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PROJECT APOLLO

TASK MSC/TRW A-97

RESULTS OF INDEPENDENT FLIGHT SOFTWARE VALIDATION TEST OF THE BURST116 PROGRAM FOR THE LM-1 MISSION

DRA

28 SEPTEMBER 1967

Prepared by
D. B. Urfrig

Prepared for
MISSION PLANNING AND ANALYSIS DIVISION
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
MANNED SPACECRAFT CENTER
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ABSTRACT

This document describes the results of flight software verification tests of the LM-1 mission. This report is submitted to the NASA Manned Spacecraft Center under MSC/TRW Task A-97, Contract NAS 9-4810. The tested phases of the LM-1 mission have been simulated with the MSC Block II Apollo Guidance Computer Simulation using the "A" release LM-1 BURST116 Flight Program. The post-boost operational trajectory has been essentially recreated by the ICS runs, and discrepancies are noted. The flight software has been exercised for nominal and various perturbed initial conditions. In addition, testing has been performed under the classification of special runs which includes checks of various computer processing operations such as uplink, Verb 74, and the tumble monitor.

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NOMENCLATURE

APS1	Ascent propulsion system first burn
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CDU	Coupling data unit
C&W	Caution and warning
DAP	Digital autopilot
DFI/TM	Development Flight Instrumentation/Telemetry
DOI	Descent orbit injection
DPS1	Descent propulsion system first burn
DPS2	Descent propulsion system second burn
ECI	Earth centered inertial
EOC	Engine-off command
FITH	Fire-in-the-hole
GSOP	Guidance Systems Operations Plan
ICS	Interpretive computer simulation
IMU	Inertial measurement unit
LGC	Lunar module guidance computer
LM	Lunar module
LMP	LM Mission Programmer
MP	Mission phase
OT	Operational Trajectory
RCS	Reaction Control System
S-IVB	Saturn IV B
S/O	Shut-off

1. INTRODUCTION AND SUMMARY

This document presents the results of software validation tests of the LM-1 mission performed under MSC/TRW Task A-97 to evaluate the adequacy of the flight software for the LM-1 mission. The test cases defined in the test plans (References 1 and 2) were simulated on the MSC Block II Apollo Guidance Computer Simulator. Vehicle dynamics and associated environments are specified by the AS-206 Simulation Environments Mod 1S for boost cases and Mod 6 for post S-IVB/LM separation runs. A definition of the vehicle constants is presented in Appendix C of Reference 3. Mod 10 of the Interpretive Computer Simulation was used with BURST116, the "A" release flight program.

Table 1 summarizes the testing and the results reported in this document. The discrepancies are summarized in Section 2. A complete discussion of the test cases is presented in the sections entitled Nominal Runs, Perturbed Runs and Special Runs. The format of each test discussion includes the test description, objectives, test results summary, and a more complete discussion of the test results followed by the presentation of actual data in the form of trajectory summaries, event summaries, phase summaries, and plots. The LM-1 testing discussed includes nominal and perturbed trajectories of mission phase 9, 11 and 13. These are the descent propulsion system first burn (DPS1) phase, descent propulsion system second burn/fire-in-the-hold/ascent propulsion system first burn (DPS2/FITH/APS1) phase, and ascent propulsion system second burn (APS2) phase, respectively. Testing of mission phases 2, 6 and 7, (boost, S-IVB/LM coast, and S-IVB/LM separation) was attempted; however, limited objectives were achieved in these mission phases because of a problem with the boost simulation.

In addition to the nominal runs and perturbed runs, which are closed loop computer runs, there are the special runs, the majority of which were performed open loop. The special runs consist of tests of specific computer processing functions such as uplink verification and studies of the tumble monitor.

The original test plan (Reference 1) included digital autopilot (DAP) testing (runs 33 to 42). Testing of the BURST116 DAP was, however, redefined and performed in accordance with the test plan of Reference 5. The results of these tests will be reported separately.

The initialization of nominal test runs was derived basically from three reference documents. These are the operational trajectory (Reference 6) from which the environment and state data were derived, the final spacecraft targeting memorandum (Reference 7) for target definitions, and Reference 8, which defines the prelaunch erasable memory load. Perturbed runs included errors in the nominal data that were derived from the various references cited.

Two primary documents were used to evaluate the performance of the flight software. These are the AS-206 Operational Trajectory (OT) (Reference 6) and the Guidance Systems Operations Plan (GSOP) (Reference 9). Mission phases were scheduled so that the burns would be consistent with the targeting of the OT. To do this required modification of the mission phase timer settings in the lunar module guidance computer (LGC) erasable memory for mission phase 13 as specified by the GSOP. Assumptions were made on various erasable memory constants, and in certain cases (e.g., COUNTBOX and VCONOM) the performance of the mission was affected. Since software performance can be greatly affected by the contents of erasable memory, it is highly desirable to control the erasable memory load for ICS validation testing. The targeting parameters used in ICS testing were consistent with those used in the OT burns. In the absence of detailed software requirements, the OT was selected for comparison purposes. Thus, many of the discrepancies presented are actually deviations from the assumed nominal performance of the OT. Additional comparison was made with the AS-206 flight plan (Reference 10) with respect to the timing of certain mission events.

By initializing each mission phase in the described manner and observing mission intervals generated by the bit-by-bit simulation, the expected timeline of this mission was synthesized for the mission phases 9, 11 and 13. This timeline is presented in Table 2. It should be emphasized that the actual mission timeline is a function of the erasable memory load in the flight computer.

The following table lists the LGC programs and identifies the extent to which they have been exercised during the tests.

LGC Programs Exercised

Program Number	Program	Extent Exercised
00	LGC Idling	Exercised before and after all Mission Phase 9, 11, and 13 runs.
01	Pre-launch Initialization	Not studied.
02	Pre-launch Gyrocompassing	Not studied.
04	Terminate Gyrocompassing	Not studied.
05	Pre-launch System Test	Not studied.
07	Pre-launch Inertial	Not studied.
11	Pre-LET Jet Boost Monitor	Limited testing only.
12	Post-LET Jet Boost Monitor	Limited testing only.
13	Coast: SIVB Attached	Limited testing only.
14	SIVB/LM Separation	Exercised in tumble monitor tests.
15	Coast: DPS Cold Soak	Not studied.
27	LGC Update	Exercised for state vectors in MP9, 11 and 13.
31	Pre-DPS1	All of mission phase 9 exercised.
32	Pre-DPS2	All of mission phase 11 exercised.
34	Pre-APS2	All of mission phase 13 exercised.
41	DPS1 Burn	All of mission phase 9 exercised.

LGC Programs Exercised (Continued)

Program Number	Program	Extent Exercised
42	DPS2 Burn-Braking	All of mission phase 11 exercised.
43	DPS2 Burn Approach	All of mission phase 11 exercised.
44	DPS2 Burn-Random Throttle	All of mission phase 11 exercised.
46	APS2 Burn	All of mission phase 13 exercised.
47	Contingency APS2	Not studied.
71	Suborbital Abort	Exercised in tumble monitor tests only.
72	Contingency Orbit Insertion	Exercised in tumble monitor tests only.
74	FITH/APS1 (Nominal FITH test)	All of mission phase 11 exercised.

Numbers assigned to test runs are consistent with those defined in References 1 and 2.

The results presented include those tests considered to be of highest priority and consistent with simulation capability and test scheduling.

Table 1. Test Results Summary

NOMINAL RUNS

Run Number	Description	Objectives	Simulation Interval	Summary of Results
1 and 2	Nominal simulation of boost	To verify the boost programs (P07, P11, P12). The objectives were to verify the LGC computations of the state vector, study event scheduling, and verify the downlink of state vector and CDU data.	Initialized during prelaunch and through coast after boost.	The limited results obtained show that the contents of the state vector and CDU registers during use of the boost monitor program (P11) are correctly downlinked.
4	Nominal simulation of DPS1	To establish a closed-loop reference simulation of the nominal DPS1 to which perturbed runs will be compared. To validate DPS1 prethrust, thrust, thrust termination, LGC/LMP sequencing, targeting, and attitude maneuvering.	Initialized prior to entrance into program P31 (pre-DPS1) through program P41 and post-thrust coast.	Compared favorably with the OT. The sequencing of events from the program P31 (pre-DPS1) through the program P41 (DPS1 burn) has been verified for the nominal conditions as prescribed in the AS-206 OT. The ullage overlap prior to DPS1 may be insufficient for the LM A or B configuration descent propulsion engine. The deviation from the OT is 2.5 n mi in apogee and 0.02 n mi in perigee.
5	Nominal simulation of the DPS2 burn	To establish a closed-loop reference simulation of the nominal DPS2 burn to which perturbed runs will be compared. To validate DPS2 targeting, attitude maneuver and LGC/LMP program sequencing through DPS burn braking, approach and random throttling.	Initialized prior to entrance into DPS2 prethrust program P32 with LGC/LMP sequencing through programs P42 (burn braking), P43 (burn approach), and terminating after the abort discrete of program P74 (FITH/APS1)	The sequencing of events from the program P32 (pre-DPS2) through the program P74 (FITH/APS1) has been performed for the nominal conditions as prescribed in the AS-206 Operational Trajectory. The sequence of events during Mission Phase 11 does not coincide with that of the OT. Timing differences range up to 12.4 seconds for the FITH maneuver. The same ullage overlap problem of run 4 applies. At the FITH guidance command the ICS and OT apogee and perigee agree to within less than 0.1 n mi. At the APS1 engine-off command the apogee differs by 2 n mi, the perigee differs by 0.04 n mi.

Table 1. Test Results Summary (Continued)

NOMINAL RUNS (Continued)

Run Number	Description	Objectives	Simulation Interval	Summary of Results
6	Nominal simulation of FITH and APS1	To establish a closed-loop reference simulation of the abort sequence leading to and through the FITH and APS1 burn. Perturbed runs will be compared to this nominal with emphasis on attitude stability during the separation sequence. The nominal run will also serve to validate the DPS2 abort FITH, and APS1 burn sequencing.	Beginning prior to APS 1 burn, sequencing through FITH program P74 and through APS1 engine - off command. This was actually run jointly with run 5.	The results of this case are contained in run number 5 above.
7	Nominal simulation of APS2 prethrust and APS2 burn.	To establish a closed-loop reference simulation for comparison purposes of the final APS burn phase; to validate the APS2 attitude maneuvers and proper LGC/ LMP mission sequencing.	Initialized prior to APS2 prethrust program P34 and run through thrust termination of APS2 burn program P46 and post thrust coast to the target.	A nominal ICS trajectory has been established for LGC programs P34 and P46 initialized with the APS2 conditions prescribed by the OT. It is found that with a consistent engine ignition time the OT and ICS attitude maneuver and ullage maneuver sequencing differ. An attitude transient has been observed in the early portion of the ICS burn. Target miss at nominal time of arrival at the target was 10. 3 n mi.

Table 1. Test Results Summary (Continued)

PERTURBED RUNS

Run Number	Description	Objectives	Simulation Interval	Summary of Results
9	Simulation of DPS1 (DOI) burn with a dispersion of the initial trajectory state vector.	To determine the effect of the the following initial state vector dispersion (with respect to nominal run 4) on the guidance system performance: $\Delta X = 2,209$ ft, $\Delta Y = 535$ ft, $\Delta Z = 33,579$ ft, $\Delta \dot{X} = 7.451$ fps, $\Delta \dot{Y} = 7.451$ fps, $\Delta \dot{Z} = 129.996$ fps } ECI	Initialized at DPS1 prethrust program (P31) through DPS1 Engine off command during program (P41).	A comparative analysis between the perturbed run and nominal run 4 revealed no significant problem areas. The target apogee value at cutoff was in error by 0.83 n mi (low). The dispersed initial state vector required 4.9 lbs of additional RCS fuel and 144.91 lbs of additional DPS fuel to achieve the desired target. The RCS fuel is attributed to higher than nominal spacecraft attitude rates.
10	Simulation of DPS1 (DOI) burn with initial nozzle offsets in pitch and roll	To determine the effects of torques caused by incorrect nozzle settings and to demonstrate the capability of DPS gimbal trim through the c.g. Initial Y nozzle offset = 2.0 deg Initial Z nozzle offset = 0.5 deg	Same as run 9.	The torques caused by the incorrect nozzle setting resulted in CDU angle excursions of 3 degrees for CDUY and 8 degrees for CDUZ. The RCS propellant used was more than double that used in the nominal. The target apogee altitude was within 0.094 n mi of the nominal value at DPS cutoff. The DPS gimbals were finally driven to within 0.1 degree of the calculated values.
11	Simulation of DPS1 (DOI) burn with initial nozzle offset in roll only	To demonstrate the capability of steering and attitude control with an initial control with an initial nozzle offset for the DPS1 burn. Initial Z nozzle offset = 0.5 deg	Same as run 9.	A comparative analysis with nominal run 4 indicates that nozzle offsets in roll cause no large dispersions in the resulting trajectory or spacecraft parameters. The target apogee altitude was achieved with an error of 0.08 n mi at DPS cutoff.

Table 1. Test Results Summary (Continued)

PERTURBED RUNS (Continued)

Run Number	Description	Objectives	Simulation Interval	Summary of Results
13	Simulation of DPS1 (DOI) burn with a 10 percent moment of inertia discrepancy between the LGC and environment data.	To investigate the sensitivity of the guidance dynamics to changes in the vehicle characteristics.	Same as run 9.	A comparative analysis between this run and the nominal run 4 indicated no significant discrepancies. The main difference was a 2-lb decrease in the RCS fuel used during the attitude maneuver. The apogee altitude was achieved with an error of 0.83 n mi at engine cutoff.
14	Simulation of DPS1 (DOI) burn with a 20 percent discrepancy between the LGC and the environment gimbal rates.	To investigate the sensitivity of the control dynamics to discrepancies between actual (environment) and LGC predictions of DPS gimbal rates; to test DPS1 targeting, and attitude control stability in the presence of these discrepancies.	Same as run 9.	A comparative analysis between this run and the nominal run 4 indicated that the DPS1 burn and the associated attitude control were performed successfully in the presence of gimbal rate discrepancies. The RCS fuel used during the burn was reduced from 3.58 lbs to 2.57 lbs due to the higher gimbal rate. The target apogee altitude was achieved within 0.69 n mi at engine cutoff
15	Simulation of DPS1 (DOI) with a thrust perburbation.	To determine the effect of a $+3\sigma$ DPS engine thrust perturbation on the guidance performance. Thrust scale factor = 1.10	Same as run 9.	A comparative analysis between the perturbed run and nominal run 4 revealed no significant problem areas resulting from the imposed thrust perturbation. The target apogee altitude was achieved with an error of 0.016 n mi at engine cutoff.
16	Simulation of DPS1 (DOI) burn with off-nominal ISP engine characteristics.	To determine the effect of a $+3\sigma$ ISP perturbation on the guidance performance. ISP scale factor = 1.03	Same as run 9.	A comparative analysis between the perturbed run and nominal run 4 revealed no problem areas resulting from the imposed ISP perturbation. The target apogee altitude was achieved with an error of 0.68 n mi at DPS engine cutoff.

Table 1. Test Results Summary (Continued)

PERTURBED RUNS (Continued)

Run Number	Description	Objectives	Simulation Interval	Summary of Results
17	IMU errors during the prethrust program and DPS1 burn followed by an uplink of a state vector update. The IMU errors are three times the one-sigma uncertainties in Table 7-12 of Reference 9.	To determine the effect of three-sigma IMU errors during this phase, assuming a perfect state vector update prior to mission phase 9, and to validate the uplink capability of a state vector update to the LGC following the burn.	Initialized prior to DPS1 prethrust program P31 through DPS1 engine-off command during program P41 and the following coast period. This is a perturbation to nominal run 4.	The flight software for programs P31 and P41 has been validated for three-sigma IMU errors, with a perfect state vector update assumed prior to mission phase 9 (DPS1). The uplink state vector update capability following DPS1 has been verified. The deviation from the nominal ICS run was 0.26 n mi in apogee and 0.003 n mi in perigee.
18	IMU errors during the DPS2 burn, approach, hover maneuver, FITH, APS1 burn followed by an uplink of a state vector update. IMU errors are the same as those in run 17.	To determine the effect of three-sigma errors on the DPS2 burn maneuver, FITH, and APS1, assuming a perfect state vector update prior to mission phase 11, and to validate the uplink capability of a state vector update to the LGC following the burn.	Initialized prior to DPS2 prethrust program P32 through APS1 burn command of program P74 and the following coast. Perturbation of a combined run of nominal runs 5 and 6.	The flight software for programs P32, P42, P43, P44 and P74 has been validated for three-sigma IMU errors with a perfect state vector update assumed prior to mission phase 11. Even with the perfect state vector update prior to mission phase 11, the three-sigma errors propagated through the DPS2/FITH/APS1 burn create errors in the final orbital perigee and apogee of 2.3 and 8.1 n mi, respectively. The uplink state vector update capability following APS1 has been verified.
20	Simulation of APS2 burn with a dispersed initial trajectory state vector.	To determine the effect of the following initial state vector dispersions (with respect to nominal run 7) on the guidance system performance: $\Delta X = -8,700$ ft $\Delta Y = 488,800$ ft $\Delta Z = 91,000$ ft $\Delta \dot{X} = -600$ fps $\Delta \dot{Y} = 48$ fps $\Delta \dot{Z} = 15.5$ fps } ECI	Initialized prior to APS2 prethrust program (P32) and continues through thrust termination of APS2 burn program (P46).	The APS2 burn associated guidance and spacecraft control were exercised with little deviation from the nominal results. The resulting target miss of 10.6 n mi compared to the nominal miss of 10.3 n mi. The resulting burn was 18.5 seconds shorter than the nominal and required 210 lbs less APS fuel due to the lower energy required.

