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**Memorandum**

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

SUBJECT LVDC Mission Defining Document for the SA-203 Mission

The purpose of this memorandum is to transmit enclosure one "The LVDC Mission Defining Document for the SA-203 Mission" to interested personnel. In the document the SA-203 mission is briefly described and a description of the LVDC Flight Program is discussed in sufficient detail to allow contractor personnel to perform the necessary studies for development of the SA-203 Launch Vehicle Digital Computer Equation Defining Document.

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ASTRIONICS LABORATORY

MISSION DEFINING DOCUMENT FOR THE SA-203 LAUNCH VEHICLE  
DIGITAL COMPUTER (LVDC)

by

R-ASTR-NG

SUMMARY

This report describes briefly the SA-203 mission. It presents a unified body of information which sets forth the known functions the LVDC will be required to perform during the SA-203 mission.

SECTION I. INTRODUCTION

The basic purpose of this document is to set forth the functions which the launch vehicle digital computer (LVDC) will be required to perform during the SA-203 mission. This report presents a unified body of information concerning the SA-203 mission which will be used in simulating the SA-203 flight equations. Where possible, data concerning the SA-203 vehicle and the SA-203 trajectory are given. Certain classified information is referenced. Although these vehicle data and trajectory data are preliminary, studies and trajectory simulation may be initiated.

SECTION II. MISSION DESCRIPTION

The SA-203 mission profile has been designed to: (1) evaluate dynamics of  $LH_2$  containment at near zero gravity, (2) provide limited S-IVB and instrument unit checkout test in orbit, and (3) demonstrate mission control and network operation. To achieve these objectives, a 185.325 km circular orbit trajectory has been selected for the SA-203 mission.

The trajectory presently planned for this mission is divided into three phases. The first phase is from liftoff to S-IB cutoff, the second phase is from S-IVB ignition to S-IVB cutoff, and the third phase is the coast phase.

SECTION III. DESCRIPTION OF THE SA-203 LAUNCH VEHICLE DIGITAL COMPUTER  
(LVDC) FLIGHT PROGRAM

An outline of the major portions of the LVDC Flight Computer Program follows. Where possible, related data and information are included.

A. Prelaunch

Until 5 seconds before launch commit, the LVDC is under the control

of the ground routines. The purpose of the ground routines is to perform certain prelaunch functions and to prepare the LVDC for entering the flight routine. At launch commit minus five seconds (guidance reference release), the ground routines transfer control to the flight program. The flight program initializes all flight variables and begins to perform navigation calculations. Ignition of the S-IB occurs at launch commit minus three seconds. If countdown is stopped before launch commit occurs, the control of the LVDC is transferred back to the ground routines. At  $T = 0$ , launch commit occurs, marking the end of the prelaunch phase of the flight program; and the flight program waits for a liftoff discrete that defines the beginning of Time Base 1.

## B. Boost Navigation

Boost navigation as used here is defined as navigation performed by the LVDC during the period of time from guidance reference release to a fixed time beyond S-IVB cutoff. During this period, the LVDC samples accelerometers, tests the accelerometer readings for reasonableness, and then uses the readings to compute gravitational accelerations and space-fixed vehicle positions, velocities, and accelerations.

The gravitational model selected for SA-203 is the Fischer Ellipsoid. The maximum number of terms needed in the expansion for the gravitational acceleration for any future Saturn IB vehicle is to be used in the flight computer.

Mission dependent quantities needed for navigation in SA-203 are as follows:

- (1) The geodetic latitude of the launch site, Complex 37-B, is 28.531424 degrees.
- (2) The firing azimuth is 72 degrees east of north.
- (3) The initial position and velocity of the vehicle (measured to the center of the IU) are:

$$X_s(0) = -5662.0936 \text{ m}$$

$$Y_s(0) = +6373352.2 \text{ m}$$

$$Z_s(0) = +17426.132 \text{ m}$$

$$\dot{X}_s(0) = +387.97790 \text{ m/s}$$

$$\dot{Y}_s(0) = 0.0$$

$$\dot{Z}_s(0) = +125.97584 \text{ m/s}$$

The  $(X_s, Y_s, Z_s)$  system is a space-fixed, right-handed, rectangular coordinate system, with its origin at the center of the earth and which becomes space-fixed at guidance reference release. The positive  $Y_s$  axis is parallel to the gravity vector at the launch site and opposite in direction. The positive  $X_s$  axis is down range and parallel to the aiming azimuth. The  $Z_s$  axis forms the right-handed system  $(X_s, Y_s, Z_s)$ .

To improve the trajectory flown by the S-IVB, the launch vehicle digital computer (LVDC) program will include a routine for smoothing M/F and will compute steering misalignment correction (SMC) terms for the  $\chi_x$  and  $\chi_z$  commands. Additionally, the LVDC will apply a digital filter to  $\chi_z$  if required.

The S-IVB is to cut off on a prescribed total velocity. The LVDC program will include a routine to predict a cutoff time so that the desired velocity will be attained.

The following IGM end conditions for the SA-203/S-IVB flight are subject to change, but such changes should be minor.

Firing azimuth, $A_a$	72 degrees
Geodetic latitude, $\phi_0$	28.531424 degrees
Longitude of descending node, $\lambda_n$	120.43206 degrees
Inclination of orbit plane, $i$	31.952112 degrees
Terminal velocity, $V_T$	7792.1414 m/s
Terminal radius, $Y_{VT}$	6557572.9 m
Components of terminal gravity	
$\ddot{X}_{vgT}$	-.0017030519 m/s <sup>2</sup>
$\ddot{Y}_{vgT}$	-9.2722517 m/s <sup>2</sup>
$\ddot{Z}_{vgT}$	+.01248589 m/s <sup>2</sup>
Components of $V_T$	
$\dot{X}_{VT}$	7792.1414 m/s
$\dot{Y}_{VT}$	0 m/s
$\dot{Z}_{VT}$	0 m/s

Path angle measured from local horizontal,  $\theta$  st 0 degrees

The above IGM end conditions may have to be updated to agree with a nominal minimum fuel run.

