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PROJECT VANGUARD REPORT NO. 31

THE VANGUARD SEQUENCE DIAGRAM, A GRAPHICAL METHOD OF PRESENTING COMPLEX SYSTEM OPERATION

W. J. D. Escher and R. W. Foster

Vehicle Branch
Project Vanguard

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NAVAL RESEARCH LABORATORY
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ABSTRACT

The Vanguard sequence diagram is introduced as a means of graphically presenting the operation of complex systems. This diagram represents system components and their changing states as they interact sequentially. Thus it shows at a glance the state of every component at any instant in a nominal operation of the system, as well as all the events occurring at any instant and the components involved in each event.

The utility of the sequence diagram is discussed and various applications are suggested. The method of interpreting the diagram is explained and illustrated in a simple example. To demonstrate a complete application, the complete nominal flight operation of the first Project Vanguard rocket test vehicle is presented as an appendix, in both sequence diagram and conventional narrative forms.

PROBLEM STATUS

This is an interim report on one phase of the problem; work is continuing.

AUTHORIZATION

NRL Problem A02-85

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INTRODUCTION

The growing need for a means of graphically presenting the operation of a complex device in which a pre-determined sequence of events occurs has led to the development of the Vanguard sequence diagram. This diagram has a wide utility to personnel in all aspects of programs concerned with complex sequenced devices, such as missiles.

The sample sequence diagram presented in Appendix A represents Project Vanguard's Initial Rocket Test Vehicle, TV-0 (Viking 13). A diagram for the satellite launching vehicle is in preparation and will be the subject of a later report.

This paper will present a specific application of the sequence diagram to a rocket-powered vehicle, stabilized and directed by internal controls components, and will depict graphically the various states which exist during the nominal launching program. In addition, a brief nomenclature is included to identify the component states and functions.

SCOPE OF THE DIAGRAM AND DEFINITIONS

The sequence diagram can relate the following:

1. The number of given states in which a component functions and the relative sequence of these states.*

2. The immediate cause and any necessary conditions for a component changing its state, and the immediate effect, if any, of the change on other components.

3. The means by which one component in changing its state affects another; e.g., by an electrical current, mechanical linkage, combustion process, etc.

4. The number of components involved, and the number of discrete events that must occur, in order to proceed from one point in a nominal program to a subsequent point; this provides an index of complexity for comparing various phases of the program.

The following three terms are used with special significance relative to the sequence diagram:

Component:

As defined here, a component may be removed from a system or assembly in the vehicle, but is not generally subject to further disassembly. Examples of components are: a relay, a gyro, or an autopilot amplifier channel. Each component is assigned a space running horizontally across the sequence diagram, with the name of the component at the left margin.

*A complete description of a component and its mode of functioning in several states, including the nature of transitions between states, can be given on auxiliary component information sheets.

Component State:

The component state is a particular condition of the component, generally a steady-state condition, characterized by the component's position, operation, input, output, etc. Examples of Component States are: for a two-position switch, off or on; for a gas generator, generating or not generating; for a propellant tank, vented, pressurized, or supplying propellant.

In the sequence diagram a component state is indicated by a bar placed in the horizontal spaces assigned to the components. Suitable nomenclature to identify the state and transitions in state is included within the bar.

Event:

An Event is generally characterized by a change in state of one or more components at a point in time. Some of these are causing changes; others are effected changes.

In the sequence diagram an event is indicated by a vertical line along which symbols are placed to differentiate cause, effect, and necessary conditions.

UTILITY OF THE DIAGRAM

The sequence diagram, as a means of relating information about systems operation, may have many areas of application. Several general and specific examples are:

1. Studies toward increasing overall reliability through redesign.

Reliability improvement studies may generally proceed along one or more of the following lines:

a. Increased component reliability.

b. Decreased complexity through reduction of the number of "series" components and/or events.

c. Replacement of "series" operation with "parallel" operation; the "redundancy" concept.

The master sequence diagram has utility as a "work-sheet" in programs that utilize lines of approach b and c, presenting directly a list of components and their modes of interaction, i.e., the overall complexity, and number of series and parallel operations involved.

2. Facilitating the interpretation of wiring diagrams, propulsion system layouts, etc.

Using the sequence diagram to establish the sequential operation of a system assists in the interpretation of other schematic presentations which may, by themselves, require tedious study to develop an overall grasp of operations. The major point here is that the state of every component can be determined from the sequence diagram at any point in an operating sequence. A wiring diagram cannot give this information unless relays are given a special code for order of operation, etc., an awkward procedure at best in the case of a complex system.

3. Basic familiarization with a rocket-powered vehicle and its constituent systems.

Once an individual has become familiar with the sequence diagram concept and its special nomenclature and symbolism, he can gain a working familiarity with the functioning of an entire vehicle as well as its constituent systems in a relatively brief period. Equipped with a sequence diagram, a person otherwise unfamiliar with a system can discuss it intelligently and concern himself with almost any basic aspect of it.

4. Evaluation of ground checkout procedures which precede a rocket launching, trouble-shooting, and estimation of the adequacy of telemetering instrumentation for post-flight analysis.

5. Electrical load profile for the flight program of a vehicle.

With the aid of the master sequence diagram and the current requirements for all individual components, an electrical load profile can be drawn for both vehicle and ground equipment for the entire launch/flight program, or portions thereof.

DESCRIPTION AND INTERPRETATION OF THE DIAGRAM

The sequence diagram is basically a means of identifying the components of a system and their changing states (horizontal lines) against events (vertical lines) occurring as time progresses (to the right).

Component and Component State

Indication of Component State

The representation of a component and its state is illustrated by the following example:

Valve "A" closed open closed

From this the following information can be gained: Valve 'A' normally has two states, open and closed; it is initially closed, opens for a time and then returns to its closed position.

Transitions in Component State

Thrust Chamber, II not-firing firing not-firing

From this, the following information can be gained: The thrust chamber (second stage), initially not-firing, undergoes a transition to its full-firing state. After a time, shut-down occurs and it returns to its initial state through another transition, of shorter duration than the initial thrust build-up.

Complex Operation

Main Oxidizer Valve closed prelim. full open closed

From this, the following information can be gained: The main oxidizer valve undergoes a transition from its closed position to a preliminary-open position, and thence, after a period of preliminary-open operation, through a considerably longer transition to the full-open position. Finally, the valve closes through a relatively short transition period.

Events; Causes and Effects

The following symbols are used:

○ Indicates a primary causing operation or operations.

● Indicates operation or operations effected.

△ Indicates a necessary condition.

▽ Indicates an either/or causal relationship.

⊕ Indicates a control-loop closure, or system feedback point.

The applicable symbols associated with a single event are tied together with a vertical line, termed the event line.

Examples:

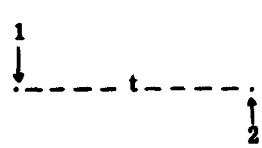
○ a Operation a causes operation b.
● b

○ a Operation a causes operation b, provided condition c exists.
● b
△ c

▽ a Either operation a or operation b causes operation c.
▽ b
● c

○ a Both operations a and b combined will cause either operation c or operation d, as well as operation e, provided condition f exists.
○ b
▼ c
▼ d
● e
△ f