Table 1. Test Results Summary (Continued)

PERTURBED RUNS (Continued)

Run Number	Description	Objectives	Simulation Interval	Summary of Results
21	IMU errors during APS2 followed by an uplink of a state vector update. IMU errors are three times the one-sigma uncertainties in Table 7-14 of Reference 9.	To continue the demonstration of the effects of a three-sigma IMU error during the APS2 burn, assuming a perfect state vector update prior to mission phase 13, and to validate the uplink capability of a state vector update to the LGC following the burn.	Initialized prior to APS2 prethrust and continued through coast following APS2 burn. This is a perturbation of nominal run 7.	An ICS trajectory has been established for three-sigma IMU errors during APS2. The resulting velocity error between the LGC and environment after the burn is 4260.0 ft and 9.25 ft/sec. Uplink of a state vector update was completed following the APS2 burn. At the intercept time there was a target miss of 14.7 n mi.
22	Simulation of APS2 burn with an initial c.g. offset along the Y and Z LM axes.	To demonstrate thrust vector and attitude control capabilities with unwanted torques due to initial c.g. offsets. Y c.g. offset error = 0.5 in. Z c.g. offset error = 0.5 in.	Same as run 20.	The APS2 burn and associated guidance and spacecraft attitude control were exercised with no significant body rates, trajectory deviations or fuel problems with initial c.g. offsets. At APS engine off, the resulting trajectory had deviations in apogee of 0.9 n mi low and in perigee of 0.5 n mi high. Target miss was 9.11 n mi compared to the nominal miss of 10.3 n mi.
23	Simulation of APS2 burn with an APS thrust perturbation.	To test APS guidance and control performance associated with a high ascent engine thrust characteristic. Thrust scale factor = 1.07	Same as run 20.	The high APS thrust resulted in a guidance cutoff 24.1 sec earlier than the nominal. The APS fuel was depleted at a T_{go} of 1.7 seconds. At cutoff, the perigee was 5.3 n mi low and apogee was 0.3 n mi high as compared to nominal run 7. The resulting target miss was 16.9 n mi compared to the nominal run miss of 10.3 n mi.

Table 1. Test Results Summary (Continued)

PERTURBED RUNS (Continued)

Run Number	Description	Objectives	Simulation Interval	Summary of Results
24	Simulation of APS2 burn with an off-nominal ISP engine characteristic.	To determine the effect of a perturbed ISP. ISP scale factor = 1.03	Same as run 20.	The APS2 trajectory achieved with a 3 percent perturbation had very small deviations from the nominal trajectory of run 7. The burn was 2.2 seconds longer than the nominal with a resulting target miss of 10.6 n mi.
43	Initial state vector errors (in the LGC) combined with IMU errors during DPS1 followed by an uplink of a state vector update. IMU errors are the same as those in run 17. The state vector errors are defined in Reference 11.	To determine the effect of three-sigma IMU errors propagated from launch through mission phase 9 and to perform a state vector update following DPS1.	Same as run 17.	The flight software for programs P31 and P41 has been validated for three-sigma IMU errors propagated through mission phase 9. The desired perigee (119.4 n mi) of the orbit was attained; however, the apogee exceeded the nominal (179.4 n mi) altitude by 7.9 n mi. The uplink state vector update capability following DPS1 has been verified.
44	Initial state vector errors (in the LGC) combined with IMU errors during DPS2 burn, FITH, and APS1 followed by an uplink of a state vector update. IMU errors are the same as those in run 17. The state vector errors are defined in Reference 11.	To determine the effect of three-sigma IMU errors propagated from launch through mission phase 11 and to perform a state vector update following APS1.	Same as run 18.	The flight software for programs P32, P42, P43, P44 and P74 has been validated for three-sigma IMU errors propagated through mission phase 11 without a state vector update prior to the burn period. The uplink state vector update capability after the APS1 burn has been verified. The perigee and the apogee of the orbit following mission phase 11 are 6.3 n mi lower and 8.1 n mi higher than the nominal, respectively.

Table 1. Test Results Summary (Continued)

PERTURBED RUNS (Continued)

Run Number	Description	Objectives	Simulation Interval	Summary of Results
45	Initial state vector errors (in the LGC) combined with IMU errors during APS2 burn followed by an uplink of a state vector update. IMU errors are the same as those in run 21. The state vector errors are defined in Reference 11.	To determine the effect of three-sigma IMU errors propagated from launch through mission phase 13 and to perform a state vector update following APS2.	Same as modified run 21.	The LGC compared with the environments had a velocity error at thrust termination of 30.16 ft/sec. Uplink of a state vector update completed following the APS2 burn. The resulting intercept error at the target was 72.2 n mi. This error suggests that a state vector update prior to the APS2 burn is desirable.
53	Simulation of DPS1 (DOI) burn with initial trajectory state vector dispersions for low perigee.	To test the guidance performance with a large dispersion in the initial orbit before the burn. The initial perigee was 81.9 n mi as opposed to the nominal of 95.5 n mi.	Same as run 9	The DPS1 guidance equations were not able to attain the final desired apogee using the nominal targeting parameters. The final perigee was 8.02 n mi lower and the apogee was 2.03 n mi higher than the nominal DPS1 (run 4) case.

Table 1. Test Results Summary (Continued)

SPECIAL RUNS

Run Number	Description	Objectives	Simulation Interval	Summary of Results
32	LGC Uplink Inputs			
	(a) LGC Clock Alignment	To test the ability of the LGC to accept a specific value of uplink clock alignment data and to accept uplink clock increment and decrement data.	Initialized during coast prior to MP13.	The LGC is capable of accepting specific clock alignment data and is capable of being incremented and decremented via uplink.
	(b) DFI-TLM Calibrate	To test the ability to initiate the LGC DFI-TLM calibrate routine via uplink.	Initialized during coast prior to MP13.	The LGC is capable of initiating the DFI-TLM calibrate routine when commanded via uplink.
	(c) LGC-LMP Commands	To test the ability of the LGC to accept LMP commands via uplink.	Initialized during coast prior to MP13.	The LGC is capable of sending single LMP commands when ordered to do so via uplink.
	(d/e) Update mission timers and mission phase registers	To verify the ability to update the mission timers and the mission phase registers.	Initialized during coast prior to MP9.	This test showed that the mission phase to be run and the time when it is to start may be updated by use of uplink.
	(g) Function Inhibit	To test the ability of the LGC to respond to an inhibit function sent via uplink and to inhibit RCS cold soak.	Initialized during the coast period prior to MP8.	Test results show that the LGC correctly inhibited the RCS cold soak (MP8) when commanded to do so via uplink.
	(i) Target update for MP9, 11 and 13	To test the ability of the LGC to accept a target update sent via uplink.	Initialized prior to respective mission phases.	This test verified that the computer accepts target update information sent via uplink.
46	S-IVB coast with the TUMBL bit set to indicate a tumble rate greater than 3 deg/sec and then changed to the inverse state.	To validate S-IVB separation in program P07 will occur with the TUMBL bit set indicating an excessive tumbling rate exists.	From entrance to program P07 through LM/S-IVB separation.	The S-IVB separation discrete is issued during program P07 even with the TUMBL bit set indicating tumbling rate greater than 3 deg/sec.

Table 1. Test Results Summary (Continued)

SPECIAL RUNS (Continued)

Run Number	Description	Objectives	Simulation Interval	Summary of Results
47	Verb 74 uplink - Orbital integration.	To verify a timing problem with the verb 74 message.	Initialized prior to DPS1 during revolution number 3.	The "Verb 74" message, if received while a segment of the orbital integration routine is being processed, will result in terminating all succeeding state vector updates. If it occurs, this condition can be corrected by issuing another "Verb 74" message.
49	Mission phase 02 (boost) with cycling through TUMTASK.	To verify that the tumble flag is set correctly indicating a tumble rate is less than or greater than 3 deg/sec.	During mission phase 02.	TUMBL (bit 13 of FLAGWRD1) is set correctly to indicate whether or not the vehicle is tumbling in excess of 3 deg/sec.
50	Mission phase 3 (Sub-orbital Abort) with a tumble rate greater than 3 deg/sec.	To validate that separation during mission phase 3 will not be permitted with a tumble rate in excess of 3 deg/sec.	During mission phase 3.	Separation was inhibited during mission phase 3 with the tumble flag set to indicate a tumble rate in excess of 3 deg/sec.
51	Mission phase 4 (Contingency Orbital Insertion) with a tumble rate greater than 3 deg/sec.	To validate that separation during mission phase 4 will not be permitted with a tumble rate in excess of 3 deg/sec.	During mission phase 4.	Separation was inhibited during mission phase 4 with the tumble flag set to indicate a tumble rate in excess of 3 deg/sec.
52	Simulation of nominal DPS2/FITH/APS1 burn with a higher than nominal number of passes (100) through the DAP Kalman filter before the trim gimbal will relinquish control to the RCS jet control.	To determine the effect of a larger than nominal value of COUNTBOX (in erasable memory) upon the DPS2/FITH/APS1 burn. The nominal value is 10.	Initialized prior to entrance into program P32 with LGC/LMP sequencing through programs P42, P43 and terminating after the abort discrete of program P44.	The mission phase 11 event timeline varies only slightly from the nominal test case. The final trajectory after APS1 exhibited errors of 19.063 n mi in apogee and 0.839 n mi in perigee. The RCS fuel consumed was 160.7 lbs compared to the nominal consumption of 28.1 lbs.

Table 2. Nominal AS-206 Timeline
(Synthesized from ICS Testing)

Time (sec)	Event	Mission Phase
	Schedule mission phase 09	8
14,126.043	Start MP9 enter program P31, pre-DPS1	9
14,128.803	Begin attitude maneuver	9
14,142.547	Complete attitude maneuver	9
14,335.908	Enter program P41, DPS1 burn	9
14,394.407	RCS ullage	9
14,401.907	DPS engine on	9
14,427.911	Increase throttle to maximum	9
14,429.866	Enable DAP gimbal trim	9
14,440.086	DPS engine off	9
14,448.057	Delta velocity monitor detects engine shutdown	9
14,538.050	Schedule mission phase 11 (MP11)	9
16,424.426	Start MP11, enter program P32, pre-DPS2	11
16,440.537	Begin attitude maneuver	11
16,460.240	Complete attitude maneuver	11
16,584.721	Enter program P41, DPS2 burn braking	11
16,607.220	RCS ullage	11
16,614.720	DPS engine on	11
16,640.719	Increase throttle to maximum	11
16,787.596	Enter high-gate targeting	11
16,952.506	Throttle control recovery	11
17,095.595	Enter program P43, low gate targeting	11
17,294.109	Enter program P44, DPS2 random throttling	11
17,346.729	APS engine arm on	11
17,346.751	Enter program P74, FITH/APS1	11
17,347.749	DPS engine arm off	11
17,351.750	APS engine off	11
17,357.562	Delta velocity monitor detects engine shutdown	11
17,387.555	Schedule mission phase 13 (MP13)	11

Table 2. Nominal AS-206 Timeline (Continued)

Time (sec)	Event	Mission Phase
22,245.059	Start MP13, enter program P34 (pre-APS2)	13
22,250.954	Begin attitude maneuver	13
22,253.757	Complete attitude maneuver	13
22,385.060	Enter program P46 (APS2 burn)	13
22,402.557	RCS ullage	13
22,415.057	APS engine on	13
22,424.063	RCS propellant feed from APS (LMP commands)	13
22,854.999	APS engine off	13
22,893.284	Enter POO, LGC idle	13
24,794.155	Target intercept	N/A

2. DISCREPANCIES

The following discrepancies have been encountered during AS-206 flight software validation testing:

1) An attitude transient is observed in the ICS runs approximately 7 seconds after the APS2 engine on command is issued. The magnitude of the transient (9-degree spike in middle gimbal) is not as large in runs with other simulations.

2) The duration of the second DPS burn during mission phase 11 was 10.8 seconds longer for the nominal ICS run than for the AS-206 OT. Timing differences between the ICS and the OT for different events during DPS2 range up to 12.4 seconds (at FITH). Ten seconds of the 12.4-second deviation between the OT and ICS FITH abort command can be attributed to a 10-second final transition subroutine during the low-gate target phase which was omitted from the OT and which exists in the flight software.

3) The AS-206 OT performed rotations about the vehicle X-axis to attain a preferred orientation during preburn attitude maneuvers. The flight software does not provide attitude control about the direction of the vehicle X-axis. Therefore, the duration of the maneuvers, the attitude histories, and the RCS propellant consumption during the prethrust attitude maneuvers differ from those predicted by the OT.

4) The targeting for mission phase 13 in the AS-206 operational trajectory defined the time of APS2 ignition as 85 seconds later than that defined in the GSOP for AS-206 (Reference 9). The APS2 ignition is performed 170 seconds (defined in fixed memory) after enabling mission phase 13. Therefore, in order to attain the targeting conditions defined in the AS-206 OT, the mission phase 13 must be enabled 85 seconds later than that time defined by the GSOP.

5) The flight program for the LM-1 mission (BURST116) commands the termination of ullage 0.5 second after the guidance command to turn on the DPS engine during mission phases 9 and 11. DPS engine data show a possible time delay in excess of 0.5 second between the engine on guidance command and the first measurable rise in thrust. Therefore, the ullage time overlap may be inadequate for proper DPS ignition.

6) In comparing ICS test results to the timing data presented in the "AS-206 Flight Plan (Final)" (Reference 10), two mission sequencing discrepancies have been encountered. First, the scheduling of the attitude maneuvers in the ICS runs differ from the flight plan by -16.2 seconds for DPS1 and +47.5 seconds for DPS2. Secondly, in the APS2 ascent feed test of RCS jets the ICS run begins the propellant feed test 0.3 second earlier, and terminates the test 22.7 seconds later than indicated in the AS-206 flight plan. This causes an additional 23 seconds of propellant cross-feed in the ICS run.

7) Attention is directed to the instanteous perigee profile during the nominal APS2 burn (Figure 8). The perigee falls under 40 miles during the burn which is below the acceptable 75 nautical miles (Reference 12) minimum limit established by flight control.

RUNS 1 AND 2 TEST RESULTS SUMMARY

Test Run Description

A simulation of the Saturn boost phase through coast and prior to separation.

Test Run Objectives

To verify the boost programs (P07, P11, P12). The objectives in light of schedule and simulator availability were to verify the LGC computations of the state vector, study event scheduling, and verify the downlink of state vector and CDU data.

Summary of Results

The results show that the contents of the state vector and CDU registers during the boost monitor program (P11) are correctly downlinked. The results obtained did not allow verification of the LGC computations of the state vector.

Discussion of Test Results

The downlink transmission of the LGC state vector RN and VN was studied. The state vector from the downlink record represented data available approximately 6.16 seconds earlier than the indicated record time. This was studied and was consistent with a 10-second downlink interval. Thus, the state vector downlink mechanization has been verified. It was also verified that the contents of the CDU registers were properly downlinked.

The Saturn boost simulation was still in a developmental stage during the preparation of this report. Due to difficulties with the simulation, at the time of publication of this report the computation of state vector data of the boost monitor program was neither verified nor found to be in error.

Sequencing of selected LGC boost monitor phases are provided in the following table.

Boost Event Timeline

	ICS Time (sec)	GSOP Time (sec)
Terminate gyro torquing	-0.137	
Call Pre-LET Jet Boost Monitor Program (P11)	-0.00998	
Start Pre-LET Jet Boost Monitor Program (P11)	-0.00057	
Set LGC clock to zero	0.0	0.0
Command +X translation on (4 jet)	105.01	--
Start Post-LET Jet Boost Monitor Program (P12)	145.0	149.0
Start abort command monitor and tumble monitor	145.01	149.0
Command +X Translation off (4 jet)	176.0	180.0

RUN 4 TEST RESULTS SUMMARY

Test Run Description

Nominal simulation of program P31 (pre-DPS1) and program P41 (DPS1 burn).

Test Run Objectives

To validate

LGC/LMP sequencing

DPS1 prethrusting calculations

Attitude maneuver

DPS1 burn

DPS1 targeting

Summary of Test Results

The sequencing of events from the program P31 (pre-DPS1) through the program P41 (DPS1 burn) has been verified for the nominal conditions as prescribed in the AS-206 Operational Trajectory.

Discussion of Test Results

One problem has been discovered within the DPS1 burn program, P41. The flight program for the AS-206 mission (BURST 116) commands the termination of the four jet ullage at 0.5 seconds after the guidance command to turn the DPS engine on. The latest test result from the DPS hardware testing in California for the "A" configuration engine show that the first measurable thrust from the DPS occurs at 1.34 seconds (minimum) after the guidance command to turn the DPS on. Therefore, there is a period of approximately 0.825 seconds without thrust between RCS decay and DPS ignition. For the "B" configuration engine, the first measurable thrust occurs after 0.595 seconds which also leaves a period without ullage overlap.

Timing

The following table summarizes the ICS and the AS-206 Operational Trajectory time of events. A complete table is provided in the Event Summary (Table 1).

Event	ICS Time (sec)	OT Time (sec)
Start mission phase 9	14, 126.0	14, 118.6
Begin attitude maneuver	14, 128.8	14, 128.6
Complete attitude maneuver	14, 142.5	14, 160.0
Ullage	14, 394.4	14, 394.1
DPS engine on	14, 401.9	14, 401.6
DPS engine off	14, 440.1	14, 440.0

Mission phase 9 was scheduled for 14, 126.0 rather than the time of the OT because the DPS engine is scheduled to be cutoff 315 seconds after the start of mission phase 9. The shorter time for completion of the attitude maneuver is attributed to the yaw maneuver performed in the OT and not performed in the ICS. Yaw (pilot) control during the DPS and APS prethrusting attitude maneuvers is not provided. This has been verified in the flight software equations. Therefore, only a pitch/roll (pilot) maneuver is performed, reducing the time and fuel consumption of the attitude maneuver.

Attitude Maneuver

The attitude maneuver for DPS1 thrusting consisted of a pitch/roll (pilot) maneuver with the following body angular excursions:

Pitch	13.75 deg
Roll	62.21 deg
Yaw	0.18 deg

The attitude maneuver consumed 3.69 pounds of RCS fuel. The RCS budget cited in the OT allows 18.95 pounds. The maximum body rate in the roll channel during the maneuver was 5.05 degrees per second. Detailed information is provided in the Phase Summary for the RCS operation during the attitude maneuver. The scheduling of the attitude maneuver in ICS run differs from that in the AS-206 flight plant in that it is 16.2 seconds early.

DPS1 Burn

The RCS ullage (using 4 jets) produced a velocity increment of 2.64 feet per second during the 7.5-second burn. The value in the OT was 3.07 feet per second. The difference in the velocity increment can be attributed to 4 jets being on with attitude control cutting down to 2 jets during part of the burn. (The OT does not incorporate a complete digital auto pilot (DAP)). Detailed information regarding the burn is contained within the Phase Summary. That is, with the termination of ullage 0.5 seconds after the engine-on command, there is a period during which ullage does not exist before the DPS thrust is built up.

The length of the DPS1 burn was 38.179 seconds as compared with 38.410 seconds in the OT.

Comparison of the state vector with the OT at DPS1 engine-off command (EOC) shows the position deviations to be 72.0, 1676.0, and 484.0 feet and the velocity deviation to be 0.119, 4.341, and 0.776 feet per second in x, y, z, ECI components, respectively. These state vector deviations at DPS1 EOC produce the parameter dispersions from the AS-206 Operational Trajectory specified in the Trajectory Summary.

The thrust characteristics used in the ICS simulation differ from the OT. LMP command 86 changes the 10 percent throttle setting thrust to 1283.0 pounds. The OT uses 1050 pounds. The maximum thrust attained in the ICS was 9885.2 pounds as compared with 9869.61 pounds in the OT.

