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HUNTSVILLE, ALABAMA

Memorandum

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HE Brown/vd/876-5342
R-ASTR-NG-107-65
DATE: October 21, 1965

TO : See Addressees

FROM : Chief, Guidance and Control Systems Analysis Branch,
R-ASTR-NG

SUBJECT : LVDC Mission Defining Document for the AS-501 Mission

In the enclosed document, the AS-501 mission is briefly described and a description of the LVDC Flight Program is discussed in sufficient detail to allow contractor personnel to begin the necessary studies for development of the AS-501 Launch Vehicle Digital Computer Equation Defining Document. The information presented in the enclosed document is supplied by various MSFC organizational elements and is the most up-to-date information supplied to this branch.

It is recognized, however, that much of this information may be modified or changed in the future. Such modifications and changes should be forwarded immediately to R-ASTR-NG. Changes and modifications to the information contained in the LVDC Mission Defining Document for the AS-501 Mission received after December 1, 1965, will not be included in The AS-501 Launch Vehicle Digital Computer Equation Defining Document.

S. M. Seltzer
S. M. Seltzer

1 Enc:
The LVDC Mission Defining Document for the AS-501 Mission

Approval:

F. B. Moore
F. B. Moore
Chief, Guidance and Control Division

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ASTRONICS LABORATORY
MISSION DEFINING DOCUMENT FOR THE AS-501 LAUNCH VEHICLE
DIGITAL COMPUTER (LVDC)

SUMMARY

This report describes briefly the AS-501 mission. It presents a unified body of information which sets forth the known functions which the LVDC will be required to perform during the AS-501 mission.

SECTION I INTRODUCTION

The basic purpose of this document is to set forth the functions which the LVDC will be required to perform during the AS-501 mission. This report presents a unified body of information concerning the AS-501 mission which will be used in simulating the AS-501 flight equations, where possible, data concerning the AS-501 vehicle and the AS-501 trajectory are given. Certain information is merely referenced. Although this vehicle and trajectory data is preliminary, studies and trajectory simulation may be initiated. As the undefined information becomes available, it will be forwarded to the interested personnel.

SECTION II LAUNCH VEHICLE MISSION OBJECTIVES

The following are the primary objectives which comprise the main purpose for conducting the mission, and which must be accomplished on AS-501, or prior to manned lunar flight, to demonstrate the capability of the vehicle to perform the required mission.

- a. Demonstrate compatibility of the launch vehicle (L/V) and space craft (S/C).
- b. Verify pre-launch and launch support equipment compatibility with L/V and S/C systems.
- c. Demonstrate the structural and thermal integrity of the L/V and S/C during all periods of powered and coasting flight and determine in-flight structural loads and dynamic characteristics.
- d. Demonstrate the L/V control and guidance systems during S-IC, S-II and S-IVB powered flight, achieve guidance cutoff, and evaluate system accuracy.
- e. Demonstrate the S-IC stage propulsion system and determine in-flight system performance parameters.
- f. Demonstrate S-IC/S-II dual plane separation.
- g. Demonstrate the S-II stage propulsion system, including the program mixture ratio shift and the propellant utilization system, and determine in-flight system performance parameters.
- h. Demonstrate S-II/S-IVB separation.
- i. Demonstrate the S-IVB stage propulsion system, including the propellant management system, and determine in-flight system performance parameters.

j. Demonstrate the capability of the S-IVB Auxiliary Propulsion System (APS) to maintain attitude control and perform required maneuvers during S-IVB powered flight and coast periods.

k. Demonstrate the adequacy of the S-IVB continuous vent system while in earth orbit.

l. Demonstrate the S-IVB stage restart capability.

m. Demonstrate L/V sequencing system.

n. Demonstrate the mission support capability required for launch and mission operations, including special tracking, telemetry, and communications system, to large post-injection altitudes.

o. Monitor the performance of the Emergency Detection System (EDS) in an open-loop configuration.

p. Determine in-flight L/V internal environment.

The following secondary objectives, which support this and succeeding missions and supply additional scientific data, shall be accomplished to the extent that the primary objectives are not compromised.

a. Determine external environment during L/V powered flight.

b. Determine the effects of flame attenuation on radio frequency radiating and receiving systems during firings of the main engine and the retro and ullage motors.