### C. S-IB Stage

The S-IB stage is guided from liftoff to approximately 151 seconds after liftoff. For the first 10 seconds after liftoff, the pitch and yaw commands ( $\chi_z$  and  $\chi_x$ ) are zero and the roll command ( $\chi_y$ ) is -12 degrees. The  $\chi_z$  command is computed as a polynomial function of time from 10 seconds after liftoff to approximately 166 seconds after liftoff. The  $\chi_y$  command is forced to zero at the rate of 1 degree per second from 10 to 22 seconds after liftoff. From 22 seconds to approximately 166 seconds after liftoff, the  $\chi_y$  command is zero. The  $\chi_x$  command is zero from 10 seconds to approximately 166 seconds after liftoff.

The most up-to-date time tilt for the first stage is found in Reference 1. The best vehicle data available for the SA-203 vehicle are contained in References 2 and 3. These documents are classified. The above preliminary data will be used in preliminary studies of the SA-203 mission.

The atmospheric model to be used in the SA-203 mission studies is the Patrick Reference Atmosphere (1963), available at the Computation Laboratory.

### D. S-IVB Stage

The S-IVB stage ignition occurs approximately 151 seconds after liftoff. The S-IVB burn is approximately 289 seconds long. At approximately 10 seconds after S-IVB ignition, the ullage cases and thermolag are jettisoned. The interactive guidance mode (IGM) guides the vehicle from approximately 15 seconds after second stage ignition (approximately 166 seconds after liftoff) to velocity cutoff of the S-IVB stage.

The thrust and mass flow rate for the S-IVB stage before velocity cutoff will be constant. The magnitudes of the thrust and mass flow rate are not available at this time.

Guidance commands during the first 15 seconds of S-IVB burn are the same as those for the last few seconds of the S-IB stage; i.e.,  $\chi_x$ ,  $\chi_y$ , and  $\chi_z$  are frozen. After ullage and thermolag jettison, the  $\chi_x$  and  $\chi_z$  guidance commands are computed by IGM. The angle  $\chi_y$  is commanded to zero until velocity cutoff of the S-IVB stage occurs. The basic IGM equations are given in "Preliminary Equations for the Two-Stage, Three-Dimensional Interactive Guidance Mode" given in Appendix A. These equations provide guidance for a vehicle with two thrust levels.

It is expected that a time tilt will be required to calculate  $\chi_x$  and  $\chi_z$  during a brief period preceding S-IVB cutoff. The exact length of this time tilt will be determined as a part of the SA-203 mission studies. Other methods of calculating  $\chi_x$  and  $\chi_z$  immediately before cutoff will be considered in an attempt to meet the desired end conditions as well as possible without significantly affecting payload.

#### E. Coast Guidance

The present guidance requirements following the S-IVB cutoff call for the longitude axis of the vehicle to be oriented parallel to the orbital plane and perpendicular to the radius vector from the center of the earth throughout the coast phase.

#### F. Orbital Navigation

After S-IVB cutoff, a navigation scheme distinct from that described in Section B is to be used. Here navigation is accomplished by direct integration of the equations of motion. This technique is preferable to that of Section B for two reasons:

- (1) It is more accurate since accelerometer bias errors are excluded.
- (2) It requires less LVDC computation time.

The exact nature of the orbital navigation routine will be determined during studies of the SA-203 mission. The effects of S-IVB venting during the coast period will be evaluated and such effects will be accounted for by the navigation routine if necessary.

#### G. Attitude Control

The platform adopted for use in the SA-203 mission is the ST-124M-III three gimbal platform. The three gimbals are to be sampled at the rate of 25 times per second during powered flight and at 25 times per second or less during coasting flight. This sampling will take place during the minor loop. The minor loop must also compute corrections in yaw, pitch, and roll attitude 25 times per second in powered flight and 25 times per second or less during coasting flight. These corrections will force the actual vehicle attitude to its desired attitude.

The minor loop will contain provisions for limiting angular rates in the guidance commands. Also in a part of the minor loop will be a scheme to limit the size of the yaw, pitch, and roll output commands transmitted to the auxiliary propulsion system.

#### H. Interrupts

Table 1 contains a list of all current interrupts to be used in the SA-203 launch vehicle data adapter (LVDA). The SA-203

LVDC flight program will contain routines to recognize each of these interrupts and to initiate appropriate action upon the receipt of any interrupt. It is anticipated that interrupt routines drawn up for the 201 LVDC flight program will also serve for the SA-203 LVDC flight program with only slight changes.

### I. Sequencing and Discrettes

The occurrence of certain events will be indicated to the LVDC either by an interrupt or by a discrete input. The LVDC may send certain messages to other portions of the vehicle either by issuing a discrete output or by generating a switch selector output. The switch selector will provide the basic communication link between the LVDC and vehicle hardware with which the LVDC communicates.

The LVDC program will initiate the start sequence for each transmission of TV coverage of the liquid propellant behavior in the S-IVB stage while in orbit. Provision to alter the start sequence in the LVDC program three times from the ground while in orbit will be made. Program alteration should include capabilities for a change in time reference as well as time differential between stations. Verification that the start sequence for each transmission of TV coverage has been updated correctly will be furnished to the ground.

The LVDC program must generate a switch selector function to stop the ullaging of the hydrogen gas while in orbit upon the receipt of a discrete input or a signal from a ground station. A decision on whether a discrete or a ground command will be used has not been made at this time.

A list of discrete inputs planned for the SA-203 mission is not available at this time but the discrettes should be similar to those given in Table 2. Similarly, a list of discrete outputs appear in Table 3. The LVDC program must be designed to accept these discrete inputs and to issue discrete outputs when needed.

Switch selector outputs will occur at a fixed time measured in one of the four definite time bases and three possible time bases. One basic routine will permit the LVDC to issue all switch selector outputs. A list of outputs for the SA-203 mission has not been published as yet. Such a list should, however, be quite similar to that for the SA-201 mission. This list appears in Appendix B.

It is important to mission success that the LVDC receive

notice of liftoff, S-IB propellant depletion, S-IB outboard engine cutoff, and S-IVB engine out. Thus the LVDC flight program for the SA-203 mission will provide backup techniques to ensure that the LVDC recognizes the occurrence of these events.

#### J. Telemetry

The 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 telemetering of data from the accumulator permits the use of identification codes which can be transmitted with the data. This technique is desirable and will be employed where possible on the SA-203 mission.