The I_{SP} characteristics were not the same as the OT. The average DPS propellant flow rate at full throttle was 31.3 pounds per second as compared with 32.37 pounds per second in the OT.

The thrust and I_{SP} differences between the ICS and the OT are the primary modeling discrepancies which affect the test cases. There were no anomalies that could not be attributed to the DPS engine model except the ullage overlap problem.

The LMP commands generated by the LGC in mission phase 9 are given in Table 3.

Plots of instantaneous apogee and perigee during the burn are provided following the phase summary.

Table 3. Nominal MP9 LMP Commands

Time (sec)	Command Number	Command Description
14, 198. 9034	236	DFI/TM calibrate - ON
14, 210. 9034	237	DFI/TM calibrate - OFF
14, 211. 0234	198	Master C&W alarm reset - COMMAND
14, 212. 8234	199	Master C&W alarm reset - COMMAND RESET
14, 223. 8634	182	Landing radar power - ON
14, 223. 9873	26	Radar self test - ON
14, 272. 8234	4	ED battery activation - ON
14, 277. 8634	8	Landing gear deploy - FIRE
14, 279. 9034	9	Landing gear deploy - FIRE RESET
14, 283. 8634	27	Radar self test - OFF
14, 335. 9434	150	Engine select - DESC ARM
14, 336. 0634	86	Manual throttle - ON (10%)
14, 385. 9873	228	DPS PQGS ARM 1 - ENABLE
14, 386. 1034	196	DPS PQGS ARM 2 - ENABLE
14, 386. 9434	244	DPS PQGS 1 - ARM
14, 387. 0634	212	DPS PQGS 2 - ARM
14, 404. 9534	5	ED battery activation - SAFE
14, 453. 0734	87	Manual throttle - RESET (30%)
14, 453. 1934	151	Engine select - DESC ARM OFF
14, 463. 1534	245	DPS PQGS 1 - OFF

Table 3. Nominal MP9 LMP Commands (Continued)

Time (sec)	Command Number	Command Description
14, 463. 2734	213	DPS PQGS 2 - OFF
14, 464. 1134	229	DPS PQGS ARM 1 - DISABLE
14, 464. 2356	197	DPS PQGS ARM 2 - DISABLE
14, 478. 1534	26	Radar self test - ON
14, 538. 1534	27	Radar self test - OFF
14, 538. 2734	183	Landing radar power - OFF

RUN 4 TRAJECTORY SUMMARY

The following are trajectory deviations observed with respect to the AS-206 Operational Trajectory at DPS1 guidance command engine off:

Altitude	48.0 ft (low)
Latitude	0.0005 deg (south)
Longitude	0.0034 deg (west)
Inertial velocity	4.38 fps (low)
Inertial flight-path angle	0.0030 deg (high)
Inertial azimuth	0.0024 deg (north)
Apogee	2.534 n mi (low)
Perigee	0.022 n mi (low)
Declination	0.001 deg (low)
Longitude of ascending node	0.0011 deg (west)
Inclination	0.0007 deg (high)
Eccentricity	0.000338 (low)
True anomaly	0.416 deg (east)
Semi-major axis	7434 feet (low)

The LGC state vector deviation from the environment in ECI at DPS1 guidance command engine off is as follows:

ΔX	18 ft
ΔY	40 ft
ΔZ	35 ft
$\Delta \dot{X}$	0.049 fps
$\Delta \dot{Y}$	0.020 fps
$\Delta \dot{Z}$	0.096 fps

Run 4 Event Summary; DPS1 Burn

Mission Event	GET (sec)	Altitude (ft)	Geodetic Latitude (deg)	Longitude (deg)	Inertial Velocity (ft/sec)	Inertial Flight-path Angle (deg)	Inertial Azimuth Angle (deg)	RCS Fuel (lb)	DPS Fuel (lb)	OGA (deg)	IGA (deg)	MGA (deg)
Simulation initialized	14,100.000	726,525	-30.911	83.251	25,464.957	-0.074	82.245	585.0	17,314	-113.1	-25.9	-5.5
Hold vehicle attitude	14,100.032	726,523	-30.910	83.253	25,464.958	-0.075	82.244	585.0	17,314	-113.1	-25.9	-5.5
Start DAP	14,105.031	726,306	-30.864	83.621	25,465.183	-0.076	82.045	585.0	17,314	-113.1	-25.9	-5.5
Hold vehicle attitude	14,105.032	726,306	-30.864	83.621	25,465.183	-0.076	82.045	585.0	17,314	-113.1	-25.9	-5.5
Start MP9	14,126.043	725,351	-30.657	85.162	25,466.170	-0.081	81.214	585.0	17,314	-113.1	-25.9	-5.5
Enter program 31 pre-DPS1 burn	14,126.045	725,351	-30.657	85.162	25,466.171	-0.081	81,214	585.0	17,314	-113.1	-25.9	-5.5
Finish orbital integration	14,128.659	725,227	-30.630	85.353	25,466.298	-0.082	81.111	585.0	17,314	-113.1	-25.9	-5.5
Begin attitude maneuver	14,128.803	725,220	-30.628	85.364	25,466.305	-0.082	81.105	585.0	17,314	-113.1	-25.9	-5.5
Complete attitude maneuver	14,142.547	724,558	-30.480	86.368	25,466.887	-0.084	80.569	581.3	17,314	-102.2	36.9	-12.7
Enter program 41 DPS1 burn	14,335.908	712,184	-27.526	100.084	25,479.640	-0.131	73.512	577.6	17,314	-102.0	37.8	-12.6
Finish orbital integration	14,341.117	711,780	-27.426	100.442	25,480.054	-0.132	73.338	577.6	17,314	-102.1	37.7	-12.6
Start reading PIPA's	14,371.906	709,316	-26.809	102.542	25,482.578	-0.138	72.325	577.5	17,314	-101.9	37.4	-12.5
Command +X translation-RCS ullage	14,394.407	707,443	-26.337	104.061	25,484.499	-0.143	71.605	577.5	17,314	-101.6	37.5	-12.5
Command DPS engine on	14,401.907	706,809	-26.176	104.565	25,487.166	-0.143	71.369	567.9	17,314	-102.1	36.7	-13.5
Command +X translation off	14,402.407	706,766	-26.165	104.598	25,487.381	-0.143	71.353	567.2	17,314	-102.1	36.7	-13.5
Increase throttle to maximum	14,427.911	704,743	-25.600	106.301	25,518.270	-0.116	70.567	565.7	17,206	-103.0	37.5	-11.3
Disable DAP trim gimbal control	14,427.918	704,743	-25.600	106.301	25,518.278	-0.116	70.567	565.7	17,206	-103.0	37.5	-11.3
Enable DAP trim gimbal control	14,429.866	704,605	-25.556	106.431	25,530.513	-0.102	70.508	564.8	17,163	-103.1	37.6	-12.4
Command DPS engine off	14,440.086	704,167	-25.322	107.110	25,624.385	0.007	70.199	564.4	16,827	-104.1	34.7	-11.9
Hold vehicle attitude	14,440.090	704,167	-25.322	107.110	25,624.419	0.007	70.199	564.4	16,827	-104.1	34.7	-11.9
DV monitor detects engine shutdown	14,448.044	704,034	-25.137	107.637	25,626.804	0.014	69.960	564.1	16,819	-104.5	34.1	-11.0
Set maximum deadband to 5 deg	14,478.047	703,658	-24.421	109.612	25,626.819	0.030	69.083	564.0	16,819	-105.3	34.1	-12.7
LGC idling	14,540.135	703,520	-22.849	113.623	25,626.090	0.062	67.375	564.0	16,819	-106.4	36.3	-12.7
Hold vehicle attitude	14,540.140	703,520	-22.849	113.623	25,626.090	0.062	67.375	564.0	16,819	-106.4	36.3	-12.7
Set maximum deadband to 5 deg	14,540.140	703.520	-22.849	113.623	25,626.090	0.062	67.375	564.0	16,819	-106.4	36.3	-12.7

Run 4 Phase Summary; DPS1 Burn

Phase	Unit	Value	GET (sec)
ATTITUDE MANEUVER SUMMARY			
Magnitude of maneuver	deg	13.7494, yaw 0.1756, pitch 62.2106, roll	
RCS jet firings		38	
RCS jet firing on-times	sec	8.608	
RCS fuel consumption	lb	3.6943	
Maximum body rates	deg/sec	-0.0317, yaw -0.9410, pitch 5.0487, roll	14, 142.547 14, 142.547 14, 142.547
Total time of maneuver	sec	13.744	
BURN SUMMARY			
Start of ullage maneuver	sec	14, 394.407	
Time duration of ullage maneuver	sec	8.000	
Delta V due to ullage maneuver	fps	2.640	
Start of burn	sec	14, 401.907	
Length of burn	sec	38.179	
Thrust maximum	lb	9, 885.20	14, 440.090

Run 4 Phase Summary; DPS1 Burn (Continued)

Phase	Unit	Value	GET (sec)
Thrust minimum	lb	1,283.00	14,404.056
Maximum acceleration	fps/sec	10.3404	14,440.086
Main engine fuel consumption	lb	494.74	
RCS fuel consumption	lb	13.1	
Time of engine-off command	sec	14,440.086	
Time after engine-off command until DV monitor detects shutdown	sec	7.954	
Maximum body rates	deg/sec	-0.0559, yaw 1.5024, pitch 0.2721, roll	
Position vector at thrust termination (ECI)	ft	-19,157,102 -4,039,590 -9,165,487	
Velocity vector at thrust termination (ECI)	fps	13,344.217 -24,339.831 7,905.559	
Maximum torque on vehicle	ft-lb	403.1042	14,402.056
Initial gimbal angles of descent engine	deg	-0.3177, yaw 2.3151, pitch	
Final gimbal angles of descent engine	deg	-0.422, yaw 2.252, pitch	

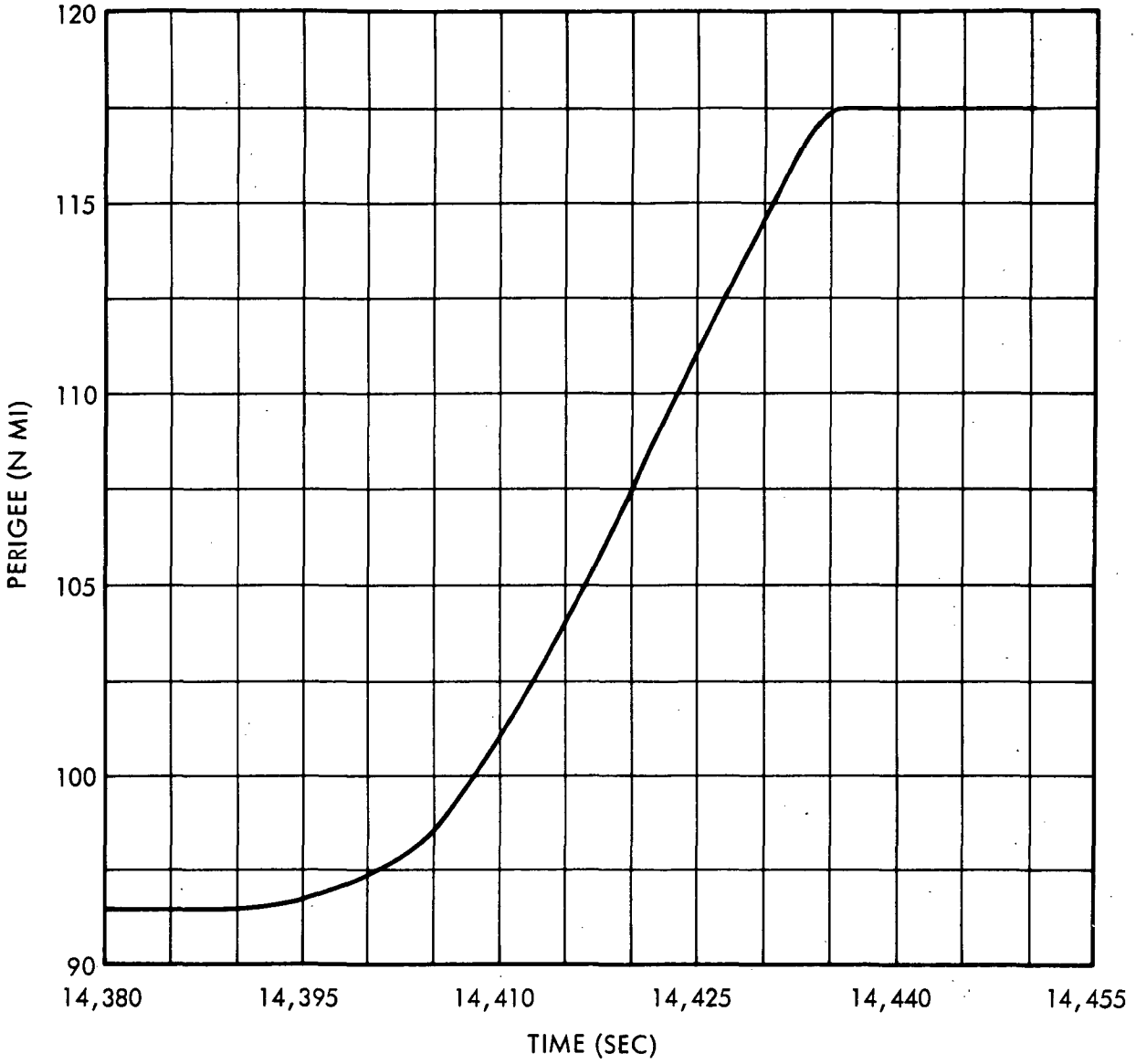

Figure 1. Run 4; DPS1 Nominal Perigee

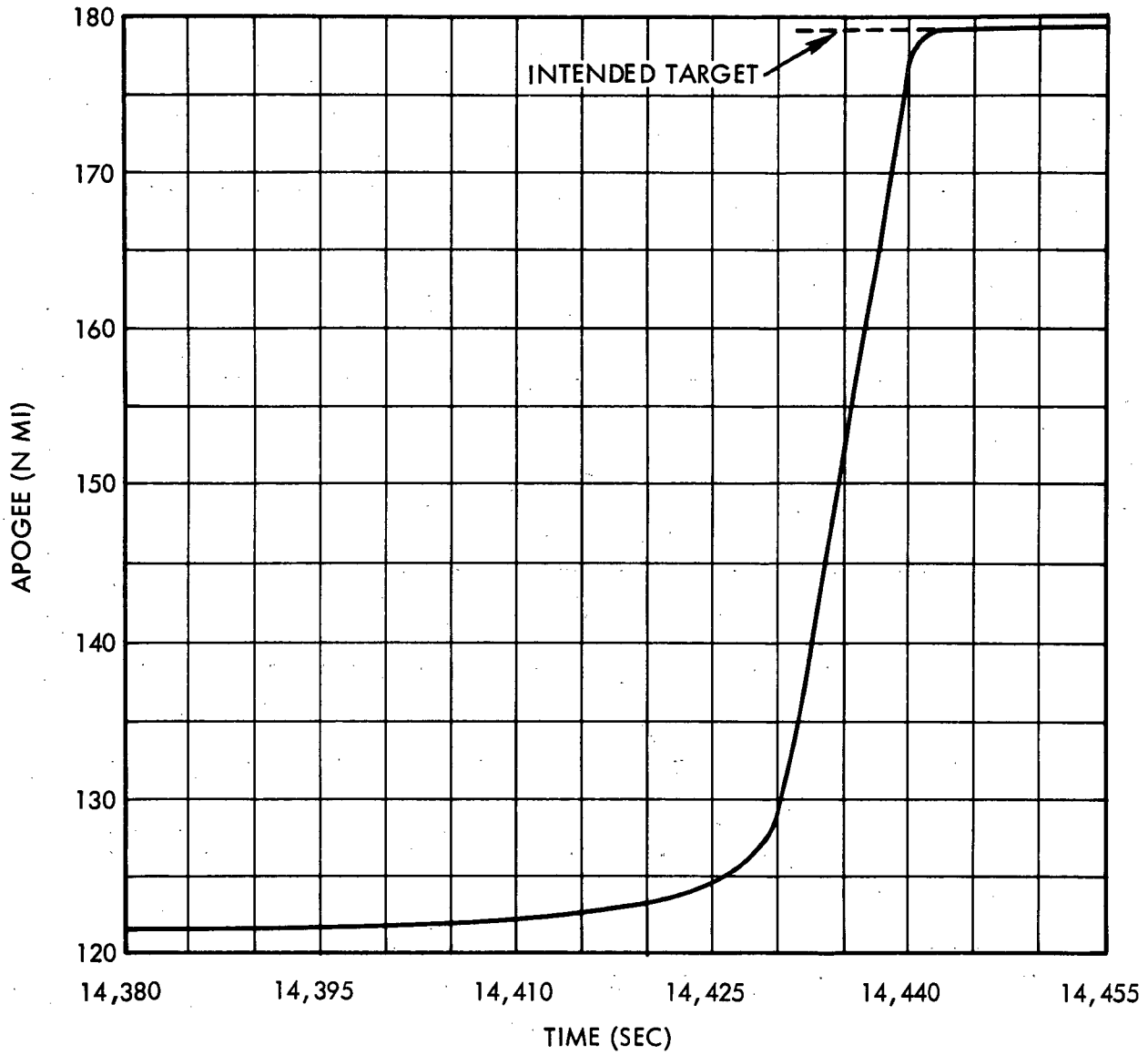

Figure 2. Run 4; DPS1 Nominal Apogee

RUNS 5 AND 6 TEST RESULTS SUMMARY

Test Run Description

Nominal simulation of program P32 (pre-DPS2), program P42 (DPS2 burn braking), program P43 (DPS2 burn approach), program P44 (DPS2 burn random throttle), and program P74 (FITH/APS1).

Test Run Objectives

To verify

LGC/LMP sequencing

DPS2 prethrusting calculations

Attitude maneuver for thrusting

DPS2 burn braking

DPS2 burn approach

DPS2 burn random throttle

FITH

APS1

Summary of Test Results

The sequencing of events from the program P32 (pre-DPS2) through the program P74 (FITH/APS1) has been verified for the nominal conditions as prescribed in the AS-206 Operational Trajectory.

The mission phase 11 sequencing of events is different from the Operational Trajectory. Timing differences range up to 12.4 seconds for the FITH maneuver.

Discussion of Test Results

Timing

The following table summarizes the ICS and OT time of events.

