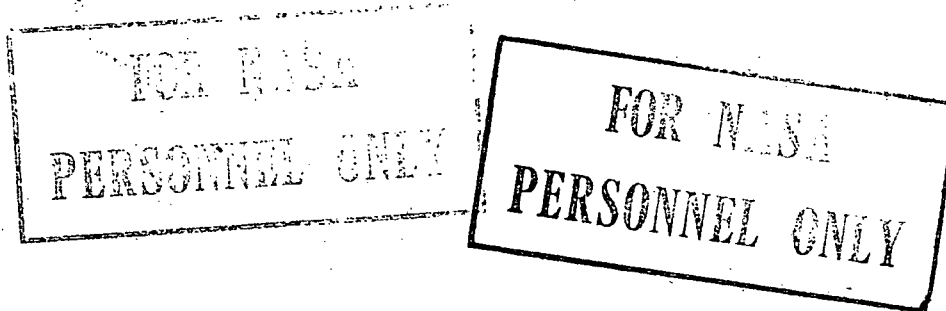


## NASA PROGRAM GEMINI WORKING PAPER NO. 5050

SPACECRAFT 8 ATTITUDE CONTROL  
ANOMALY REPORT

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HOUSTON, TEXAS

JUNE 27, 1966

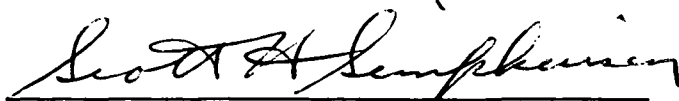
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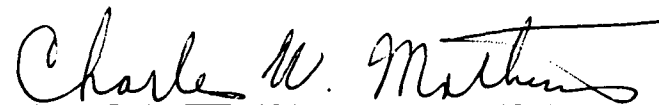
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NATIONAL AERONAUTICS AND SPACE ADMINISTRATION  
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HOUSTON, TEXAS  
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## FOREWORD

The attitude control anomaly which occurred on the Gemini VIII mission became the focus of attention of many Manned Spacecraft Center and vehicle contractor personnel. The authors sincerely acknowledge the contributions of the personnel who participated on the Mission Evaluation Team, and in the testing, analyses, and planning of design modifications and procedural changes for subsequent flights. To a considerable measure, this document is a report of their contributions. In addition to the basic work accomplished by a large number of people, the following personnel assisted directly in the documentation of this report:

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## CONTENTS

| Section                                      | Page |
|----------------------------------------------|------|
| FOREWORD . . . . .                           | iii  |
| 1.0 PURPOSE . . . . .                        | 1    |
| 2.0 SUMMARY . . . . .                        | 1    |
| 3.0 DESCRIPTION OF EVENTS . . . . .          | 1    |
| 4.0 DISCUSSION OF ANALYSIS RESULTS . . . . . | 2    |
| 5.0 ACTION TAKEN . . . . .                   | 5    |
| 5.1 Spacecraft Tests . . . . .               | 5    |
| 5.2 Systems Analyses . . . . .               | 6    |
| 5.3 Quality Evaluation . . . . .             | 9    |
| APPENDIX A . . . . .                         | A-1  |
| APPENDIX B . . . . .                         | B-1  |
| APPENDIX C . . . . .                         | C-1  |
| APPENDIX D . . . . .                         | D-1  |
| APPENDIX E . . . . .                         | E-1  |

## TABLES

| Table |                                          | Page |
|-------|------------------------------------------|------|
| I     | SUMMARY OF POSTULATED FAILURES . . . . . | 12   |

## FIGURES

| Figure |                                                                                                                                                       |    |
|--------|-------------------------------------------------------------------------------------------------------------------------------------------------------|----|
| 1      | OAMS Propellant consumption during TCA 8<br>quiescent period . . . . .                                                                                | 16 |
| 2      | Electrical circuitry associated with TCA 8 . . . . .                                                                                                  | 17 |
| 3      | Circuit conditions necessary in order for a single<br>high-resistance short circuit to allow the oxidizer<br>solenoid valve only to be open . . . . . | 18 |

## 1.0 PURPOSE

The purpose of this report is to document (1) the characteristics of the Spacecraft 8 attitude control anomaly; (2) the analyses which were undertaken to identify the cause of the anomaly; (3) the results of the analyses; (4) the action taken to avoid a recurrence of the anomaly; and (5) the procedures established to effect rapid vehicle control by the crew in the event of a recurrence of this anomaly on future spacecraft.

## 2.0 SUMMARY

The Spacecraft 8 Orbital Attitude and Maneuver System (OAMS) thrust chamber assembly (TCA) 8 started to fire in an uncontrolled and intermittent manner while the spacecraft was docked with the Gemini Agena Target Vehicle (GATV). By undocking the two vehicles, the crew isolated the problem to the spacecraft, and they regained control by opening the circuit breakers to remove power from the OAMS and by activating and using the Reentry Control System (RCS). Analysis reveals that the probable cause of the thruster firing was a short circuit to spacecraft ground which allowed current to flow through the thruster valve solenoid coils, thus causing them to open the poppet valves. The intermittent nature of the fault has not been clearly established, but it may have resulted from an intermittent short circuit or a combination of short-circuited and open-circuited wires.

## 3.0 DESCRIPTION OF EVENTS

The Gemini VIII attitude control anomaly occurred during revolution 5, approximately 26 minutes after docking, and while the spacecraft was out of range of network stations and tracking ships. Prior to the anomaly, the GATV was commanded by the flight crew to yaw the docked vehicles 90°. This maneuver was successfully completed in 55 seconds and with a yaw rate very close to the normal 1.5 deg/sec.

At 7:00:00 ground elapsed time (g.e.t.), the docked spacecraft-GATV combination had been configured for the platform parallelism test, the Attitude Control System (ACS) was in flight control mode 3, and the GATV recorder had been turned on by a command from the flight crew. At 7:00.26.7 g.e.t., roll and yaw rates began to develop without the crew detecting any visual or audible evidence of spacecraft thruster firing. In an attempt to isolate the source of the anomaly, the GATV ACS was deactivated by a command from the crew, and the spacecraft OAMS was

activated in the pulse mode at 7:00:38.2 g.e.t. From 7:00:38.2 to 7:10:55 g.e.t., the crew attempted to control the spacecraft by utilizing the Attitude Control and Maneuver Electronics (ACME) in direct, rate command, and pulse modes without being able to completely stabilize the docked vehicles. Thruster 8 either ceased to fire, or operated at a low thrust level for 4 minutes 42.9 seconds during this 10-minute period. This further complicated the task of isolating the cause of the anomaly.

The GATV ACS was again commanded on to determine if the GATV thrusters would reduce the angular rate. No improvement was noted and the ACS was turned off at 7:12:38.6 g.e.t. The crew, in an effort to isolate the problem, switched to secondary Attitude Control Electronics (ACE) but with no apparent success. At 7:15:12.3 g.e.t., after the crew had determined that all attitude rates had been sufficiently reduced to avoid recontact, the vehicles were undocked by using the OAMS forward-firing thrusters for separation.

After undocking, the angular rates immediately started to increase, thus verifying that the problem was in the spacecraft attitude control system. As rates increased to 30 deg/sec, the crew selected the OAMS rate command mode. Rates were slightly reduced; however, the ACME bias power was inadvertently interrupted and this deactivated all control of the spacecraft but left TCA 8 firing. As rates began increasing toward a level of 300 deg/sec, the crew activated the RCS in the previously selected rate command mode; however, with no ACME bias power, no control could be obtained. Subsequently, the OAMS circuit breakers were opened; the RCS was placed in DIRECT-DIRECT, which did not require ACME; and the rates were controlled using both rings of the RCS. After the crew determined that control was available with the RCS in DIRECT-DIRECT, the RCS A-ring was turned off. Use of the RCS B-ring slowly decreased the angular rates and the spacecraft was finally brought to a stable attitude at 7:25:30 g.e.t. Response in the other control modes was then regained by resetting the ACME circuit breakers and switches. Control of the spacecraft with the OAMS was later reestablished after TCA 8 had been deactivated by placing its circuit breaker in the open position.

#### 4.0. DISCUSSION OF ANALYSIS RESULTS

The failure to maintain attitude control was characterized by a "thruster on" condition of the spacecraft OAMS TCA 8. Prior to the anomaly, no inadvertent thrust had occurred; and at the onset of the problem the valves were closed, and the OAMS control power was off. In this configuration, the ACME system is disabled and should not signal any thruster to fire. A mechanical failure would require the highly unlikely opening of the independent oxidizer and fuel valves at the same instant and against their respective closing springs and system

pressure. In the following discussion, it should become clear that the cause of the inadvertent firing was a short circuit to spacecraft ground in the circuitry between the Orbital Attitude and Maneuver Electronics (OAME) package and the thruster valve solenoid coils.

The following information is presented as being pertinent to the analysis of the problem:

(a) At 7:00:26.785 g.e.t., TCA 8 turned on for 4.9 seconds, turned off for 4.0 seconds, and then turned on again. The thruster on-off telemetry data and the rate-gyro telemetry data verified this condition. At 7:00:38.285, the OAMS was activated to stabilize the docked spacecraft-GATV combination. The telemetry data indicated that TCA 8 stayed on for the remainder of the mission. However, the rate-gyro telemetry data indicate that at 7:02:37.4 TCA 8 either stopped thrusting or the thrust level was sharply reduced. There was evidence of a continuing low level of constant thrust. TCA 8 remained in this mode until 7:07:20.3 g.e.t., at which time the rate-gyro data indicate that TCA 8 resumed operation with a full thrust and that it continued operating until the circuit breaker was opened at approximately 7:18:15 g.e.t., although some variations in its thrust level occurred immediately subsequent to undocking. During the 4-minute 42.9-second interval that TCA 8 was inoperative or was thrusting at a very low level, the rate-gyro telemetry data show periods of roll-left and yaw-left acceleration without any other thruster being active. This acceleration is in the range of that which could be caused by TCA 8 expelling only oxidizer.

(b) Figure 1 depicts for the period of degraded thrust, a comparison of propellant usage calculated from propellant temperature and pressure parameters with propellant usage calculated from thruster activities during the same period. Three curves are portrayed. The first curve is based on the measured thrust activity of TCA's 1 through 7 and assumes that both the fuel and the oxidizer valves of TCA 8 were closed. The second curve is based on the same activity of TCA's 1 through 7 plus a continuous flow of oxidizer only from TCA 8 during this period. The third curve includes flow of both oxidizer and fuel and is included to aid in the interpretation of the other two curves. (Based on rate data, the third curve is not a possible mode of TCA activity.) The effect of temperature on flow rate has been included in the calculation of the data. Based on the data, it is evident that no conclusion may be drawn which eliminates or confirms either hypothesis. However, when the rate data are considered, and in view of completely nominal GATV operation for the rest of the mission, it must be acceded that this degraded thrust probably originated from the spacecraft and, more precisely, from TCA 8.

(c) Normal operation of the OAMS thrusters is obtained by continuously applying 24 V dc to one terminal of the thruster valve solenoids

and grounding the other terminal through the OAME. Each OAMS thruster is operated by simultaneously energizing the fuel and oxidizer solenoid valves with one transistorized valve driver in the OAME package. The grounding circuit is shown in figure 2.

Enclosures 1 through 4 are extracted sections of the Gemini VIII Mission Report and provide a detailed analysis of the respective operations and systems related to the anomaly in support of the contents of this report:

- (a) Pilots Report - Appendix A
- (b) Guidance and Control - Appendix B
- (c) Propulsion System - Appendix C
- (d) Electrical System - Appendix D

The possible causes of the control anomaly have been carefully weighed and considered in a detailed study of all available data including the results of investigative action taken as detailed in Section 5.0 of this report. A set of postulated failures has been derived and table I is a listing of these postulated failures in relation to the known factors and the sequence of events for the anomaly. Most of the possible causes are ruled out on the basis of inconsistency with all known factors, although each could provide a solution to some of the factors involved. These possibilities are separately listed in table I a. Based on evidence uncovered to date, the most probable cause is that a short circuit occurred either at the four-wire junction or between this junction and the fuel-valve solenoid. This was probably followed with a rupture of wire so that the wire from the solenoid became open circuited while the other end of the ruptured wire remained short circuited to ground during the degraded thrust period. Finally, the open-circuit wire was again recontacted and remained short circuited at least until the circuit breaker was opened.

It is noted that if the low-level continuous thrust during the quiescent period is attributed to some cause other than the flow of oxidizer only from TCA 8, the probability of the above solution of the anomaly is not materially affected. The factors, (1) a continuous telemetry indication of TCA 8 being on, (2) the inability to fire the TCA 8 thruster on command, and (3) the failure of attempted thruster operation using either the primary or the secondary drive circuits of the ACME, are effective in limiting the anomaly to an area between the four-wire junction and either the fuel or oxidizer-valve solenoid.

## 5.0 ACTION TAKEN

The following is a summary of investigative actions taken as a result of the spacecraft anomaly and the results of each action. Also included is a summary of preventive measures which have been accomplished and a listing of procedures which have been formulated to assure recovery of spacecraft control in the event of a similar occurrence.

### 5.1 Spacecraft Tests

A series of tests to investigate the OAMS thruster anomaly were conducted on Spacecraft 8 during the postflight evaluation at the contractor's facility. These tests were conducted in response to Spacecraft Test Requests (STR's) written during the evaluation. Additional tests were conducted on equipment similar to that installed in the Spacecraft 8 adapter equipment section which was not recovered.

5.1.1 Propulsion (STR's 8030 and 8513).— Six solenoid valves were dissected and visually inspected to evaluate the quality of the wiring insulation and potting. Four of these valves were removed from TCA's 5B and 3A of the Spacecraft 8 RCS. TCA 5B was selected because it was manufactured at approximately the same time as the OAMS TCA 8. The other two valves inspected were selected at random from scrapped valves located at the Manned Spacecraft Center and at the spacecraft contractor's plant.

The valves and the electrical risers were sectioned and inspected and no indication of poor quality or any other abnormality that would contribute to a solenoid-valve malfunction was found.

Two TCA propellant valves with the same configuration as those on Spacecraft 8 were subjected to a series of functional and high-potential dielectric-strength tests to determine the effect of usage on dielectric characteristics. The valves tested had accumulated a total of 1230.6 seconds of firing time and 25 100 valve cycles. These valves proved to be unaffected by their previous usage. In addition, a 1000 V ac dielectric test was employed rather than the normal 500 V ac test.

5.1.2 Hand controller and attitude control system (STR's 8034 and 8503).— An analysis of the attitude hand controller was performed to isolate any abnormal condition. The Pre-installation Acceptance (PIA) test of the hand controller revealed some force measurements that were out-of-specification; however, no wiring problems existed inside the handle. When the cover was removed, the performance of the PIA test yielded handle forces within specification tolerances. The investigation was continued to verify continuity of the wiring and control switches in the

attitude control system. The cover of the ACE package was removed before starting the test. Evidence of salt-water corrosion and arcing were visible. The tests were performed using the Aerospace Ground Equipment (AGE) connectors to the maximum extent possible. Some abnormal readings were encountered, but later these were resolved as having been caused by the condition of the ACE package. During the next tests, the flight wires were disconnected from the ACE and their continuity to the spacecraft wiring was checked. No abnormal readings were found. The evidence of arcing in the ACE indicated that the ACME control 1 and 2 circuit breakers may have been on at landing. The results of these tests indicated no anomalies in the spacecraft reentry-section wiring.