Time Delay, or Timing Operation



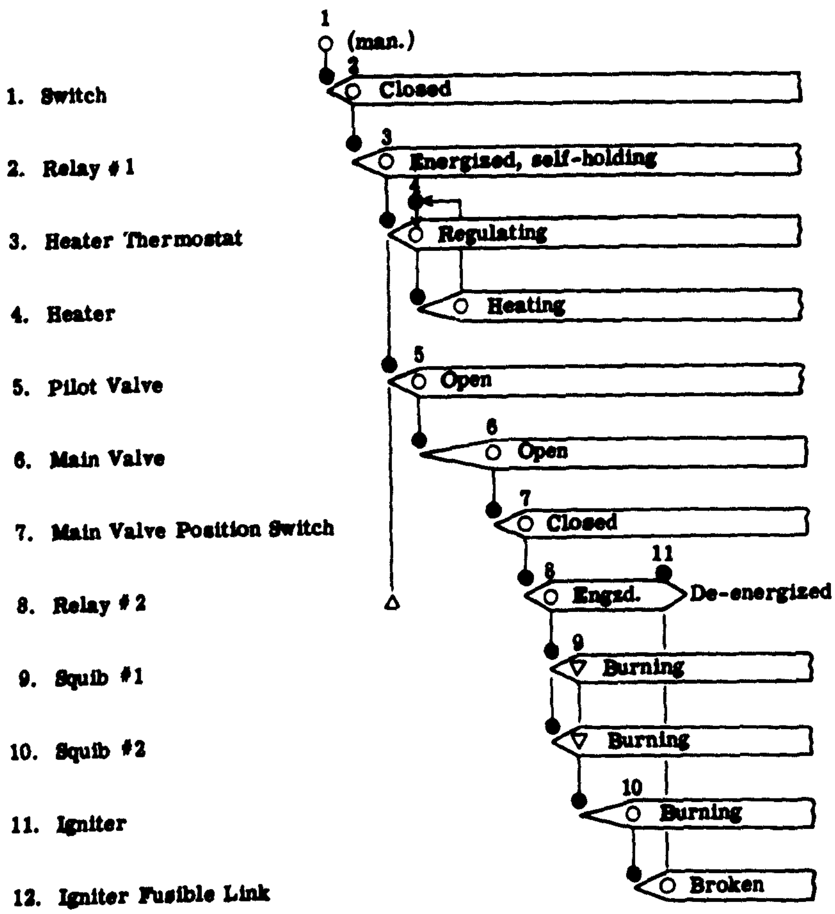
The above is interpreted as:

From event 1, a period of t seconds ensues before event 2 occurs.

ILLUSTRATIVE SEQUENCE DIAGRAM

The following is a sample sequence diagram in which the preceeding terminology and symbolism are employed to represent a chain of events. Components are shown in the left-hand column, and are numbered from top to bottom. Events in time proceed to the right and are numbered from left to right, indicating their sequence.

The interpretation of this diagram is as follows (numbers in parentheses refer to component identification numbers): The switch (1) is manually closed, causing Relay #1 (2) to become energized and self-holding. Provided that Relay #2 (8) is de-energized, the operation of Relay #1 (2) causes the heater thermostat (3) to start regulating the heater (4), and the pilot valve (5) to open. Opening of the pilot valve (5) causes the main valve (6) to open, in a somewhat longer opening period. In opening, the main valve (6) causes its position switch (7) to close, energizing Relay #2 (8). This relay operation causes both squibs (9) and (10) to begin burning, either of which is capable of causing the igniter (11) to start burning. When the igniter (11) burns it breaks its fusible link (12) which in turn causes Relay #2 (8) to become de-energized.



(12 Components, 11 Events)

Appendix A

COMPLETE SEQUENCE DIAGRAM AND DESCRIPTION OF A VANGUARD TEST VEHICLE

In the following pages, the complete nominal program of an actual large rocket flight will be described in both narrative and sequence diagram fashion. The master sequence diagram will be found inside the back cover of this report. The numbers assigned to the various components on the sequence diagram appear in parentheses in the narrative.

DESCRIPTION OF THE VEHICLE

Vanguard Test Vehicle 0 (TV-0) was the thirteenth Viking Rocket Test Vehicle (RTV-N-12b) and was constructed by The Martin Company of Baltimore, Maryland for the Naval Research Laboratory. A single-staged vehicle, its airframe was a cone-tipped cylinder with four equi-spaced delta-shaped fins at its base (Figs. A1 and A2). A liquid-propellant rocket engine (XLR 10-RM-2) provided a sea-level thrust of 20,300 pounds for a period of 105.9 seconds. The propellants, liquid oxygen and ethyl alcohol, were injected into the combustion chamber by a turbopump driven by the decomposition products of highly concentrated hydrogen peroxide. A schematic drawing of the propulsion system is shown in Fig. A3.

The vehicle was to have been attitude-stabilized by internal controls until nose-cone separation. The trajectory (Fig. A4) was established by timer-controlled precession of the vertical gyro about its pitch reference axis.

Controlling moments about the pitch and yaw axes were provided by the gimbaled thrust chamber. Control about the vehicle's roll axis was obtained through movable aerodynamic surfaces at the tips of two opposite fins during those portions of the flight when dynamic pressure was sufficient for tab control. At lift-off and at high altitude, a reaction jet system supplanted the roll tabs. After power plant cut-off reaction jet control about all three axes was employed.

The instrumented nose cone, containing tracking and telemetering equipment, was designed to be disengaged from the remainder of the vehicle on the descending leg of the trajectory. The cone was designed to withstand the stresses of atmospheric re-entry and to be aerodynamically stable until impact.

A small sphere containing a prototype Minitrack transmitter was to be ejected for test tracking purposes shortly after cutoff.

TV-0 was launched from Cape Canaveral at Patrick Air Force Base, Florida, at 0103 EST on 8 December 1956.