SECTION III LAUNCH VEHICLE MISSION PROFILE

The trajectory presently planned for this mission is divided into eight phases. The first phase is from liftoff to the S-IC stage cutoff. The second phase is from the S-IC stage cutoff to the S-II stage cutoff. The third phase is the short coast phase between the S-II cutoff and the S-IVB ignition. The fourth phase is from the first S-IVB stage ignition to the first cutoff of the S-IVB stage. The fifth phase is the first coast phase of the S-IVB/IU stage and the attached space craft (S-IVB/IU/SC). The sixth phase is from the second S-IVB ignition to the second S-IVB cutoff. The seventh phase is the second coast phase of the S-IVB/IU/SC. The eighth phase is the coast phase of the S-IVB/IU stage after the S-IVB/IU/SC separation.

SECTION IV S-IC STAGE GUIDANCE

The S-IC stage guidance is presented in Reference 1.

The logic for the roll guidance commands may have to be modified to inhibit the initiation of the removal of the initial roll error if an engine out occurs before the vehicle has safely cleared the launch facility.

SECTION V GUIDANCE COMMANDS FROM TILT ARREST OF THE S-IC STAGE TO THE FIRST CUTOFF OF THE S-IVB STAGE

The Iterative Guidance Mode (IGM) given in Reference 1 will guide the vehicle in pitch and yaw from a fixed time after the signal to cut off the outboard engines of the S-IC stage is given until the first cutoff of the S-IVB stage. The inputs to the "G" matrix, and the "G" matrix are computed at Guidance Reference Release (GRR) and held constant throughout this portion of flight. The IGM data for this portion of the flight is presented in References 2 and 3.

Since the time that the programmed mixture ratio (PMR) shift occurs in the S-II stage is not an input to the LVDC program, the IGM equations may have to be modified to detect the PMR shift and to provide smooth steering commands during this period of time.

SECTION VI ATTITUDE REQUIREMENTS FOR THE PARKING ORBIT

The attitude requirements available for the parking orbit of the AS-501 mission are presented in Reference 4.

SECTION VII GUIDANCE COMMANDS FOR THE SECOND BURN OF THE S-IVB STAGE

At a fixed time from the time that restart preparations are initiated, the inputs required to initialize the IGM equations and the equations defining the hypersurface will be computed. These equations are presented in Reference 1.

The IGM equations presented in Reference 1 will guide the vehicle in pitch and yaw from a fixed time from the time that restart preparations are initiated until the second cutoff of the S-IVB stage.

Since the time of the PRM shift in the second burn of the S-IVB stage is not an input to the LVDC program, the IGM equations may have to be modified to detect the PRM shift and to provide smooth steering commands during this time.

SECTION VIII ATTITUDE REQUIREMENTS FOR THE COAST PHASE AFTER THE SECOND S-IVB CUTOFF

The attitude requirements available for the coast phase after the second S-IVB cutoff of the AS-501 mission are presented in Reference 4.

SECTION IX RE-IGNITION EQUATIONS

The re-ignition equations given in Reference 1 will specify when to start the restart preparations phase for the second S-IVB burn.

SECTION X NAVIGATION FROM GUIDANCE REFERENCE RELEASE (GRR) TO SOME FIXED TIME AFTER THE FIRST S-IVB CUTOFF

The Fischer's model of the earth will be used for all navigation phases. The number of harmonics needed in the gravitational equations and the integration technique used during this phase of the flight will be determined from AS-501 simulation studies.

The LVDC flight program will initialize the navigation routine at GRR.

SECTION XI NAVIGATION DURING COAST

The orbital navigation equations for the two coast phases are not defined at this time. The orbital navigation equations when defined will be used from some fixed time after the first S-IVB cutoff until some fixed time after the signal to begin restart preparation has been given. These equations will also be used from some fixed time after the second S-IVB cutoff until the launch vehicle mission has been completed.

SECTION XII NAVIGATION DURING THE SECOND S-IVB BURN

The navigation equations for this phase of the flight is the same as those presented in Section X.

SECTION XIII ATTITUDE ERROR EQUATIONS

The attitude error equations are defined in Reference 5. Attitude error equations are defined in Reference 5. Attitude error signals will be computed at the rate of 25 times per second during flight. Provisions will be made in the flight program to change the rate of computation of the attitude error signals for the coast phases of the flight. Also provisions will be made in the flight program to change the limits on the inputs and outputs of the attitude error equations and the scale factors used in the equations for each phase of the flight. The limits on the inputs and outputs of the attitude error equations are not defined at this time.

SECTION XIV STEERING MISALIGNMENT CORRECTIONS (SMC) TERMS

The SMC terms presented in Reference 6 will be used during the power phases of the S-II and the S-IVB stages. The SMC terms will be computed at least once each major comp cycle of the flight program. The SMC gains for each stage will be determined from the AS-501 simulation studies.