5.1.3 Electrical wire bundle clamps.- A detailed evaluation of the wiring was conducted to investigate the condition of cable clamps and wire-bundle chaffing protection. Ten areas were investigated where wire-bundle clamps were close to wire-bundle branch segments. Wire bundles with bent radii under clamps were particularly selected. The areas were photographed and the clamps were then removed to inspect for damage to wire bundles caused by clamping. No damage was found. Clamp cushions were also examined for cold flow and the results were negative.

## 5.2 Systems Analyses

5.2.1 Propulsion system.- A review of valve design, testing procedures, and system tests was conducted. Acceptance test data for TCA 8, and the history-of-failure records of all Gemini thruster solenoid valves during manufacturing, development, qualification, and reliability testing were examined. The probability that the failure can be attributed to a short circuit within the valves is considered remote.

The coil windings are insulated from the bobbin by two layers of mica and a silicon varnish in addition to the wiring insulation. The coil is insulated from the valve case by fiberglass wrappings and silicon varnish. The coil lead wires are insulated by Teflon sleeving in addition to the normal insulation and are also potted with Sylgard in the valve riser to within a very short distance of the solder pins on the electrical receptacle. Soldered connections to the receptacle are protected by Teflon sleeves extending from the receptacle into the potting compound.

A review of all pertinent valve test results for this thruster was accomplished and no unusual data were noted. Each valve of this type received a 1000-volt rms dielectric-strength test, a 500-V dc insulation-resistance check, and a coil-resistance test after completion of solenoid assembly. These tests were then repeated during acceptance testing except that a 500-V rms level was used during the dielectric test. Coil-resistance and dielectric-strength (500-V rms) tests were

conducted again during engine pre-delivery acceptance and in PIA testing. During all 500-V rms dielectric-strength tests, the potential was applied for 1 minute with an allowable maximum current of 500  $\mu$ A. The minimum allowable insulation resistance is 500 M $\Omega$ . During dielectric-strength testing performed in PIA tests, the flow of current between the pins of the electrical receptacle and the oxidizer valve case was 47  $\mu$ A, and similarly for the fuel valve, the current was 39  $\mu$ A. The coil resistances were 43.1 ohms and 42.7 ohms on the oxidizer and fuel valves, respectively, and were within the 42 ( $\pm$ 2) ohm limits. X-rays taken during manufacturing of the fuel and oxidizer valves for TCA 8 show that these valves were assembled normally in the riser to the receptacle, the most suspected area.

Relevant valve failures encountered on all configurations (25 and 100-pound thrusters) and modifications (Spacecraft 2 through 6 types) were reviewed by the spacecraft contractor, the thruster manufacturer, and the NASA. These revealed only one failure which could have produced the anomaly. A metal chip between the coil and solenoid case caused a short circuit which would have had the effect of either grounding the power supply or of actuating the valve, depending upon attachment of the coil lead. This type of failure would normally be detected by means of the dielectric-strength tests; however, this particular valve did not have the chip and burr controls that were exercised on the valves used for Spacecraft 4 and subsequent spacecraft. The sample size investigated was in excess of 2000 valves. During pre-delivery acceptance testing, a total of 11 thrusters were rejected for failure to pass the dielectric requirements previously discussed. None of these thrusters were ever close to the point of indicating an incipient short circuit to ground.

5.2.2 Attitude control and maneuver electronic (ACME).— The OAME circuitry was reviewed and it was determined that a short circuit in the driver transistors or in the circuitry between the driver transistors and the output or AGE terminal connectors (connectors 5J2 and J1 — see fig. 2) could cause TCA 8 to fire. A malfunction in other portions of the ACME could cause inadvertent thruster firings, but would fire a pair of thrusters rather than a single thruster.

This analysis limited the area of possible failure within the OAME to the following:

- (a) A short circuit in relay K106
- (b) A short circuit in diode CR20
- (c) A short circuit to ground in the wiring connecting relay K106, diodes CR20 and CR3, and the pin in connector 5J2 leading to the thruster 8 solenoid valves

- (d) A short circuit in the wiring leading to AGE terminal J1
- (e) A short in the driver transistors.

The crew reported they had switched from the primary to the secondary drivers. If this action were accomplished while the OAMS power switch was turned on, it would eliminate the driver transistors and the circuit between the driver transistors and relay K106 as suspect.

Any of the five possible short circuits previously listed would normally activate both the oxidizer and fuel solenoids, and would simultaneously cause a telemetry indication of thruster ON. An interruption of this short circuit would cause both solenoids to drop out and close the fuel and oxidizer poppet valves. The same interruption would cause a telemetry thruster-off indication.

If it were possible to have a high-resistant short circuit in the OAME package that would cause the fuel solenoid to drop out without affecting the oxidizer solenoid, the resultant voltage at the input to the telemetry system high-level multiplexer would be greater than the 5- to 11-V minimum required to cause a telemetry indication of TCA 8 off. This is illustrated in figure 3. There were periods positively established during the anomaly, when the telemetry indicated a thrusting and no acceleration resulted. Because the telemetry data are not consistent with the known factors, the only possibility that the OAME package caused the Gemini VIII anomaly would have to include a simultaneous and separate failure in the telemetry system high-level multiplexer or associated wiring which resulted in the continuous telemetry indication of TCA 8 being on. The failure history of the components were reviewed and no failures were recorded which could result in a short circuit to ground. The Spacecraft 8 OAME had no failures during buildup, or pre-delivery acceptance, or PIA testing. There were no ACME problems during Spacecraft Systems Tests (SST). Component installation drawings and procedures were reviewed in detail to determine if a probability for misinterpretation existed. All drawings and procedures were found to be adequate.

The system was then reviewed to determine if improvements were required or could be effected. It was decided to coat all exposed electrical circuitry in the OAME package with a soft epoxy conformal coating to prevent the occurrence of an electrical short by foreign material being introduced into the OAME package. There is no history of any foreign material having been found in any OAME package; however, the coating would guard against this eventuality.

5.2.3 Instrumentation system.- The design of the PCM high-level multiplexer (which accepts the TCA 8 on-off inputs) and its associated connectors and wiring was reviewed.

The design of the modules and printed circuit boards surrounding the parameter module in question was investigated to determine the possible existence and characteristics of ground circuitry or mechanical structure in the proximity of the signal circuits.

The TCA input is isolated from the instrumentation system by a 105 000-ohm resistance. The cable area containing the wiring from the input connectors to the Microdot connectors was investigated. All shielded wiring within this section has an outer cover of transparent insulation. The entire cable area is filled with high-density foam potting which presents any relative motion between wires, connectors, and structure. The modules are also foam potted to the individual mother boards, and the mother boards are separated with a layer of approximately 1/16 inch of mica-mat and mylar insulation board.

A review of the failure history of the connectors involved revealed that six failures of this type connector had occurred. In one of the failures, two pins broke off within the connector; this condition was detected when the connector was demated. The remaining five failures were caused by misalignment of the connector pins when the connector was mated. As a result of this misalignment, the affected pin was crushed within its individual pin well. None of the recorded failure modes of these connectors displayed any tendency to expose the faulty pin to other circuitry in the vicinity or to ground. Any failure which existed prior to launch and which would result in an open-circuited or short-circuited connector pin will be detected by normal testing.

Nothing was found in the design of the instrumentation system which would be suspected of causing an anomaly such as that experienced on Spacecraft 8.

### 5.3 Quality Evaluation

5.3.1 Test histories.- A list of postulated failure modes was derived as part of the anomaly investigation. The test histories of components which could contribute to postulated failure modes were reviewed to determine if there was any history of failures similar to the postulated failure modes. The results of this analysis was negative. The only spacecraft system test failures similar to the Gemini VIII postulated failures were experienced during the SEDR 371-4 and 383-7 tests. In both instances, test histories of TCA's indicated inadvertent firings caused by cable clamps short circuiting a wire bundle.

5.3.2 Special evaluation of quality control.- A special quality evaluation of the spacecraft wiring was conducted on the Spacecraft 6 and Spacecraft 7 reentry sections and on the Spacecraft 9 adapter-assembly electrical harnesses. The purpose of these evaluations was to

determine the adequacy of the quality of the wiring harness, the wire protective techniques, the inspection criteria, and the effectiveness and timeliness of the wiring-harness inspections. The following are examples of some of the discrepant conditions that were found:

(a) Wire bundles laying against structure edges, rivet heads, nuts, bolt heads, and coaxial-cable fittings. In these cases, neither the wire bundle nor the edge, et cetera, was covered to prevent contact and consequent wire insulation damage.

(b) Excessively long ground wires

(c) Wire breakouts from wire bundles where the wire broken out was under tension

(d) Excessive harness lengths.

As a result of this evaluation, the following actions were taken:

(a) Reworked discrepant conditions in Spacecraft 9 adapter assembly

(b) Established more stringent criteria for wire installation and inspection

(c) Established a formal physical spacecraft inspection, prior to shipment, to reinforce in-process inspection during spacecraft fabrication

(d) Established a more rigid spacecraft receiving inspection at Kennedy Space Center and implemented formal shakedown inspections at specific milestones in the preflight test plan

(e) Established a special NASA spacecraft acceptance inspection team to perform detailed spacecraft inspections with the results of these inspections being reported at the Spacecraft Acceptance Review (SAR) Board meetings.

Ground rules covering critical wiring installation aspects were documented and coordinated between the NASA Gemini Program Office and the spacecraft contractor. Beginning on April 28, 1966, approximately 200 contractor personnel involved in the manufacturing, inspection, and engineering of the Gemini spacecraft are being refamiliarized with these ground rules in 4 hours of class training each.

5.3.3 Design changes.- Design changes resulting from the Spacecraft 8 anomaly investigation were as follows:

(a) OAMS thruster disabling: A single switch which will provide the crew with a rapid means of disabling all OAMS thrusters has been incorporated into the OAMS circuitry.

(b) Circuitry protection: All exposed electrical circuitry in the OAME package has been coated with a soft conformal epoxy to protect against possible inadvertent electrical short circuits.

(c) Wiring configuration: Grommet material has been added to the structure in six general areas to increase clearance of wire bundles. The Z-103 fairing has been trimmed to increase clearance between the fairing and the wire bundle. Engineering orders have been issued to remove the tape from the TCA heater and solenoid wiring.

(d) Wire-bundle changes: Specially selected clamps are being used exclusively for Gemini wire-bundle retention.

5.3.4 Flight procedures.-- Flight procedures have been re-evaluated and revised to provide the crew with optimum operating procedures for all known possible flight emergencies. A copy of these procedures is attached as Appendix E.

TABLE I.- SUMMARY OF POSTULATED FAILURES

a. Postulated failures not considered to be possible causes of attitude control anomaly

| Item no. | Postulated failure                                                                    | Remarks                                                                                                                                                                                                                                                                                                                                                            |
|----------|---------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1        | OAME diode CR20 short-circuited internally                                            | (a) <u>Period of degraded thrust due to flow of oxidizer only:</u><br>This failure cannot cause indications of thruster firing when the thruster is off, nor does it allow for degraded thruster performance (one solenoid operating separately). Furthermore, a diode junction short circuit is not usually intermittent.                                         |
|          |                                                                                       | (b) <u>Period of degraded thrust not due to flow of oxidizer only:</u><br>This failure does not allow a telemetry indication of thruster on when the thruster is not firing.                                                                                                                                                                                       |
| 2        | OAME diode CR20 case short-circuited to ground                                        | (a) <u>Period of degraded thrust due to flow of oxidizer only:</u><br>This failure could be an intermittent short-circuit which would cause on-off operation but could not cause degraded operation or a telemetry indication of thruster on when thruster was not firing. This failure also does not allow for failure of the thruster to fire when commanded ON. |
|          |                                                                                       | (b) <u>Period of degraded thrust not due to flow of oxidizer only:</u><br>This failure does not allow for a telemetry indication of thruster on while thruster was off or for the failure of the thruster to respond to ON commands during this period.                                                                                                            |
| 3        | OAME relay K106 armature short-circuited                                              | Same remarks as item 2                                                                                                                                                                                                                                                                                                                                             |
| 4        | OAME internal wiring short-circuited to ground                                        | Same remarks as item 2                                                                                                                                                                                                                                                                                                                                             |
| 5        | OAME primary valve-driver transistor Q16 short-circuited                              | Same remarks as item 2 except that, in addition, the crew reports that they selected secondary valve-drivers. This would require that transistor Q14 also be short-circuited or that the secondary system was selected for a small interval of time such that evidence of improvement was not noticeable.                                                          |
| 6        | Wiring short-circuited to ground between OAME connector J1, pin I, and connector 700Y | Same remarks as item 2                                                                                                                                                                                                                                                                                                                                             |

TABLE I.- SUMMARY OF POSTULATED FAILURES - Continued

a. Postulated failures not considered to be possible causes of attitude control anomaly - Continued

| Item no. | Postulated failure                                                                                                                                                                                                                                                                                                         | Remarks                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7        | Wiring short circuited to ground between TCA 8 ground side and OAME connector J2, pin W                                                                                                                                                                                                                                    | Same remarks as item 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 8        | Instrumentation high-level multiplexer TCA 8 on-off input short circuited to ground                                                                                                                                                                                                                                        | Same remarks as item 2                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 9        | Instrumentation high-level multiplexer TCA 8 on-off input wire broken and short circuiting intermittently to ground                                                                                                                                                                                                        | <p>(a) <u>Period of degraded thrust due to flow of oxidizer only:</u><br/>This failure does not allow for degraded operation with only one solenoid operating.</p> <p>(b) <u>Period of degraded thrust not due to flow of oxidizer only:</u><br/>This failure would permit intermittent operation of thruster and a telemetry indication of thruster on with thruster not firing, but does not allow for failure of the thruster to fire when commanded ON.</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
| 10       | One of the TCA 8 solenoid valves internally short circuited to ground. The short circuit was intermittent at first, then changed to short out more of the coil winding such that one solenoid became de-energized. The short circuit later returned to the original configuration and both solenoid valves were energized. | <p>(a) <u>Period of degraded thrust due to flow of oxidizer only:</u><br/>This failure does not agree with all telemetry data because a short circuit which would short out a portion of the coil windings sufficient to deenergize the solenoid would cause an increase in common control bus current, and a corresponding drop in voltage. The common control bus voltage, however, increased during this period as shown by telemetry data. Also, the construction and insulation of the solenoid is such that an internal short circuit is unlikely.</p> <p>(b) <u>Period of degraded thrust not due to flow of oxidizer only:</u><br/>An internal intermittent short circuit that would permit both valves to close would not allow for telemetry indications of thruster on when the thruster was off. The failure to respond to commands would require that one solenoid coil be open as well as intermittently short circuited to ground.</p> |