Event	ICS Time (sec)	OT Time (sec)
Start MP11	16424.4	16382.4
Ullage	16607.2	16605.7
DPS engine on	16614.7	16613.1
Maximum throttle	16640.7	16640.0
High-gate target	16787.6	16786.0
Throttle recovery	16952.5	16960.0
Low-gate target	17095.6	17084.1
Random throttling	17294.1	17282.3
FITH abort	17346.7	17334.3
APS cutoff	17351.7	17339.3

A complete table of events is provided in the Event Summary.

For the long duration of the DPS2 burn, it is not possible to completely determine the effect of the discrepancies in the DPS engine model characteristics upon the timing of events. The ICS results are considered to be more indicative of the actual flight profile.

The 12.4-second deviation in the time of the FITH abort test may require re-evaluation of the ground tracking time table. Ten seconds of the 12.4-second deviation between the OT and ICS FITH abort command can be attributed to a 10-second final transition subroutine during the low-gate target phase, which was omitted from the OT and exists in the flight software.

Attitude Maneuver

The attitude maneuver for the DPS2 thrusting consists of a pitch/roll (pilot) maneuver with the following body angular excursions:

Pitch	1.87 deg
Roll	95.89 deg
Yaw	0.25 deg

The maximum angular rate about the roll axis during the maneuver was 6.51 degrees per second.

The total RCS propellant consumption during the burn was 3.9385 pounds. This compares with the 18.950 pound RCS propellant budget allowance cited in the OT.

The final vehicle X-axis direction cosine was -0.43284035, 0.27093034, and 0.85979415 as compared with -0.42321590, 0.29647427, and 0.85614759 for the OT. The dot product determines the angle between the two directions to be 1.58 degrees. The attitude maneuver was found to occur 47.54 seconds later in ICS testing than scheduled in the AS-206 flight plan (Reference 10).

Additional information regarding the attitude maneuver is contained within the Phase Summary.

DPS2 Burn

The following table defines the thrust levels obtained in the ICS for various commanded thrust values in the flight computer as compared with the OT.

Commanded Percent	ICS Thrust (lb)	OT Thrust (lb)
10	1283.00	1050.42
20	1820.52	2122.80
30	2780.49	3124.40
40	4312.96	4198.86
50	5679.57	5250.00
Full Throttle	9885.18	9869.81

The differences in the thrust levels for commanded values from 10 percent to full throttle affects the timing of the DPS2 burn sequencing. However, the final trajectory is not significantly different. This is illustrated by the following table of orbital parameters for the ICS and the OT at the FITH abort command.

Orbital Parameter	ICS	OT
Apogee (n mi)	186.438	186.5
Perigee (n mi)	168.443	168.4
Declination (deg)	26.1214	26.301
Longitude of ascending node (deg)	272.0714	271.866
Inclination (deg)	28.7202	28.768
Eccentricity	0.002487	0.002503
True anomaly (deg)	341.7208	339.745
Semi-major axis (ft)	21,980,984	21,980,940.

The total RCS propellant consumed during the DPS2 burn was 25.909 pounds. This compares with an RCS budget value of 33.404 pounds in the OT. See the Phase Summary for more detailed information.

FITH Abort/APS1 Burn

The environment program appears to contain an error which turns the APS engine off for 0.3 seconds and creates a torque on the vehicle just after the FITH command is issued. Therefore, the results of the simulation for the APS1 are qualitatively accurate, but quantitatively in error.

One important fact has been discovered with regard to this anomaly in the simulator model. An attitude transient at FITH can create orbital trajectory errors.

The following table illustrates the desired CDU values and the actual CDU values which are a result of the 3000 foot-pound torque on the ascent stage just after FITH.

Time (sec)	Desired CDUXD	Actual CDUX	Desired CDUYD	Actual CDUY	Desired CDUZD	Actual CDUZ
17342.000	127.24	125.57	-41.77	-43.09	-36.34	-36.47
17344.000	127.24	126.17	-41.77	-42.36	-36.34	-36.52
17346.000	127.24	126.55	-41.77	-41.98	-36.34	-36.21
17346.729 (FITH)	127.24	126.57	-41.77	-41.96	-36.34	-35.90
17348.000	126.57	128.33	-41.96	-38.83	-35.90	-32.55
17350.000	126.57	127.07	-41.96	-41.55	-35.90	-36.72

The flight software provides for the desired CDU values to take the actual values of the CDU's at FITH. This is illustrated in the above table.

The CDUZ value changed approximately 4 degrees in a 2.0-second period and then returned to the desired CDU value.

The following table of orbital parameters when compared with the above errors at FITH illustrate the effect of the attitude transient on the final trajectory at APS1 cutoff.

Orbital Parameter	ICS	OT
Apogee (n mi)	185.037	187.0
Perigee (n mi)	168.439	168.4
Declination (deg)	26.0502	26.231
Longitude of ascending node (deg)	272.2944	272.126
Inclination (deg)	28.6732	28.714
Eccentricity	0.002295	0.002572
True anomaly (deg)	341.2111	340.428
Semi-major axis (feet)	21,976,716.	21,982,521.

The burn was intended to expend the energy in the direction of the orbital angular momentum, thus changing only the inclination of the orbit.

The LMP commands generated by the LGC in mission phase 11 are given in Table 4. Plots of perigee, apogee, latitude, longitude, and thrust magnitude are presented following the phase summary.

Table 4. Nominal MP11 LMP Commands

Time (sec)	Command Number	Command Description
16, 425. 4464	236	DFI/TM calibrate - ON
16, 437. 4464	237	DFI/TM calibrate - OFF
16, 437. 5703	198	Master C&W alarm reset - COMMAND
16, 439. 4864	199	Master C&W alarm reset - COMMAND RESET
16, 440. 4464	182	Landing radar power - ON
16, 440. 5703	26	Radar self test - ON
16, 500. 4464	27	Radar self test - OFF
16, 584. 8064	150	Engine select - DESC ARM
16, 594. 7704	86	Manual throttle - ON (10%)
16, 598. 7264	228	DPS PQGS ARM 1 - ENABLE
16, 598. 8464	196	DPS PQGS ARM 2 - ENABLE
16, 599. 8064	244	DPS PQGS 1 - ON
16, 599. 9264	212	DPS PQGS 2 - ON
17, 316. 1187	222	ECS ascent water coolant valve - OPEN
17, 318. 1565	223	ECS ascent water coolant valve - OPEN RESET
17, 345. 1565	38	Abort stage - ARM
17, 346. 1185	22	Abort stage - COMMAND
17, 347. 7965	151	Engine select - DESC ARM OFF
17, 358. 5964	39	Abort stage - COMMAND RESET
17, 359. 5564	183	Landing radar power - OFF

Table 4. Nominal MP11 LMP Commands (Continued)

Time (sec)	Command Number	Command Description
17, 367. 5964	245	DPS PQGS 1 - OFF
17, 367. 7186	213	DPS PQGS 2 - OFF
17, 368. 5564	229	DPS PQGS ARM 1 - OFF
17, 368. 6764	197	DPS PQGS ARM 2 - OFF

RUNS 5 AND 6 TRAJECTORY SUMMARY

The following are trajectory deviations with respect to the AS-206 Operational Trajectory at FITH guidance command:

Time	12.401 sec (later)
Altitude	810. ft (low)
Latitude	0.1875 deg (south)
Longitude	0.8484 deg (east)
Inertial velocity	0.3 fps (high)
Inertial flight-path angle	0.0054 deg (high)
Inertial azimuth	0.2979 deg (south)
Apogee	0.062 n mi (low)
Perigee	0.043 n mi (high)
Declination	0.1793 deg (low)
Longitude of ascending node	0.1514 deg (east)
Inclination	0.0478 deg (low)
Eccentricity	0.0000157 (low)
True anomaly	1.9758 deg (east)
Semi-major axis	44.0 ft (high)

The following are trajectory deviations with respect to the AS-206 Operational Trajectory at APS1 guidance commanded engine-off:

Time	12.378 sec (later)
Altitude	798. ft (low)
Latitude	0.1883 deg (south)
Longitude	0.8452 deg (east)
Inertial velocity	3.04 fps (high)
Inertial flight-path angle	0.0067 deg (high)
Inertial azimuth	0.3050 deg (south)
Apogee	1.963 n mi (low)
Perigee	0.039 n mi (high)
Declination	0.1808 deg (low)
Longitude of ascending node	0.1684 deg (east)
Inclination	0.0408 deg (low)
Eccentricity	0.0002768 (low)

True anomaly	0.6831 deg (east)
Semi-major axis	5805.0 ft (low)

The LGC state vector deviations from the environment in earth centered inertial (ECI) coordinates at FITH/APS1 guidance command are as follows:

ΔX	77 ft
ΔY	72 ft
ΔZ	31 ft
$\Delta \dot{X}$	0.294 fps
$\Delta \dot{Y}$	0.061 fps
$\Delta \dot{Z}$	0.105 fps

Runs 5 and 6 Event Summary; DPS2/FITH/APS1 Burn

Mission Event	GET (sec)	Altitude (ft)	Geodetic Latitude (deg)	Longitude (deg)	Inertial Velocity (ft/sec)	Inertial Flight-path Angle (deg)	Inertial Azimuth Angle (deg)	RCS Fuel (lb)	DPS Fuel (lb)	OGA (deg)	IGA (deg)	MGA (deg)
Simulation initialized	16, 402. 383	1, 001, 109	30. 977	-135. 756	25, 287. 521	0. 345	82. 556	585. 0	16, 756	129. 4	34. 4	-7. 2
Command DPS engine off	16, 402. 395	1, 001, 111	30. 977	-135. 755	25, 287. 518	0. 345	82. 557	585. 0	16, 756	129. 4	34. 4	-7. 2
Schedule MP11	16, 402. 403	1, 001, 112	30. 977	-135. 754	25, 287. 517	0. 345	82. 557	585. 0	16, 756	129. 4	34. 4	-7. 2
Turn DAP on	16, 407. 414	1, 001, 920	31. 020	-135. 392	25, 286. 608	0. 344	82. 754	585. 0	16, 756	129. 4	34. 4	-7. 2
Start MP11	16, 424. 426	1, 004, 627	31. 155	-134. 162	25, 283. 562	0. 338	83. 424	585. 0	16, 756	129. 4	34. 4	-7. 2
Enter major mode 32 pre-DPS2	16, 424. 428	1, 004, 627	31. 155	-134. 162	25, 283. 561	0. 338	83. 424	585. 0	16, 756	129. 4	34. 4	-7. 2
Finish orbital integration	16, 425. 751	1, 004, 835	31. 165	-134. 066	25, 283. 327	0. 337	83. 477	585. 0	16, 756	129. 4	34. 4	-7. 2
Begin attitude maneuver	16, 440. 537	1, 007, 136	31. 272	-132. 994	25, 280. 731	0. 332	84. 063	585. 0	16, 756	129. 4	34. 4	-7. 2
Set minimum deadband	16, 441. 660	1, 007, 309	31. 279	-132. 912	25, 280. 536	0. 332	84. 108	585. 0	16, 756	129. 4	34. 4	-7. 2
Complete attitude maneuver	16, 460. 240	1, 010, 127	31. 398	-131. 561	25, 278. 182	0. 324	84. 849	581. 1	16, 756	80. 4	-64. 4	-37. 3
Enter major mode 42 DPS2 burn-braking	16, 584. 721	1, 027, 103	31. 777	-122. 457	25, 257. 950	0. 277	89. 886	576. 3	16, 756	79. 9	-65. 1	-37. 2
Command DPS engine off	16, 584. 724	1, 027, 104	31. 777	-122. 456	25, 257. 950	0. 277	89. 886	576. 3	16, 756	79. 9	-65. 1	-37. 2
Start reading PIPA's	16, 601. 419	1, 029, 113	31. 773	-121. 233	25, 255. 623	0. 270	90. 566	576. 3	16, 756	79. 8	-64. 7	-37. 5
Command +X translation on (4 jet)	16, 607. 220	1, 029, 795	31. 768	-120. 808	25, 254. 829	0. 268	90. 802	576. 3	16, 756	79. 7	-64. 6	-37. 7
Command DPS engine on	16, 614. 720	1, 030, 666	31. 760	-120. 258	25, 253. 974	0. 264	91. 102	566. 6	16, 756	80. 2	-63. 8	-36. 5
Command +X translation off (4 jet)	16, 615. 220	1, 030, 724	31. 760	-120. 222	25, 253. 873	0. 264	91. 121	565. 9	16, 756	80. 3	-63. 7	-36. 4
Command full throttle	16, 640. 719	1, 033, 578	31. 712	-118. 355	25, 252. 660	0. 253	92. 083	564. 7	16, 649	79. 4	-65. 6	-35. 9
Throttle control regained	16, 952. 506	1, 040, 604	30. 240	-95. 755	25, 253. 450	-0. 174	95. 245	561. 3	6, 156	96. 7	-54. 0	-39. 3
Enter major mode 43 DPS2 burn approach	17, 095. 595	1, 028, 543	29. 161	-85. 544	25, 384. 411	-0. 151	97. 680	560. 7	3, 576	114. 0	-41. 9	-36. 0
Enter major mode 44 random throttle	17, 294. 109	1, 018, 420	26. 995	-71. 680	25, 361. 553	-0. 049	101. 544	560. 5	1, 239	126. 1	-44. 0	-32. 3
Command APS engine on	17, 346. 729	1, 016, 593	26. 268	-68. 089	25, 365. 901	-0. 045	102. 382	559. 1	0	126. 6	-42. 0	-35. 9
Command +X translation off (4 jet)	17, 346. 730	1, 016, 593	26, 267	-68. 089	25, 365. 901	-0. 045	102. 382	559. 1	0	126. 6	-42. 0	-35. 9
Enter major mode 74 - FITH/APS1	17, 346. 751	1, 016, 592	26. 267	-68. 087	25, 365. 902	-0. 045	102. 383	559. 1	0	126. 6	-42. 0	-35. 9
DPS engine arm off	17, 347. 749	1, 016, 558	26. 253	-68. 019	25, 364. 970	-0. 044	102. 396	558. 6	0	128. 0	-39. 4	-33. 3
Command APS engine off	17, 351. 750	1, 016, 427	26. 196	-67. 748	25, 363. 560	-0. 042	102. 424	557. 5	0	127. 5	-41. 2	-36. 2
Command DPS engine off	17, 351. 752	1, 016, 427	26. 196	-67. 748	25, 363. 559	-0. 042	102. 424	557. 5	0	127. 5	-41. 2	-36. 2
DV monitor detects engine shutdown	17, 357. 552	1, 016, 238	26. 112	-67. 354	25, 363. 888	-0. 041	102. 604	557. 1	0	127. 5	-42. 1	-37. 0
Terminate average g routine	17, 387. 552	1, 015, 273	25. 661	-65. 330	25, 364. 695	-0. 038	103. 540	556. 9	0	126. 2	-42. 5	-35. 2
Set maximum deadband	17, 387. 552	1, 015, 273	25. 661	-65. 330	25, 364. 695	-0. 038	103. 540	556. 9	0	126. 2	-42. 5	-35. 2
Schedule MP13	17, 387. 555	1, 015, 273	25. 661	-65. 329	25, 364. 695	-0. 038	103. 540	556. 9	0	126. 2	-42. 5	-35. 2
Enter major mode 0 - LGC idling	17, 389. 637	1, 015, 206	25. 628	-65. 189	25, 364. 753	-0. 038	103. 604	556. 9	0	126. 3	-42. 9	-35. 3
Set maximum deadband	17, 389. 642	1, 015, 206	25. 628	-65. 189	25, 364. 753	-0. 038	103. 604	556. 9	0	126. 3	-42. 9	-35. 3

Runs 5 and 6 Phase Summary; DPS2/FITH/APS1 Burn

Phase	Unit	Value	GET (sec)
ATTITUDE MANEUVER SUMMARY			
RCS jet firings		54	
RCS jet firing on-times	sec	8.827	
RCS fuel consumption	lb	3.9385	
Maximum body rates	deg/sec	-0.1820, yaw 0.1974, pitch 6.5094, roll	16,460.240 16,460.240 16,442.240
Total time of maneuver	sec	19.703	
BURN SUMMARY			
Start of ullage maneuver	sec	16,607.220	
Time duration of ullage maneuver	sec	8.000	
Start of burn	sec	16,614.720	
Length of burn	sec	738.842	
Thrust maximum	lb	10,310.35	16,952.506
Maximum acceleration	fps/sec	16.5038	16,952.506
Main engine fuel consumption	lb	16,756.13	
RCS fuel consumption	lb	18.8	

Runs 5 and 6 Phase Summary; DPS2/FITH/APS1 Burn (Continued)

Phase	Unit	Value	GET (sec)
Time of engine-off command	sec	17, 351. 750	
Time after engine-off command until DV monitor first detects shutdown	sec	1. 812	
Maximum body rates	deg	0. 1138, yaw 1. 4541, pitch -6. 2170, roll	
Position vector at APS1 thrust termination (ECI)	ft	17, 223, 892 9, 573, 125 9, 621, 371	
Velocity vector at APS1 thrust termination (ECI)	ft/sec	-9, 943. 911 22, 805. 898 -4. 932. 534	
Maximum torque on vehicle	ft-lb	1, 630. 1234	17, 347. 749
Initial gimbal angles of main engine	deg	-0. 3177, yaw 2. 3151, pitch	
Final gimbal angles of main engine	deg	-0. 514, yaw 2. 414, pitch	