SECTION XV ALGORITHMS

The algorithms adapted for the LVDC flight program must be compatible with the range of variables expected in all APOLLO Saturn V missions including those special conditions given in Section XVI and must not contribute significantly to computation errors.

SECTION XVI SCALING

All quantities in the AS-501 LVDC flight program will be scaled for:

1. All Apollo Saturn V missions.
2. Forty-five degree plane change.
3. For any orbital conditions which the Apollo Saturn V vehicle is capable of achieving.

SECTION XVII SMOOTHING

If simulation studies reveal that any parameters in the LVDC flight program need smoothing, the technique for smoothing will be developed in the AS-501 simulation studies.

SECTION XVIII BACKUPS FOR CRITICAL EVENTS

All events which define a new time base for the LVDC flight program will be backed up by the LVDC flight program.

SECTION XIX ALTERNATES MODES OF OPERATIONS

Alternate modes of operation for accelerometer, gimbal angle, attitude error signal, and switch selector failures will be included in the LVDC flight program.

SECTION XX VEHICLE AND AERODYNAMIC DATA

The vehicle and aerodynamic data needed to initiate simulation studies may be found in References 7 through 13. Table 1 contains the latest control gains. The nozzle diameter of the F-1 and J-2 engines is 143.6 and 77.794 inches respectively.

SECTION XXI TERMINAL CONDITIONS AND INITIALIZATION OF PARAMETERS THAT ARE A FUNCTION OF THE LAUNCH TIME OR THE AIMING AZIMUTH

About ten minutes before liftoff, the expected time of liftoff relative to midnight, T_L , will be given to the LVDC. At GRR the flight program will initialize all parameters which are a function of launch time or the aiming azimuth. The aiming azimuth, A_z , for the AS-501 mission is defined by the following equation:

$$A_z = A_{z0} + A_{z1} T_L + A_{z2} T_L^2 + A_{z3} T_L^3.$$

For the AS-501 mission, $A_{z1} = A_{z2} = A_{z3} = 0$ and $A_{z0} = 72$ degrees.

The AS-501 vehicle will be launched from complex 39-A. The geodetic latitude of the complex 39-A is 28.6474722 degrees.

TABLE 1: CONTROL GAINS FOR THE AS-501 VEHICLE

PHASE OF FLIGHT		a_0 (p & y) (deg/deg)	a_1 (p & y) (deg/deg/s)	a_0 (r) (deg/deg)	a_1 (r) (deg/deg/s)	ϵ_2 (deg/m/s ²)
S-IC	0 - 110 s.	.40	.50	.38	.14	0
	110 s. - cutoff	.20	.30	.38	.14	0
S-II	0 - 120 s.	.75	1.27	.25	.20	N.A.
	120 s. - 200 s.	.55	.93	.25	.20	N.A.
	200 s. - 265 s.	.42	.70	.25	.20	N.A.
	265 s. - cutoff	.34	.57	.25	.20	N.A.
S-IVB (First Burn)	0 - 100% First Burn	.80	1.00	1.00	5.00	N.A.
S-IVB (Second Burn)	0 - 75% Second Burn	.80	1.00	1.00	5.00	N.A.
	75% - cutoff	.80	.70	1.00	5.00	N.A.
S-IVB Coast	Parking & Waiting Orbits	1.00	5.00	1.00	5.00	N.A.

The desired terminal conditions for the first and second S-IVB burn are given in Reference 2.

SECTION XXII SEQUENCE OF EVENTS

The most up-to-date list of the sequence of events for the AS-501 mission is contained in Reference 14. A current list of interrupts, discrete outputs, and discrete inputs are given in Tables 2, 3 and 4 respectively. The flight program will be written such that the sequence of events can process at the rate of one per 100 milliseconds if required.

SECTION XXIII TELEMETRY REQUIREMENTS

The launch vehicle data adapter (LVDA) is designed to provide automatic telemetering of many important quantities. However, to ensure the receipt of all desired data at ground stations, the LVDA must telemeter certain data from the LVDC memory or from the LVDC accumulator.

The quantities telemetered from the LVDC must include the following:

1. Three fine gimbals angle readings (25 times per second).
2. The normal navigation quantities including position, velocity, gravitational acceleration and velocity, thrust velocity, thrust acceleration, and the smoothed value of M/F.
3. Important IGM, re-ignition, and hypersurface variables including x_x , x_y , and x_z .
4. Accelerometer readings together with the time of accelerometer samplings.
5. Total gimbal angles and ladder outputs (all at the rate of once per computation cycle).
6. The times of all discrete inputs, discrete outputs and interrupts (except the minor loop).
7. The contents of the error monitor register.