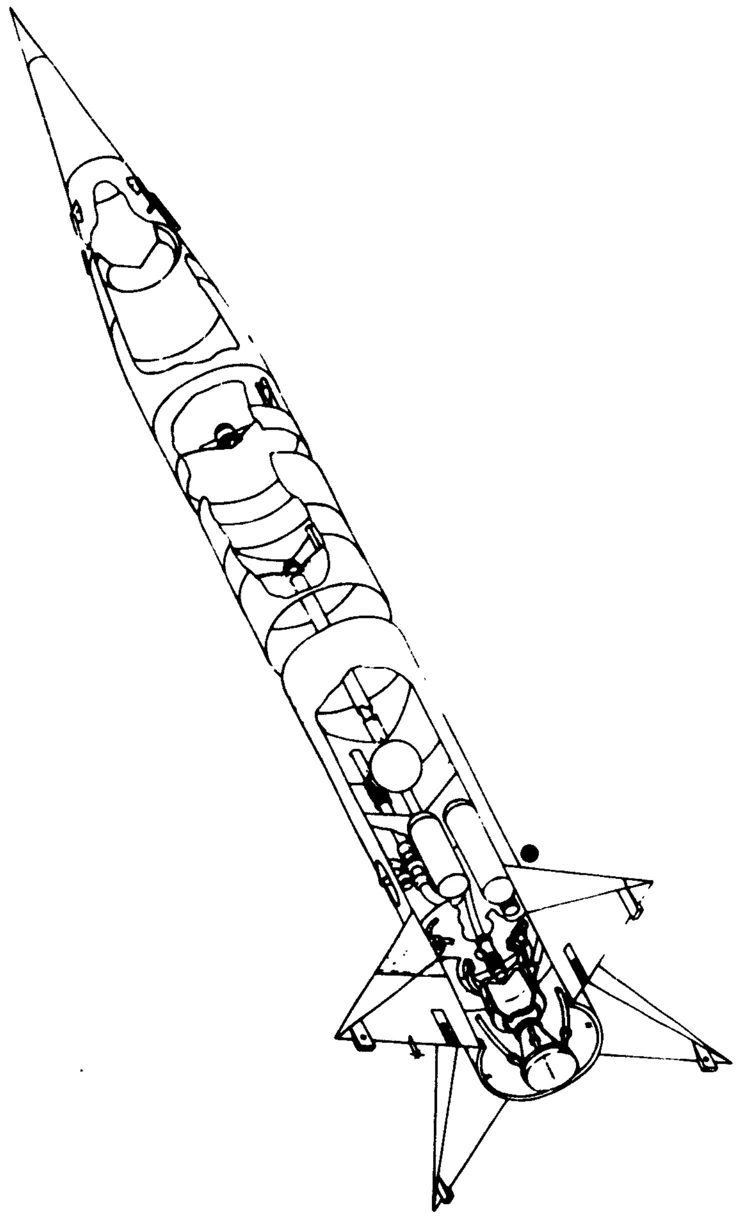


Fig. 1 - Isometric view of TV-0 showing major component locations

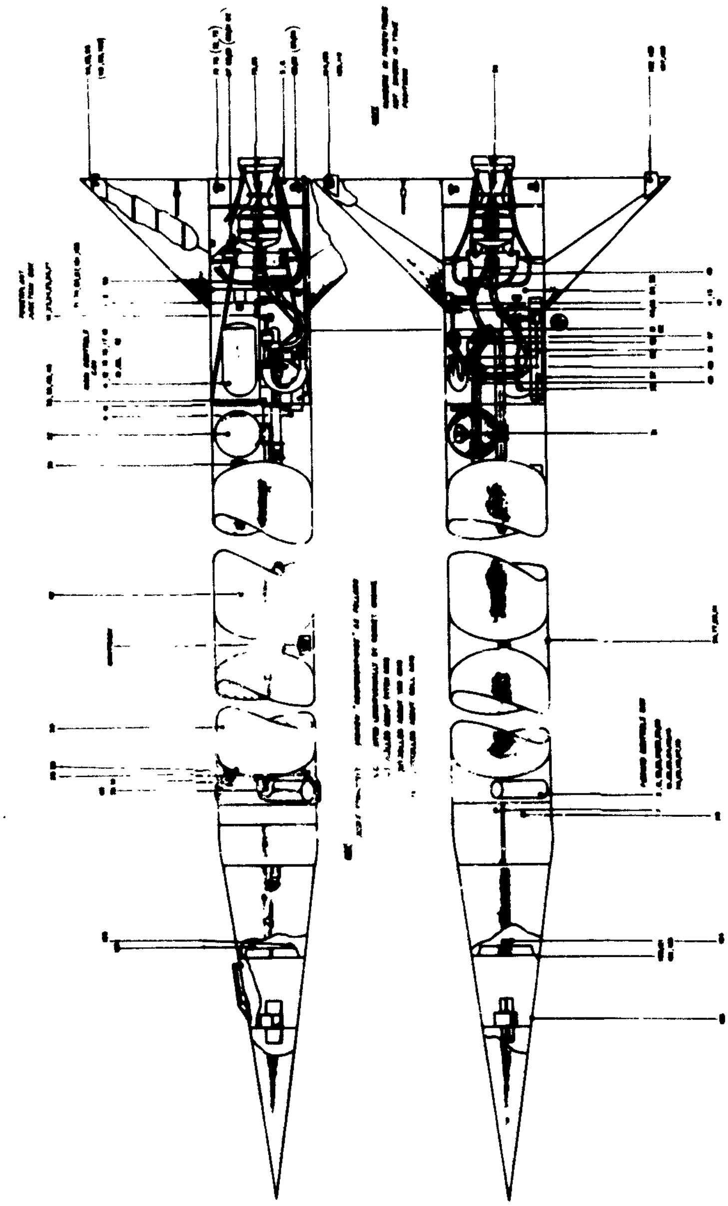


Fig. 2 - Component locations in TV-0 (numbers correspond to component numbers shown on TV-0 master sequence diagram)

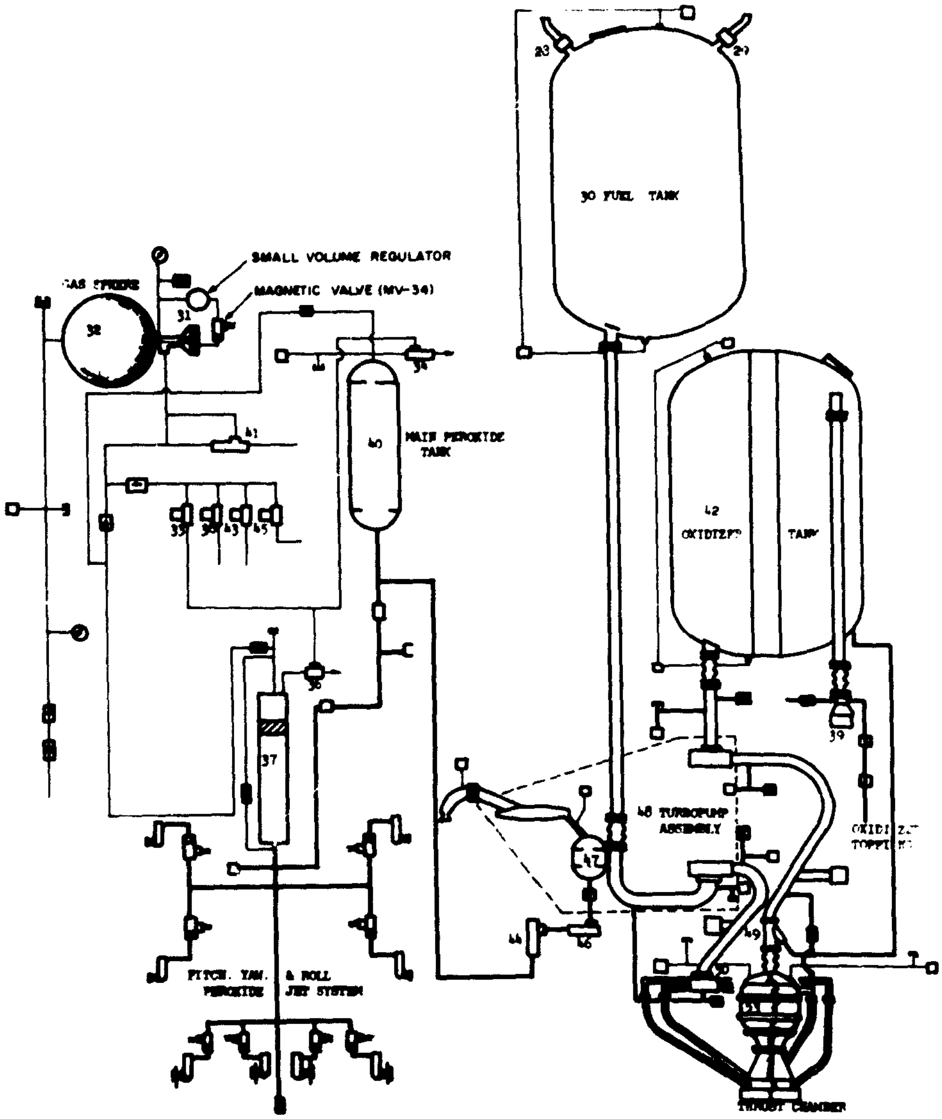


Fig. 3 - TV-0 propulsion system schematic diagram (numbers correspond to component numbers shown on TV-0 master sequence diagram)

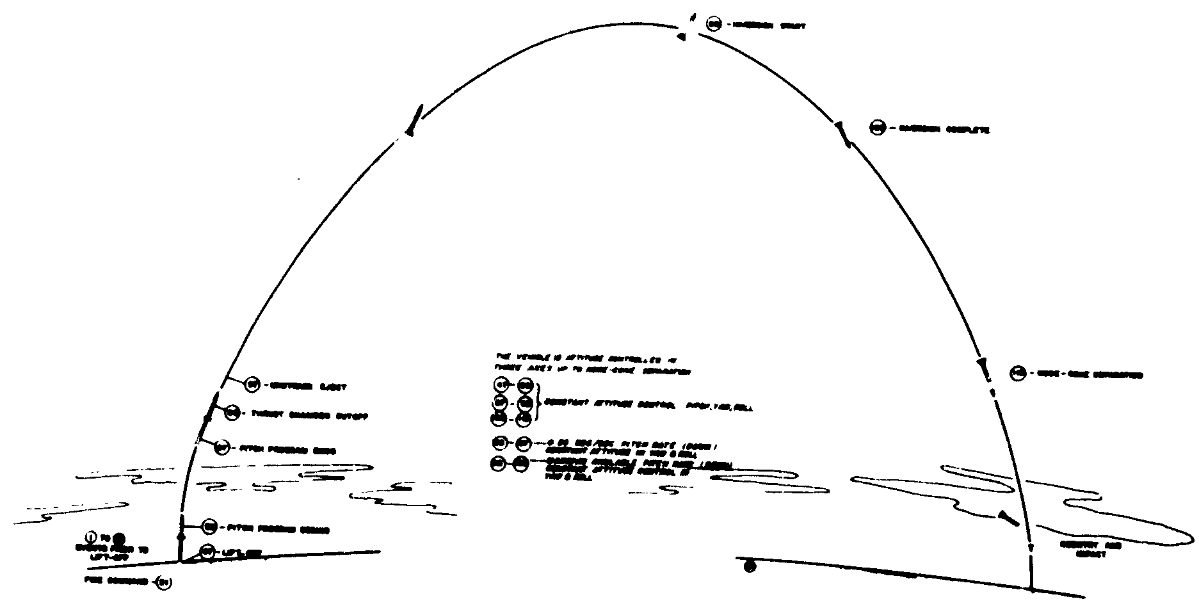


Fig. 4 - Events sequenced along trajectory for nominal TV-0 launch-flight program (numbers correspond to event numbers shown on TV-0 master sequence diagram)