Because of limitations on the telemetry hardware, telemetry from the LVDC must be held to around 200 words per minute. The quantities telemetered from the LVDC must include the following:

- (1) Three fine gimbal 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 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 and outputs and of all interrupts (except the minor loop).
- (7) The contents of the error monitor register.

#### K. Algorithms

Algorithms for the computation of elementary functions, including sine, cosine, arctangent, arcsine, logarithm, and square root, have been provided for the LVDC flight program for the SA-201 mission. These or similar algorithms will be a part of the flight program for the SA-203 mission. The algorithms adopted must be compatible with the range of variables expected in all Saturn IB missions including



those special conditions included in Section L and must not contribute significantly to computation errors.

L. Scaling

All quantities in the SA-203 LVDC will be scaled for:

- (1) All Saturn IB missions.
- (2) Thirty degree dog legs.
- (3) For any orbital conditions which the Saturn IB vehicle is capable of achieving.

M. Data Compression

Since the SA-203 mission will not have continuous coverage by tracking, some type of data compression will be applied to the components of inertial velocity, gimbal angles, guidance commands, components of space-fixed velocity, displacement and gravitational accelerations, attitude error signals, and the pitch, yaw and roll signals to the auxiliary propulsion system.

TABLE I  
Interrupts

<u>LVDA Name</u>	<u>Function</u>	<u>Applicable to SA-203</u>
Interrupt		
1	Spare	---
2	S-IB Low Level Sense	Yes
3	Program Re-Cycle	Yes
4	S-IVB Engine Out	Yes
5	S-I Propellant Depletion	Yes
6	S-II Propellant Depletion	No
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)	No
11	Switch Selector Interrupt	Yes
12	Timed Minor Loop Interrupt	Yes

TABLE 2  
Discrete Inputs

<u>LVDA Name</u>	<u>Function</u>	<u>Applicable to SA-203</u>
DIN 1	RCA 110A Sync	Yes
2	Command Receiver Sync	Yes
3	Auto Vent - Low Limit	No
4	Spare	---
5	Spare	---
6	S-IVB Inject Delay	No
7	Spare	---
8	Spare	---
9	Control Computer Switched to Spacecraft	No
10	S-II/S-IVB Separation	No
11	S-II Skirt Separation	No
12	S-I Separation	Yes
13	S-II Engine Out	No
14	S-I Outboard Engine Out	Yes
15	S-I Inboard Engine Out	Yes
16	Prepare for GRR	Yes
17	Spare	---
18	Spare	---
19	Spare	---
20	S-IVB Thrust Sequence Start	No

TABLE 2 (Cont)

Discrete Inputs

<u>LVDA Name</u>	<u>Function</u>	<u>Applicable to SA-203</u>
DIN 21	Spare	---
22	Spare	---
23	Spare	---
24	Liftoff	Yes

DIS 1 THRU 8 SPARE

TABLE 3

## Discrete Outputs

<u>LVDA Name</u>	<u>Function</u>	<u>Applicable to SA-203</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	No
7	Spare	---
8	Spare	---
9	Spare	---
10	Spare	---
11	Spare	---
12	Spare	---
13	Spare	---

REFERENCES:

- Reference 1 "Nominal Reference Trajectory for the Saturn IB-SA-203,"  
Chrysler TB-AE-65-128, February 1, 1965.
- Reference 2 "Saturn IB, SA-203 Design Mass Characteristics,"  
R-P&VE-VAW-65-17
- Reference 3 "Corrections to Design Mass Characteristic Memorandums,"  
R-P&VE-VAW-65-29

APPENDIX A

PRELIMINARY 3D IGM EQUATIONS FOR THE SATURN IB LAUNCH VEHICLE

## PRELIMINARY 3D IGM EQUATIONS FOR THE SATURN IB LAUNCH VEHICLE

- $(X_S, Y_S, Z_S)$  Space-fixed rectangular coordinate system with its origin at the center of the earth. The  $Y_S$  axis is parallel to the gravity vector at the launch site and is positive in the opposite direction of the gravity vector. The  $X_S$  axis is parallel to the earth-fixed firing azimuth and is positive down range. The  $Z_S$  axis completes the right-handed system  $(X_S, Y_S, Z_S)$ .
- $(X_4, Y_4, Z_4)$  Space-fixed rectangular coordinate system with its origin at the center of the earth. The  $Y_4$  axis passes through the point of intersection of the orbit plane with the equator (the descending node of the orbit plane). The  $X_4$  axis lies in the desired orbit plane  $90^\circ$  down range from the  $Y_4$  axis. The  $Z_4$  axis is perpendicular to the orbit plane and completes the right-handed system  $(X_4, Y_4, Z_4)$ .
- $(X_V, Y_V, Z_V)$  A right-handed rectangular coordinate system with its origin at the center of the earth. The  $Y_V$  axis lies in the orbit plane at an angle  $\psi_T$  from the  $Y_4$  axis. The  $X_V$  axis lies in the orbit plane  $90^\circ$  down range from the  $Y_V$  axis. The  $Z_V$  axis is collinear with the  $Z_4$  axis and completes the right-handed system  $(X_V, Y_V, Z_V)$ .
- $X_S, Y_S, Z_S$  Displacement components measured in the space-fixed  $(X_S, Y_S, Z_S)$  system.
- $\dot{X}, \dot{Y}, \dot{Z}$  Velocity components measured in the space-fixed  $(X_S, Y_S, Z_S)$  system.
- $\ddot{g}_{XS}, \ddot{g}_{YS}, \ddot{g}_{ZS}$  Gravitational components measured in the space-fixed  $(X_S, Y_S, Z_S)$  system.
- $R$  Magnitude of radius vector from center of the earth to the vehicle measured in the  $(X_S, Y_S, Z_S)$  system.
- $V$  Magnitude of velocity vector in the  $(X_S, Y_S, Z_S)$  system.