The telemetry requirements for the two coast phases are not defined at this time.

SECTION XXIV CUTOFF EQUATIONS

The first and second S-IVB cutoffs will be a function of velocity.

TABLE 2

Interrupts

<u>LVDA Name</u>	<u>Function</u>	<u>Applicable to AS-501</u>
Interrupt		
1	Spare	---
2	S-IC Low Level Sense	Yes
3	RCA 110 Interrupt	Yes
4	S-IVB Engine Out	Yes
5	S-I Propellant Depletion	Yes
6	S-II Propellant Depletion	Yes
7	Guidance Reference Release	Yes
8	Command Receiver Interrupt A	Yes
9	TLC-Simultaneous Memory Error	Yes
10	Data Ready from Computer Interface Unit (CIU)	Yes
11	Switch Selector Interrupt	Yes
12	Timed Minor Loop Interrupt	Yes

TABLE 3
Discrete Outputs

<u>LVDA Name</u>	<u>Function</u>	<u>Applicable to AS-501</u>
DO 1	Reset (LIRO)	Yes
2	RCA 110A Interrupt	Yes
3	Spare	---
4	Guidance Failure	Yes
5	Spare	---
6	Thrust Indication to S/C	Yes
7	Spare	---
8	Spare	---
9	Spare	---
10	C Band Transponder Inhibit 1	Yes
11	C Band Transponder Inhibit 2	Yes
12	Indication of Guidance Reference Release	Yes
13	Guidance Error and TLC	Yes

TABLE 4

Discrete Inputs

<u>LVDA Name</u>	<u>Function</u>	<u>Applicable to AS-501</u>
DIN 1	RCA 110A Sync	Yes
2	Command Receiver Sync	Yes
3	Auto Vent 2	Yes
4	Auto Vent 1	Yes
5	S-IVB Engine Out	Yes
6	S-IVB Inject Delay	Yes
7	Spare	---
8	Spare	---
9	Control Computer Switched to Space Craft	Yes
10	S-II/S-IVB Separation	Yes
11	S-II Skirt Separation	Yes
12	S-I Separation	Yes
13	S-II Engine Out	Yes
14	S-I Outboard Engine Out	Yes
15	S-I Inboard Engine Out	Yes
16	Prepare for GRR	Yes
17	S/C Initiation of S-II/S-IVB Separation	Yes
18	Spare	---
19	Spare	---
20	S-IVB Thrust Sequence Start	Yes

TABLE 4 (cont)
Discrete Inputs

<u>LVDA Name</u>	<u>Function</u>	<u>Applicable to AS-501</u>
DIN 21	Spare	---
22	Spare	---
23	Spare	---
24	Liftoff	Yes

DIS 1 THROUGH 8 SPARE

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Addressees:

R-AERO-DIR Dr. Geissler
 R-AERO-D Mr. Horn
 R-AERO-DA Mr. Winch
 R-AERO-DA Mr. Tucker
 R-AERO-DA Mrs. Chandler
 R-AERO-DAG Mr. A. W. Deaton
 R-AERO-DAG Mr. Telfer
 R-AERO-DAG Mr. Buckelew
 R-AERO-DAP Mr. Cremin
 R-AERO-F Mr. Lindberg
 R-AERO-FMT Mr. Hardage
 R-AERO-FST Mr. Horst
 R-P&VE-DIR Mr. Cline
 R-P&VE-P Mr. Paul
 R-P&VE-PPE Mr. McKay
 R-P&VE-VOI Mr. Byers
 I-MO-NGR Dr. Speer
 I-MO-F Mr. Casey
 I-V-E Mr. Bell
 R-ASTR-DIR Dr. Haeussermann
 R-ASTR-F Mr. Hosenthien
 R-ASTR-F Mr. Blackstone
 R-ASTR-F Mr. Scofield
 R-ASTR-N Mr. Moore
 R-ASTR-NG Mr. Seltzer
 R-ASTR-NGD Mr. Brooks
 R-ASTR-NGD Mr. Chubb
 R-ASTR-NGD Mr. Brown (20)
 R-ASTR-NGD Mr. Jones
 R-ASTR-NGI Mr. Blanton
 R-ASTR-NGI Mr. Winkler
 R-ASTR-NG (IBM) Mr. Hudson (3)
 R-ASTR-EAA Mr. Mathews
 R-ASTR-IP Mr. Golden

cc:

R-AERO-P Mr. Teague
 R-AERO-P Mr. McNair
 R-AERO-P Mr. Morgan
 R-AERO-G Mr. Baker
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