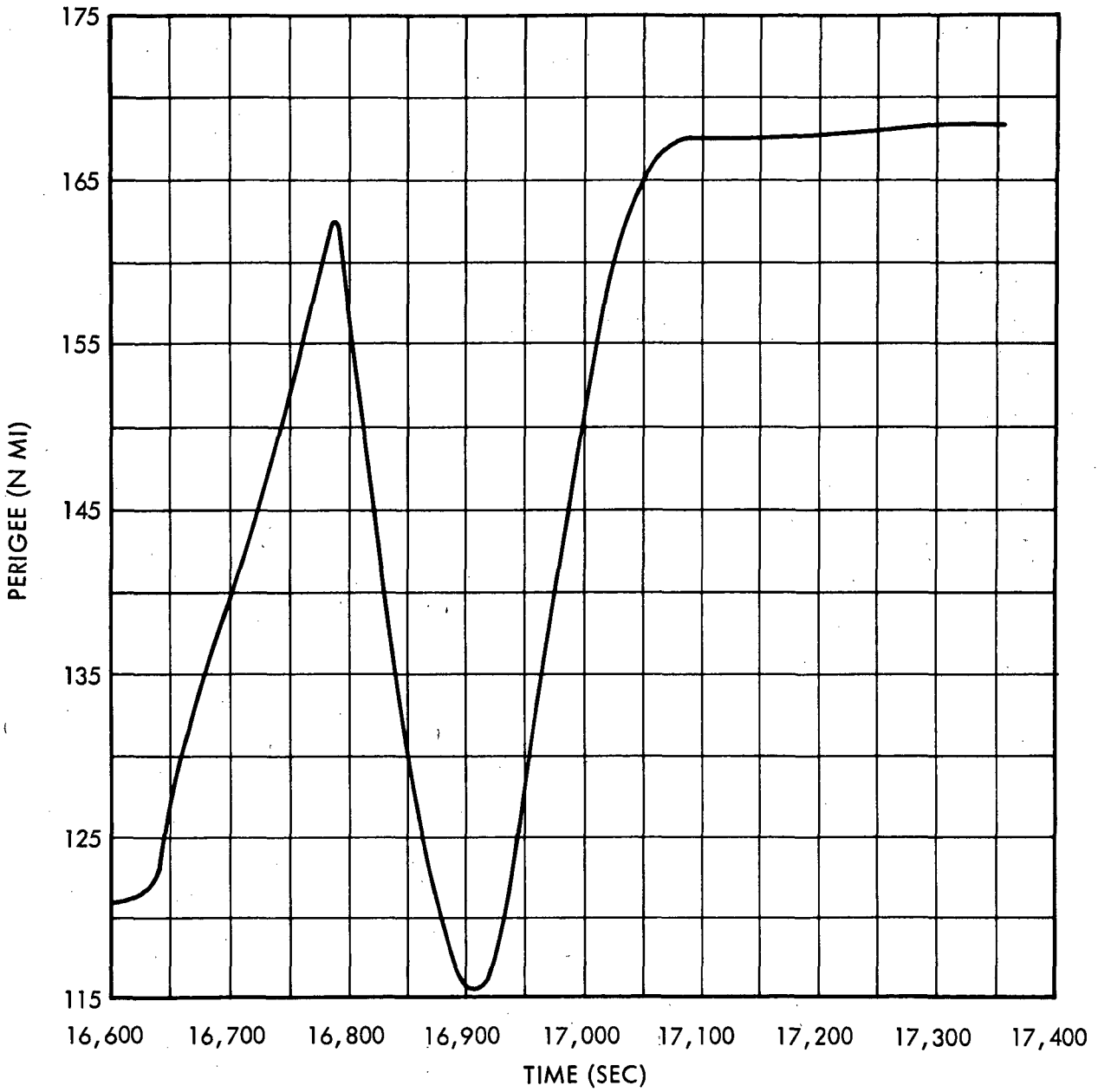

Figure 3. Run 5; DPS2 Nominal Instantaneous Perigee

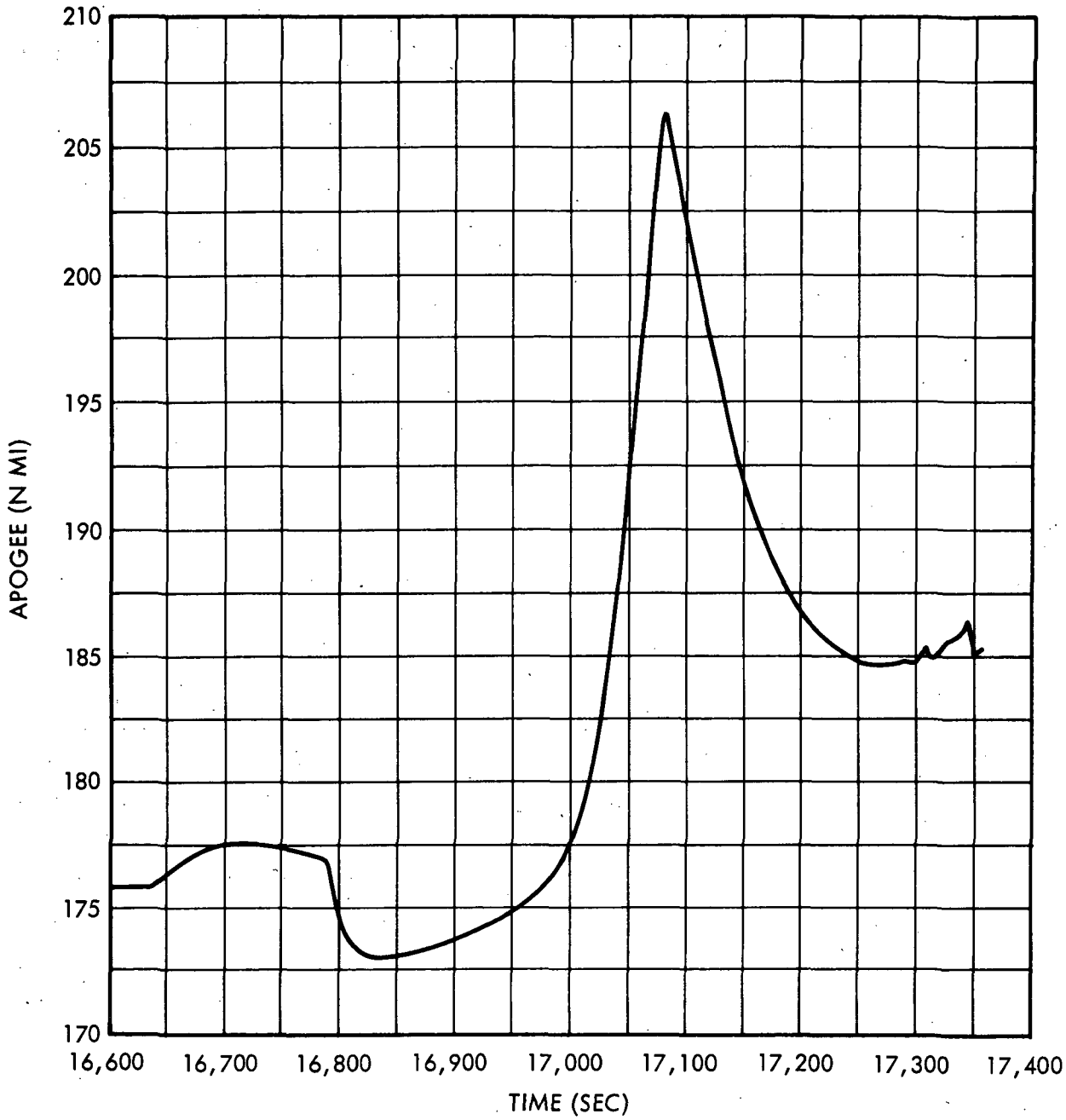

Figure 4. Run 5; DPS2 Nominal Instantaneous Apogee

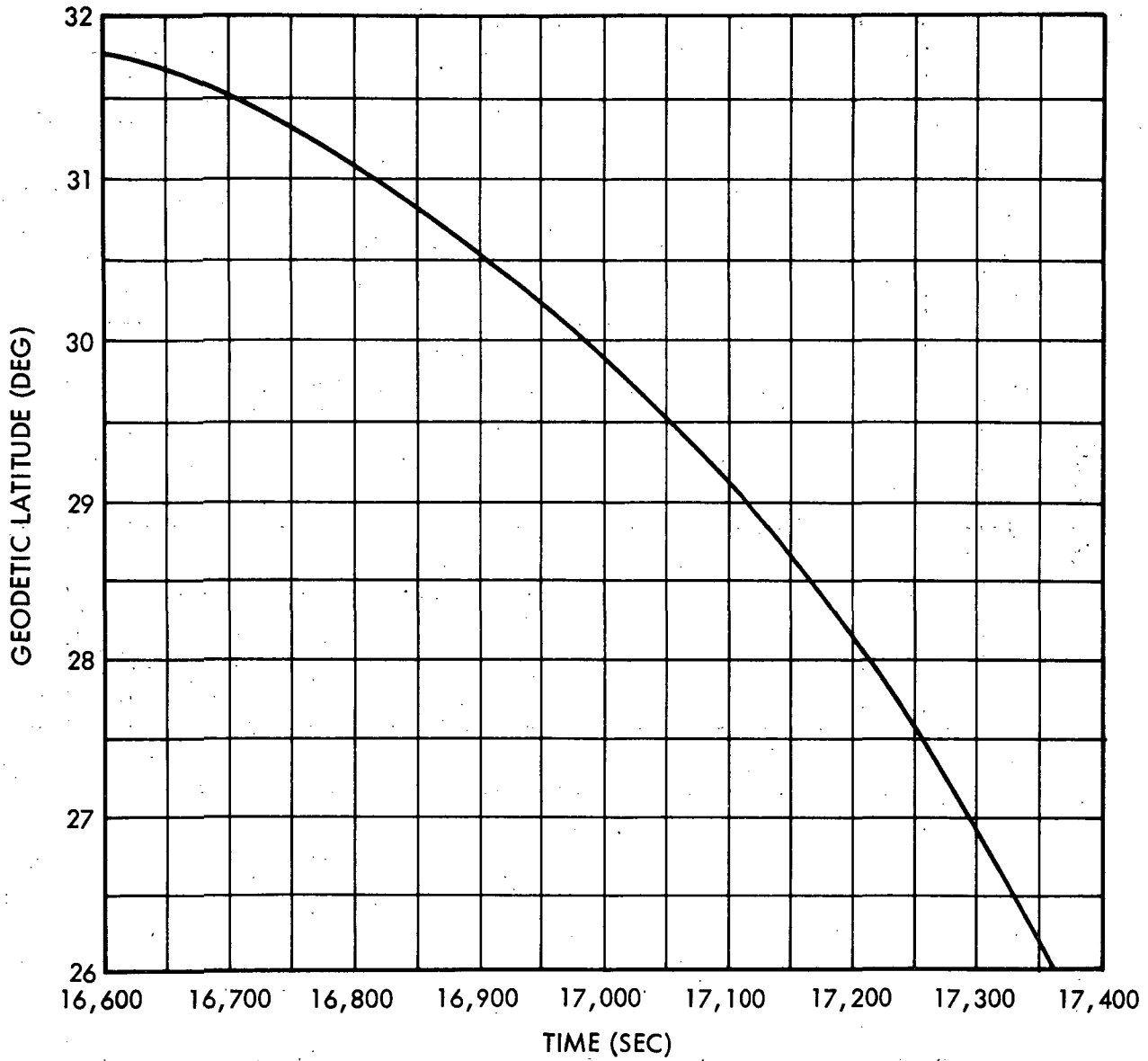

Figure 5. Run 5; DPS2 Nominal Geodetic Latitude

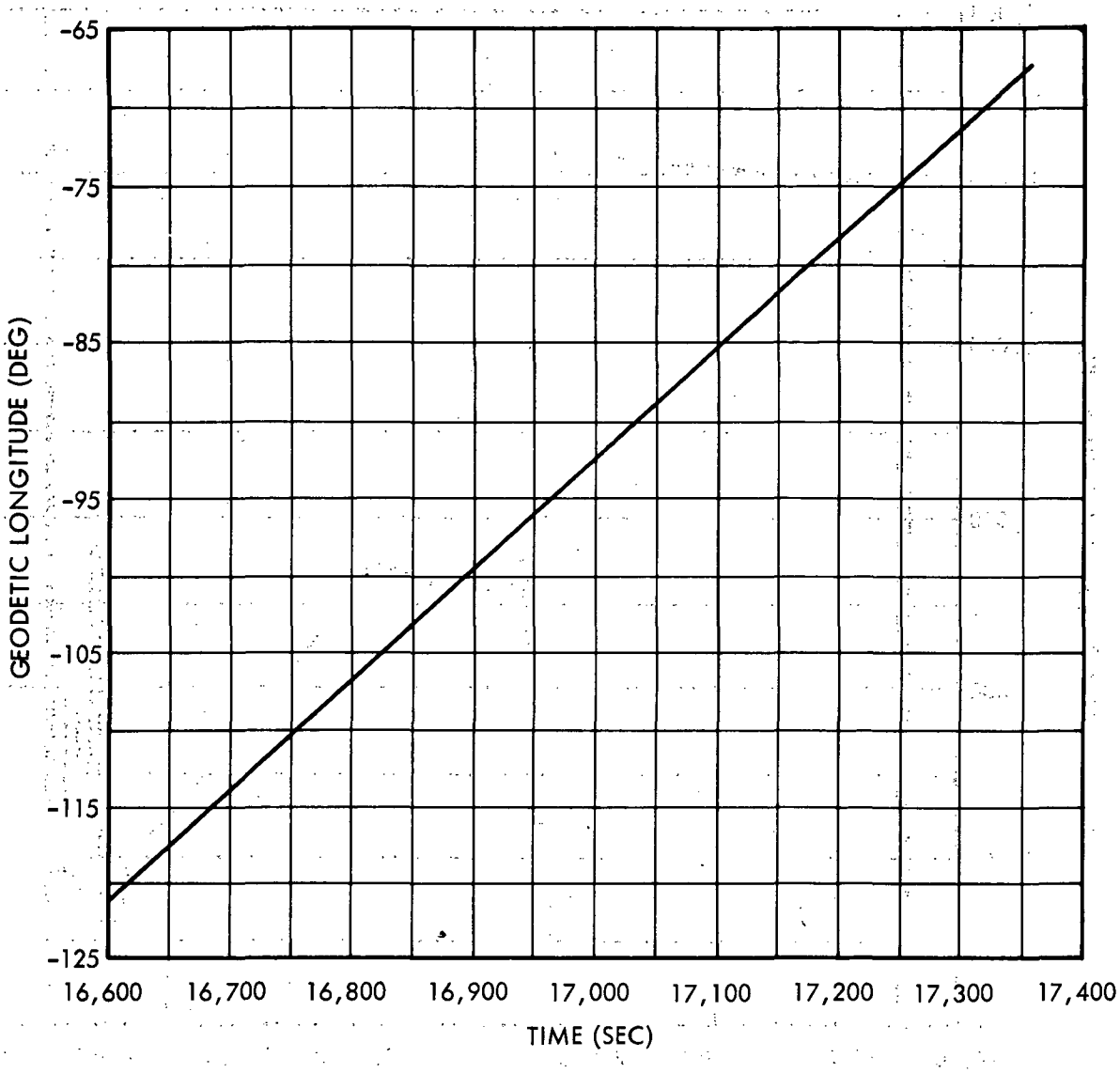

Figure 6. Run 5; DPS2 Nominal Longitude

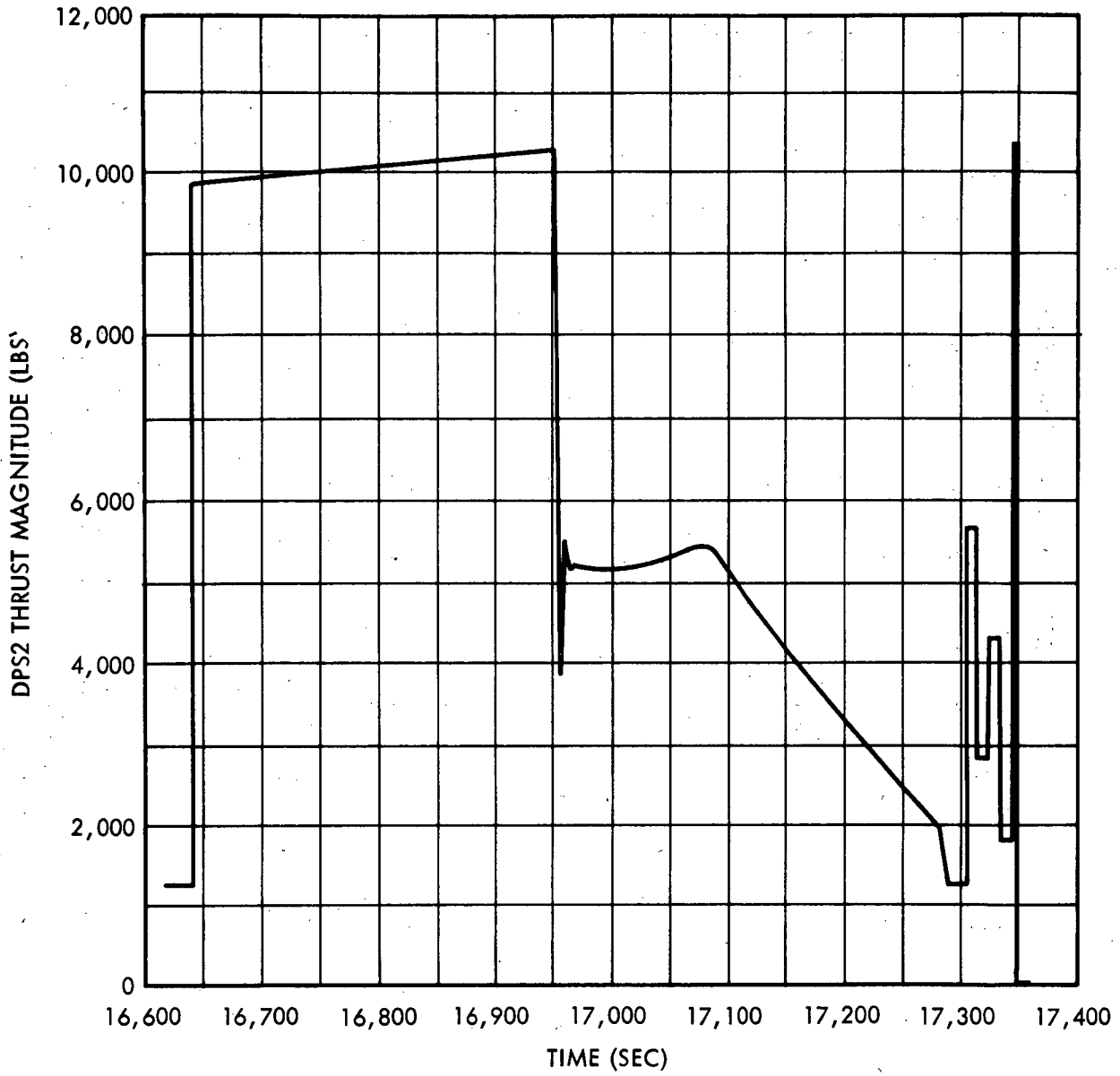

Figure 7. Run 5; DPS2 Nominal Thrust Magnitude

RUN 7 TEST RESULTS SUMMARY

Test Run Description

Nominal simulation of APS2 prethrust and APS2 burn.

Test Run Objectives

To establish a closed-loop reference simulation for comparison purposes of the final APS burn phase; to verify the APS2 prethrusting attitude maneuver, the APS2 burn, and proper LGC/LMP mission sequencing.

Summary of Test Results

A nominal ICS trajectory has been established for LGC programs P34 and P46 initialized with the APS2 conditions prescribed by the OT. It is found that with a consistent engine ignition time the OT and ICS attitude maneuver and ullage maneuver sequencing differ. An attitude transient has been observed in the early portion of the ICS burn. Target miss at time of arrival at the target was 10.3 n mi.