$Y_{VT}$	Desired terminal radius vector magnitude.
$A_a$	Aiming azimuth measured positive east of north.
$\varphi_0$	Geodetic latitude of the launch site.
$\lambda_L$	Longitude of the launch meridian measured from a space-fixed reference point.
$\lambda_N$	Longitude of the line of nodes measured from a space-fixed reference point.
$i$	Inclination of the orbit plane to the plane of the equator.
$\epsilon$	Constant used to determine when to stop computation of $\tilde{\chi}_x$ , $\tilde{\chi}_z$ , $N_1$ , $N_2$ , $N_3$ and $N_4$ .
$\delta$	A constant tolerance placed on velocity cutoff.
$\psi_T$	Total predicted range angle measured in the orbit plane relative to the $Y_4$ axis.
$X_v, Y_v, Z_v$	Components of displacement measured in the $(X_v, Y_v, Z_v)$ system.
$\dot{X}_v, \dot{Y}_v, \dot{Z}_v$	Components of velocity measured in the $(X_v, Y_v, Z_v)$ system.
$\ddot{X}_{vg}^*, \ddot{Y}_{vg}^*, \ddot{Z}_{vg}^*$	Average gravitational components measured in the $(X_v, Y_v, Z_v)$ system.
$\Delta \dot{\xi}_v^*, \Delta \dot{\eta}_v^*, \Delta \dot{\zeta}_v^*$	First estimate of components of the inertial velocity to be gained measured in the $(X_v, Y_v, Z_v)$ system.
$\Delta \dot{\xi}_v, \Delta \dot{\eta}_v, \Delta \dot{\zeta}_v$	Corrected components of the inertial velocity to be gained measured in the $(X_v, Y_v, Z_v)$ system.
$\tilde{\chi}_x, \tilde{\chi}_z$	Angles needed to direct the thrust vector so that the components of inertial velocity to be gained will be achieved.
$N_2$	Time rate of change of the yaw steering signal.
$N_4$	Time rate of change of the pitch steering signal.

$\left(\frac{F}{m}\right)_i$	Instantaneous magnitude of inertial acceleration vector.
$X_4, Y_4, Z_4$	Components of displacement measured in the $(X_4, Y_4, Z_4)$ system.
$\dot{X}_4, \dot{Y}_4, \dot{Z}_4$	Components of velocity measured in the $(X_4, Y_4, Z_4)$ system.
$V_4$	Magnitude of velocity vector relative to the $(X_4, Y_4, Z_4)$ system.
$[A_{PR4}]$	System of 4 rotation matrices needed to go from the $(X_S, Y_S, Z_S)$ coordinate system to the $(X_4, Y_4, Z_4)$ coordinate system.
$\Delta t$	Length of one computation cycle.
$V_{ex1}$	Constant exhaust velocity of first guided stage.
$V_{ex2}$	Constant exhaust velocity of second guided stage.
$T_{1i}$	Time remaining before mixture ratio shift occurs.
$T_{2i}$	Time remaining before velocity cutoff occurs.
$T_{2i}'$	First estimate of time remaining until velocity cutoff.
$\Delta T_{2i}$	Correction to $T_{2i}$ .
$\tau_{1i}$	Instantaneous value of $V_{ex1} / \left(\frac{F}{m}\right)_i$ during first guided stage.
$\tau_{2i}$	Instantaneous value of $V_{ex2} / \left(\frac{F}{m}\right)_i$ during second guided stage. Constant during first burn.
$V_T$	Magnitude of desired terminal velocity.
$\dot{X}_{vT}, \dot{Y}_{vT}, \dot{Z}_{vT}$	Components of desired terminal velocity in the $(X_v, Y_v, Z_v)$ system.
$\ddot{X}_{vgT}, \ddot{Y}_{vgT}, \ddot{Z}_{vgT}$	Components of terminal gravitation measured in the $(X_v, Y_v, Z_v)$ system.

$\chi_x^i, \chi_z^i$

Yaw and pitch steering signals relative to the  $(X_L, Y_L, Z_L)$  system.

$X_S^i, Y_S^i, Z_S^i$

Components of a unit vector needed to determine the steering signals relative to the  $(X_S, Y_S, Z_S)$  system.

$\chi_z, \chi_x$

Steering signals in pitch and yaw relative to the  $(X_S, Y_S, Z_S)$  system.

Preset:

$$(\lambda_N - \lambda_L), i, \varphi_0, A_a, V_{ex1}, V_{ex2}, \tau_{2i}, T_{2i}, T_{1i}, \dot{X}_{vT}, \dot{Y}_{vT}, \dot{Z}_{vT}$$

$$Y_{vT}, Z_{vT}, \ddot{X}_{vgT}, \ddot{Y}_{vgT}, \ddot{Z}_{vgT}, V_T, \epsilon, \delta, K_1, K_2, \Delta t$$

Precompute:

$$[\varphi A] = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos \varphi_0 & \sin \varphi_0 \\ 0 & -\sin \varphi_0 & \cos \varphi_0 \end{bmatrix} \begin{bmatrix} \sin A_a & 0 & \cos A_a \\ 0 & 1 & 0 \\ -\cos A_a & 0 & \sin A_a \end{bmatrix}$$

$$[(\lambda_N - \lambda_L)] = \begin{bmatrix} \cos(\lambda_N - \lambda_L) & -\sin(\lambda_N - \lambda_L) & 0 \\ \sin(\lambda_N - \lambda_L) & \cos(\lambda_N - \lambda_L) & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$[i] = \begin{bmatrix} \cos i & 0 & \sin i \\ 0 & 1 & 0 \\ -\sin i & 0 & \cos i \end{bmatrix}$$

$$[A_{PR4}] = [i] [(\lambda_N - \lambda_L)] [\varphi A]$$

$$[A_{PR4}]^T = \text{Transpose of } [A_{PR4}]$$

$$1. V = \sqrt{(\dot{X}^2 + \dot{Y}^2 + \dot{Z}^2)}$$

$$2. \left(\frac{F}{m}\right)_i^2 = (\ddot{X}_I^2 + \ddot{Y}_I^2 + \ddot{Z}_I^2)$$

$$3. \left(\frac{F}{m}\right)_i = \sqrt{\left(\frac{F}{m}\right)_i^2}$$

$$4. \begin{bmatrix} \ddot{g}_{x4} \\ \ddot{g}_{y4} \\ \ddot{g}_{z4} \end{bmatrix} = [A_{PR4}] \begin{bmatrix} \ddot{g}_{xs} \\ \ddot{g}_{ys} \\ \ddot{g}_{zs} \end{bmatrix}$$

$$5. \begin{bmatrix} \dot{X}_4 \\ \dot{Y}_4 \\ \dot{Z}_4 \end{bmatrix} = [A_{PR4}] \begin{bmatrix} \dot{X} \\ \dot{Y} \\ \dot{Z} \end{bmatrix}$$