TABLE I.- SUMMARY OF POSTULATED FAILURES - Continued

## a. Postulated failures not considered to be possible causes of attitude control anomaly - Concluded

| Item no. | Postulated failure                                                                                                                                                                                                                                                                                                | Remarks                                                                                                                                                                                                                                                                                                                                      |
|----------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 11       | An intermittent short circuit as described in items 1, 2, 3, 4, 5, 6, 7, and 8, or in the solenoid valve, or at a splice accompanied by an intermittently clogged fuel or oxidizer valve, or both, and an intermittent failure of the TCA 8 instrumentation.                                                      | <p>(a) <u>Period of degraded thrust due to flow of oxidizer only:</u><br/>These failure modes agree with all telemetry data; however, the complex nature of such a combination of failures makes them highly improbable.</p> <p>(b) <u>Period of degraded thrust not due to flow of oxidizer only:</u><br/>Same as preceding remark (a).</p> |
| 12       | The wire, L933F22, connecting the high-level multiplexer to the TCA 8 instrumentation, short circuited to ground intermittently and open circuited to the multiplexer. The low-level accelerations experienced while TCA 8 was inoperative was caused by fuel and oxidizer rotating in the GATV propellant tanks. | <p>(a) <u>Period of degraded thrust due to flow of oxidizer only:</u><br/>Not applicable.</p> <p>(b) <u>Period of degraded thrust not due to flow of oxidizer only:</u><br/>This failure does not allow for failure of the TCA 8 to fire when commanded ON during the period when it was not failed on.</p>                                  |

## b. Postulated failures considered to be possible causes of the anomaly

|    |                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                                                                                                                                              |
|----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 13 | The four-wire splice connecting the ground side of the TCA 8 fuel and oxidizer solenoid valves, TCA 8 instrumentation, and the OAME TCA 8 valve-driver intermittently short circuited all wires to ground. The splice then failed such that one TCA 8 solenoid-valve wire became separated while the other wires remained short circuited. Later, all wires again short circuited to ground and remained short circuited. | <p>(a) <u>Period of degraded thrust due to flow of oxidizer only:</u><br/>This failure could agree with all telemetry data.</p> <p>(b) <u>Period of degraded thrust not due to flow of oxidizer only:</u><br/>Not applicable.</p>                                            |
| 14 | The four-wire splice (described in item 13) failed with the thruster-solenoid ground wires intermittently short circuiting to ground and the OAME valve driver and instrumentation leads either short circuited or open circuited.                                                                                                                                                                                        | <p>(a) <u>Period of degraded thrust due to flow of oxidizer only:</u><br/>This failure agrees with all telemetry indications.</p> <p>(b) <u>Period of degraded thrust not due to flow of oxidizer only:</u><br/>This failure could agree with all telemetry indications.</p> |

TABLE I.- SUMMARY OF POSTULATED FAILURES - Concluded

b. Postulated failures considered to be possible causes of the anomaly - Concluded

| Item no. | Postulated failure                                                                                                                                                                                                                                               | Remarks                                                                                                                                                                                                                                                                                                                                                       |
|----------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 15       | The wire, L933C22, that connected the ground side of the fuel solenoid to the four-wire splice (described in item 13) either broke or was cut, and the end coming from the solenoid short circuited intermittently with the OAME end of wire remaining grounded. | <p>(a) <u>Period of degraded thrust due to flow of oxidizer only:</u><br/>This failure could agree with telemetry indications.</p> <p>(b) <u>Period of degraded thrust not due to flow of oxidizer only:</u><br/>This failure could agree with all telemetry indications only if both ends of wire L933C22 intermittently short circuited simultaneously.</p> |

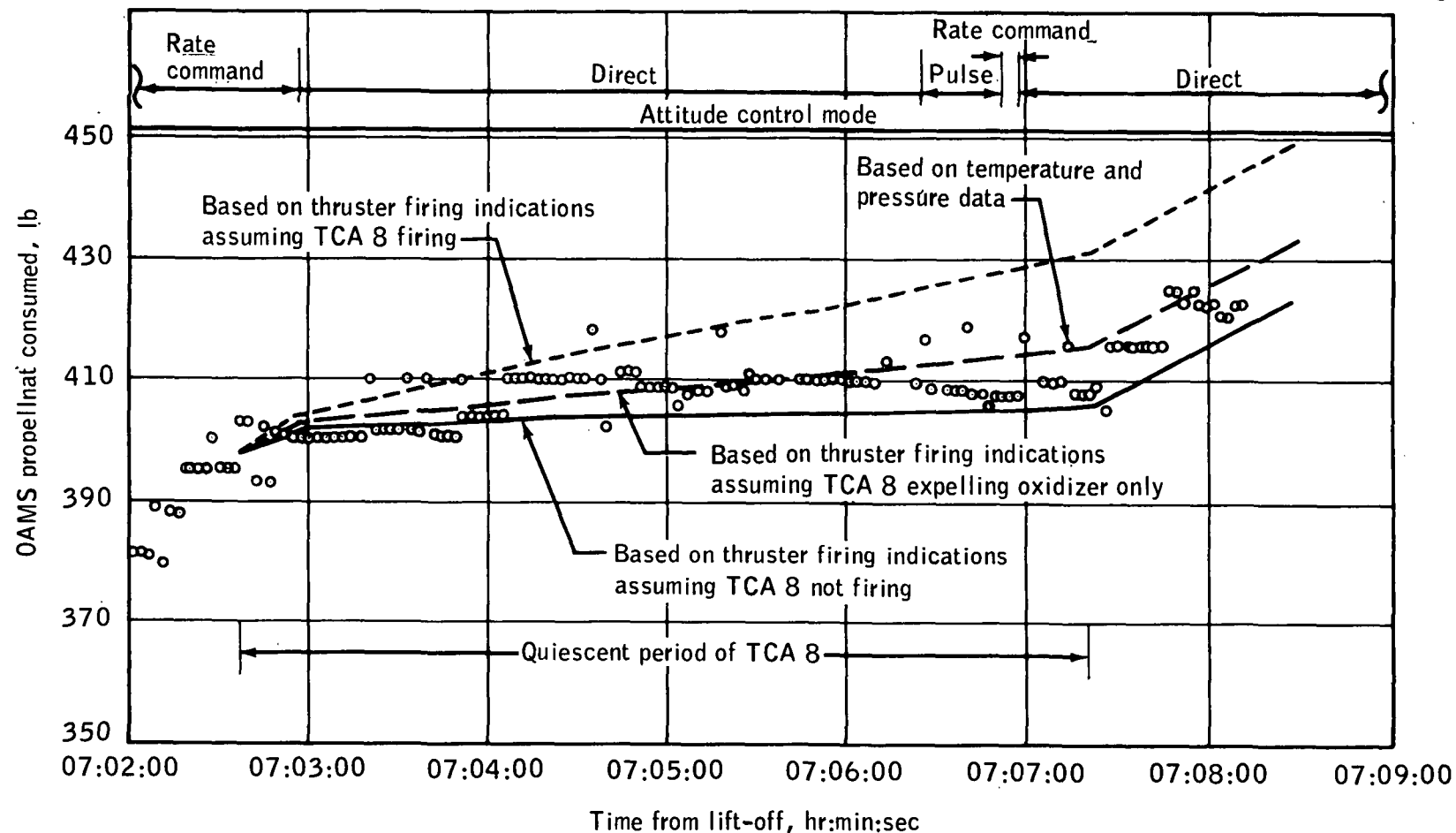


Figure 1. - OAMS propellant consumption during TCA 8 quiescent period.

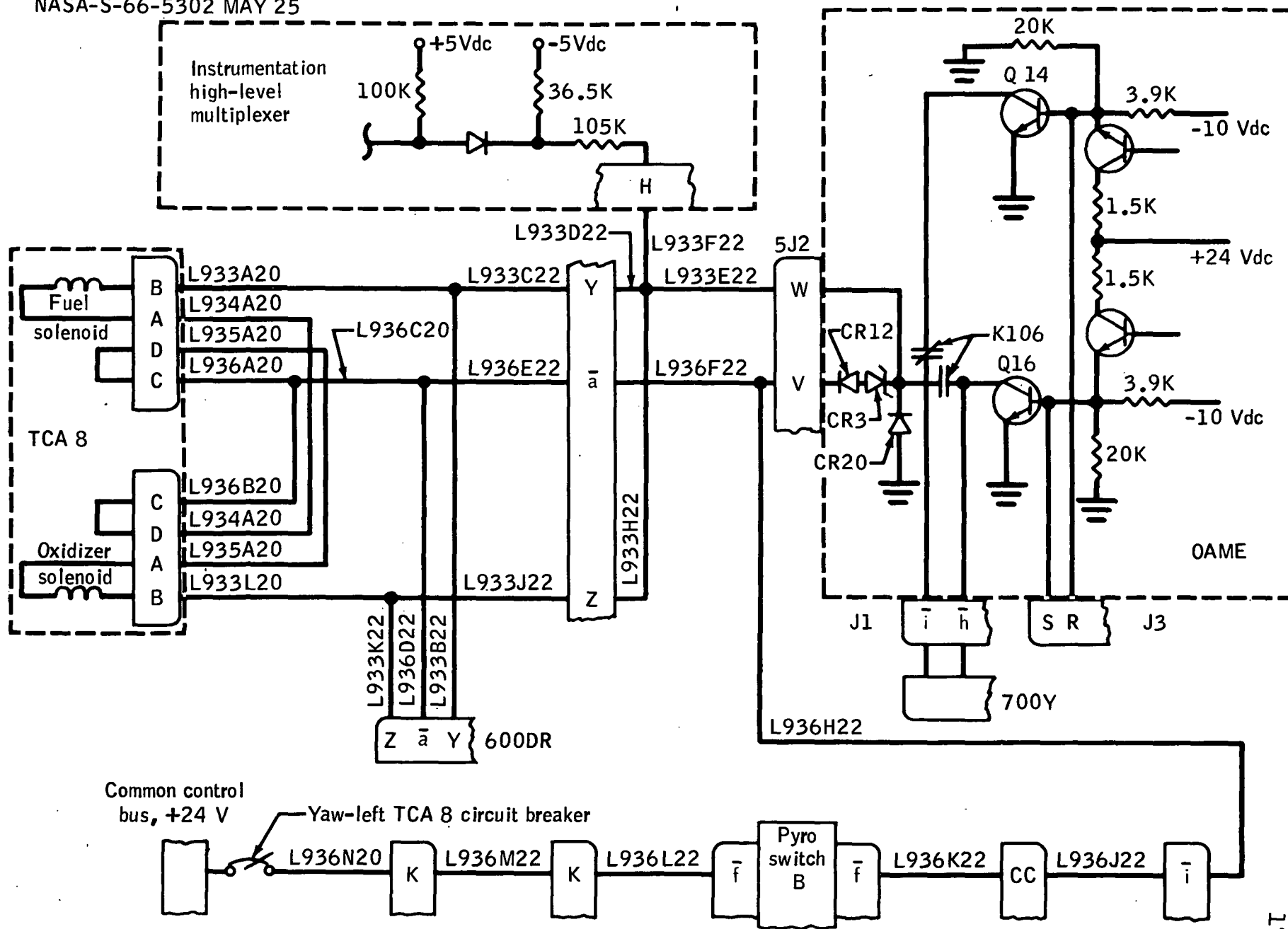


Figure 2. - Electrical circuitry associated with TCA 8.

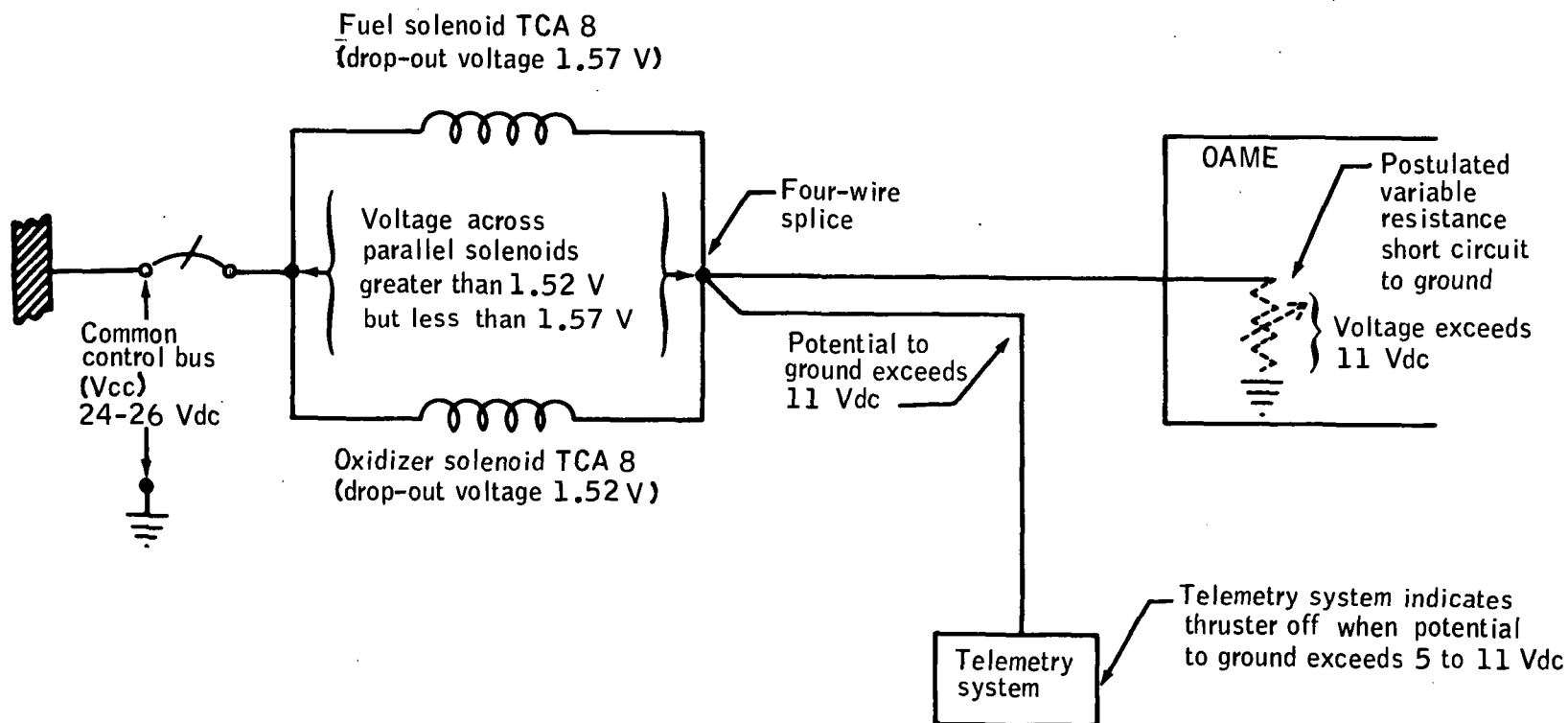


Figure 3. - Circuit conditions necessary in order for a single high-resistance short circuit to allow the oxidizer solenoid valve only to be open.

APPENDIX A

PILOT'S REPORT

(Excerpted from Section 7.1.2 of the  
Gemini Program Mission Report for Gemini VIII)

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**7.1.2.9 Control system problem.**- At approximately 7 hours g.e.t., the two spacecraft were configured for the platform-parallelism test, which was to have provided a comparison of the spacecraft and GATV attitude reference systems. The GATV Attitude Control System (ACS) was active, and the TDA L-band transponder was off. The spacecraft attitude-control power switch and maneuver-control switches were off. The radar was off, and the control mode switch was in PULSE.

Shortly after sending encoder command 041 (recorder ON), roll and yaw rates were observed to be developing. No visual or audible evidence of spacecraft thruster firing was noted, and the divergence was attributed to the GATV.