NARRATIVE DESCRIPTION OF TV-0 OPERATING SEQUENCE

Flight Power On

At T-5 minutes in the normal launching count-down, the vehicle electrical system is transferred from the ground power supply to the vehicle battery (9). The switching is achieved by momentarily closing the "Power Transfer" switch (G2) of the blockhouse firing station; this applies ground power to the vehicle power stepping relay (1), causing it to be actuated and mechanically retained in its energizing position and thus applying vehicle power to the coil of the main vehicle power transfer contactor (2) which in turn becomes energized in the closed position. This operation disconnects the vehicle main power bus (10) from its ground power connection and connects it to the positive terminal of the vehicle battery. In addition, provided that the controls manual switch (11), is closed, the controls-can bus (12) is energized; and provided that the safety key (13) is removed from its socket in the aft section of the vehicle's external conduit, the powerplant junction box bus (14) is energized.

Pressurization

At T-90 seconds the vehicle's oxidizer tank (42), main peroxide tank (35), and controls peroxide tank (37) are pressurized. The blockhouse firing station pressurization switch (G4) is momentarily closed causing the pressurization relay (24) in the vehicle's powerplant junction box to be actuated and mechanically retained in its "latched" position - provided that the fuse security relay (G6) is energized closed, indicating continuity through the igniter fusible link (G12). Actuation of the pressurization relay (24) does the following: (a) turns on the vehicle's gas regulator (31) allowing it to reduce and regulate the high-pressure gas sphere (32) source to approximately 450 psi and supply gas to the vehicle propulsion system as required; (b) energizes the oxidizer tank vent valve's pilot solenoid valve (38) which pneumatically closes the oxidizer tank vent valve (39); (c) energizes the peroxide tanks' vent valves' pilot solenoid valve (33) which pneumatically closes the main peroxide tank vent valve (34) and the controls peroxide vent valve (36); (d) allows the oxidizer tank pressure-regulating system (consisting of a two-position pressure sensitive switch (40) and a two-solenoid valve electric regulator (41)) to bring the oxidizer tank (42) to, and maintain it at rated pressure so that the pressure in the oxidizer pump inlet line is held within the required limits.

Fire

At T-2 seconds the fire command is given by closing and holding closed the fire cut-off switch (G5) of the blockhouse firing station to the "Fire" position. (It is necessary that the switch be held closed until the rocket engine begins operating.) Provided that the igniter fuse link security relay (G6) is energized (closed), and that the power security relay (G3) is energized (closed, indicating that the vehicle's power stepping relay (1) is in the energizing position), then the igniter contactor (G8) in the remote junction station is energized (closed). This provides electrical current through the igniter heaters (G10) which causes the igniter (G11) to commence burning. Shortly thereafter, the igniter's fusible link (G12) is broken by the heat, causing the igniter fuse security relay to be de-energized (open). This, providing the fire cut-off switch is still being held in the "Fire" position and the power security relay is in the energized position, causes the nose-plug drop contactor (G9) in the remote junction station to become energized (closed). This applies 35-volt dc power, provided by a special power supply in the remote junction station, to the nose-plug solenoid (G13) causing it to actuate and disconnect the nose plug (G14) from the vehicle. The dropping of the nose plug breaks the circuit continuity of the nose-plug security relay (G7), causing it to be de-energized (open). This, provided that the fire cut-off switch is still being held in the "Fire" position and that the power security relay (G3) is energized, causes the fuse security relay to be de-energized, and the fire relay (26) in the vehicle's powerplant junction box to be actuated and mechanically retained in its "latched" position. This energizes the hydraulic peroxide valve's pilot valve (45) and pneumatic peroxide valve's pilot valve (43) to the open position. The opening of the pneumatic peroxide valve (44) by control gas pressure is relatively rapid, whereas the opening of the hydraulic peroxide valve (46) is delayed by means of a hydraulic control orifice. Since the two peroxide valves are in series, the hydraulic valve actually controls the flow of peroxide from the pressurized main peroxide tank into the peroxide decomposer (47) where it is catalytically decomposed into water vapor and oxygen at high temperature. This high-energy gas flows into the driving turbine of the rocket engine's turbopump assembly (48) causing it to accelerate to operating speed. During this acceleration, (a) the oxidizer pump causes the oxidizer valve (49) to be opened by the increasing oxidizer pressure and the oxidizer pump outlet pressure switch (51) to be opened, (b) the fuel pump causes the fuel valve (50) to be opened by the increasing fuel pressure and the fuel pump outlet pressure switch (52) to be opened, and (c) the hydraulic pump (20), which is mechanically coupled to the turbopump, is accelerated to operating speed. With fuel being supplied by the fuel tank (30), raised to a high pressure in the fuel pump, and admitted to the thrust chamber (53) by the fuel valve; and with oxidizer being supplied by the oxidizer tank, raised to a high pressure in the oxidizer pump, and admitted to the thrust chamber through the oxidizer valve; and provided the igniter is still burning in the thrust chamber; combustion begins and thrust increases until the operating chamber pressure is attained.

Lift-Off

When the developed thrust exceeds the vehicle weight plus disconnecting forces, the vehicle lifts off the launching stand. Lift-off causes (a) the power and control circuits' tail disconnect plug (G15) to become disconnected, (b) the instrumentation circuits' tail disconnect plug (G16) to become disconnected, (c) the GLM lift-off switch (5) to be opened, (d) the NRL lift-off switch (6) to be closed, and (e) the ground hydraulic disconnect (G17) to be closed. Disconnecting the power and control circuits' tail plug removes the ground gyro-nulling amplifier signals from the vertical (pitch and yaw) and the roll gyro torquers, thereby freeing the gyros for flight reference. In opening, the "GLM" lift-off switch causes the take-off relay (3) in the main controls can to be de-energized (open). In becoming de-energized the take-off relay causes the GLM timer (8) to start operating and the roll jet system to become armed. In closing, the NRL lift-off switch causes the NRL timer (7) to start operating.

Vertical Flight

For the first ten seconds of flight the vehicle is maintained in a fixed vertical attitude. In pitch and yaw, this is achieved through operation of the control system loops consisting of a vertical gyro (65, 78), autopilot amplifiers (66, 79), transfer valves (67, 80), hydraulic actuators (68, 81), and the gimbaled thrust chamber (70, 83). In roll, the loop consists of the roll gyro (91), autopilot amplifier (92), and solenoid valve and fin-mounted jet pairs (102-105, 107-110). In addition, the roll aerodynamic control system controls the hydraulically actuated tabs (96, 100) on two of the fins; these tabs, however, are not fully effective during the early and late portions of powered flight because of the low dynamic pressure due to low velocity and low air density respectively. During these periods, therefore, the roll jet system is energized to maintain constant roll attitude.