Discussion of Test Results

The ICS has been initialized so that the second ascent propulsion system burn occurs over North America at a mission time of 22,415.057 seconds GET. This burn ignition is consistent with the requirements of the OT.

A summary of the sequence of events for the nominal APS2 run (number 7) is presented in Table 5. However, a qualifying statement should be made with respect to the scheduling of mission phase initialization. The flight program incorporates a fixed delay of 170 seconds from entry into mission phase 13 to APS2 ignition. In order to allow the burn to coincide with that of the OT, mission phase 13 was scheduled at 22,245.059 seconds GET.

The LMP commands generated during mission phase 13 were reviewed and are consistent with the sequence specified by the GSOP. The LMP commands and their scheduled sequencing are presented in Table 6.

Attitude Maneuver

The ICS preburn attitude maneuver is initiated at 22, 253. 757 seconds GET which is 79. 040 seconds later than the preburn attitude maneuver of the OT. This initiation is considered acceptable as it falls within the mission phase 13 preburn interval prescribed by the GSOP.

The body attitude and gimbal angles of the test run were initialized as those in the OT prior to the attitude maneuver. During reorientation the LGC commanded maneuver is such that the vehicle thrust axis assumes the required attitude without commanding a rotation about the thrust axis. This differs from the OT which commands a minus 2-degree per second rotation rate about the LM yaw (thrust) axis as a part of the attitude maneuver. As a result the only basis of attitude comparison between the OT and ICS attitudes after this maneuver is by comparing the direction cosines of the yaw axis.

At the completion of the attitude maneuver the X (YAW) direction cosines of the OT are

$$U_{x_{OT}} = \begin{matrix} -0.47566 \\ -0.13529 \\ 0.86916 \end{matrix}$$

The ICS exhibits the following yaw axis characteristics:

Pointing Errors Between Nominal ICS Run and Operational Trajectory

Event	ICS Time (sec GET)	Direction Cosines Ux_{ICS}	Vehicle Pointing Error with OT(deg)
End of attitude maneuver	22, 253. 757	-0. 47127 -0. 14420 0. 87012	0. 59
Enter program 46 APS2 burn	22, 385. 060	-0. 46501 -0. 14809 0. 87283	0. 99
Begin RCS ullage	22, 402. 557	-0. 46597 -0. 14929 0. 87212	0. 98

Attitude rates of -4.7 degrees per second about the vehicle Z (roll) axis and 0.8165 degree per second about the Y axis are experienced during the maneuver. The maneuver is completed in 2.803 seconds requiring 0.545 pound of RCS fuel with 10 jet fires for a total jet on time of 1.156 seconds.

APS2 Burn

The second APS burn is of long duration (440 seconds) with the thrust axis directed essentially in the direction of the orbital angular momentum vector. The run has been initialized so that the ICS burn simulation is scheduled to initiate at a time consistent with that of the OT. A summary of key burn parameters is presented in the Burn Phase Summary.

The orbit at thrust termination in the OT is characterized by an apogee altitude of 172 nautical miles and a perigee altitude of 128 nautical miles; this compares with the ICS apogee of 172 nautical miles and perigee of 134 nautical miles. The burn is initiated at 22,415.057 seconds GET at which time the commanded thrust attitude is held constant until about 22,420 seconds GET.

The Lambert routine is entered once at about 22,252.0 seconds GET, which is approximately 163 seconds prior to the burn. The next time it is entered is between 22,420.0 and 22,422.0 seconds GET, which is about 6 seconds after the engine is commanded on. An attitude transient occurred at about this first pass through the Lambert routine. This condition is observed in other simulations, although the deviations are not as extreme. Plots of the gimbal angles are provided following the APS2 phase summary. The transient can be seen as a spike in all gimbals at 22,421 seconds GET. The transient will also be discussed in the digital autopilot results documentation. Through most of the burn, the Lambert routine is cycled through about every 2 seconds until the engine is commanded off at which time the Lambert velocity vector is held constant. This Lambert cycling rate is considered acceptable. It was anticipated in scientific simulations (performed on Task A-103) that the routine would be cycled only every other pass (every 4 seconds) through the guidance loop. In the ICS nominal run it was cycled about 90 percent of the 2-second guidance intervals. The burn was terminated with a guidance cutoff.

The instantaneous apogee and perigee are changed during the burn. Plots of these parameters are presented following the APS2 phase summary summary. It should be noted that during the burn the perigee drops to about 38 miles and violates the minimum 75 n mi specified in the mission rules of Reference 12.

Targeting Accuracy

The APS2 burn is targeted to achieve an intercept position vector at a specified intercept time of 24, 794. 15527 seconds GET. The following table is provided to present a comparison in targeting accuracy between the OT, ICS, and a scientific APS2 burn (Reference 13).

Vehicle Position Vector at Intercept Time 24,794.155 Seconds GET

	Desired Target ECI (ft)	OT Target Intercept (ft) (via interpolation)	Scientific Target Intercept	ICS Target Intercept (ft)
X	-19,323,293.0	-19,254,934.0	*	-19,312,933.0
Y	7,751,929.0	7,683,031.0	*	7,695,498.0
Z	-6,420,691.0	-6,510,341.0	*	-6,445,589.0
Error magnitude from desired target		132,124.0 ft** 21.7 n mi**	19.8 n mi** 11.2 n mi***	62,543.0 ft*** 10.3 n mi***

*Not available
**Fuel depletion
***Guidance cutoff

The above table shows an ICS target miss of 10.3 miles as compared with the OT target miss of 21.7 miles. This accuracy probably results from the fact that the ICS run experiences a guidance cutoff of the engine. It should be noted that if the RCS cross feed is achieved, the APS propellant is expended 1.56 seconds prior to a normal guidance cutoff, and an additional error may occur.

Propellant Consumption

In the ascent configuration the LM propulsion system consists of two propulsion systems. First, there is the ascent engine, which is used to provide a translational thrust of 3500 pounds with no thrust vector control capability. Second, there is the 16-jet RCS system, which is used to accomplish attitude maneuvers, translation for ullage, and moment control.

The propellant expenditure characteristics were reviewed and compared to the data presented in the OT. This comparison is presented in the following table.

RCS Engine Propellant Consumption during Mission Phase 13

Event	Amount Expended (lb) ICS	OT	Deviation from OT (percent)
Reorientation attitude maneuver and coast to APS2 ullage	3.6	7.920	-45
APS2 ullage maneuver	19.3	5.712	+340
APS2 burn	58.5	157.620	-37
Total	81.4	171.252	-47

The results show that the OT was conservative in its estimate of RCS propellant consumed. The added ICS propellant demand of the ullage maneuver is explained by the extra 9 seconds of the ICS ullage maneuver.

The ascent engine characteristics correspond to those specified in the OT with the ICS model using 3500 pounds thrust at a propellant expenditure rate of 11.3269 pounds per second.

In the ICS the initial APS2 propellant loading is 5007 pounds. The engine is commanded off with 27 pounds of fuel left resulting in a total propellant usage of 4980 pounds.

The ICS model does not simulate the APS feed of the RCS jets. The LMP correctly commands the RCS jets to be fed by the ascent tanks between 22,425 and 22,790 seconds GET, but the ICS environments did not simulate the switch. When comparing the ascent feed test scheduling of the ICS run to that in the "AS-206 Flight Plan" (Reference 10), it is found that the ICS test is initiated 0.3 second earlier and terminated 22.7 seconds later than that in the flight plan. Thus, an additional 23 seconds of propellant crossfeed occurs. During the feed test period the RCS engines use 44.6 pounds of fuel. Assuming that in the mission the switch is achieved, this will cause the ascent engine to run 17.6 pounds short of fuel. At an ascent fuel consumption rate of 11.33 pounds per second, a time-to-go of about 1.55 seconds will remain at fuel depletion.

RUN 7 TRAJECTORY SUMMARY

The following are trajectory deviations with respect to the AS-206 OT at 22, 860 seconds GET. Both the OT and the ICS simulation have completed their APS 2 burns by this time.

	Deviation (ICS-OT)
Altitude	-986. 0 ft
Latitude	-0. 084 deg
Longitude	-0. 025 deg
Inertial velocity	11. 96 fps
Inertial flight-path angle	-0. 0163 deg
Inertial azimuth	-0. 2107 deg
Apogee	-0. 264 n mi
Perigee	6. 561 n mi

The deviation of the LGC state vector from the environment state vector just after engine off is as follows:

	Deviation (LGC-ENV)
ΔX	61 ft
ΔY	-127 ft
ΔZ	-31 ft
$\Delta \dot{X}$	-0. 075 fps
$\Delta \dot{Y}$	0. 006 fps
$\Delta \dot{Z}$	0. 030 fps
ΔVMAG	0. 01 fps

The magnitude of target misses at T_{INT} are given below

OT	21. 7 n mi miss
ICS	10. 3 n mi miss
Scientific	11. 0 n mi miss

Table 5. Sequence of Events for Nominal APS2 (Run 7)

Event	ICS Time, GET (sec)	OT Time, GET (sec)	Error $T_{ICS} - T_{OT}$	Comments
Simulation initialization	22, 200. 000	*		
Start mission phase 13	22, 245. 059	22, 151. 914	93. 145	This error included to obtain coincident thrusting
Enter program 34 (pre-APS2)	22, 245. 061	*	*	
Begin attitude maneuver	22, 250. 954	22, 171. 914	79. 040	More confidence is assigned to ICS timing.
Complete attitude maneuver	22, 253. 757	22, 260. 000	-13. 757	
Enter program 46 (APS2 Burn)	22, 385. 060	*	*	
Start reading PIPA's	22, 385. 069	*	*	
RCS ullage on	22, 402. 577	22, 411. 914	-9. 357	ICS ullage is 9 sec longer than OT
Command APS engine on	22, 415. 057	22, 415. 414	-0. 357	Acceptable
RCS ullage off	22, 415. 557	22, 415. 914	-0. 357	Acceptable
Command APS engine off	22, 854. 999	22, 842. 432	12. 567	ICS was able to exercise commanded EOC prior to fuel depletion because of RCS not being switched to the APS propellant

*Not available

Table 5. Sequence of Events for Nominal APS2 (Run 7)(Continued)

Event	ICS Time, GET (sec)	OT Time, GET (sec)	Error $T_{ICS} - T_{OT}$	Comments
End of tail off	*	22, 842. 640	*	
Hold attitude (deadband = 5 deg)	22, 855. 000	*	*	
Terminate reading PIPA's	22, 891. 216	*	*	

*Not available

Table 6. LMP Commands During MP13

Time (sec)	Command Number	Command Description
22, 251. 0234	236	DFI/TM calibrate - ON
22, 263. 0234	237	DFI/TM calibrate - OFF
22, 263. 1434	198	Master C&W alarm reset - COMMAND
22, 265. 0634	199	Master C&W alarm reset - COMMAND RESET
22, 385. 0650	134	Engine select - ASC ARM
22, 424. 0634	126	Ascent feed valve - ARM
22, 425. 1434	60	RCS ascent feed valves, Sys A - OPEN
22, 425. 2634	172	RCS main S/O valves, Sys A - CLOSE
22, 427. 0634	61	RCS ascent feed valves, Sys A - OPEN RESET
22, 427. 1874	173	RCS main S/O valves, Sys A - CLOSE RESET
22, 435. 1034	62	RCS ascent feed valves, Sys B - OPEN
22, 435. 2235	174	RCS main S/O valves, Sys B - CLOSE
22, 437. 1434	63	RCS ascent feed valves, Sys B - OPEN RESET
22, 437. 2634	175	RCS main S/O valves, Sys B - CLOSE RESET
22, 445. 0634	252	RCS manifold crossfeed valve - OPEN
22, 447. 1034	253	RCS manifold crossfeed valve - OPEN RESET
22, 789. 1034	254	RCS manifold crossfeed valve - CLOSE
22, 790. 0634	188	RCS main S/O valves, Sys A - OPEN
22, 790. 1874	76	RCS ascent feed valves, Sys A - CLOSE
22, 791. 1435	255	RCS manifold crossfeed valve - CLOSE RESET

Table 6. LMP Commands During MP13 (Continued)

Time (sec)	Command Number	Command Description
22, 792. 1034	189	RCS main S/O valves, Sys A - OPEN RESET
22, 792. 2235	77	RCS ascent feed valves, Sys A - CLOSE RESET
22, 800. 1434	190	RCS main S/O valves, Sys B - OPEN
22, 800. 2634	78	RCS ascent feed valves, Sys B - CLOSE
22, 801. 1034	127	Ascent feed valve - SAFE
22, 802. 0634	191	RCS main S/O valves, Sys B - OPEN RESET
22, 802. 1913	79	RCS ascent feed valves, Sys B - CLOSE RESET
22, 862. 3034	135	Engine select - ASC ARM OFF

Run 7 Event Summary, APS2 Burn

Mission Event	GET (sec)	Altitude (ft)	Geodetic Latitude (deg)	Longitude (deg)	Inertial Velocity (ft/sec)	Inertial Flight-path Angle (deg)	Inertial Azimuth Angle (deg)	RCS Fuel (lb)	DPS Fuel (lb)	OGA (deg)	IGA (deg)	MGA (deg)
Simulation initialized	22, 200. 000	1, 039, 264	27. 711	-132. 841	25, 341. 690	-0. 105	81. 618	585. 0	5, 007	97. 9	-43. 8	-38. 3
Hold vehicle attitude	22, 200. 031	1, 039, 263	27. 711	-132. 839	25, 341. 691	-0. 105	81. 620	585. 0	5, 007	97. 9	-43. 8	-38. 3
Start MP13	22, 245. 059	1, 037, 604	28. 107	-129. 690	25, 343. 857	-0. 102	83. 177	585. 0	5, 007	97. 9	-43. 8	-38. 3
Enter program 34 pre-APS2 burn	22, 245. 061	1, 037, 604	28. 107	-129. 690	25, 343. 857	-0. 102	83. 177	585. 0	5, 007	97. 9	-43. 8	-38. 3
Begin attitude maneuver	22, 250. 954	1, 037, 385	28. 153	-129. 277	25, 344. 138	-0. 102	83. 384	585. 0	5, 007	97. 9	-43. 8	-38. 3
Complete attitude maneuver	22, 253. 757	1, 037, 281	28. 174	-129. 080	25, 343. 850	-0. 101	83. 482	584. 5	5, 007	103. 6	-34. 2	-35. 7
Enter program 46 APS2 burn	22, 385. 060	1, 032, 320	28. 810	-119. 779	25, 350. 393	-0. 091	88. 177	582. 6	5, 007	104. 0	-34. 0	-35. 3
Start reading PIPA's	22, 385. 069	1, 032, 320	28. 810	-119. 778	25, 350. 394	-0. 091	88. 177	582. 6	5, 007	104. 0	-34. 0	-35. 3
Command +X translation RCS ullage	22, 402. 557	1, 031, 650	28. 841	-118. 533	25, 351. 190	-0. 090	88. 811	582. 4	5, 007	103. 7	-33. 9	-35. 4
Command APS engine on	22, 415. 057	1, 031, 171	28. 855	-117. 642	25, 349. 584	-0. 089	89. 230	563. 1	5, 007	104. 3	-33. 5	-35. 5
RCS ullage off	22, 415. 557	1, 031, 151	28. 853	-117. 6059	25, 349. 44	-0. 087	89. 246	562. 3	5, 006	104. 4	-33. 4	-35. 5
Command APS engine off	22, 854. 999	1, 031, 085	28. 646	-86. 527	25, 265. 363	0. 084	89. 788	504. 6	29	80. 7	-29. 3	-37. 4
Hold vehicle attitude	22, 855. 000	1, 031, 085	28. 646	-86. 527	25, 265. 365	0. 084	89. 788	504. 6	29	80. 7	-29. 3	-37. 4
Terminate reading PIPA's	22, 891. 216	1, 032, 296	28. 628	-83. 960	25, 264. 458	0. 070	91. 080	504. 4	27	72. 2	-35. 5	-38. 0
Hold vehicle attitude	22, 893. 284	1, 032, 357	28. 625	-83. 813	25, 264. 386	0. 070	91. 154	504. 4	27	71. 7	-35. 9	-38. 0

Run 7 Phase Summary; APS2 Burn

Phase	Unit	Value	GET (sec)
ATTITUDE MANEUVER SUMMARY			
RCS jet firings		10	
RCS jet firing on-times	sec	1.156	
RCS fuel consumption	lb	0.5452	
Maximum body rates	deg/sec	-0.0559, yaw	22,253.757
		0.8165, pitch	22,253.757
		-4.7043, roll	22,253.757
Total time of maneuver	sec	2.802	
BURN SUMMARY			
Start of ullage maneuver	sec	22,402.557	
Time duration of ullage maneuver	sec	13.000	
Start of burn	sec	22,415.057	
Length of burn	sec	439.942	
Thrust maximum	lb	3,500.00	
Thrust minimum	lb	3,500.00	
Maximum acceleration	fps/sec	23.0387	22,822.003
Main engine fuel consumption	lb	4,980.0	

Run 7 Phase Summary;APS2 Burn (Continued)

Phase	Unit	Value	GET (sec)
RCS fuel consumption	lb	77.8	
Time of engine-off command	sec	22, 854.999	
Maximum body rates	deg/sec	-0.2401, yaw -6.3173, pitch 3.0999, roll	