Commands were sent to de-energize the GATV ACS, geocentric rate, and horizon sensors, and the spacecraft Orbital Attitude and Maneuver System (OAMS) was activated.

The rates were reduced to near zero, but began to increase upon release of the hand controller. The ACS was commanded on to determine if GATV thruster action would help reduce the angular rates. No improvement was noted and the ACS was again commanded off. Plumes from a GATV pitch thruster were visually observed, however, during a period when the ACS was thought to be inactivated.

After a period of relatively stable operation, the rates once again began to increase. The spacecraft was switched to secondary bias power, secondary logics, and secondary drivers in an attempt to eliminate possible spacecraft control-system discrepancies. No improvement being observed, a conventional troubleshooting approach with the OAMS completely de-energized was attempted, but subsequently abandoned because of the existing rates.

An undocking was performed when the rates were determined to be low enough to preclude any recontact problems. Approximately a 3 ft/sec velocity change was used to effect separation of the two vehicles.

Angular rates continued to rise, verifying a spacecraft control-system problem. The hand controller appeared to be inactive. The Reentry Control System (RCS) was armed and, after trying ACME-DIRECT and then turning off all OAMS control switches and circuit breakers, was found to be operative in DIRECT-DIRECT. Angular rates were reduced to small values with the RCS B-ring. Inspection of the OAMS revealed that the number 8 thruster had failed open. Some open Attitude Control and Maneuver Electronics (ACME) circuit breakers probably accounted for the inoperative hand controller noted earlier. All yaw thrusters other than number 8 were inoperative. Pitch and roll control were maintained by using the pitch thrusters.

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APPENDIX B

GUIDANCE AND CONTROL

(Excerpted from Section 5.1.5 of the  
Gemini Program Mission Report for Gemini VIII)

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### 5.1.5.3 Control system performance evaluation. - Continued

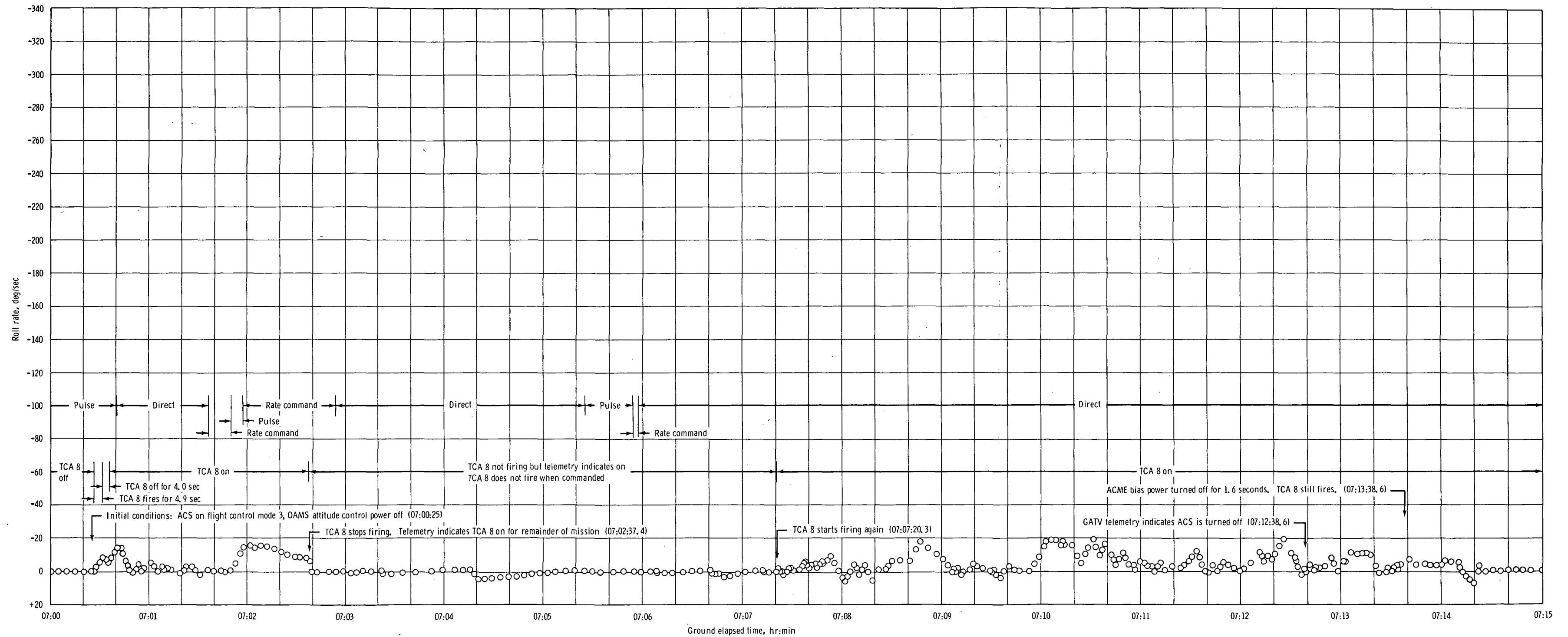
At 7:00:26.7 g.e.t., approximately 27 minutes after docking, the telemetry signal from thruster 8 indicated ON for 4.9 seconds, OFF for 4.0 seconds, then ON for the remainder of the flight. The spacecraft/GATV combination was being controlled by the GATV Attitude Control System (ACS) at this time in Flight Control Mode 3. The system was gyrocompassing, in-plane, with geocentric (GEO) rate ON. The OAMS attitude control power was OFF, the ACME mode select switch was in PULSE, and the IMU was in ORB RATE. In this configuration, the ACME is incapable of transmitting valid firing commands to the thrusters.

Figure 5.1.5-19 contains the sequence of significant events as they occurred during the anomaly plotted in relation to spacecraft roll rate. As indicated, the initial telemetry firing indications from thruster 8 were correct, in that the dynamic response matched the disturbance which should have been present. The first corrective action was taken, with the ACME in pulse mode, 11.5 seconds after the anomaly occurred. This mode was ineffective due to the short firing times associated with pulsed operation; therefore, DIRECT and then RATE COMMAND were selected with more success. In fact, while in the rate-command mode, the rates were essentially reduced to zero. At 7:02:37.4 g.e.t., the dynamic responses indicate that thruster 8 stopped firing, although the telemetry indication remained ON. Low grade accelerations were present which were representative of those which can result from a thruster expelling oxidizer only. Accelerations of this order could also have been obtained from the GATV ACS (for which no telemetry data are available), but in a very unlikely set of conditions. During this period, several firing commands were sent to thruster number 8 with no response. At 7:07:20.3 g.e.t., after an interval of 4 minutes 42.9 seconds, the original disturbance returned, indicating that thruster number 8 was again operating at or near full thrust. From this time until the spacecraft was separated from the GATV at 7:15:12.3 g.e.t., the disturbance was present and, as seen in figure 5.1.5-20, was controllable in the direct mode. The pitch and yaw rates were held to low values during this period; however, the roll rate did exceed 10 deg/sec for a total of approximately 100 seconds in six 15-to-20 second intervals. Each time the roll rate exceeded 10 deg/sec, it was quickly brought back to near zero using the direct control mode, and did not exceed 20 deg/sec at any time prior to undocking. The status of the GATV ACS throughout this period is uncertain except for one data point at 7:12:38.6 g.e.t., but appears from combined-vehicle acceleration calculations to have been cycled ON and OFF several times. The selection of redundant ACME logic and secondary thruster valve-driver circuitry, as reported by the crew, cannot be corroborated because these functions were not telemetered; however, the data does indicate that ACME bias power was turned off

momentarily at 7:13:38.8 g.e.t. There was no telemetry channel to indicate the utilization of the yaw/pitch roll-logic switch or the motorized fuel shut-off valves; however, by analyzing the combination of thruster firings in response to roll hand-controller commands, it was determined that the pitch logic was not selected for roll control during the anomaly period.

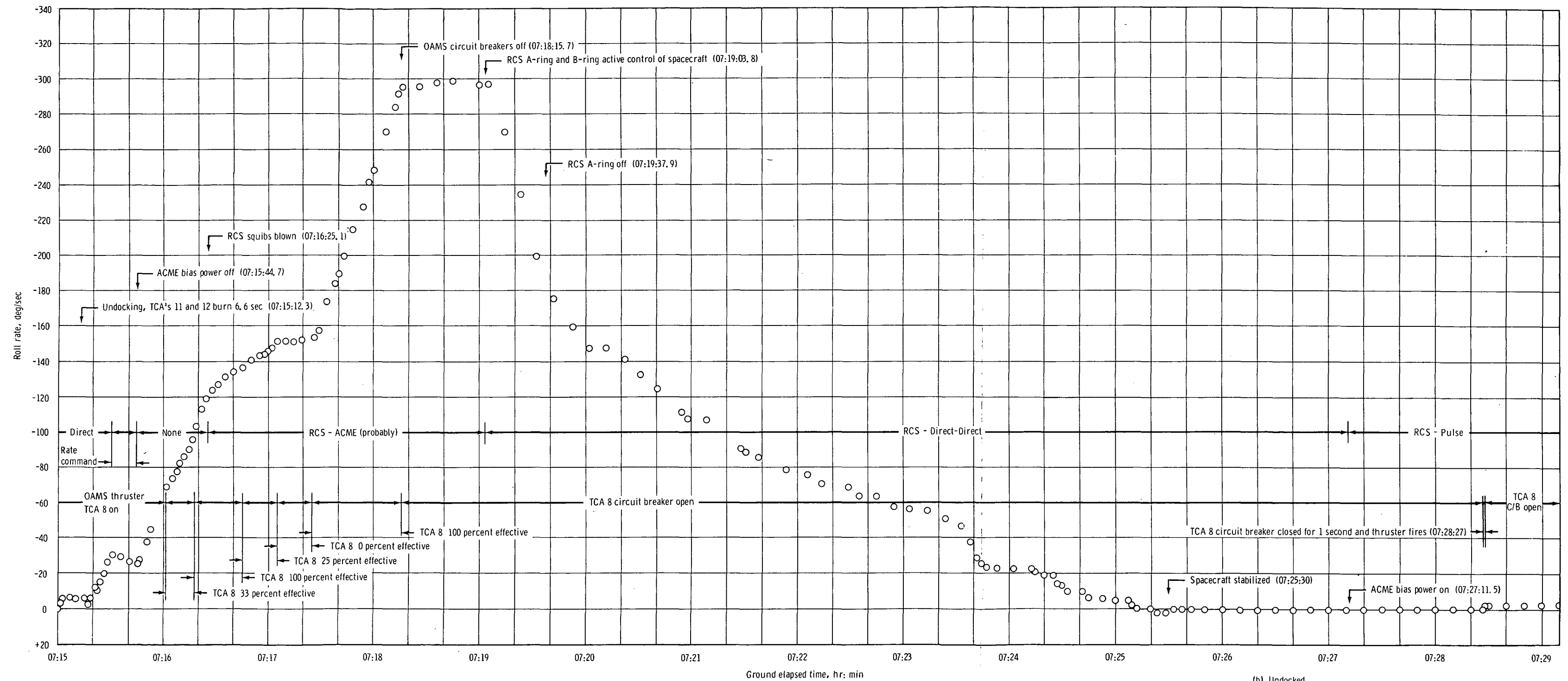
Separation from the GATV occurred at 7:15:12.3 g.e.t. with thrusters 11 and 12 firing for 6.6 seconds. Rates at this time were +3, -5, and -2 deg/sec in pitch, roll, and yaw, respectively. After separation, moderate hand-controller activity was present, although the direct mode was not sufficient to contain the roll rate. At 7:15:44.7 g.e.t., the ACME bias power was inadvertently removed, disabling the control system, and the roll rate increased to 296 deg/sec over the next three minutes, due to the uncontrolled firing of thruster 8, although short periods of intermittent or degraded thruster 8 performance appeared to exist. It is clear that the crew was not aware that ACME bias power was off because significant hand-controller activity is evident during this period. As noted in figure 5.1.5-19, the RCS squib valves were actuated at 7:16:25.1 g.e.t., but no RCS thrusters were fired until 7:19:03.8 g.e.t., probably because the ACME-DIRECT switch was in the ACME position with the ACME bias power off. When the ACME-DIRECT switch was apparently placed in the DIRECT position, RCS control was normal. The disturbance torque from thruster 8 ceased at 7:18:15.7 g.e.t. when the OAMS attitude-thruster circuit breakers were opened. Control was regained using the RCS in DIRECT-DIRECT. Subsequent checks of the OAMS thruster 8 circuit breaker and the RCS using ACME modes indicated correct ACME performance; in addition, telemetry indications and fault characteristics lead to the conclusion that the malfunction probably was external to the control system. (See sections 5.1.7 and 5.1.8 for further discussions of the flight-control anomaly.)

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(a) Docked.

Figure 5, 1, 5-19, - Spacecraft roll rates during anomaly.



(b) Undocked

Figure 5.1.5-19. - Concluded.

NASA-S-66-3539 APR 21

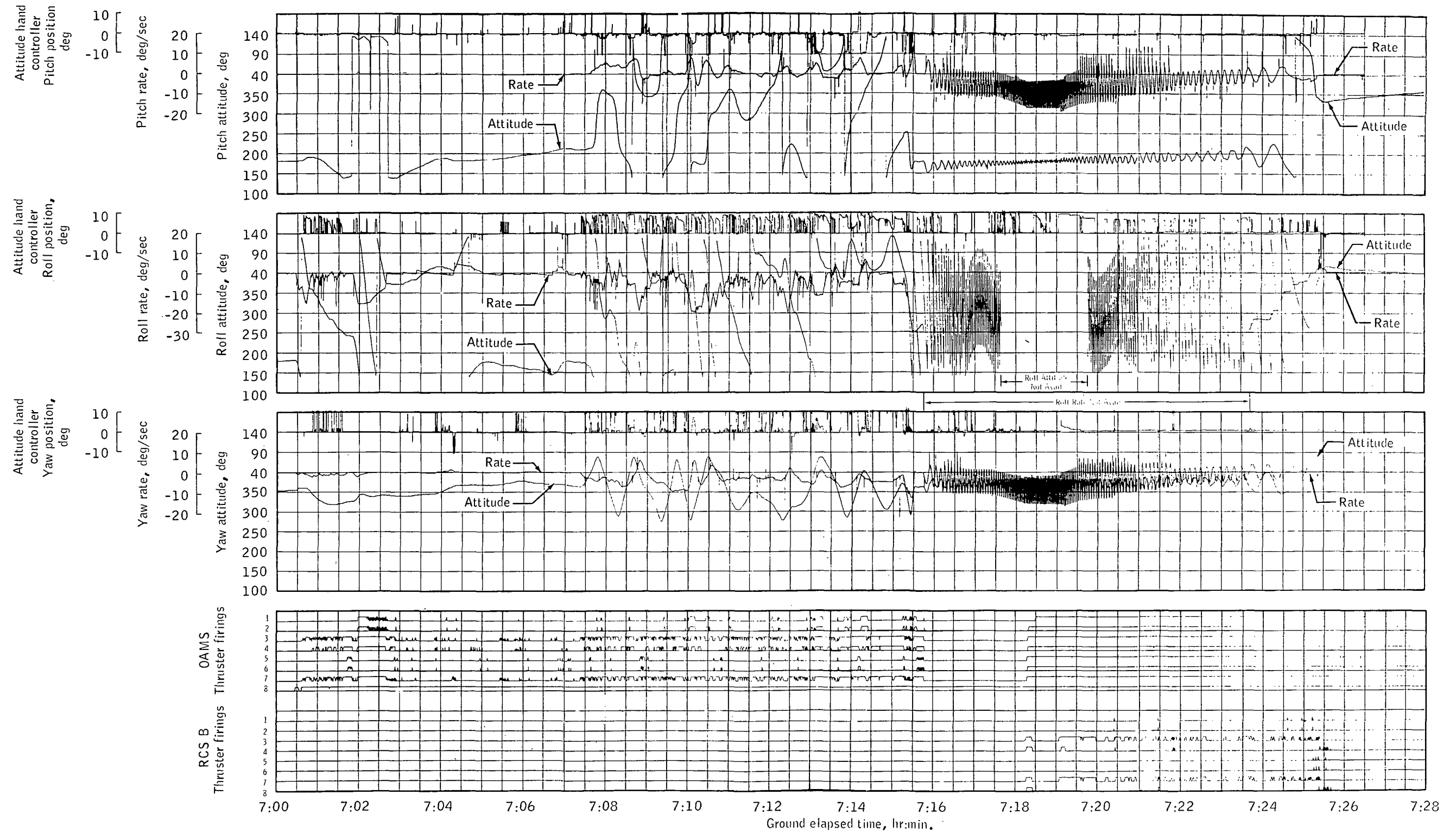


Figure 5.1.5-20. - Attitude control anomaly - time history.