Pitch Program In

At T+10 seconds the GLM timer initiates a pitch program by causing the "down" command relay (57) in the forward control can to become energized (closed), provided no flight-path-trimming ground commands have been received (thereby energizing (closed) the Up, Right, or Left command relays (58-60)). The Down command relay, when closed, provides a torquing current to the pitch and yaw precession axis torquers via the cosine and sine resolver amplifier units (64,62) located in the forward controls can. These units apportion currents to both the pitch and yaw torquers to produce a gyro precession of 0.25 deg/sec in the trajectory plane, more or less independently of any vehicle roll attitude error. The vehicle is constrained to fly along a path which is programmed in the trajectory plane at the gyro precession rate.

Roll Jets Off

At T+21 seconds the GLM timer de-energizes the roll jet system and roll control is by fin tabs alone until T+90 seconds.

Cut-Off Armed

At T+30 seconds the NRL timer supplies voltage to the fuel and oxidizer pump outlet pressure switches, thus arming the normal cut-off initiation system.

Fuel Vents Closed

At T+60 seconds the GLM timer energizes the fuel tank vent relay (23) to the "unlatched" position where it is mechanically retained. This applies power to the electrically operated fuel tank vent valves (28, 29) which then close.

Pitch Program Terminated

At T+85 seconds the GLM timer de-energizes (open) the Down command relay, removing the vertical gyro torquer excitation and thereby stopping the pitch program. Attitude control in all three axes is then reinstated by the fixed reference thus established.

Roll Jets On

At T+90 seconds the GLM timer energizes the roll jet circuits, causing the roll jets to maintain the roll attitude in the region of diminishing dynamic pressure and resultant tab ineffectiveness. The GLM timer stops after conducting this final function.

Cut-Off

Exhaustion of fuel or oxidizer is expected to take place at approximately 105 seconds and will be sensed by the closing of the appropriate pump outlet pressure switch. The closing of either of these two switches once in the armed condition (T+30 seconds) will energize (closed) the propulsion cut-off relay (27) which is electrically self-holding, and energize the pressurizing relay and the fire relay to their "unlatched" positions where they are mechanically retained. In becoming "unlatched," the fire relay causes both the hydraulic and pneumatic peroxide valves' pilot valves to be de-energized (closed). These pilot valves, in closing, cause the flow of peroxide to the peroxide decomposer to cease, resulting in no further driving gas being admitted to the turbopump, and consequently in its deceleration. The resultant rapidly decreasing fuel and oxidizer pump outlet pressures bring about a decrease in the thrust chamber pressure and hence in the thrust. The spring-loaded fuel and oxidizer valves close when the propellant pressure has become sufficiently low, cutting off the propellant flow altogether. Although energizing power to the oxidizer tank and peroxide tank vent valves' pilot valves, which are maintaining the tank vents closed, is no longer supplied by the unlatched pressurizing relay, the energized propulsion cut-off relay takes over this function; thus no tank venting occurs upon cut-off. However, unlatching the pressurizing relay de-energizes (closed) the main gas regulator ending its regulated gas supply function. The oxidizer tank off-on pressure regulation system is also made non-operative.

Post Cut-Off Attitude Control

The propulsion cut-off relay (27) upon being energized (closed) causes the controls cut-off relay (4) in the main controls can to be energized (closed), thus energizing the pitch and yaw peroxide jet system (consisting of four autopilot-controlled solenoid valves which supply hydrogen peroxide to four small rocket motors whose high-velocity gas streams produce attitude-corrective thrust), and energizing the roll jet system if it has failed to become energized by the NRL timer at T+90 seconds (premature cut-off).

Minitrack Eject

At T+120 seconds the NRL timer provides power to the two bellows-contained squibs ("caterpillars") of the Minitrack transmitter ejection system, causing them to ignite and expand. Either squib alone is capable of withdrawing the releasing key, allowing the compressed spring to extend the carriage and eject the small sphere, with its "roll-up" antennas, which contains the Minitrack transmitter.

Separation Armed

At approximately T+122 seconds the NRL timer energizes (closed) the separation arming relay (113) in the forward controls can, thus preparing the vehicle for the subsequent inversion maneuver and nose-cone separation.

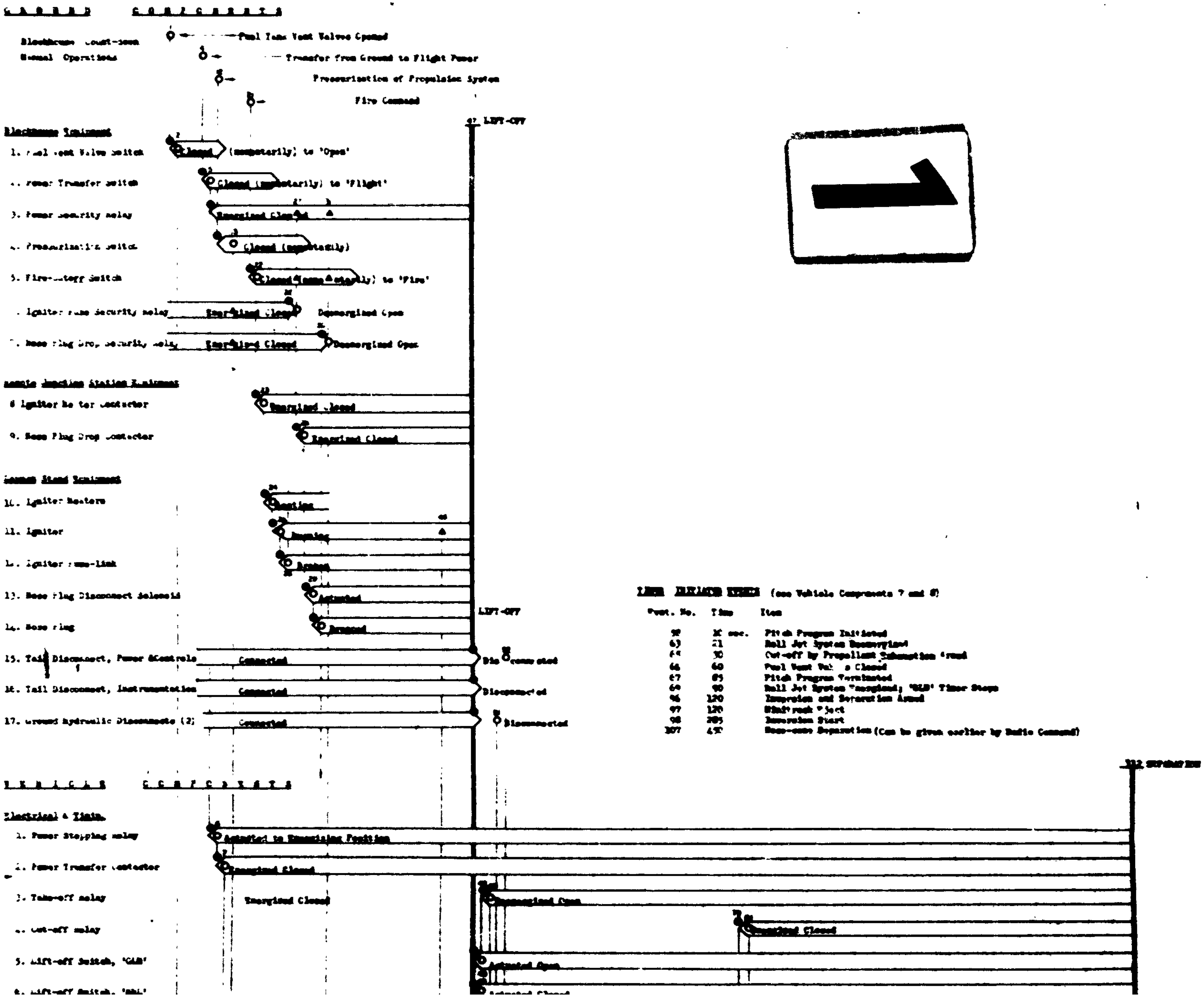
Inversion Maneuver

At approximately T+318 seconds the NRL timer causes the inversion start relay (114) to be energized (closed) and the time delay relay (115) to begin its delay period provided the inversion stop relay (117) is de-energized. These components are part of the vehicle's inversion maneuver system located in the forward controls can. The inversion start relay causes the fast-slow precession relay (55) to be energized (closed) in fast position, resulting in full voltage excitation of the vertical gyro pitch precession axis torquer and thus in maximum-rate precession of the vertical gyro about the vehicle's pitch axis. The jet attitude control system then rotates the vehicle in the pitch plane. After a slight angular displacement the increasing inversion gyro pitch signal output combined with the vertical gyro pitch signal in a mixing amplifier circuit, cause the sigma relay (116) to be de-energized. Following this the time delay relay reaches the end of its delay period and becomes energized, permitting the sigma relay, on becoming re-energized after the vehicle has attained the designated pitch orientation (nominally 163.9 degrees from the vertical), to energize (closed) the inversion stop relay. This de-energizes the inversion start and fast-slow precession relays, removing the vertical gyro pitch torquer excitation and re-establishing the vehicle in a constant-attitude-control state at the desired nose-cone re-entry angle.

