPS Burn Phase

Perform steering. The desired results of the burn are:

- V (400K ft) = 36,337 fps
- γ (400K t) = -7.13 deg
- Specified splash point (use C = 1 in cross-product equation).

3.8 Preentry Phase

(a) Maneuver at 4 deg/sec to the CM/SM separation attitude (+X S/C axis 60 deg above $\vec{V}$ and in trajectory plane) (see Ref: Par. 7c).

(b) Initiate CM/SM separation on T_{ff} interrupt.

(c) Maneuver to entry attitude (see Ref: Par. 7c or e) at 4 deg/sec.

3.9 Entry Phase

Control the lift vector direction to:

(a) Cover an approximately 2500-mile entry range

(b) Steer to splash target

(c) Approximate lunar return heating rates and loads.

4. UPLINK TELEMETRY REQUIREMENTS

Similar to AS-501. Details to be furnished by MSC.

5. DOWNLINK REQUIREMENTS

Similar to AS-501. Details to be furnished by MSC.

6. AGC SIGNAL INTERFACE REQUIREMENTS

A sufficient list of interface control document (ICD) titles is given in Section 3.2 of R-537 (Ref: Par. 7c). If any of these documents is revised or updated for the AS-502 equipment, the AS-502 version is to be used as an interface reference. Section 3.2 of R-537 also lists the required AGC output discretes to the MCP. These will be the same for AS-502.

7. REFERENCES

a. "Mission Requirements for Apollo Spacecraft Development for Apollo-Saturn AS-501/502," TRW Systems, dated 27 July 1965.

b. "AS-501 Guidance and Navigation Operational Software Requirements," TRW Systems, dated 15 December 1965.

c. "System Operations Plan for AS-501, Preliminary," MIT Document R-537, dated February 1966 (Confidential).

d. Memo 66-FM2/AGPS-21, 6 April 1966 (gives necessary revisions to Reference c).

e. "AS-502 (AFRM-020) Preliminary Spacecraft Reference Trajectory," MSC Internal Note 65-FM-167, dated 22 December 1965.