APPENDIX C

PROPULSION SYSTEM

(Excerpted from Section 5.1.8 of the  
Gemini Program Mission Report for Gemini VIII)

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### 5.1.8.1 Orbital Attitude and Maneuver System. - Continued

Figure 5.1.5-19 shows that nominal thrust was being produced by thruster 8 at the beginning of the failure period, 7:00:26 g.e.t., and during the firing at 7:17:30 g.e.t., just prior to opening the circuit breaker. However, during this interval, accelerations were indicated to be less than nominal in a few instances. In one case, thruster 8 ceased to fire while the spacecraft and the GATV were still docked, (from 7:02:37 to 7:07:20 g.e.t.), but a small roll acceleration reflecting a 0.5-pound disturbance force was recorded. This force was approximately the same as that produced by oxidizer flow alone; however, the corresponding yaw accelerations appeared to be lower than that expected. The value in yaw was very small and in the same order of magnitude as the accuracy of the data. Varying accelerations after undocking but prior to opening the circuit breakers are presumed to result from intermittent thruster firings or from closing and opening the motor valves; however, the crew did not report operating the motor valves at this time. The thrust levels of thruster 8 are believed to have been nominal whenever both propellant valves were open. This is based on the nominal accelerations measured just prior to opening the circuit breaker and on OAMS thruster lifetime capabilities.

During troubleshooting of the OAMS after the spacecraft was stabilized, rates produced by attitude thrusters decreased to essentially zero until 7 hours 40 minutes g.e.t. when pitch thrusters 1 and 2 appeared to be producing some low-level thrust. By 7 hours 50 minutes g.e.t., pitch-control authority was fully restored, and at 9 hours 5 minutes g.e.t., the yaw thrusters appear to have been operating normally. These changes in thrust are attributed to the closing and opening of the motor valves. The precise total sequence of events cannot be obtained because motor-valve positions were not telemetered. After opening the valves, satisfactory pitch-thruster performance was restored prior to the restoration of the yaw-thruster performance because a greater amount of pitch control was first demanded. (Approximately 1.5 seconds were required to restore full control authority to pitch thrusters 1 and 2; 1.9 seconds to pitch thrusters 5 and 6; 0.7 second to yaw thrusters 3 and 4; and 0.9 second to yaw thruster 7.) A large number of pulses, ranging from 17 on thrusters 3 and 4 to 60 on thruster 2, were required to restore engine performance due to the use of the pulse mode. In this mode, a 20-millisecond signal is transmitted to fire the thrusters. The phenomenon associated with opening and closing the motor valves has been experienced previously and is under investigation to determine the cause.

The sequence of events during the failure period is presented in section 5.1.5.3. At the time of failure, thruster 3 had been off for 27 minutes. There was no apparent anomalous performance of this thruster prior to the firing that occurred at 7:00:26 g.e.t., nor was its duty cycle any more severe than that of the other engines.

The valves on thruster 3 opening unintentionally was probably caused by an electrical short to ground. The design of the control system is such that voltage is normally applied to one end of the solenoid coils and a firing command is effected by grounding the other end of the coils. As discussed in section 5.1.7, there were several locations in the spacecraft at which the fault could have occurred. One possible location is within the valve itself. However, from a review of the valve design, the acceptance test data of thruster 8, and the past history of the failure records of all Gemini valves during manufacturing, development, qualification, and reliability testing, the probability that the failure can be attributed to a short within the valve, other than from an isolated quality-type problem, is considered remote.

The regulator maintained 298 to 300 psia throughout the flight. No tendency to creep was observed. From 7:11:29.4 hours g.e.t. until adapter separation, the regulated pressure data indicated essentially zero pressure. This can only be attributed to a failure in the regulated pressure transducer or its associated circuitry. Satisfactory regulator performance has been verified by spacecraft angular accelerations, indicating correct propellant pressure at the injector, as well as from the F-package transducer which, at the time of the indicated failure, was sensing correct ullage pressure in the reserve fuel tank.

The total quantity of usable oxidizer and fuel was 411 and 340 pounds, respectively. When referenced to the preflight-determined mixture ratio of 1.05, 698 pounds of propellant would have been available to the crew. The propellant consumed during the mission is compared with the preflight planned usage rate in figure 5.1.8-1; also included are the mixture ratios used to establish the flight propellant quantities. The figure also shows the ground-computed values as determined from the general gaging equation during the flight and from the flight values read by the crew from the onboard propellant quantity indicator (PQI). The PQI value at activation was 101 percent, as compared to a preflight estimated value of 105 percent. This introduced an initial +4 percent correction factor in addition to corrections required for mixture ratio excursions from the fixed QPI gage reference of 1.05. When the readings obtained from the crew were corrected for the flight mixture ratio variations and decreased by 4 percent, the values correlated closely with the ground-computed values.

A comparison of the two measurements of propellant quantity, PQI and the gaging equation, shows good agreement. The propellant required through docking was somewhat greater than the flight-plan estimates. This was caused partly by the added real-time requirement of a plan-change and a vernier height-adjust maneuver, which consumed 27.6 pounds of maneuver propellant. Additional quantities were also consumed because the maneuver firing durations were greater than planned due to the post-maneuver corrections discussed previously. The lower flight mixture ratio realized up through docking, as compared with the pre-flight estimates, indicates that more attitude propellant was required than had been planned.

During the period 7:00:26 to 7:25:30 g.e.t., the attitude thrusters consumed 190 pounds of propellant, according to the results obtained from the gaging equation. From engine acceptance-test data measured by the manufacturer and the flight engine firing-duration data, 203 pounds were consumed by all attitude thrusters, which is in agreement with the gaging-equation results within the accuracy of the system.

#### 5.1.8.2 Reentry Control System.- Continued

Activation of the RCS occurred at approximately 7:16:25 g.e.t. to enable the crew to control spacecraft rates following spacecraft GATV separation. Typical rates measured during operation of the RCS, presented in table 5.1.8-IV, show nominal performance of the system. Although the first RCS firing indication occurred at 7:18:15.2 g.e.t., when yaw-right and yaw-left B-ring engines (3, 4, 7, and 8) appear to have received an 8.9-second-duration firing signal, the first actual RCS firing command occurred at 7:19:03 g.e.t. with both A and B rings operational and normal system response was observed. ACME bias power had been off since 7:15:45 g.e.t., and there was no hand-controller movement. Also, the control system does not contain the logic which would provide yaw or roll, simultaneous left and right commands. The most reasonable explanation is that the two RCS B-ring yaw circuit breakers were inadvertently cycled, thereby providing the false 8.9-second engine-firing indication.

After system activation, the A-ring and B-ring regulators, respectively, remained within a range of 296 (+2, -0) psia and 298 (+6, -0) psia. The minimum B-ring source pressurant temperature of 35° F reflected a high control-system demand rate. The 72° to 101° F oxidizer-feed temperature range encountered is well within the operational capability of the system.

The A-ring was turned off at 7:19:38 g.e.t. after 79.7 seconds of firing time accumulated over 4 pulses. The B-ring was then used to achieve control, with the command pilot using 126 pulses and an accumulated firing time of 306.4 seconds, until 7:31:25.7 g.e.t. when the

B-ring was turned off. A check of the B-ring system operation from 9:01:49 to 9:07:27 g.e.t. in pulse and orbit rate-command modes showed nominal performance. A final check of the A-ring operation in rate-command, pulse, direct, and reentry rate-command modes, performed from 9:52:19 to 9:54:07 g.e.t., also provided nominal data.

TABLE 5.1.8-IV.- OAMS AND RCS ATTITUDE ENGINE  
PERFORMANCE <sup>a</sup>

| Engine numbers | Thrust, lb |        | Angular acceleration, deg/sec <sup>2</sup> |        |
|----------------|------------|--------|--------------------------------------------|--------|
|                | Preflight  | Flight | Preflight                                  | Flight |
| OAMS           |            |        |                                            |        |
| 1-2            | 45.7       | 43     | 3.7                                        | 3.5    |
| 3-4            | 46.1       | 44     | 3.7                                        | 3.5    |
| 5-6            | 45.8       | 44     | 3.7                                        | 3.5    |
| 7-8            | 46.4       | 43     | 3.7                                        | 3.6    |
| RCS A-ring     |            |        |                                            |        |
| 1-2            | 46.9       | 44     | 3.5                                        | 3.3    |
| 3-4            | 47.1       | 44     | 3.5                                        | 3.4    |
| 5-6            | 47.0       | 44     | 3.5                                        | 3.4    |
| 4-8            | 46.9       | 47     | 1.7                                        | 1.7    |
| RCS B-ring     |            |        |                                            |        |
| 1-2            | 46.9       | 44     | 3.5                                        | 3.3    |
| 3-7            | 47.3       | 47     | 1.7                                        | 1.7    |
| 5-6            | 47.1       | 44     | 3.5                                        | 3.3    |
| 4-8            | 47.0       | 47     | 1.7                                        | 1.7    |

<sup>a</sup> Typical values determined at various times throughout the mission.

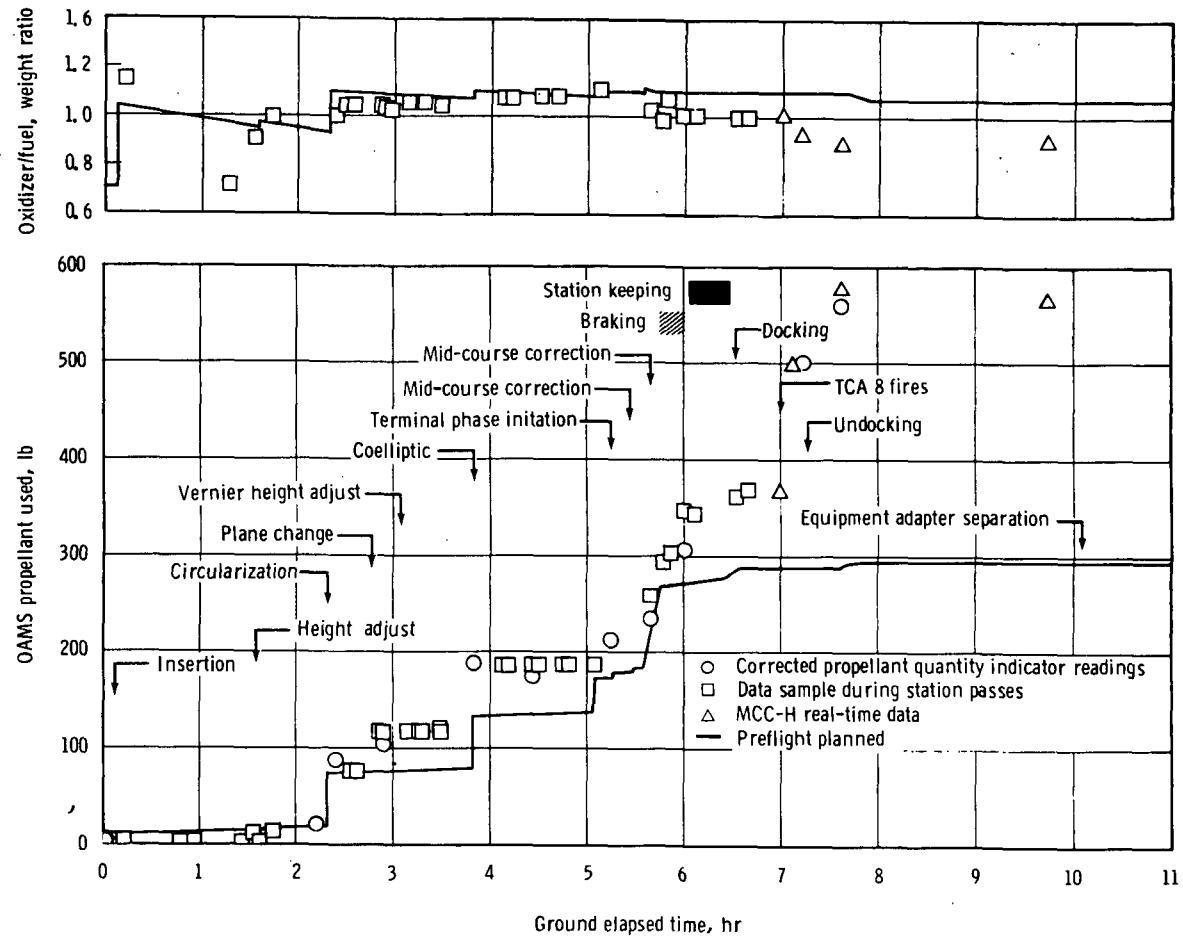


Figure 5.1.8-1 - OAMS propellant consumption.

APPENDIX D

ELECTRICAL SYSTEM

(Excerpted from Section 5.1.7 of the  
Gemini Program Mission Report for Gemini VIII)

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5.1.7.4 Control system anomaly. - Figure 5.1.7-6 shows a more detailed plot of control-bus voltage from the initial inadvertent firing of OAMS thruster 8 to the eventual in-flight identification and correction of the problem. This period can be divided into seven parts:

(a) 7:00:26.7 to 7:02:37.4 g.e.t. - This period was characterized by voltage transients caused by thruster 8 first coming on, then going off, then staying on continuously, and by the counter thruster responses commanded by the flight crew.

(b) 7:02:37.4 to 7:07:20.3 g.e.t. - In this period, although telemetry was indicating thruster 8 to be on, spacecraft dynamics indicated that thruster 8 was not producing significant thrust; however, a low-grade spacecraft acceleration, representative of the thrust obtained when only the oxidizer valve is open, was present (see section 5.1.5). The average bus voltage should have recovered to the initial value of 25.35 volts at this time; therefore, the incomplete recovery of the bus voltage to only 25.20 volts supports the possibility of a single thruster solenoid being energized. It is important to note that during this 4 minutes 53 second period, thruster 8 was commanded on in several command modes, was indicated on continuously by telemetry, but apparently did not fire at any time.