Nose-Cone Separation

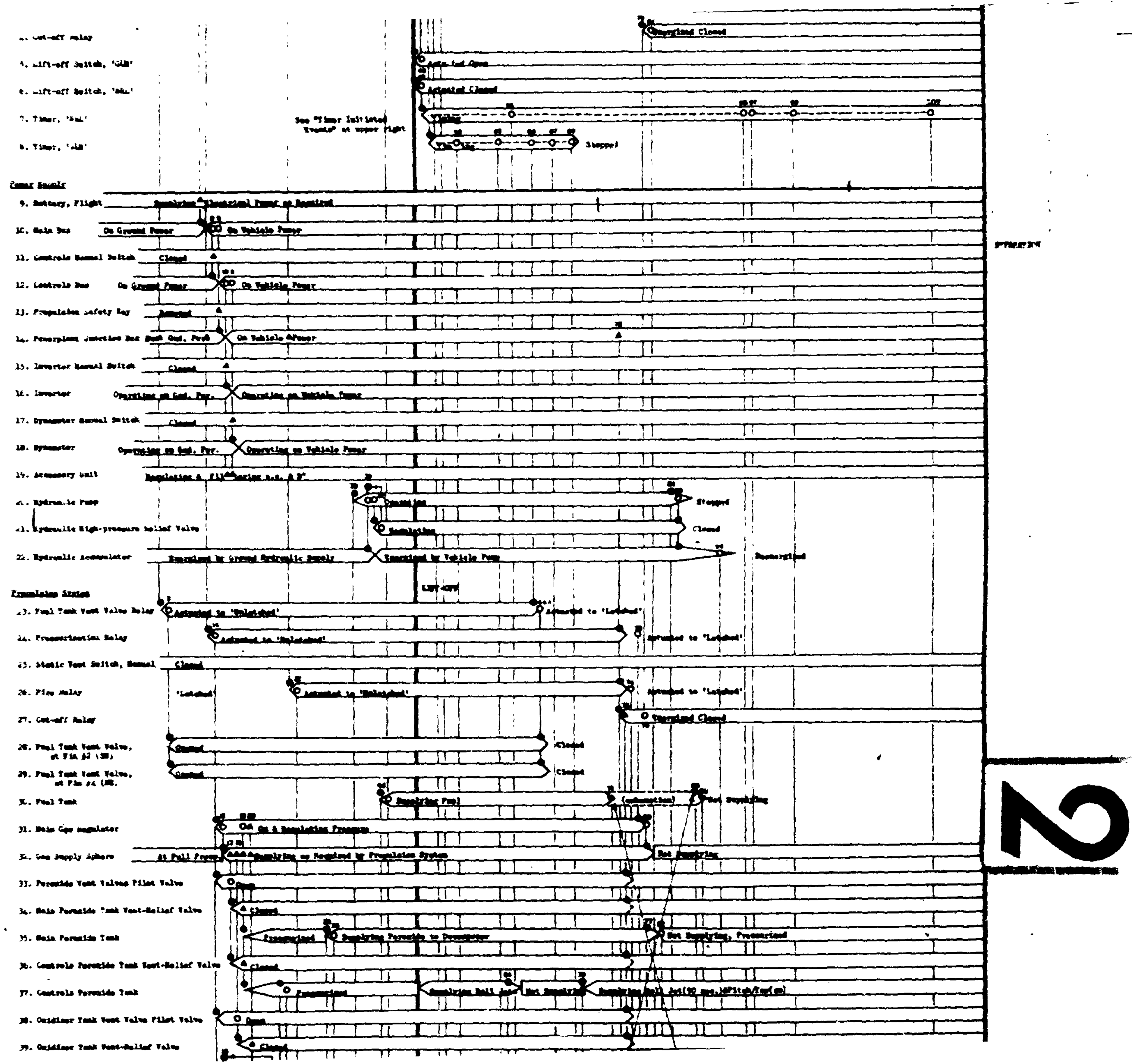
At T+463 seconds the NRL timer (provided a separation ground command has not been transmitted) causes the blow-off (separation) relay (119) to be energized (closed); this energizes the four nose-cone explosive bolts (120-123). When all four bolts have detonated, the compressed spring (124) separates the nose cone (126), breaking the electrical disconnects (125). The separated nose cone is thereby oriented for optimum re-entry, i.e., at a minimum angle of attack.