$$6. \begin{bmatrix} X_4 \\ Y_4 \\ Z_4 \end{bmatrix} = [A_{PR4}] \begin{bmatrix} X_s \\ Y_s \\ Z_s \end{bmatrix}$$

$$7. V_4 = \sqrt{\dot{X}_4^2 + \dot{Y}_4^2 + \dot{Z}_4^2}$$

8. If fuel mixture switch is on: Go to 12  
If fuel mixture switch is off: Go to 9

$$9. T_{1i} = T_{1i} - \Delta t$$

$$10. \tau_{1i} = Vex_1 / \left(\frac{F}{m}\right)_i$$

$$11.. T_{2i}' = T_{2i}$$

Go to 15

$$12. \quad T_{2i}' = T_{2i} - \Delta t$$

$$13. \quad \tau_{2i} = V_{ex2} / \left( \frac{F}{m} \right)_i$$

$$14. \quad T_{1i} = 0$$

$$15. \quad L_1 = V_{ex1} \ln \frac{\tau_{1i}}{\tau_{1i} - T_{1i}}$$

$$16. \quad J_1 = \tau_{1i} L_1 - V_{ex1} T_{1i}$$

$$17. \quad S_1 = T_{1i} L_1 - J_1$$

$$18. \quad Q_1 = \tau_{1i} S_1 - V_{ex1} \frac{T_{1i}^2}{2}$$

$$19. \quad L_2' = V_{ex2} \ln \frac{\tau_{2i}}{\tau_{2i} - T_{2i}'}$$

$$20. \quad J_2' = \tau_{2i} L_2' - V_{ex2} T_{2i}'$$

$$21. \quad S_2' = T_{2i}' L_2' - J_2'$$

$$22. \quad T^* = T_{1i} + T_{2i}'$$

$$23. \quad L_0 = L_1 + L_2'$$

$$24. \quad d_2 = V_4 T^* + S_2' + T_{2i}' L_1 - \frac{1}{2} \frac{L_2'}{V_{ex2}} (\tau_{2i} - T_{2i}') (L_0 + V_4 - V_T)$$

$$25. \quad \psi_T = \tan^{-1} \left( \frac{X_4}{Y_4} \right) + \frac{1}{Y_{VT}} (S_1 + d_2)$$

$$26. \dot{X}_V = \dot{X}_4 \cos \psi_T - \dot{Y}_4 \sin \psi_T$$

$$27. \dot{Y}_V = \dot{X}_4 \sin \psi_T + \dot{Y}_4 \cos \psi_T$$

$$28. \dot{Z}_V = \dot{Z}_4$$

$$29. Y_V = X_4 \sin \psi_T + Y_4 \cos \psi_T$$

$$30. Z_V = Z_4$$

$$31. \ddot{X}_{VG}^* = \frac{1}{2} [\ddot{g}_{X4} \cos \psi_T - \ddot{g}_{Y4} \sin \psi_T + \ddot{X}_{VG T}]$$

$$32. \ddot{Y}_{VG}^* = \frac{1}{2} [\ddot{g}_{X4} \sin \psi_T + \ddot{g}_{Y4} \cos \psi_T + \ddot{Y}_{VG T}]$$

$$33. \ddot{Z}_{VG}^* = \frac{1}{2} [\ddot{g}_{Z4} + \ddot{Z}_{VG T}]$$

$$34. \Delta \dot{\xi}_V^* = \dot{X}_{VT} - \dot{X}_V - \ddot{X}_{VG}^* T^*$$

$$35. \Delta \dot{\eta}_V^* = \dot{Y}_{VT} - \dot{Y}_V - \ddot{Y}_{VG}^* T^*$$

$$36. \Delta \dot{\zeta}_V^* = \dot{Z}_{VT} - \dot{Z}_V - \ddot{Z}_{VG}^* T^*$$

$$37. a_T = \frac{1}{2} \left[ \frac{(\Delta \dot{\xi}_V^*)^2 + (\Delta \dot{\eta}_V^*)^2 + (\Delta \dot{\zeta}_V^*)^2}{L_0} - L_0 \right]$$

$$38. \Delta T_{2i} = a_T \left( \frac{\tau_{2i} - T_{2i}^i}{Vex_2} \right)$$

$$39. T_{2i} = T_{2i}^i + \Delta T_{2i}$$

$$40. \quad T' = T^* + \Delta T_{2i}$$

$$41. \quad \Delta \dot{\xi}_V = \Delta \dot{\xi}_V^* - \ddot{X}_{VG}^* \Delta T_{2i}$$

$$42. \quad \Delta \dot{\eta}_V = \Delta \dot{\eta}_V^* - \ddot{Y}_{VG}^* \Delta T_{2i}$$

$$43. \quad \Delta \dot{z}_V = \Delta \dot{z}_V^* - \ddot{Z}_{VG}^* \Delta T_{2i}$$

$$44. \quad \tilde{\chi}_X = \tan^{-1} \left[ \frac{\Delta \dot{z}_V}{(\Delta \dot{\xi}_V^2 + \Delta \dot{\eta}_V^2)^{1/2}} \right]$$

$$45. \quad \tilde{\chi}_Z = \tan^{-1} \left( \frac{\Delta \dot{\eta}_V}{\Delta \dot{\xi}_V} \right)$$

$$46. \quad L_2 = L_2^i + a_T$$

$$47. \quad L = L_1 + L_2$$

$$48. \quad J_2 = J_2^i + T_{2i} a_T$$

$$49. \quad S_2 = T_{2i} L_2 - J_2$$

$$50. \quad J = J_1 + J_2 + T_{1i} L_2$$

$$51. \quad S = S_1 + S_2 + T_{2i} L_1$$

$$52. \quad d_4 = Q_1 + T_{1i} S_2$$

$$53. \quad d_5 = T_{2i} J_1$$



$$54. Q_2 = \tau_{2i} S_2 - Vex_2 \frac{T_{2i}^2}{2}$$

$$55. Q = d_4 + d_5 + Q_2$$

$$56. K = S \cos \tilde{\chi}_x$$

$$57. M = Q \cos \tilde{\chi}_x$$

$$58. G = Z_V - Z_{VT} + \dot{Z}_V T' + \frac{\ddot{Z}^*}{2} \frac{vG}{(T')^2} + S \sin \tilde{\chi}_x$$