(c) 7:07:20.3 to 7:15:44.7 g.e.t. - During this period, thruster 8 once more was on continuously and the bus voltage transients indicate the continued countering efforts by commanded thruster firings. At 7:15:12 g.e.t., thrusters 11 and 12 (forward-firing maneuver thrusters) were fired, separating the spacecraft and the Gemini Agena Target Vehicle (GATV).

(d) 7:15:44.7 to 7:18:15.7 g.e.t. - The RCS was activated during this period. Just prior to this operation it is a possibility that the motor valves were closed because, electrically, thruster 8 appears to have been on; however, spacecraft dynamics indicate it was not thrusting from 7:17:04 to 7:17:24 g.e.t. At 7:17:24 g.e.t., though not recorded, the motor valves would have to have been reopened, as spacecraft dynamics indicated that thruster 8 was thrusting. No electrical change was evident at that time.

(e) 7:18:15.7 to 7:19:03.8 g.e.t. - At the start of this period, the OAMS thruster circuit breakers for the solenoid-valve power were opened. Thruster 8 was off; this is evident in the telemetry records from the recovery of the bus voltage and from the spacecraft dynamics.

(f) 7:19:03.8 to 7:25:30 g.e.t. - In this period, the continuous set of voltage transients indicated the activity of the RCS thrusters when commanded by the flight crew in gaining control of the spacecraft. At 7:25:30 g.e.t., the rates were nulled in all axes.

(g) 7:25:30 to 7:28:30 g.e.t. - The flight crew reactivated the OAMS and found that thruster 8 would fire continuously when its circuit breaker was closed, even when the hand controller was in a neutral position. The voltage transient at 7:28:27 g.e.t. amounted to a depression of 1.25 volts in bus voltage when only the one thruster, no. 8, was firing.

The following four facts stand out from the preceding data:

(a) Telemetry indicated thruster 8 was on for 4.9 seconds and off for 4.0 seconds at the beginning of this sequence, then on for the remainder of this period.

(b) During the period from 7:02:37.4 to 7:07:20.3 g.e.t. when thruster 8 was not full on, it was commanded on several times without a successful reaction.

(c) The only times after the malfunction started when common-control-bus data, spacecraft-dynamics data, and telemetry bi-level data agree that thruster 8 was off was during the times when the thruster 8 circuit breaker was opened.

(d) There were periods of low-grade accelerations that were indicative of a single thruster valve opening. These occurred in periods (b) and (d) of figure 5.1.7-6.

From the above facts, it may be deduced that the failure was electrical rather than mechanical, and was complex in nature.

The circuits involved with the anomalous condition of the flight control system are shown in figure 5.1.7-7. The firing of the thrusters is normally accomplished by switching one end of each of the fuel and oxidizer solenoid coils to ground by means of transistor switches. The transistor switches are activated by logic circuits, commanded directly by the flight crew or automatically by the control system. Either primary or secondary transistor switching circuits may be selected by the crew.

From figure 5.1.7-7 it can be seen that the thruster will fire if,

(a) False inputs are sent to the valve drivers

- (b) The valve drivers malfunction
- (c) A low-resistance short exists in any of the wiring from the solenoids to the drivers
- (d) A wire failure exists in the thruster solenoids.

Failure modes 1 and 2 can be eliminated for three reasons:

- (a) The flight crew reported switching from the primary to the secondary drivers without a successful commanded response from thruster 8.
- (b) A failure in this portion of the circuitry will not explain the low-grade accelerations characteristic of a single thruster valve operating.
- (c) If it were possible to have a high-resistance short sufficient to drop out only one solenoid (2.0 volts across the solenoid), then the telemetry voltage would be greater than 15 volts. Hence, telemetry would have indicated off rather than on as it did during periods of low-grade accelerations.

It is evident from the above that the failure was in the solenoids or in the spacecraft wiring between the solenoids and the junction of the two solenoid ground returns.

Further isolation of the failure has met with little success. The fault is not a simple one; it must vary in resistance sufficiently to enable either or both thruster solenoids to fire and still meet the ON requirements of telemetry (less than 5 volts).

On Spacecraft 9 and subsequent spacecraft, the OAMS thrusters will be powered from a separate bus which will be armed and disarmed by a single switch. This will provide the crew with a rapid means of disabling all OAMS thrusters before dynamic rates have time to build up.

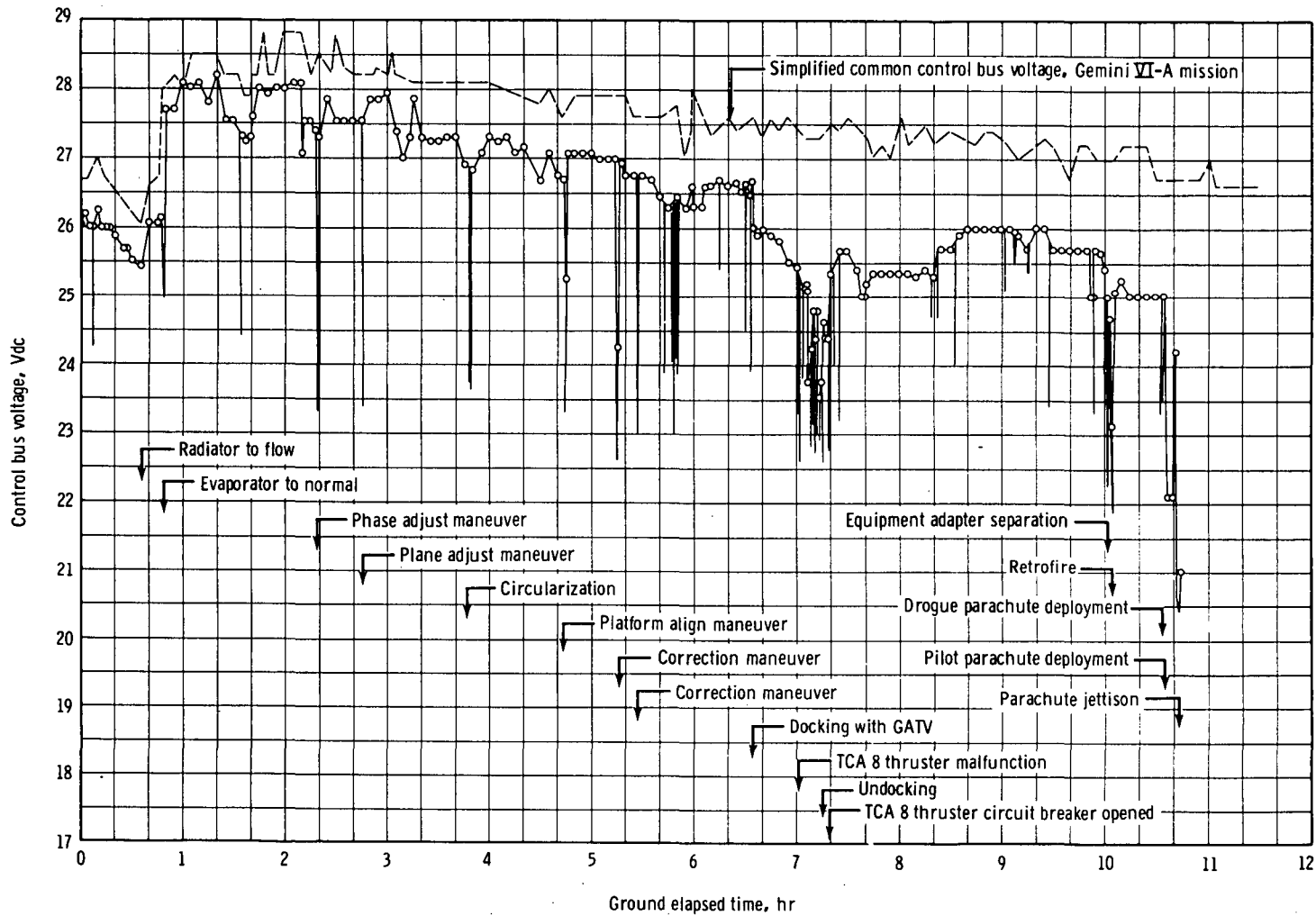


Figure 5.1.7-5 - Common control bus voltage performance.

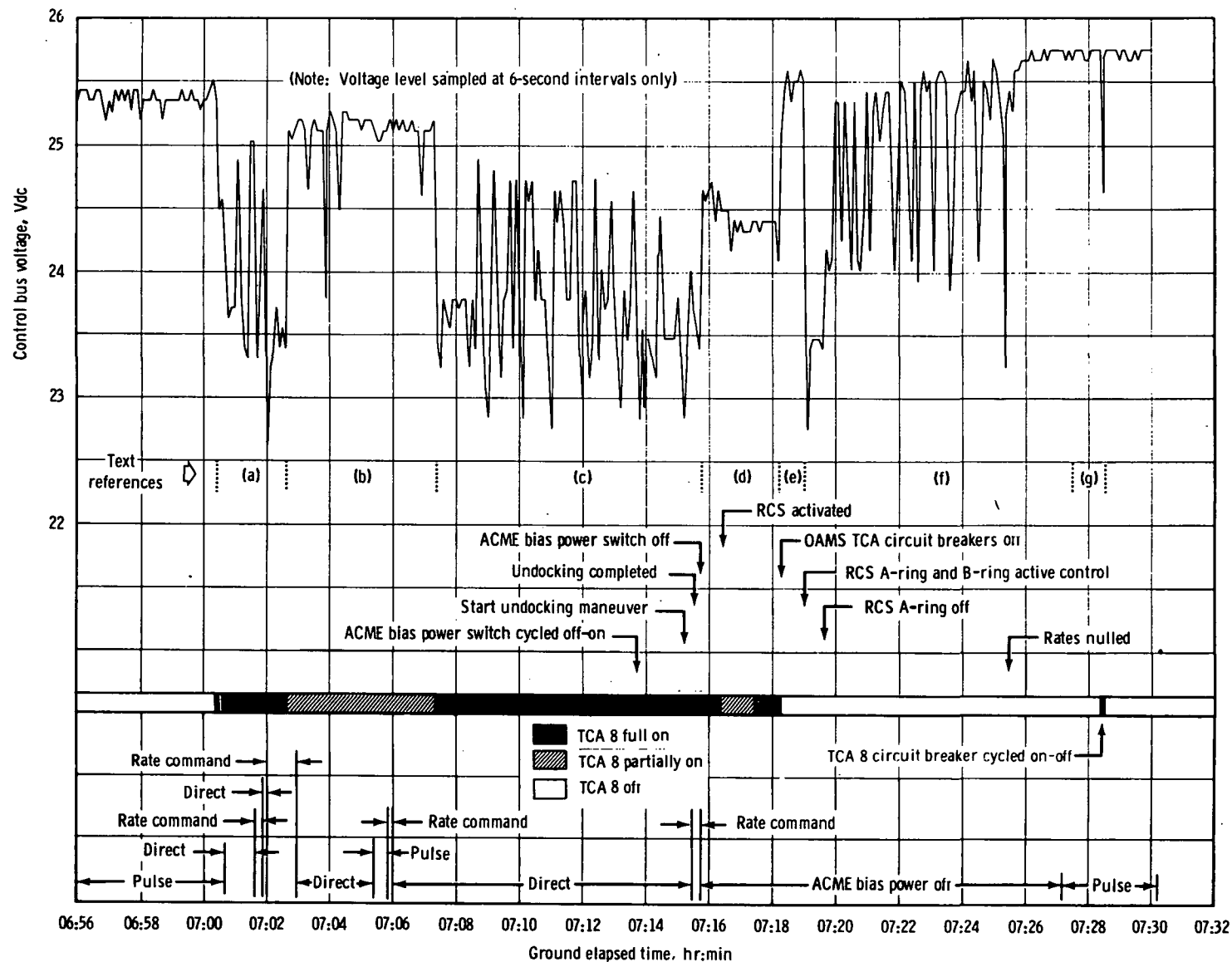


Figure 5.1.7-6 - Common control bus performance during OAMS thruster malfunction period.

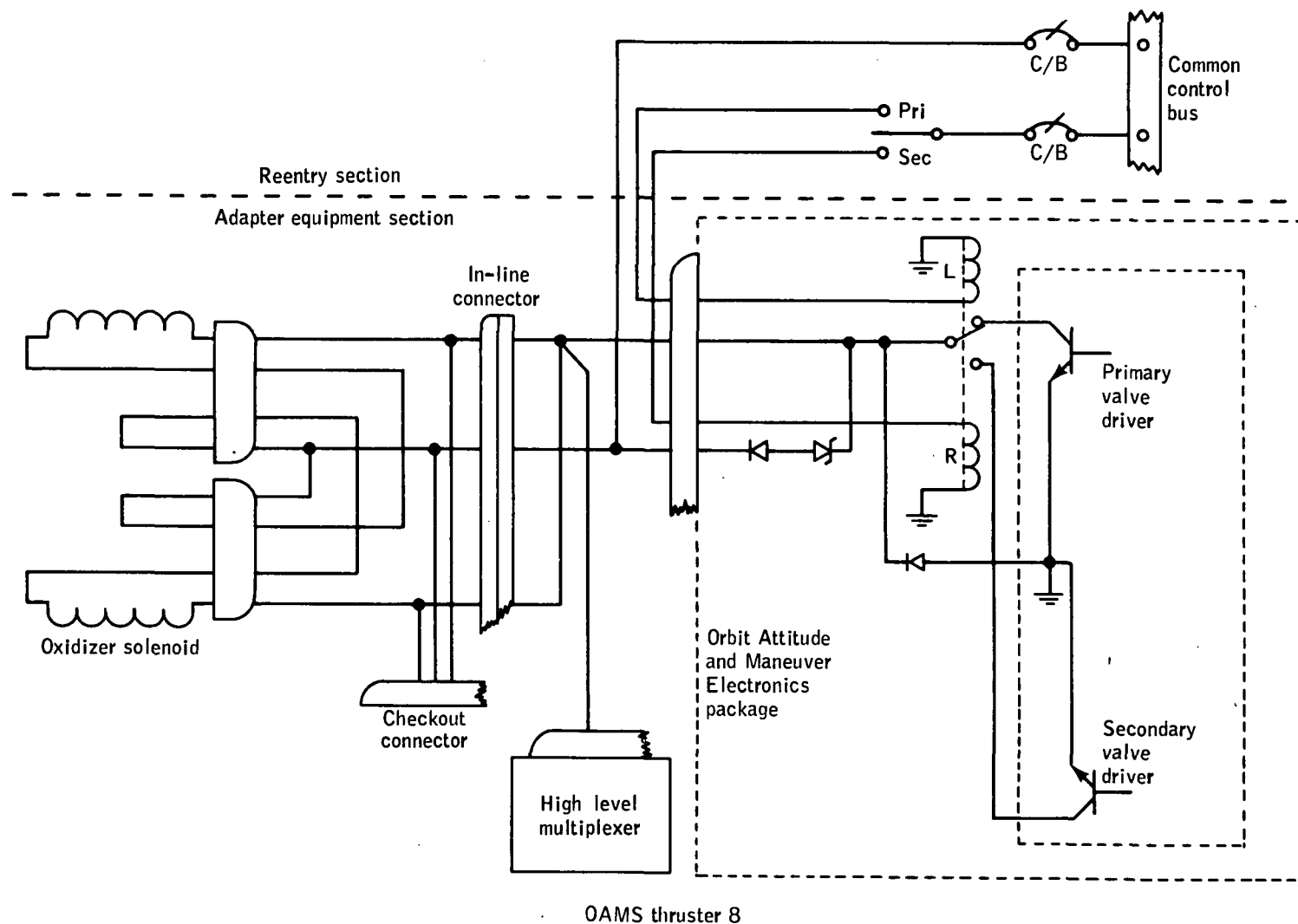


Figure 5.1.7-7 - Wiring schematic of critical area.