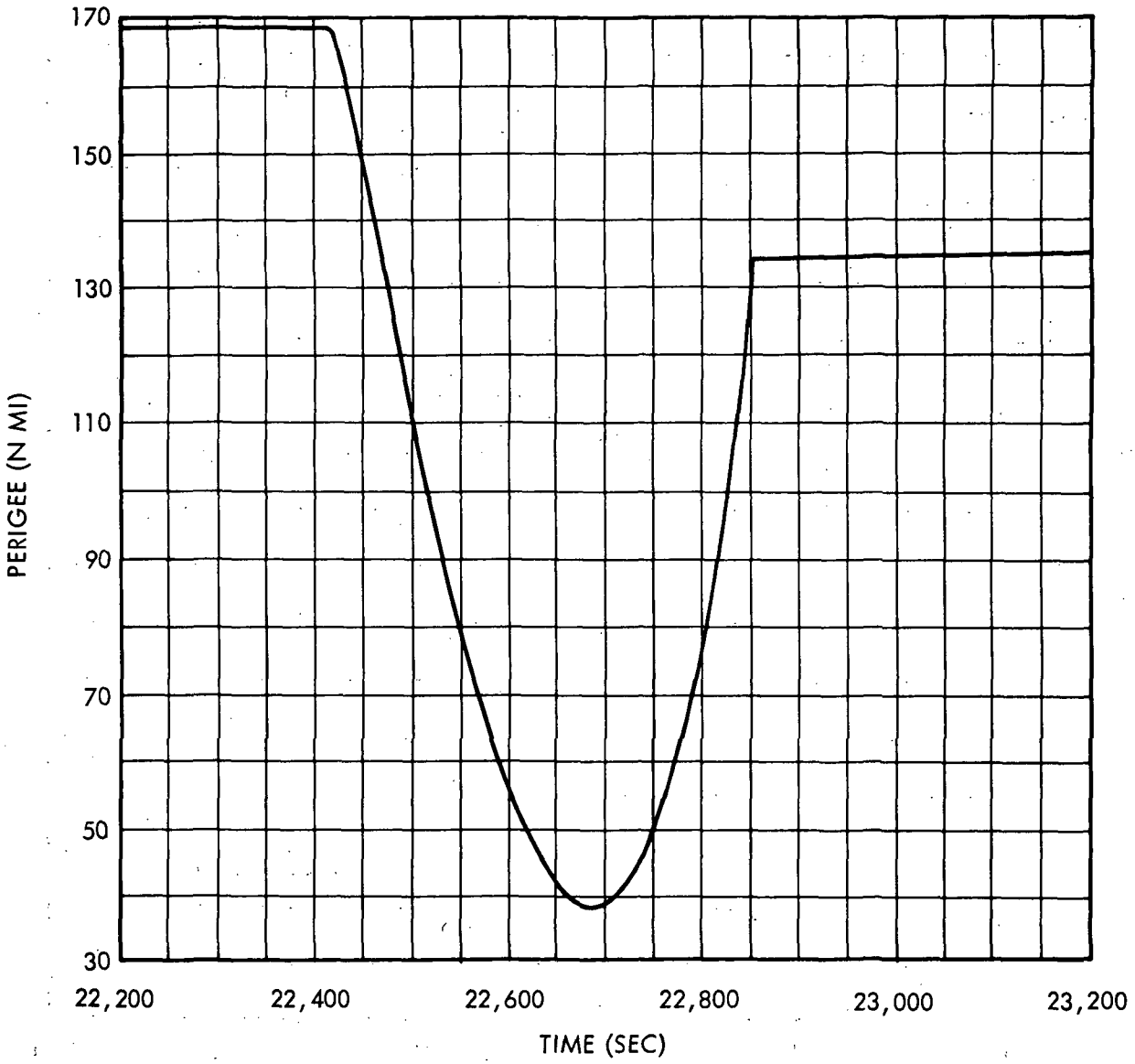

Figure 8. Run 7; APS2 Nominal Instantaneous Perigee

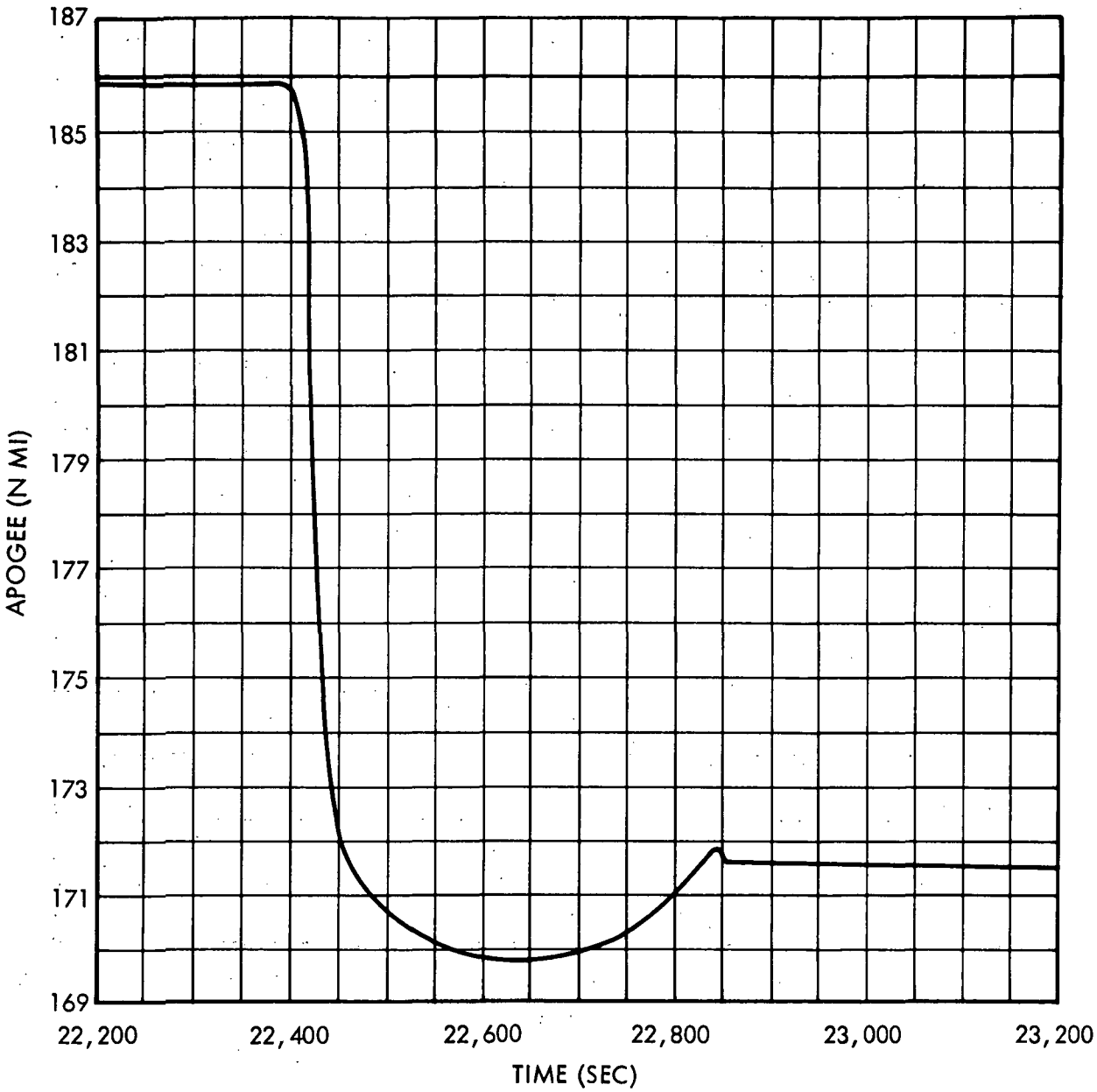

Figure 9. Run 7; APS2 Nominal Instantaneous Apogee

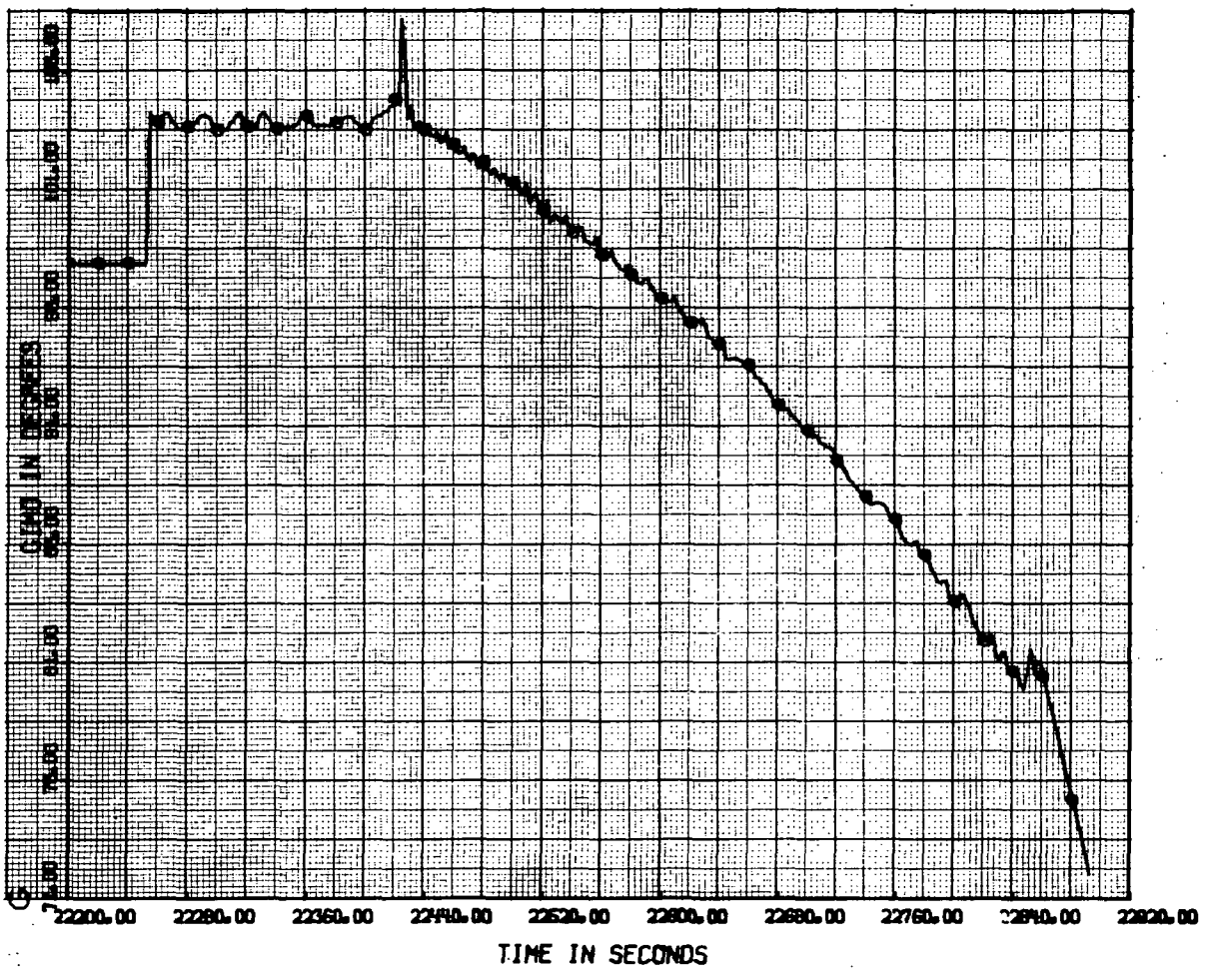

Figure 10. Run 7; APS2 Nominal Outer Gimbal Angle

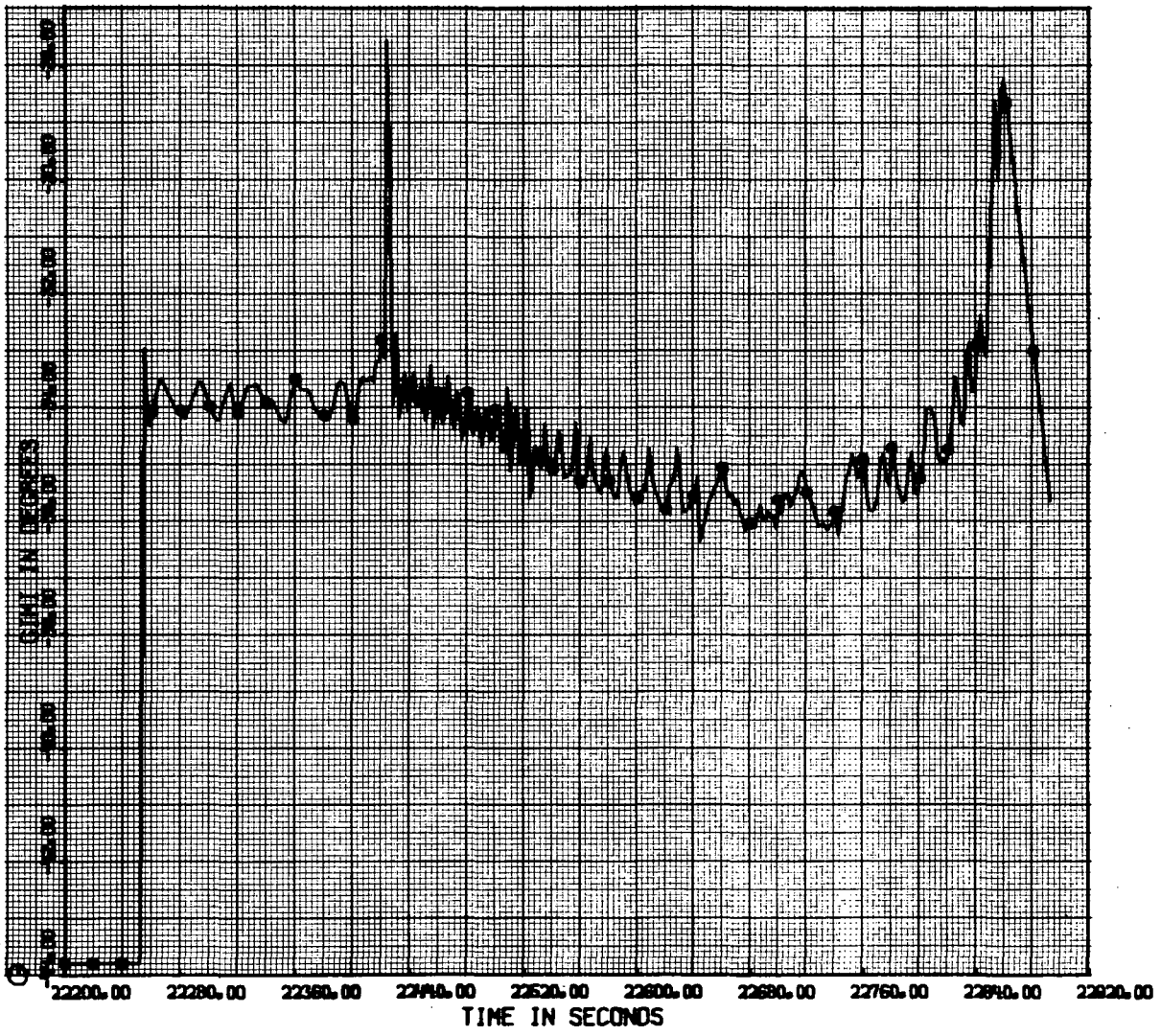

Figure 11. Run 7; APS2 Nominal Inner Gimbal Angle

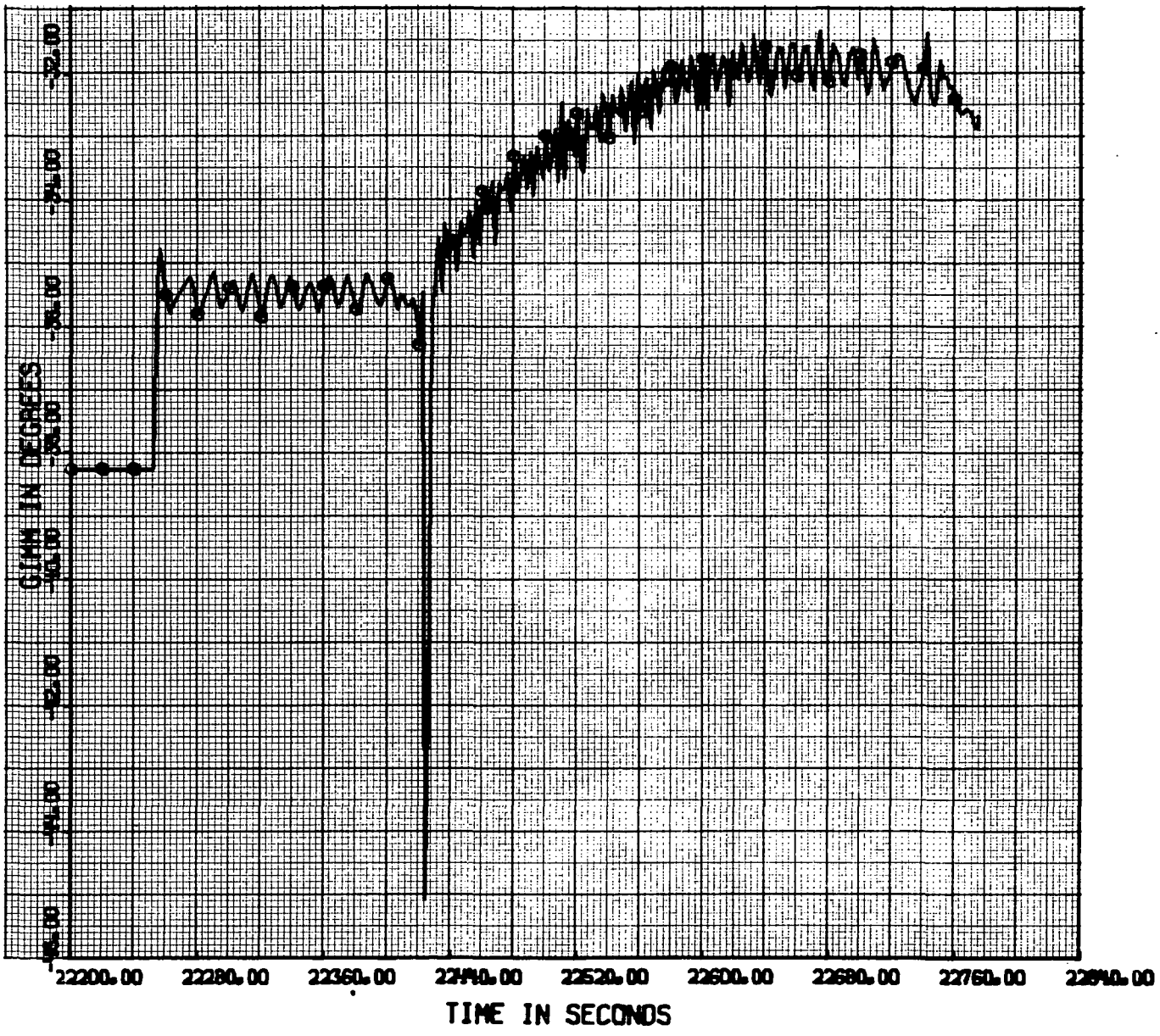

Figure 12. Run 7; Nominal Middle Gimbal Angle

RUN 9 TEST RESULTS SUMMARY

Test Run Description

Dispersion of the initial trajectory state vector.

Test Run Objectives

To determine the effect of the following initial state vector dispersions (with respect to nominal run 4) on the guidance system performance:

$$\left.\begin{array}{ll} \Delta X = 2209 \text{ ft (high)} & \Delta \dot{X} = 7.451 \text{ fps (low)} \\ \Delta Y = 535 \text{ ft (high)} & \Delta \dot{Y} = 10.939 \text{ fps (low)} \\ \Delta Z = 33579 \text{ ft (high)} & \Delta \dot{Z} = 129.996 \text{ fps (high)} \end{array}\right\} \text{ ECI}$$

Summary of Test Results

A comparative analysis between the perturbed run and nominal run 4 (DPS1 burn) revealed no significant problem areas resulting from the dispersion of the initial trajectory state vector.