$$59. N_1' = \frac{GJ}{KJ - LM}$$

$$60. N_1 = N_1' (1 - K_1(N_1')^2)$$

$$61. N_2 = N_1' \frac{L}{J}$$

$$62. L' = L \cos \tilde{\chi}_x$$

$$63. P' = N_2 \sin \tilde{\chi}_x$$

$$64. H = \cos \tilde{\chi}_x + N_1' \sin \tilde{\chi}_x$$

$$65. C_1 = \tau_{1i} J_1 - Vex_1 \frac{T_{1i}^2}{2}$$

$$66. C_2 = (\tau_{2i} + 2T_{1i}) J_2 - Vex_2 \frac{T_{2i}^2}{2}$$

$$67. J' = HJ - P'(C_1 + C_2 + T_{1i}^2 L_2)$$

$$68. D' = HS - P'Q$$

$$69. G' = Y_V - Y_{VT} + \overset{\circ}{Y}_V T' + \frac{\overset{\circ}{Y}_V^*}{2} (T')^2 + D' \sin \tilde{\chi}_Z$$

$$70. K' = D' \cos \tilde{\chi}_Z$$

$$71. D_1 = \tau_{1i} Q_1 - Vex_1 \frac{T_{1i}^3}{6}$$

$$72. D_2 = (\tau_{2i} + 2T_{1i}) Q_2 - Vex_2 \frac{T_{2i}^3}{6}$$

$$73. M' = \cos \tilde{\chi}_Z [HQ - P'(D_1 + D_2 + T_{1i}^2 S_2 + T_{2i} C_1)]$$

$$74. N_3' = \frac{G'J'}{K'J' - L'M'}$$

$$75. N_3 = N_3' (1 - K_2(N_3')^2)$$

$$76. N_4 = N_3 \frac{L'}{J'}$$

$$77. T_{2i} \leq \epsilon$$

If Yes: Go to 78

If No: Go to 80.

$$78. \text{ Freeze: } \tilde{\chi}_X, \tilde{\chi}_Z, N_1, N_2, N_3, N_4; \text{ Set } N_5 = 1$$

$$79. t_2 = t_2 + \Delta t$$

Go to 81.

$$80. \text{ Set: } N_5 = 0$$

$$81. \quad \chi'_X = \tilde{\chi}'_X - N_1 + N_2 N_3 t_2$$

$$82. \quad \chi'_Z = \tilde{\chi}'_Z - N_3 + N_4 N_5 t_2 - \psi_T - \frac{\pi}{2}$$

$$83. \quad [\chi'_X]^T = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos \chi'_X & -\sin \chi'_X \\ 0 & \sin \chi'_X & \cos \chi'_X \end{bmatrix}$$

$$84. \quad [\chi'_Z]^T = \begin{bmatrix} \cos \chi'_Z & -\sin \chi'_Z & 0 \\ \sin \chi'_Z & \cos \chi'_Z & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

$$85. \quad \begin{bmatrix} X'_S \\ Y'_S \\ Z'_S \end{bmatrix} = [A_{PR4}]^T [\chi'_Z]^T [\chi'_X]^T \begin{bmatrix} 0 \\ 1 \\ 0 \end{bmatrix}$$

$$86. \quad \chi'_Z = \tan^{-1} \left( -\frac{X'_S}{Y'_S} \right)$$

$$87. \quad \chi'_X = \tan^{-1} \left[ \frac{Z'_S}{\sqrt{(X'_S)^2 + (Y'_S)^2}} \right]$$

$$88. \quad |V - V_T| \leq \delta$$

Cutoff

APPENDIX B  
PRELIMINARY FLIGHT SEQUENCE FOR SA-201

GEORGE C. MARSHALL SPACE FLIGHT CENTER  
HUNTSVILLE, ALABAMA

*Memorandum*

Mr. Mathews/ns/876-8550 *EP*  
Memo #R-ASTR-EAA-2-65

TO Distribution

FROM Chief, Electrical Systems Integration  
Division, R-ASTR-E

SUBJECT Preliminary Flight Sequence for SA-201

DATE January 5, 1965

*LEP*  
*LEP*  
*RGS*

1. Enclosed is the preliminary list of in-flight time sequenced events for all vehicle discrete functions that are initiated through the S-IB, S-IVB, and IU Switch Selectors.
2. Time Base #1 ( $T_1$ ) is initiated by liftoff.
3. Time Base #2 ( $T_2$ ) is initiated by the actuation of the S-IB Propellant Level Sensors.
4. Time Base #3 ( $T_3$ ) is initiated by S-IB outboard engine cutoff.  $T_3$  may be started prior to the completion of  $T_2$ . Nominal burning would provide propellant depletion and outboard cutoff at  $T_2 + 8$  seconds. Failure to deplete propellants in allowed time will result in outboard engine cutoff by timed backup at  $T_2 + 8.4$  seconds.
5. Time Base #4 ( $T_4$ ) is initiated by S-IVB Engine Cutoff.
6. A discrete signal will be given to the Launch Vehicle Digital Computer System as a reference for each time base.
7. Any addition to, or deviation from, the enclosure should be coordinated through R-ASTR-EAA, Mr. Mathews, 876-8550.