## APPENDIX E

### CONTROL SYSTEM MALFUNCTION PROCEDURES

(Excerpted from Section III of  
Gemini Operations Handbook for Spacecraft IX)

## **SECTION 3.4**

# **CONTROL SYSTEMS**

Prepared by WSE  
 Checked by WSE  
 Approved by WSE

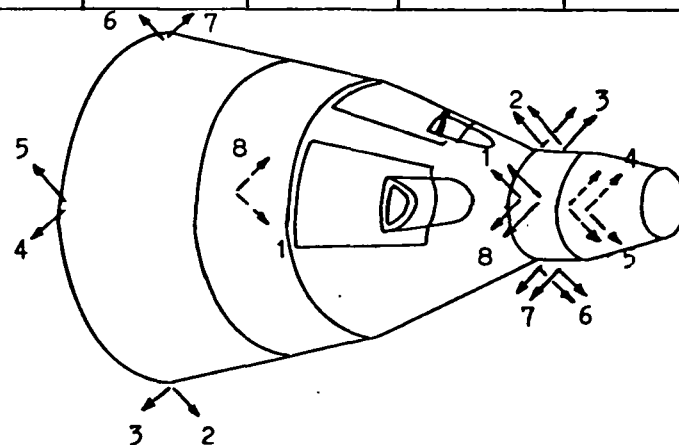
 Flight Crew Support Division  
 Mission Operations Branch  
 Date 5/10/66  
 GENI OPERATIONS HANDBOOK  
 S/C 10 Rev Orig  
 Section 3.4.1 Pg 1

# NORMAL ATTITUDE JET FIRING LOGIC

|            |     | Pitch Up | Pitch Down | Yaw Right | Yaw Left | Pitch Up & Yaw Rt | Pitch Up & Yaw Left | Pitch Dn & Yaw Rt | Pitch Dn & Yaw Left |                 |
|------------|-----|----------|------------|-----------|----------|-------------------|---------------------|-------------------|---------------------|-----------------|
|            |     | 5,6      | 1,2        | 3,4       | 7,8      | 3,4,5,6           | 5,6,7,8             | 1,2,3,4           | 1,2,7,8             |                 |
| Roll Right | 3,7 | 3,5,6,7  | 1,2,3,7    | 3,4,7     | 3,7,8    | 3,4,5,6,7         | 3,5,6,7,8           | 1,2,3,4,7         | 1,2,3,7,8           | ROLL JETS - YAW |
|            | 1,5 | 1,5,6    | 1,2,5      | 1,3,4,5   | 1,5,7,8  | 1,3,4,5,6         | 1,5,6,7,8           | 1,2,3,4,5         | 1,2,5,7,8           | - PITCH         |
| Roll Left  | 4,8 | 4,5,6,8  | 1,2,4,8    | 3,4,8     | 4,7,8    | 3,4,5,6,8         | 4,5,6,7,8           | 1,2,3,4,8         | 1,2,4,7,8           | - YAW           |
|            | 2,6 | 2,5,6    | 1,2,6      | 2,3,4,6   | 2,6,7,8  | 2,3,4,5,6         | 2,5,6,7,8           | 1,2,3,4,6         | 1,2,6,7,8           | - PITCH         |
| Yaw Right  | 3,4 | 3,4,5,6  | 1,2,3,4    |           |          |                   |                     |                   |                     |                 |
| Yaw Left   | 7,8 | 5,6,7,8  | 1,2,7,8    |           |          |                   |                     |                   |                     |                 |

## NOTES:

1. Numbers indicate attitude thrusters actuated by single axis or multiple axes commands during normal operation.
2. Degraded system response is created by some multiple-axis commands due to opposing thruster firings.
3. When using RCS jets, only rows designated ROLL JETS - YAW are applicable for roll.



| SYMPTOM                                                                                                                                                                             | FAILURE                                                                   | PROCEDURE                                                                                                                                                                                                                                                                                                                                     | REMARKS                                                                                                                                                                                                                                                                                                                                                                                                   |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 2. Onboard OAMS regulated pressure reads 50 psi below normal regulated Pressure. Ground confirms regulated pressure normal (295 $\pm$ 15) and onboard gauge readout (245 $\pm$ 15). | Main oxidizer tank empty.                                                 | <ol style="list-style-type: none"> <li>1. BUS ARM Switch - EXP</li> <li>2. AGENA CNTL SQUIB 1 and 2 C/B'S - Closed</li> <li>3. OAMS RESVR Switch --SQUIB</li> <li>4. Verify onboard gage increases to normal regulated pressure of 295 <math>\pm</math> 15.</li> <li>5. OAMS RESVR Switch - SAFE</li> <li>6. BUS ARM Switch - SAFE</li> </ol> | <ol style="list-style-type: none"> <li>3. When directed by ground. Ground has TM of regulated pressure, as well as onboard gage pressure.</li> <li>5. OAMS reserve tank contains an estimated 23.4 pounds of usable oxidizer. (A more accurate prediction of usable oxidizer in the reserve tank will be available after the actual oxidizer system volume is determined following servicing.)</li> </ol> |
| Prepared by <u>          </u><br>Checked by <u>          </u><br>Approved by <u>          </u>                                                                                      | Flight Crew Support Division<br>Mission Operations Branch<br>Date 5/10/66 | Control System<br>Malfunction Procedures                                                                                                                                                                                                                                                                                                      | Gemini Operations Handbook<br>S/C 10 Rev Orig<br>Section 3.4.1 Pg 2                                                                                                                                                                                                                                                                                                                                       |

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| SYMPTOM                                                                      | FAILURE                                                                    | PROCEDURE                                                                                                                                                                                                                                                                                                                                                                          | REMARKS                                                                                                                                                                 |
|------------------------------------------------------------------------------|----------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. Excess tumble rates during sleep period (not docked)                      | Excessive venting                                                          | 1. Rate Gyro SWS(3) - PRI<br>2. AC POWER - ACME<br>3. Verify ATTITUDE CONTROL - RATE CMD<br>4. OAMS CNTL PWR SW - ON<br>5. Control S/C                                                                                                                                                                                                                                             | 1. 30 sec spin up for spec. performance.<br><br>4. Remove window curtains                                                                                               |
| 2. Excess tumble rates during sleep period (docked)                          | a. ACS failure.<br>b. Excessive venting from Agena.                        | 1. Command Agena - OFF (400)<br>2. Rate Gyro SWS(3) - PRI<br>3. AC POWER - ACME<br>4. Verify ATTITUDE CONTROL - RATE CMD<br>5. OAMS CNTL PWR SW - ON<br>6. Control S/C<br><br>IF UNCOMMANDED THRUSTS CONTINUE AND ARE UNACCEPTABLE.<br><br>7. MANEUVER CONTROLLER - ON<br>8. TDA CONTROL UNDOCK SW - UNDOCK<br>9. Thrust to clear Agena<br>10. Maintain visual contact with Agena. | 2. 30 sec spin up for spec. performance.<br><br>5. Remove window curtain<br><br>9. As soon as docking latches release.                                                  |
| 3. Uncommanded attitude rates while docked with Agena.                       | ACS Failure.<br>Excessive venting from Agena.                              | 1. Command Agena OFF (400)<br>2. VERIFY ATTITUDE CONTROL - RATE CMD<br>3. OAMS PWR SW - ON<br>4. Control S/C<br><br>IF UNCOMMANDED THRUSTS CONTINUE AND ARE UNACCEPTABLE.                                                                                                                                                                                                          | 1. DURING EVA, PILOT will reenter S/C at first indication of failure.<br><br>DURING EVA, MAINTAIN CONTROL WITH OAMS SYSTEM UNTIL PILOT REENTERS S/C PRIOR TO UNDOCKING. |
| Prepared by <u>RH/3</u><br>Checked by <u>RH/3</u><br>Approved by <u>RH/3</u> | Flight Crew Support Division<br>Mission Operations Branch<br>Date: 5/10/66 | CONTROL SYSTEM<br>MALFUNCTION PROCEDURES                                                                                                                                                                                                                                                                                                                                           | Gemini Operations Handbook<br>S/C 10 Rev Orig.<br>Section 3.4.2 Pg 1                                                                                                    |

| SYMPTOM                                                                   | FAILURE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                             | PROCEDURE                                                                                                                             | REMARKS                                                                                         |
|---------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
|                                                                           |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     | 5. MANEUVER CONTROLLER - ON<br>6. TDA CONTROL UNDOCK SW - UNDOCK<br>7. Thrust to clear Agena<br>8. MAINTAIN VISUAL CONTACT WITH AGENA | 7. As soon as docking latches release.                                                          |
| 4. Uncommanded rates, uncommanded thrust or improper control response.    | <p><u>WARNING:</u> IF EVA, PILOT WILL REENTER S/C AS SOON AS POSSIBLE AFTER DETECTION OF MALFUNCTION. ACCOMPLISH ONLY STEPS NECESSARY FOR PILOT TO REENTER S/C OR SECURE TO THE S/C FOR TROUBLE SHOOTING. PILOT REMAIN IN SIGHT OF CMD PILOT.</p> <p><u>NOTE:</u> To identify and isolate failures <u>during</u> EVA operation insure the PROP gage is set for OAMS source pressure; and the IVIs ON, computer in NAV. Prior to EVA switch to PRE LN and back to NAV (this zeros the IVI's). Enter zeros in addresses 25, 26, and 27. Push START COMP.</p> <p>When in an automatic mode (HOR SCAN, RATE CMD or PLAT) - High rates (above 1°/sec) or unacceptable oscillations of S/C are noted:</p> | 1. ATTITUDE CONTROL - DIRECT<br>2. Control S/C                                                                                        | 1. Direct mode will bypass ACME failures<br>2. Refer to WARNING.                                |
| Prepared by <u>RHB</u><br>Checked by <u>RHB</u><br>Approved by <u>RHB</u> | Flight Crew Support Division<br>Mission Operations Branch<br>Date 5/10/66                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           | CONTROL SYSTEM<br>MALFUNCTION PROCEDURES                                                                                              | Gemini Operations Handbook<br>S/C <u>10</u> Rev <u>Orig</u><br>Section <u>3.4.2</u> Pg <u>2</u> |

| SYMPTOM                                                                                  | FAILURE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | PROCEDURE                                                                                                                                                                                                                                                    | REMARKS                                                                                                                                                                                                                                                                                                   |
|------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                          | <p>When in direct or pulse mode; or when rates are low (or have been controlled in DIRECT); or many thrusters are firing, or control degraded (ie. no dangerous rates): Refer to WARNING.</p> <p>OMIT STEPS 1 and 2,</p> <p>3. OAMS CNTL PWR SW - OFF</p> <p>If the IVIs are counting up at this time; and maneuver control is necessary-----</p> <p>Determine failed thruster/s</p> <p>Open CB/s</p> <p>Maneuver as required</p> <p>Continue Procedure</p> <p>4. RATE GYROS (3) - PRI</p> <p>5. Verify:</p> <p>PLATFORM SW - OFF</p> <p>COMPUTER SW - OFF</p> <p>AC power - ACME</p> <p>6. FDM - RATES</p> <p>7. ATTITUDE CONTROL - DIRECT</p> <p>8. All (16) OAMS CBs - OPEN</p> <p>9. Determine failed thrusters:</p> <p>From direction of rate; determine failed thruster most likely to be failed with thrust ON:</p> <p>IF ROLL LEFT---Close OAMS CBs except 2, 4, 6 and 8</p> <p>IF ROLL RIGHT---Close OAMS CBs except 1, 3, 5 and 7</p> <p>IF PITCH UP---Close OAMS CBs except 5, 6 and 10</p> <p>IF PITCH DOWN---Close OAMS CBs except 1, 2 and 9</p> <p>IF YAW LEFT---Close OAMS CBs except 7, 8 and 11</p> <p>If YAW RIGHT---Close OAMS CBs except 3, 4 and 12</p> | <p>4. RATE GYROS (3) - PRI</p> <p>5. Verify:</p> <p>PLATFORM SW - OFF</p> <p>COMPUTER SW - OFF</p> <p>AC power - ACME</p> <p>6. FDM - RATES</p> <p>7. ATTITUDE CONTROL - DIRECT</p> <p>8. All (16) OAMS CBs - OPEN</p> <p>9. Determine failed thrusters:</p> | <p>OAMS CNTL PWR SW ON FOR MANEUVER THEN OFF</p> <p>4. 30 sec spin up for spec. performance if off.</p> <p>5. Read 26V AC.</p> <p>6. FDI's indicate rates</p> <p>8. Note any popped CBs.</p> <p>9. If failed off see chart 6a.</p> <p>Use IVI indications to help isolate maneuver thruster failures.</p> |
| <p>Prepared by <u>RAH</u></p> <p>Checked by <u>RAH</u></p> <p>Approved by <u>RAH</u></p> | <p>Flight Crew Support Division</p> <p>Mission Operations Branch</p> <p>Date 5/10/66</p>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                      | <p>CONTROL SYSTEM</p> <p>MALFUNCTION PROCEDURES</p>                                                                                                                                                                                                          | <p>Gemini Operations Handbook</p> <p>S/C <u>10</u> Rev Orig</p> <p>Section <u>3.4.2</u> Pg <u>3</u></p>                                                                                                                                                                                                   |

| SYMPTOM                                                                   | FAILURE                                                                   | PROCEDURE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | REMARKS                                                             |
|---------------------------------------------------------------------------|---------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------|
|                                                                           |                                                                           | <p>10. OAMS CNTL PWR SW - ON</p> <p>11. Reduce rates</p> <p>12. Valve drivers and bias power SWs to primary. Check related CBs closed. And Roll Jets Sw - Yaw</p> <p>13. Close remaining CBs one at a time to identify malfunctioning engine.</p> <p>IF IDENTIFIED: (PRIMARY MODE)</p> <p>14. Affected CB/s -- OPEN</p> <p>15. Switch; Roll Jets Sw to Pitch, and all redundant control system sws to secondary.</p> <p>16. Affected CB/s -- Closed</p> <p>IF NOT IDENTIFIED (OR CORRECTED ABOVE):</p> <p>17. Switch Roll Jets Sw, valve drivers and Bias Power one at a time to identify malfunction.</p> <p>If identified in Direct Mode, remain on operational part of redundant system or with thruster CB/s open as required. Check DIRECT MODE in all three axes, if malfunction is determined to be a thruster/s failed closed refer to procedure 6 and chart 6a.</p> <p>IF FAILURE NOT IDENTIFIED IN DIRECT MODE:</p> <p>18. Verify ACME logic in primary.<br/>ATTITUDE CONTROL - RATE CMD</p> <p>19. Verify operation in all 3 axes.</p> | <p>If not proceed to STEP 17</p> <p>TO CHECK SECONDARY MODE</p>     |
| Prepared by <u>RHB</u><br>Checked by <u>RHB</u><br>Approved by <u>RHB</u> | Flight Crew Support Division<br>Mission Operations Branch<br>Date 5/10/66 | CONTROL SYSTEM<br>MALFUNCTION PROCEDURES                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | Gemini Operations Handbook<br>S/C 10 Rev Orig<br>Section 3.4.2 Pg 4 |