NAVY-DPPO PRNC. WASH. D C

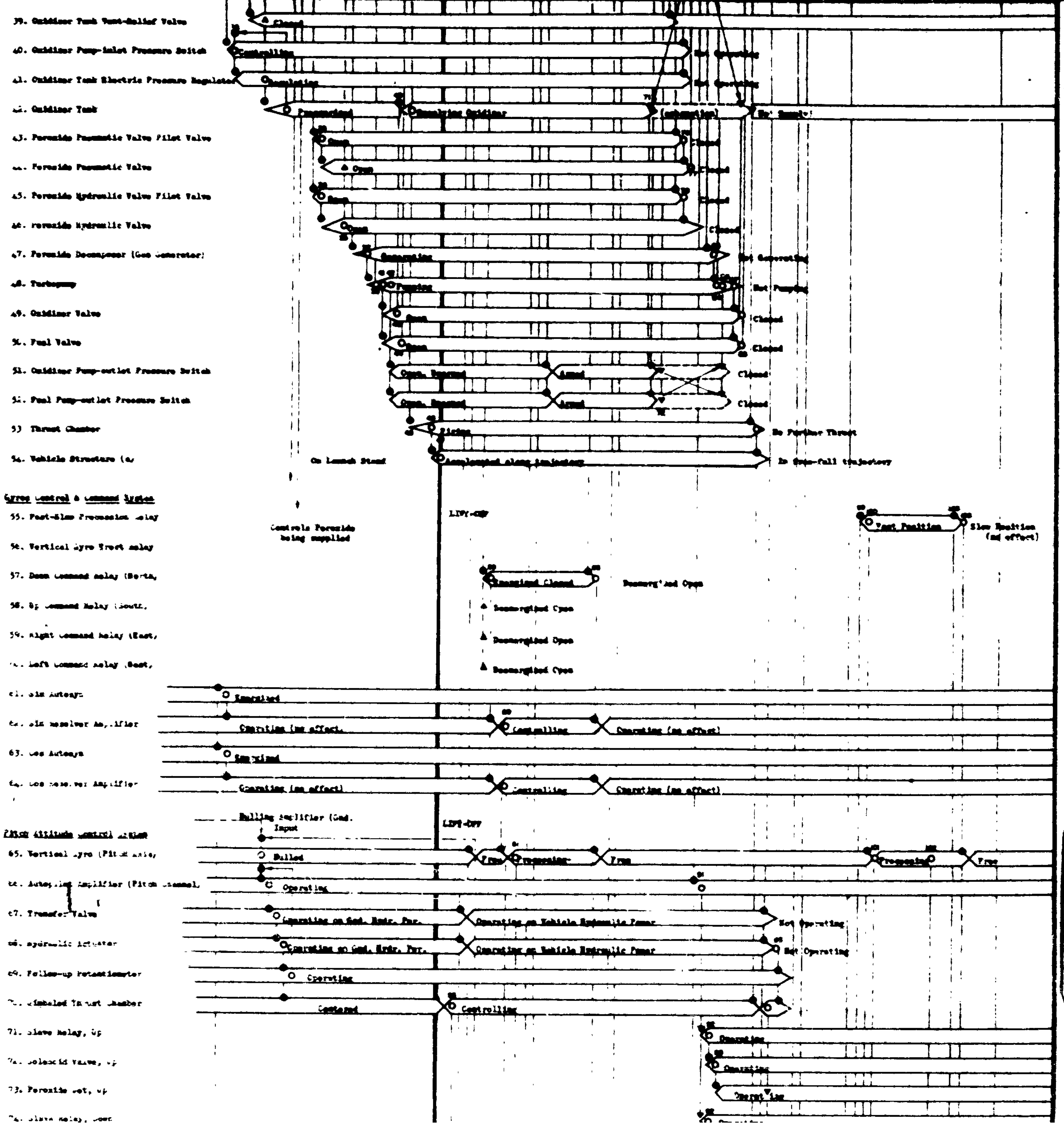


LATER FLIGHT EVENTS (see Vehicle Components 7 and 8)

Event. No.	Time	Item
[illegible]	[illegible] sec.	Pitch Program Initiated
63	21	Roll Jet System [illegible]
6[illegible]	30	Cut-off by Propellant Exhaustion [illegible]
66	60	Fuel Vent Val[illegible] Closed
67	65	Pitch Program Terminated
6[illegible]	90	Roll Jet System [illegible]; 'GAB' Timer Stops
96	120	Inversion and Separation Armed
97	120	[illegible] Eject
98	205	Inversion Start
107	4[illegible]	Nose-cone Separation (Can be given earlier by Radio Command)