H. J. Fichtner

Enclosure: a/s

Distribution: See attached list

TIME SEQUENCE SA-201

Nominal Flight Time	Function	Switch Selector			Time From Base
		Code	Stage	Chan	
0.0	<u>Liftoff - Start of Time Base No. 1 (T<sub>1</sub>)</u>				T <sub>1</sub> + 0.0
10.0	Command to Change From S-IB Single Engine-out to Multiple Engine-out Capability	0001 0001	S-IB	16	T <sub>1</sub> + 10.0
14.0	Command S-IB or S-IVB EDS Engine Cutoff Enable	0011 0001	I. U.	38	T <sub>1</sub> + 14.0
14.1	Command S-IB or S-IVB EDS Engine Cutoff Enable	0010 0001	I. U.	53	T <sub>1</sub> + 14.1
25.0	Command S-IB Telemeter Calibrate ON	0101 1111	S-IB	2	T <sub>1</sub> + 25.0
30.0	Command S-IB Telemeter Calibrate OFF	0000 1111	S-IB	39	T <sub>1</sub> + 30.0
39.0	Command Tape Recorder Record	0110 0101	S-IB	107	T <sub>1</sub> + 39.0
60.0	Command Flight Control Computer Switch Point No. 1	0111 1110	I. U.	43	T <sub>1</sub> + 60.0
90.0	Command Flight Control Computer Switch Point No. 2	0100 0001	I. U.	21	T <sub>1</sub> + 90.0
111.0	Command Control Accelerometer Power OFF	0111 0101	I. U.	106	T <sub>1</sub> + 111.0
120.0	Command S-IB Telemeter Calibrate ON	0101 1111	S-IB	2	T <sub>1</sub> + 120.0
120.1	Command Flight Control Computer Switch Point No. 3	0101 0001	I. U.	22	T <sub>1</sub> + 120.1

TIME SEQUENCE SA-201 (Cont'd)

Nominal Flight Time	Function	Switch Selector			Time From Base'
		Code	Stage	Chan	
125.0	Command S-IB Telemeter Calibrate OFF	0000 1111	S-IB	39	$T_1 + 125.0$
131.3	Command Arm Level Sensors	0111 0111	S-IB	104	$T_1 + 131.3$
132.0	Command S-IB Engine Out Auto-Abort Inhibit Enable	0000 1110	I. U.	51	$T_1 + 132.0$
132.1	Command S-IB Engine Out Auto-Abort Inhibit	0001 1110	I. U.	35	$T_1 + 132.1$
136.3	<u>S-IB Propellant Level Sensor Actuation - Start of Time Base No. 2 (<math>T_2</math>)</u>				$T_2 + 0.0$
136.4	Command Pre-valves Pilot Valves OFF	0110 1001	S-IVB	83	$T_2 + 0.1$
136.5	Command I. U. Tape Recorder Record	0000 1111	I. U.	39	$T_2 + 0.2$
137.5	Command S-IVB Tape Recorder Emergency Playback Enable ON	0110 0101	S-IVB	107	$T_2 + 1.2$
138.3	Command Inboard Engine Cutoff	0100 0100	S-IB	98	$T_2 + 2.0$
140.0	Command Q-Ball Power OFF	0111 1111	I. U.	1	$T_2 + 3.7$

TIME SEQUENCE SA-201 (Cont'd)

Nominal Flight Time	Function	Switch Selector			Time From Base
		Code	Stage	Chan	
141.7	Command Engine 200W. Instrumentation Heaters OFF	0001 1111	S-IVB	17	$T_2 + 5.4$
141.8	Command Engine 20W. Instrumentation Heaters ON	0011 0011	S-IVB	18	$T_2 + 5.5$
141.9	Command Rate Gyros OFF	0101 1010	S-IVB	100	$T_2 + 5.6$
142.6	Command Charge Ullage Ignition ON	0111 0100	S-IVB	54	$T_2 + 6.3$
143.3	Command Arm S-IB Fuel Depletion Probes and Electrically Interconnect Outboard Engines Thrust OK Switches	0000 0110	S-IB	97	$T_2 + 7.0$
144.3	<u>S-IB Outboard Engine Cutoff - Start of Time Base No. 3 (<math>T_3</math>)</u>				$T_3 + 0.0$
144.7	Command Cutoff Outboard Engine (Time Backup)	0011 0011	S-IB	18	$T_2 + 8.4$
145.0	Command Fire Ullage Ignition ON	0101 0100	S-IVB	56	$T_3 + 0.7$
145.1	Command Initiate S-IB/S-IVB Separation Explosive Nuts and Initiate Retro Rockets Firing	0010 0010	S-IB	23	$T_3 + 0.8$
146.4	Command S-IVB LH <sub>2</sub> Chillown Pump OFF	0110 1011	S-IVB	59	$T_3 + 2.1$



TIME SEQUENCE SA-201 (Cont'd)

Nominal Flight Time	Function	Switch Selector			Time From Base
		Code	Stage	Chan	
146.5	Command S-IVB LOX Chillover Pump OFF	0010 0010	S-IVB	23	T <sub>3</sub> + 2.2
146.6	Command S-IVB LOX Chillover Pump Purge Control Valve OFF	0100 0001	S-IVB	21	T <sub>3</sub> + 2.3
146.7	Command S-IVB Engine Start ON	0001 0011	S-IVB I. U.	9	T <sub>3</sub> + 2.4
146.8	Command S-IVB Engine Start Interlock Bypass ON	0000 0100	S-IVB	74	T <sub>3</sub> + 2.5
146.9	Command S-IVB Engine Burning No. 1 Relay ON	0001 1001	S-IVB	68	T <sub>3</sub> + 2.6
147.0	Command S-IVB LOX Tank Flight Press System ON	0111 1001	S-IVB	103	T <sub>3</sub> + 2.7
147.1	Command S-IVB Engine Ready Bypass	0110 0011	S-IVB	10	T <sub>3</sub> + 2.8
147.2	Command S-IVB Engine Start OFF	0101 1101	S-IVB	27	T <sub>3</sub> + 2.9
147.7	Command S-IVB Injection Temp. Detected Bypass	0111 0011	S-IVB	11	T <sub>3</sub> + 3.4
150.0	Command I. U. Water Coolant Valve Open	0110 0101	I. U.	107	T <sub>3</sub> + 5.7
151.1	Command S-IVB PU Activate ON	0000 0010	S-IVB	5	T <sub>3</sub> + 6.8
152.8	Command S-IVB Tape Recorder Fast Record OFF	0111 0101	S-IVB	106	T <sub>3</sub> + 8.5
157.4	Command S-IVB Charge Ullage Jettison ON	0110 0100	S-IVB	55	T <sub>3</sub> + 13.1

TIME SEQUENCE SA-201 (Cont'd)