| SYMPTOM                                                                   | FAILURE                                                                    | PROCEDURE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | REMARKS                                                                                                                                                                                        |
|---------------------------------------------------------------------------|----------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                           |                                                                            | <p>If malfunction evident:</p> <p>20. Affected thruster CB/s - OPEN</p> <p>21. Select secondary ACME logic and close CB/s.</p> <p>IF FAILURE IDENTIFIED AND CLEARED -- Continue mission.</p> <p>IF NOT IDENTIFIED:</p> <p>22. RATE GYROS--SEC</p> <p>IF FAILURE IDENTIFIED -- CONTINUE MISSION</p> <p>IF FAILURE EVIDENT BUT NOT IDENTIFIED - OPEN CB/s or select other MODE (Failure in Rate CMD)</p> <p>IF NOT IDENTIFIED:</p> <p>23. AC POWER - IGS<br/>POWER-UP PLATFORM</p> <p>24. ATTITUDE CONTROL - PLAT</p> <p>IF MALFUNCTION EVIDENT -- CONTINUE MISSION IN OTHER MODE</p> <p>IF FAILURE NOT IDENTIFIED:</p> <p>25. ATTITUDE CONTROL - PULSE</p> <p>26. Verify operation in all 3 axes.</p> <p>IF FAILURE IDENTIFIED -- CONTINUE MISSION IN OTHER MODE</p> <p>IF FAILURE NOT IDENTIFIED:</p> <p>27. ATTITUDE CONTROL - HOR<br/>SCAN</p> | <p>20. Refer to step 9.</p> <p>IF PLATFORM ON AT START OF MALFUNCTION.</p> <p>26. If thrusters fire continuous with control handle deflection (short circuit of ground sw) use other mode.</p> |
| Prepared by <u>RHB</u><br>Checked by <u>RHB</u><br>Approved by <u>RHB</u> | Flight Crew Support Division<br>Mission Operations Branch<br>Date: 5/10/66 | CONTROL SYSTEM<br>MALFUNCTION PROCEDURES                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Gemini Operations Handbook<br>S/C <u>10</u> Rev <u>Orig</u><br>Section <u>3.4.2</u> Pg <u>5</u>                                                                                                |

| SYMPTOM                                                                                            | FAILURE                                                                                  | PROCEDURE                                                                                                                                                                                                | REMARKS                                                                                                 |
|----------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
|                                                                                                    |                                                                                          | <p>IF FAILURE IDENTIFIED:</p> <p>28. SCANNER SW - SEC</p> <p>29. Verify operation of pulse mode in yaw axis.</p>                                                                                         | <p>29. PULSE MODE failure does not affect automatic HOR SCAN in pitch and roll.</p>                     |
| <p>5. ANYTIME S/C RATES BECOME INTOLERABLE.</p> <p><u>WARNING:</u></p> <p>ONLY AFTER UNDOCKING</p> |                                                                                          | <p>1. OAMS CNTL PWR SW - OFF</p> <p>2. OAMS PROP MOTOR VALVE SW - CLOSED</p> <p>3. Activate RCS</p> <p>4. VERIFY ATTITUDE CONTROL - DIRECT</p> <p>5. Control S/C</p> <p>6. VERIFY RCS POWER - DIRECT</p> | <p>6. With HAND CONTROLLER inoperative go to PLAT MODE and Power-up IGS.</p>                            |
| <p>Prepared by <u>RA13</u></p> <p>Checked by <u>RA13</u></p> <p>Approved by <u>RA13</u></p>        | <p>Flight Crew Support Division</p> <p>Mission Operations Branch</p> <p>Date 5/10/66</p> | <p>CONTROL SYSTEM</p> <p>MALFUNCTION PROCEDURES</p>                                                                                                                                                      | <p>Gemini Operations Handbook</p> <p>S/C <u>10</u> Rev Orig</p> <p>Section <u>3.4.2</u> Pg <u>6</u></p> |

| SYMPTOM                                                                  | FAILURE                                                                                                                  | PROCEDURE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | REMARKS                                                                                                                                                                                                                                                                       |
|--------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 6. Degraded attitude control (Determined by Procedure 4)                 | Mechanical failure of fuel and/or oxidizer solenoid valves (or open circuitry between solenoid coils and valve drivers). | <p>1. OAMS PROP MOTOR VALVE Switch - CLOSED</p> <p>2. ATTITUDE CONTROL HANDLE-actuate alternately to energize and de-energize malfunctioning thruster.</p> <p>3. OAMS PROP MOTOR VALVE Switch - OPEN</p> <p>4. ATTITUDE CONTROL HANDLE - actuate in malfunctioning axis.</p> <p>5. ATTITUDE CONTROL Mode Switch - RATE CMD.</p> <p>6. If a pitch thruster has failed, ROLL JETS switch - YAW (and visa versa).</p> <p>7. Accomplish attitude changes by combinations of pitch, roll, and yaw commands. An alternate means of control for pitch or yaw can be accomplished by using only one of the two aft or two forward maneuver thrusters respectively. This must be done in DIRECT mode.</p> | <p>1. Only with ground's approval.</p> <p>2. This helps to relieve pressure in propellant lines with possible correction to malfunctioning solenoid valve.</p> <p>4. If thruster fires, malfunction is corrected. If thruster does not fire, accomplish step 5 through 7.</p> |
| Prepared by <u>RHB</u><br>Checked by <u>TH</u><br>Approved by <u>RHB</u> | Flight Crew Support Division<br>Mission Operations Branch<br>Date 5/10/66                                                | CONTROL SYSTEM<br>MALFUNCTION PROCEDURES                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                         | Gemini Operations Handbook<br>S/C <u>10</u> Rev <u>Orig</u><br>Section <u>3.4.2</u> Pg <u>7</u>                                                                                                                                                                               |

6a. MALFUNCTIONING ATTITUDE THRUSTER ISOLATION

| COMMAND    | REACTION                | THRUSTER FAILED CLOSED<br>(WILL NOT FIRE) | REMARKS                     |
|------------|-------------------------|-------------------------------------------|-----------------------------|
| Pitch down | Pitch down & Roll left  | 1                                         |                             |
|            | Pitch down & Roll right | 2                                         |                             |
| Pitch up   | Pitch up & Roll left    | 5                                         |                             |
|            | Pitch up & Roll right   | 6                                         |                             |
| Yaw right  | Yaw right & Roll left   | 3                                         |                             |
|            | Yaw right & Roll right  | 4                                         |                             |
| Yaw left   | Yaw left & Roll left    | 7                                         |                             |
|            | Yaw left & Roll right   | 8                                         |                             |
| Roll right | Roll right & Pitch up   | 1                                         | If ROLL JETS switch - PITCH |
|            | Roll right & Pitch down | 5                                         | ↓                           |
|            | Roll right & Yaw left   | 3                                         | - YAW                       |
|            | Roll right & Yaw right  | 7                                         | ↓                           |
| Roll left  | Roll left & Pitch up    | 2                                         | If ROLL JETS switch - PITCH |
|            | Roll left & Pitch down  | 6                                         | ↓                           |
|            | Roll left & Yaw left    | 4                                         | - YAW                       |
|            | Roll left & Yaw right   | 8                                         | ↓                           |

Prepared by gpc  
 Checked by gpc  
 Approved by gpc

Flight Crew Support Division  
 Mission Operations Branch  
 Date 5/10/66

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 S/C 10 Rev Orig  
 Section 3.4.2 Pg 8

| SYMPTOM                                                                   | FAILURE                                                                                                                                                 | PROCEDURE                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       | REMARKS                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |
|---------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 7. Abnormal decrease in OAMS source pressure.                             | <p>Mechanical failure of a fuel or oxidizer solenoid valve (not seated).</p> <p>Leak in fuel or oxidizer lines downstream of the propellant valves.</p> | <p>IF PRESSURE DECREASE SLOW:</p> <p>1. ATTITUDE CONTROL - RATE CMD</p> <p>After S/C stable.</p> <p>2. OAMS CNTL PWR SW - OFF</p> <p>3. Note rate (or NO rate)</p> <p>IF PRESSURE DECREASE RAPID:</p> <p>Omit steps 1, 2 and 3 ---</p> <p>4. OAMS PROP MOTOR VALVE SW - CLOSED</p> <p>5. OAMS CNTL PWR SW - ON</p> <p>6. MANEUVER CONTROLLER SW - ON</p> <p>7. Actuate ATTITUDE CONTROL HANDLE AND MANEUVER CONTROLLER in all axes.</p> <p>8. OAMS CNTL PWR SW - OFF</p> <p>9. MANEUVER CONTROLLER SW - OFF</p> | <p>3. If solenoid valve failed open rate build up may indicate failure.</p> <p>4. Valve requires 5 sec to close. If leak does not stop it is upstream of motor valves and this procedure will not correct malfunction.</p> <p>7. This may correct the malfunction since pressure is relieved in the manifold.</p> <p>Further, it will bleed the manifold through the solenoid valves and decrease (in the event of a manifold leak) leakage into the adapter section.</p> |
| Prepared by <u>RAV</u><br>Checked by <u>RAV</u><br>Approved by <u>RAV</u> | Flight Crew Support Division<br>Mission Operations Branch<br>Date: 5/10/66                                                                              | CONTROL SYSTEM<br>MALFUNCTION PROCEDURES                                                                                                                                                                                                                                                                                                                                                                                                                                                                        | Gemini Operations Handbook<br>S/C 10 Rev Orig<br>Section 3.4.2 Pg 9                                                                                                                                                                                                                                                                                                                                                                                                       |

| SYMPTOM                                                                    | FAILURE                                                                                                                                      | PROCEDURE                                                                                                                                                                                                                                                                                                                                                                                                                                                                          | REMARKS                                                                                                                                                                                                                                                                                                                                                           |
|----------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                            |                                                                                                                                              | <p><u>Note:</u> Since it is not possible to determine if leak has been stopped without possible fuel or oxidizer loss, the OAMS PROP MOTOR VALVE SW should be left CLOSED until the OAMS is required for orbit adjustment etc.</p> <p><u>Note:</u> Anytime the PROP MOTOR VALVE is re-opened, yaw full left until thruster fires and actuate all thrusters to insure manifold fully pressurized.</p> <p>10.. OAMS REG SW - SQUIB<br/>11. CONTROL PRESSURE MANUALLY WITH PULSE.</p> |                                                                                                                                                                                                                                                                                                                                                                   |
| 8. Abnormal decrease in RCS RING A or B source pressure (System activated) | <p>Mechanical failure of a solenoid valve (valve not seated).</p> <p>Leak in fuel or oxidizer lines downstream of the PROPELLANT valves.</p> | <p>1. Affected RCS PROP MOTOR VALVE switch - CLOSED<br/>2. Affected RCS ATTITUDE CONTROL switch - ON</p> <p>3. Actuate ATTITUDE CONTROL HANDLE in all axes.</p>                                                                                                                                                                                                                                                                                                                    | <p>1. &amp; 2.<br/>If leak does not stop, it is upstream of motor valves, and there is no correction.</p> <p>3. This may possibly correct malfunction since pressure is relieved relieved from the manifold. Further, it will bleed the manifold through the solenoid valves and decrease (in event of a leaking manifold) leakage into the R &amp; R Section</p> |
| Prepared by <u>RHB</u><br>Checked by <u>RHB</u><br>Approved by <u>RHB</u>  | Flight Crew Support Division<br>Mission Operations Branch<br>Date 5/10/66                                                                    | CONTROL SYSTEM<br>MALFUNCTION PROCEDURES                                                                                                                                                                                                                                                                                                                                                                                                                                           | Gemini Operations Handbook<br>S/C <u>10</u> Rev <u>Orig</u><br>Section <u>3.4.2</u> Pg. <u>10</u>                                                                                                                                                                                                                                                                 |

| SYMPTOM                                                                                          | FAILURE                                                                                                               | PROCEDURE                                                                                                                                                                       | REMARKS                                                                                                                                                                                                                                                                                            |
|--------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                                                  |                                                                                                                       | 4. Affected RCS ATTITUDE CONTROL Switch - OFF                                                                                                                                   | 4. Affected power and propellant switches should remain OFF except when the system is needed for retrofire and reentry.                                                                                                                                                                            |
| 9, 10, & 11<br>Low OAMS regulated pressure (below 230 psi) as read onboard and ground telemetry. | 9. Regulator failed closed.                                                                                           | 1. Verify:<br>OAMS CNTL PROP C/B - Closed<br>OAMS CNTL REG 1 & 2 C/B's Closed.<br>2. OAMS REG Switch - PULSE.<br><br>3. OAMS REG Switch - SQUIB.<br>4. OAMS REG Switch - PULSE. | 2. If pressure rises, symptom was due to an overpressure failure of the regulator. See next failure. If pressure does not rise and it is ascertained that the main fuel tank is not empty, accomplish steps 3 & 4.<br><br>4. Maintain pressure at approx 295 psi as req'd. Do not exceed 340 psia. |
|                                                                                                  | 10. Regulator failed open. (Automatic pressure switch had closed N.O.S.V. and OAMS usage has decreased the pressure). | 1. OAMS REG Switch - PULSE (as required).                                                                                                                                       | Use PULSE position as required to maintain pressure at approx. 295 psi as required. Do not exceed 340 psia.                                                                                                                                                                                        |
| Prepared by <u>RAT</u><br>Checked by <u>RAT</u><br>Approved by <u>RAT</u>                        |                                                                                                                       | Flight Crew Support Division<br>Mission Operations Branch<br>Date 5/10/66                                                                                                       | CONTROL SYSTEM<br>MALFUNCTION PROCEDURES                                                                                                                                                                                                                                                           |
| MSC Form 460 (May 64)                                                                            |                                                                                                                       | Gemini Operations Handbook<br>S/C 10 Rev Orig<br>Section 3.4.2 Pg 11                                                                                                            |                                                                                                                                                                                                                                                                                                    |

| SYMPTOM                                          | FAILURE                                                                           | PROCEDURE                                                                                                      | REMARKS                                                                        |
|--------------------------------------------------|-----------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|
|                                                  | 11. Clogged line filter/s.                                                        | The RCS system will not be activated and used after OAMS pressure is depleted unless designated by the ground. | OAMS system will be lost when pressure is depleted.                            |
| 12. High OAMS regulated pressure (above 380 psi) | Overpressure failure of the OAMS regulator and automatic pressure switch failure. | 1. OAMS REG Switch - SQUIB<br>2. OAMS REG Switch - PULSE                                                       | Maintain pressure at approximately 295 psi as required. Do not exceed 340 psi. |

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|-------------------------------|------------------------------|------------------------------------------|-----------------------------------|
| Prepared by <u><i>RAH</i></u> | Flight Crew Support Division | CONTROL SYSTEM<br>MALFUNCTION PROCEDURES | Gemini Operations Handbook        |
| Checked by <u><i>RAH</i></u>  | Mission Operations Branch    |                                          | S/C <u>10</u> Rev <u>Orig</u>     |
| Approved by <u><i>RAH</i></u> | Date 5/10/66                 |                                          | Section <u>3.4.2</u> Pg <u>12</u> |