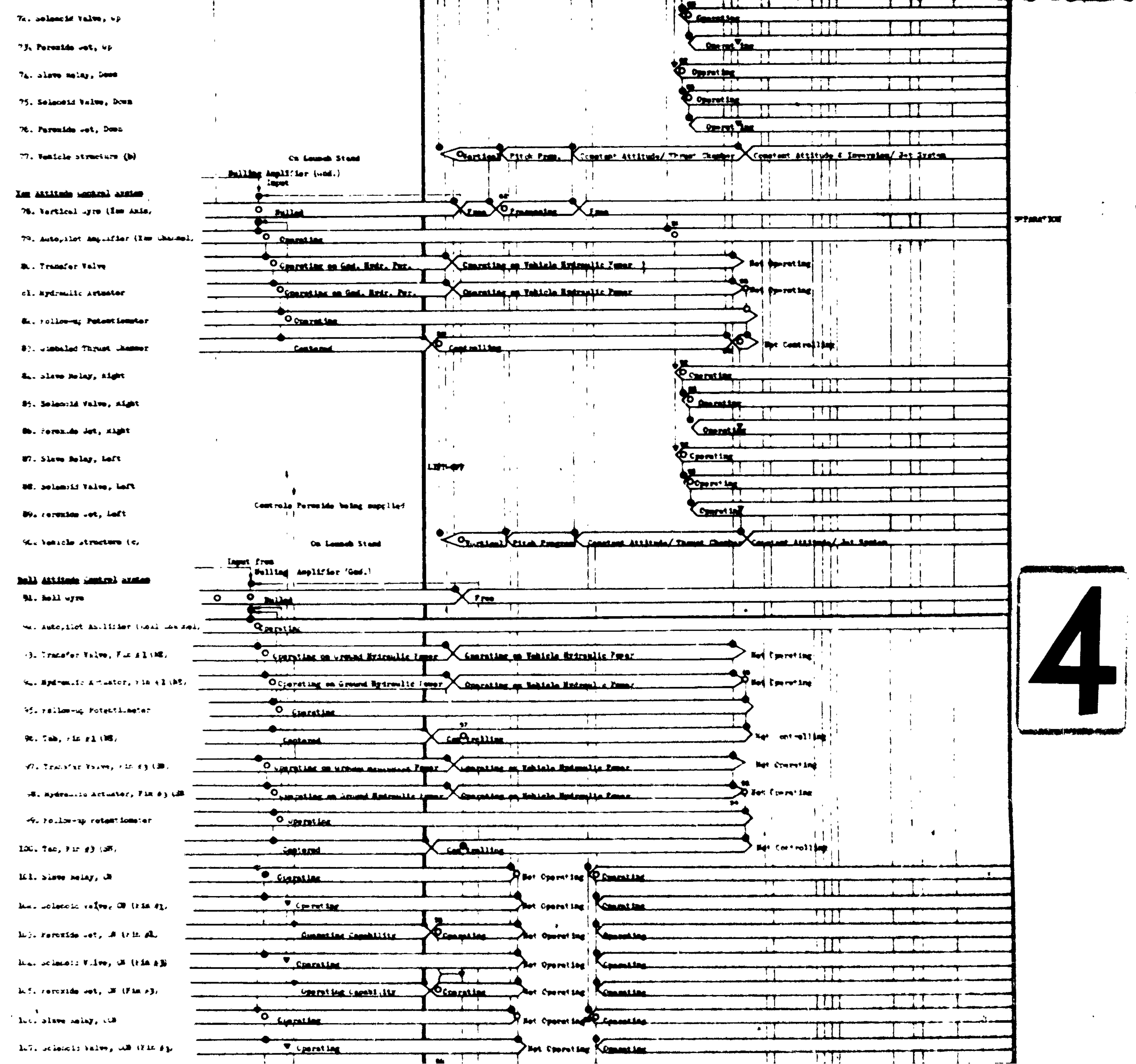


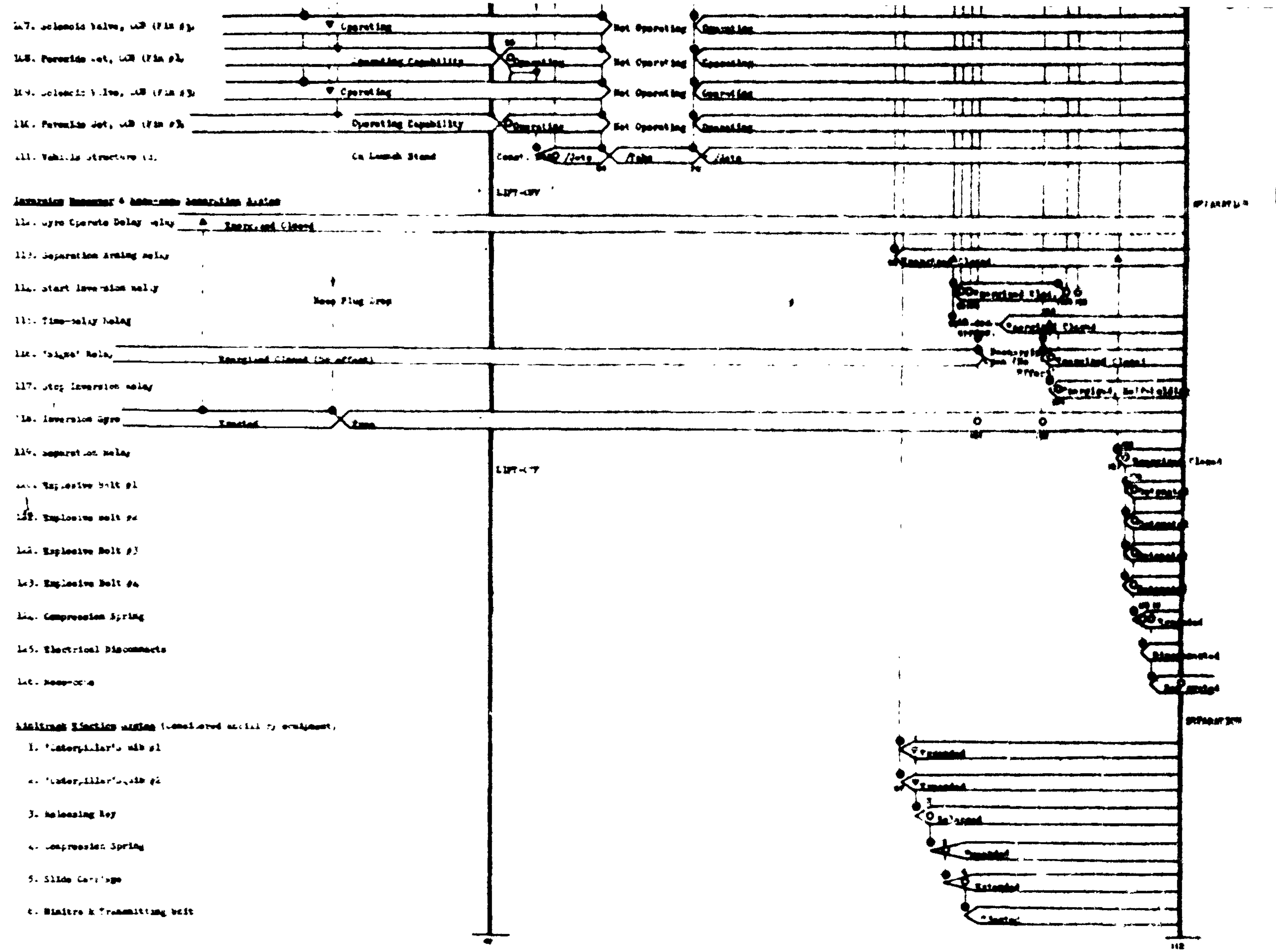
Power Supply
9. Battery, Flight
10. Main Bus
11. Controls Manual Switch
12. Controls Bus
13. Propulsion Safety Key
14. Powerplant Junction Box
15. Inverter Manual Switch
16. Inverter
17. Dynamotor Manual Switch
18. Dynamotor
19. Accessory Unit
20. Hydraulic Pump
21. Hydraulic High-pressure Relief Valve
22. Hydraulic Accumulator
Propulsion System
23. Fuel Tank Vent Valve Relay
24. Pressurization Relay
25. Static Vent Switch, Manual
26. Fire Relay
27. Cut-off Relay
28. Fuel Tank Vent Valve, at Fin #2 (3R)
29. Fuel Tank Vent Valve, at Fin #4 (3R)
30. Fuel Tank
31. Main Gas Regulator
32. Gas Supply Sphere
33. Peroxide Vent Valves Pilot Valve
34. Main Peroxide Tank Vent-Relief Valve
35. Main Peroxide Tank
36. Controls Peroxide Tank Vent-Relief Valve
37. Controls Peroxide Tank
38. Oxidizer Tank Vent Valve Pilot Valve
39. Oxidizer Tank Vent-Relief Valve
See "Timer Initiated Events" at upper right
LIFT-OFF
On Ground Power
On Vehicle Power
Closed
Energized Closed
Actuated Open
Actuated Closed
Stopped
Operating on Gnd. Pwr.
Operating on Vehicle Power
Energized by Ground Hydraulic Supply
Energized by Vehicle Pump
Deenergized
Actuated to 'Unlatched'
Actuated to 'Latched'
'Latched'
Supplying Fuel
(exhaustion)
Not Supplying
On & Regulating Pressure
At Full Press.
Supplying as Required by Propulsion System
Open
Pressurized
Supplying Peroxide to Decomposer
Not Supplying, Pressurized



39. Oxidizer Tank Vent-Relief Valve
40. Oxidizer Pump-inlet Pressure Switch
41. Oxidizer Tank Electric Pressure Regulator
42. Oxidizer Tank
43. Peroxide Pneumatic Valve Pilot Valve
44. Peroxide Pneumatic Valve
45. Peroxide Hydraulic Valve Pilot Valve
46. Peroxide Hydraulic Valve
47. Peroxide Decomposer (Gas Generator)
48. Turbopump
49. Oxidizer Valve
50. Fuel Valve
51. Oxidizer Pump-outlet Pressure Switch
52. Fuel Pump-outlet Pressure Switch
53 Thrust Chamber
54. Vehicle Structure (a)
Gyros Control & Command System
55. Fast-Slow Precession Relay
56. Vertical Gyro Erect Relay
57. Down Command Relay (North)
58. Up Command Relay (South)
59. Right Command Relay (East)
60. Left Command Relay (West)
61. Sin Autosyn
62. Sin Resolver Amplifier
63. Cos Autosyn
64. Cos Resolver Amplifier
Pitch Attitude Control System
65. Vertical Gyro (Pitch Axis)
66. Autopilot Amplifier (Pitch Channel)
67. Transfer Valve
68. Hydraulic Actuator
69. Follow-up Potentiometer
70. Gimbaled Thrust Chamber
71. Slave Relay, Up
72. Solenoid Valve, Up
73. Peroxide Jet, Up
74. Slave Relay, Down
Closed
Controlling
Not Operating
Regulating
Pressurized
Supplying Oxidizer
Open
Closed
Operating
Not Operating
Pumping
Not Pumping
Open, Unarmed
Armed
Firing
No Further Thrust
On Launch Stand
Accelerated along trajectory
In Free-fall trajectory
Controls Peroxide being supplied
LIFT-OFF
Fast Position
Slow Position (no effect)
Energized Closed
Deenergized Open
Energized
Operating (no effect)
Controlling
Nulling Amplifier (Gnd. Input)
Nulled
Free
Precessing
Operating on Gnd. Hydr. Pwr.
Operating on Vehicle Hydraulic Power
Centered

3


72. Solenoid Valve, Up
73. Peroxide Jet, Up
74. Slave Relay, Down
75. Solenoid Valve, Down
76. Peroxide Jet, Down
77. Vehicle structure (b)
Yaw Attitude Control System
78. Vertical Gyro (Yaw Axis)
79. Autopilot Amplifier (Yaw Channel)
80. Transfer Valve
81. Hydraulic Actuator
82. Follow-up Potentiometer
83. Gimbaled Thrust Chamber
84. Slave Relay, Right
85. Solenoid Valve, Right
86. Peroxide Jet, Right
87. Slave Relay, Left
88. Solenoid Valve, Left
89. Peroxide Jet, Left
90. Vehicle structure (c)
Roll Attitude Control System
91. Roll Gyro
On Launch Stand
Input from Nulling Amplifier (Gnd.)
Nulled
Free
Caged
Precessing
Operating
Operating on Gnd. Hydr. Pwr.
Operating on Vehicle Hydraulic Power
Not Operating
Centered
Controlling
Not Controlling
Vertical
Pitch Prog.
Constant Attitude/ Thrust Chamber
Constant Attitude & Inversion/ Jet System
Constant Attitude/ Jet System
Controls Peroxide being supplied
LIFT-OFF
SEPARATION
Operating on Ground Hydraulic Power
Operating Capability
4



LEGEND

- ○ Operations Causing
- ● Operations Effected
- ▲ Necessary Conditions
- ▼ Either/Or Relationship
- ● Control Loop Closure Point

(Connected by vertical Event Line)

- - - - Time Function
═ Component State
< Transient in Changing State

MASTER SEQUENCE DIAGRAM
PROJECT VANGUARD
TEST VEHICLE No 0 (TV-0)

FINAL ISSUE 21 DECEMBER 1956

5

FR 4748 - AD C 343044
4767 - AD O 341439
4728 - AD O 342793
4717 - not in DTIC
4800 - AD C 342755
4815 - AD C 342991
4860 - AD 0 342505
4880 - AD C 343187
4890 - AD O 343093
4900 - AD C 342883
4910 - AD O 343031
4930 - AD O 342912
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Judi Griffin
(202) 767-3425
Judi.griffin@nrl.nvy.mil

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