Nominal Flight Time	Function	Switch Selector			Time From Base
		Code	Stage	Chan	
159.8	Command S-IVB Fire Ullage Jettison ON	0001 1010	S-IVB	57	T <sub>3</sub> + 15.5
159.9	L.E.T. Jettison Command "A"	0010 1110	I. U.	52	T <sub>3</sub> + 15.6
160.0	L.E.T. Jettison Command "B"	0011 1110	I. U.	36	T <sub>3</sub> + 15.7
163.1	Command S-IVB Ullage Charging OFF	0101 1100	S-IVB	88	T <sub>3</sub> + 18.8
163.2	Command S-IVB Ullage Firing OFF	0010 1011	S-IVB	73	T <sub>3</sub> + 18.9
164.3	Command I. U. Tape Recorder Record OFF	0001 1111	I. U.	17	T <sub>3</sub> + 20.0
166.7	Command S-IVB Tape Recorder Emergency Playback Enable OFF	0100 0101	S-IVB	108	T <sub>3</sub> + 22.4
272.6	Command S-IVB TM Special Calibrate Relays ON	0100 1010	S-IVB	62	T <sub>3</sub> + 128.3
272.7	Command S-IVB TM Regular Calibrate Relays ON	0011 1010	S-IVB	64	T <sub>3</sub> + 128.4
277.2	Command S-IVB TM Regular Calibrate Relays OFF	0010 1010	S-IVB	65	T <sub>3</sub> + 132.9
277.3	Command S-IVB TM Special Calibrate Relays OFF	0000 0111	S-IVB	63	T <sub>3</sub> + 133.0
352.1	Command S-IVB TM Regular Calibrate Relays ON	0011 1010	S-IVB	64	T <sub>3</sub> + 207.8
356.6	Command S-IVB TM Regular Calibrate Relays OFF	0010 1010	S-IVB	65	T <sub>3</sub> + 212.3

TIME SEQUENCE SA-201 (Cont'd)

Nominal Flight Time	Function	Switch Selector			Time From Base
		Code	Stage	Chan	
445.1	Command Flight Control Computer Switch Point No. 4	0110 0001	I. U.	4	$T_3 + 300.8$
446.7	Command S-IVB Engine Burning No. 1 Relay OFF	0010 1001	S-IVB	69	$T_3 + 302.4$
505.1	Command Flight Control Computer Switch Point No. 5	0011 0010	I. U.	44	$T_3 + 360.8$
538.7	Command S-IVB Point Level Sensor Arming	0000 0110	S-IVB	97	$T_3 + 394.4$
546.7	<u>S-IVB Engine Cutoff - Start of Time Base No. 4 (<math>T_4</math>)</u>				$T_4 + 0.0$
546.7	Command S-IVB Engine Cutoff ON	0100 1101	S-IVB I. U.	12	$T_4 + 0.0$
546.8	Command S-IVB Engine Cutoff OFF	0111 0010	S-IVB	13	$T_4 + 0.1$
547.1	Command S-IVB Point Level Sensor Disarming	0100 0100	S-IVB	98	$T_4 + 0.4$
547.2	Command S-IVB Pre-valves Pilot Valve ON	0001 0110	S-IVB	82	$T_4 + 0.5$
547.3	Command S-IVB Chilldown Shutoff Pilot Valve ON	0101 0101	S-IVB	91	$T_4 + 0.6$
547.4	Command S-IVB LOX Tank Flight Press System OFF	0111 0111	S-IVB	104	$T_4 + 0.7$

TIME SEQUENCE SA-201 (Cont'd)

Nominal Flight Time	Function	Switch Selector			Time From Base
		Code	Stage	Chan	
547.5	Command S-IVB Coast Period ON	0110 1010	S-IVB	79	$T_4 + 0.8$
547.6	Command S-IVB PU Inverter and DC Power OFF	0011 1111	S-IVB	8	$T_4 + 0.9$
547.7	Command S-IVB Engine 20W Instrumentation Heaters OFF	0101 0010	S-IVB	19	$T_4 + 1.0$
547.8	Command S-IVB PU Activate OFF	0010 1101	S-IVB	6	$T_4 + 1.1$
547.9	Command S-IVB Auxiliary Hydraulic Pump OFF	0011 1100	S-IVB	29	$T_4 + 1.2$
569.7	Command S-IVB TM Special Calibrate Relays ON	0100 1010	S-IVB	62	$T_4 + 23.1$
569.8	Command S-IVB TM Regular Calibrate Relays ON	0011 1010	S-IVB	64	$T_4 + 23.2$
574.2	Command S-IVB TM Regular Calibrate Relays OFF	0010 1010	S-IVB	65	$T_4 + 27.5$
574.3	Command S-IVB TM Special Calibrate Relays OFF	0000 0111	S-IVB	63	$T_4 + 27.6$
575.7	Command S-IVB Single Sideband Group OFF	0100 1110	S-IVB	41	$T_4 + 29.0$
575.8	Command S-IVB SSB Transmitter OFF	0010 0001	S-IVB	53	$T_4 + 29.1$
576.7	Command S-IVB Tape Recorder Playback ON	0100 1001	S-IVB	66	$T_4 + 30.0$
606.7	Command S-IVB Tape Recorder Playback OFF	0011 0111	S-IVB	67	$T_4 + 60.0$

TIME SEQUENCE SA-201 (Concluded)

Nominal Flight Time	Function	Switch Selector			Time From Base
		Code	Stage	Chan	
606.9	Command S-IVB Chilldown Shutoff Pilot Valve OFF	0011 0101	S-IVB	92	T <sub>4</sub> + 60.2
607.0	Command S-IVB Pre-valves Pilot Valves OFF	0110 1001	S-IVB	83	T <sub>4</sub> + 60.3
626.7	Command S-IVB Flight S.C.O. Group OFF	0101 0011	S-IVB	45	T <sub>4</sub> + 80.0
628.7	Command S-IVB Flight Transmitter Group OFF	0000 1110	S-IVB	51	T <sub>4</sub> + 82.0
628.8	Command S-IVB Orbit Transmitter Group OFF	0000 1100	S-IVB	49	T <sub>4</sub> + 82.1
646.7	Command I. U. Tape Recorder Playback	0010 1111	I. U.	40	T <sub>4</sub> + 100.0
676.7	Command I. U. Tape Recorder Playback OFF	0011 0011	I. U.	18	T <sub>4</sub> + 130.0
687.0	Command I. U. Tape Recorder Playback Reverse	0101 0010	I. U.	19	T <sub>4</sub> + 140.3
717.0	Command I. U. Tape Recorder Playback Reverse OFF	0110 0010	I. U.	3	T <sub>4</sub> + 170.3