Discussion of Test Results

The analysis of Run 9 may be described as a comparative analysis rather than a general performance analysis that only the differences between the perturbed run and the nominal run 4 were considered to be of interest.

As a result of the initial dispersed trajectory conditions, the computed orbit insertion parameters at TIG differ somewhat from the nominal values as indicated below:

Parameter	Run 9	Run 4 - Nominal	Deviation
TIG (sec)	14,397.170	14,401.910	4.740 sec (early)
	118.0286	119.7113	1.6827 fps (low
VG (fps)	-85.3170	-33.9935	51.3235 fps (high)
	-136.6834	-92.4596	44.2238 fps (high)
	23,761.8093	23,691.9695	69.8398 fps (high)
VD (fps)	3,337.8595	3,369.0273	31.1678 fps (low)
	-9,107.5527	-9,172.3381	64.7854 fps (low)

Dispersion of the initial trajectory state vector was observed to produce a minor perturbing effect on virtually every trajectory parameter throughout the entire DPS1 simulation. At guidance command DPS1 engine off, the errors in apogee and perigee altitude, respectively, were 0.83 nautical miles (low) and 6.78 nautical miles (low).

The trajectory state vector dispersion resulted in approximately a 29 percent increase in the total amount of propellant used during the run. The propellant usage, however, appears consistent with the required increase in orbital energy. The propellant usage is tabulated below for comparison:

Propellant Used	Run 9 (lb)	Run 4 (lb)	Deviation (lb)
Total RCS	25.86	20.96	4.90
Total DPS	639.65	494.74	144.91
Total (RCS + DPS)	665.51	515.70	149.81

As indicated below, approximately 94.5 percent of the increased RCS propellant usage occurred during the DPS1 burn phase. The increase in propellant may be attributed to higher than nominal spacecraft attitude rates and a 4-second longer burn.

Quantity	Run 9	Run 4	Deviation
Number RCS fires	97	66	31
RCS propellant used	17.895 lb	13.261 lb	4.634 lb
RCS on-time	43.887 sec	32.713 sec	11.174 sec

No attitude instabilities were observed to result from dispersion of the initial trajectory conditions. Nevertheless, the analysis did reveal a definite perturbing effect on the spacecraft attitude and attitude rates.

Upon completion of the attitude maneuver, the desired (or commanded) CDU values were observed to differ considerably from the respective nominal values as indicated:

Quantity	Run 9 (deg)	Run 4 (deg)	Deviation (deg)
XCDUD	-89.6704	-101.8540	12.1826 (low)
YCDUD	49.1968	37.6831	11.5137 (high)
ZCDUD	-25.2795	-12.6563	12.6232 (high)

During the DPS1 burn, the spacecraft attitude rates were observed to differ considerably from the nominal values. The maximum observed angular rates are listed below for comparison:

Quantity	Run 9 (deg/sec)	Run 4 (deg/sec)
CUX	-0.1511	-0.0554
CUY	-2.6990	1.5082
CUZ	2.7225	-0.4194

The desired CDU values following the burn phase deviated significantly from the nominal values. The initialization of the desired CDU values during post-DPS burn hold-vehicle-attitude maneuvers are listed below for comparison:

Hold-vehicle-attitude following command DPS engine off:

Quantity	Run 9 (deg)	Run 4 (deg)	Deviation (deg)
XCDUD	-89.5495	-104.1060	14.5564
YCDUD	58.4802	34.7278	23.7524
ZCDUD	-16.4465	-11.8982	4.5483

Hold-vehicle-attitude following LGC idling:

Quantity	Run 9 (deg)	Run 4 (deg)	Deviation (deg)
XCDUD	-85.7153	-106.3920	20.6767
YCDUD	59.5789	36.2549	23.3240
ZCDUD	-17.2595	-12.6563	4.6032

RUN 9 TRAJECTORY SUMMARY

State vector dispersion of nominal run 4

The parameters listed in the first column represent the trajectory deviations from the nominal at simulation initialization. The parameters listed in the second column represent the trajectory deviations from the nominal at DPS1 guidance command engine off.

Parameter	Deviations at Simulation Initialized	Deviations at DPS1 Engine Off
Time	0	0.310 sec (early)
Altitude	19192 ft (low)	41,311 ft (low)
Geodetic latitude	0.0735 deg (north)	0.1671 deg (north)
Geodetic longitude	1.2843 deg (west)	1.3061 deg (west)
Inertial velocity	2.90 fps (high)	35.08 fps (high)
Inertial flight-path angle	0.1483 deg (high)	0.0025 deg (high)
Inertial azimuth	0.2478 deg (south)	0.1921 deg (south)
Inertial longitude	0	0.0230 deg (west)
Declination	0.0735 deg (low)	0.1667 deg (low)
Radius vector magnitude	19,113 ft (low)	41,154 ft (low)
Apogee altitude (targeting parameter)	1.56 n mi (high)	0.83 n mi (low)
Perigee altitude	12.4425 n mi (low)	6.7752 n mi (low)
Orbit period	12.186 sec (fast)	8.608 sec (fast)

The following parameters represent the deviation in ECI coordinates between the LGC state vector estimates and the environment (for the perturbed run only) at DPS1 guidance engine off.

ΔX	16 ft (high)
ΔY	100 ft (high)
ΔZ	45 ft (low)

$\Delta\dot{X}$	0.097 fps (high)
$\Delta\dot{Y}$	0.044 fps (high)
$\Delta\dot{Z}$	0.124 fps (high)

Run 9 Event Summary; DPS1 Burn

Mission Event	GET (sec)	Altitude (ft)	Geodetic Latitude (deg)	Longitude (deg)	Inertial Velocity (fps)	Inertial Flight-path Angle (deg)	Inertial Azimuth Angle (deg)	RCS Fuel (lb)	DPS Fuel (lb)	OGA (deg)	IGA (deg)	MGA (deg)
Simulation initialized	14, 100. 000	707, 333	-30. 837	81. 967	25, 467. 862	-0. 223	81. 997	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Hold vehicle attitude	14, 100. 032	707, 329	-30. 837	81. 969	25, 467. 866	-0. 223	81. 996	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Start DAP	14, 105. 031	706, 781	-30. 789	82. 337	25, 468. 483	-0. 224	81. 797	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Hold vehicle attitude	14, 105. 032	706, 781	-30. 789	82. 337	25, 468. 483	-0. 224	81. 797	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Start MP9	14, 126. 043	704, 428	-30. 576	83. 877	25, 471. 122	-0. 230	80. 969	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Enter program 31 pre-DPS1 burn	14, 126. 045	704, 427	-30. 576	83. 877	25, 471. 123	-0. 230	80. 969	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Finish orbital integration	14, 128. 749	704, 119	-30. 547	84. 075	25, 471. 468	-0. 231	80. 863	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Begin attitude maneuver	14, 128. 894	704, 102	-30. 545	84. 086	25, 471. 487	-0. 231	80. 857	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Complete attitude maneuver	14, 144. 857	702, 264	-30. 368	85. 250	25, 473. 340	-0. 234	80. 236	581. 1	17, 314	-89. 9	48. 5	-25. 6
Enter program 41 DPS1 burn	14, 331. 168	677, 699	-27. 475	98. 470	25, 500. 706	-0. 283	73. 455	577. 3	17, 314	-89. 7	49. 4	-25. 3
Finish orbital integration	14, 335. 158	677, 119	-24. 398	98. 744	25, 501. 345	-0. 283	73. 321	577. 3	17, 314	-89. 8	49. 3	-25. 3
Start reading PIPA's	14, 367. 166	672, 392	-26. 754	100. 932	25, 506. 542	-0. 290	72. 267	577. 2	17, 314	-89. 6	49. 0	-25. 4
Command +X translation - RCS ullage	14, 389. 667	668, 996	-26. 279	102. 455	25, 510. 271	-0. 295	71. 547	577. 2	17, 314	-89. 5	49. 2	-25. 0
Command DPS engine on	14, 397. 177	667, 855	-26. 116	102. 960	25, 513. 227	-0. 293	71. 311	567. 6	17, 314	-90. 0	48. 4	-26. 3
Command +X translation off	14, 397. 677	667, 779	-26. 106	102. 993	25, 513. 454	-0. 293	71. 296	566. 8	17, 314	-90. 1	48. 3	-26. 4
Increase throttle to maximum	14, 423. 179	664, 141	-25. 538	104. 699	25, 541. 038	-0. 247	70. 510	564. 1	17, 206	-92. 5	45. 0	-22. 9
Disable DAP trim gimbal control	14, 423. 206	664, 138	-25. 537	104. 701	25, 541. 070	-0. 247	70. 509	564. 1	17, 206	-92. 4	45. 0	-23. 0
Enable DAP trim gimbal control	14, 425. 156	663, 887	-25. 493	104. 831	25, 551. 217	-0. 227	70. 451	563. 4	17, 162	-90. 8	49. 2	-27. 7
Command DPS engine off	14, 439. 776	662, 856	-25. 155	105. 803	25, 659. 460	0. 010	70. 007	560. 0	16, 682	-89. 6	58. 5	-16. 5
Hold vehicle attitude	14, 439. 780	662, 856	-25. 155	105. 804	25, 659. 489	0. 010	70. 007	560. 0	16, 682	-89. 6	58. 5	-16. 4
DV monitor detects engine shutdown	14, 447. 299	662, 743	-24. 978	106. 303	25, 661. 292	0. 018	69. 784	559. 2	16, 674	-90. 8	57. 3	-15. 7
Set maximum deadband to 5 degrees	14, 477. 300	662, 432	-24. 254	108. 279	25, 661. 234	0. 036	68. 911	559. 1	16, 674	-89. 2	57. 9	-17. 5
LGC idling	14, 539. 388	662, 501	-22. 665	112. 293	25, 660. 257	0. 071	67. 214	559. 1	16, 674	-85. 7	59. 6	-17. 3
Hold vehicle attitude	14, 539. 392	662, 501	-22. 665	112. 294	25, 660. 257	0. 071	67. 214	559. 1	16, 674	-85. 7	59. 6	-17. 3
Set maximum deadband to 5 degrees	14, 539. 393	662, 501	-22. 665	112. 294	25, 660. 257	0. 071	67. 214	559. 1	16, 674	-85. 7	59. 6	-17. 3

Run 9 Phase Summary; DPS1 Burn

Phase	Unit	Value	GET (sec)
ATTITUDE MANEUVER SUMMARY			
RCS jet firings		52	
RCS jet firing on-times	sec	8.856	
RCS fuel consumption	lb	3.9296	
Maximum body rates	deg/sec	0.1109, yaw	14,132.000
		0.3983, pitch	14,132.000
		6.2452, roll	14,132.000
Total time of maneuver	sec	15.963	
BURN SUMMARY			
Start of ullage maneuver			14,389.667
Time duration of ullage maneuver	sec	8.010	
Start of burn			14,397.177
Length of burn	sec	46.132	
Thrust maximum at 92.5 percent throttle setting	lb	9,891.81	14,440.002
Thrust minimum at 10 percent throttle setting	lb	1,283.00	14,399.312
Maximum acceleration	fps/sec	10.3984	14,440.002
Main engine fuel consumption	lb	639.65	
RCS fuel consumption	lb	17.2	
Time of engine off command			14,439.776

Run 9 Phase Summary; DPS1 Burn (Continued)

Phase	Unit	Value	GET (sec)
Time after engine off until DV monitor first detects shutdown	sec	3.533	
Maximum body rates	deg/sec	-0.1511, yaw -2.6990, pitch 2.7225, roll	
Position vector at thrust termination (ECI)	ft	-19,148,957, yaw -4,019,091, pitch -9,094,282, roll	
Velocity vector at thrust termination (ECI)	fps	1,306.479, yaw -24,349.616, pitch 7,993.141, roll	
Maximum torque on vehicle	ft-lb	1,946.6319	14,439.166
Initial gimbal angles of main engine	deg	-0.3177, pitch 2.3151, roll	
Final gimbal angles of main engine	deg	-0.507, pitch 2.182, roll	

RUN 10 TEST RESULTS SUMMARY

Test Run Description

Simulation of DPS1 burn with initial nozzle offsets in pitch and roll.

Test Run Objectives

To determine the effects of torques caused by incorrect nozzle settings and to demonstrate the capability of trimming the DPS gimbal so that the thrust vector passes through the center of gravity.

Summary of Test Results

The gimbal trim capability of the LGC has been verified and the DPS1 burn was properly exercised in the presence of the initial nozzle offsets.

Discussion of Test Results

A comparative analysis between the perturbed run and the nominal run revealed no problem areas. The attitude maneuver prior to thrusting was nominal, requiring 13.7 seconds and 3.7 pounds of RCS fuel. The initial nozzle offset torques were reflected in the maximum excursions of the CDU angles. The perturbed CDUY angles varied from 39.7 to 33.1 degrees as compared to 36.99 to 34.4 degrees for the nominal run. The perturbed CDUZ angles varied from -23.1 to -9.3 degrees as compared to -15.4 to -11.1 degrees for the nominal run. The RCS fuel used during the DPS1 burn was increased to 8.5 pounds for 69 firings compared to 3.6 pounds for 32 firings for the nominal. The RCS on-time was also increased to 20.29 seconds compared to the nominal 8.46 seconds. The target parameter (apogee altitude) was achieved from the DPS1 cutoff conditions with an error of 0.094 nautical miles. The final DPS gimbal trim settings of -1.3431 and 3.1253 degrees compare favorably with the calculated angles of -1.30 and 3.073 degrees for JPY and JPZ, respectively.

RUN 10 TRAJECTORY SUMMARY

The following are the trajectory deviations observed with respect to the nominal DPS1 (run 4) parameters evaluated at DPS1 guidance command engine off:

Altitude	5.0 ft
Latitude	0.0 deg
Longitude	0.0 deg
Inertial velocity	0.17 fps
Inertial flight-path angle	0.001 deg
Inertial azimuth	0.008 deg
Apogee	0.094 n mi
Perigee	0.001 n mi

The LGC state vector deviation from the environment in ECI at DPS1 guidance command engine off is as follows:

ΔX	19 ft
ΔY	39 ft
ΔZ	35 ft
$\Delta \dot{X}$	0.037 fps
$\Delta \dot{Y}$	0.040 fps
$\Delta \dot{Z}$	0.097 fps

Run 10 Event Summary; DPS1 Burn

Mission Event	GET (sec)	Altitude (ft)	Geodetic Latitude (deg)	Longitude (deg)	Inertial Velocity (fps)	Inertial Flight-path Angle (deg)	Inertial Azimuth Angle (deg)	RCS Fuel (lb)	DPS Fuel (lb)	OGA (deg)	IGA (deg)	MGA (deg)
Simulation initialized	14, 100.000	726, 525	-30.911	83.251	25, 464.957	-0.074	82.245	585.0	17, 314	-113.1	-25.9	-5.5
Hold vehicle attitude	14, 100.032	726, 523	-30.910	83.253	25, 464.958	-0.075	82.244	585.0	17, 314	-113.1	-25.9	-5.5
Start DAP	14, 105.031	726, 306	-30.864	83.621	25, 465.183	-0.076	82.045	585.0	17, 314	-113.1	-25.9	-5.5
Hold vehicle attitude	14, 105.032	726, 306	-30.864	83.621	25, 465.183	-0.076	82.045	585.0	17, 314	-113.1	-25.9	-5.5
Start MP9	14, 126.043	725, 351	-30.657	85.162	25, 466.170	-0.081	81.214	585.0	17, 314	-113.1	-25.9	-5.5
Enter program 31 pre-DPS1 burn	14, 126.045	725, 351	-30.657	85.162	25, 466.171	-0.081	81.214	585.0	17, 314	-113.1	-25.9	-5.5
Finish orbital integration	14, 128.659	725, 227	-30.630	85.353	25, 466.298	-0.082	81.111	585.0	17, 314	-113.1	-25.9	-5.5
Begin attitude maneuver	14, 128.803	725, 220	-30.628	85.364	25, 466.305	-0.082	81.105	585.0	17, 314	-113.1	-25.9	-5.5
Complete attitude maneuver	14, 142.537	724, 559	-30.480	86.367	25, 466.877	-0.084	80.569	581.3	17, 314	-102.3	37.1	-12.7
Enter program 41 DPS1 burn	14, 335.908	712, 185	-27.526	100.084	25, 479.640	-0.131	73.512	577.7	17, 314	-101.9	38.0	-12.7
Finish orbital integration	14, 341.107	711, 780	-27.426	100.441	25, 480.053	-0.132	73.338	577.7	17, 314	-101.9	38.0	-12.8
Start reading PIPA's	14, 371.906	709, 317	-26.809	102.542	25, 482.578	-0.138	72.325	577.6	17, 314	-101.6	37.9	-12.9
Command +X translation - RCS ullage	14, 394.407	707, 443	-26.337	104.061	25, 484.500	-0.143	71.605	577.6	17, 314	-102.2	37.4	-12.5
Command DPS engine on	14, 401.917	706, 808	-26.175	104.565	25, 487.187	-0.143	71.369	567.8	17, 314	-102.3	36.8	-13.5
Command +X translation off	14, 402.417	706, 766	-26.165	104.599	25, 487.408	-0.143	71.353	567.0	17, 314	-102.3	36.7	-13.6
Increase throttle to maximum	14, 427.919	704, 747	-25.600	106.301	25, 518.013	-0.114	70.568	562.5	17, 206	-103.9	33.2	-23.1
Disable DAP trim gimbal control	14, 427.938	704, 746	-25.600	106.302	25, 518.037	-0.114	70.568	562.5	17, 206	-103.9	33.2	-23.1
Enable DAP trim gimbal control	14, 429.891	704, 608	-25.555	106.432	25, 529.721	-0.100	70.507	560.7	17, 162	-103.8	33.7	-17.2
Command DPS engine off	14, 440.086	704, 172	-25.322	107.110	25, 624.217	0.006	70.207	559.3	16, 828	-103.7	35.1	-11.2
Hold vehicle attitude	14, 440.090	704, 172	-25.322	107.110	25, 624.251	0.006	70.206	559.3	16, 827	-103.7	35.1	-11.2
DV monitor detects engine shutdown	14, 448.049	704, 034	-25.137	107.638	25, 626.645	0.012	69.968	559.2	16, 819	-104.1	34.6	-10.0
Set maximum deadband to 5 degrees	14, 478.048	703, 638	-24.421	109.612	25, 626.686	0.028	69.090	559.0	16, 819	-104.6	34.2	-11.9
LGC idling	14, 540.135	703, 458	-22.850	113.624	25, 626.007	0.061	67.382	559.0	16, 819	-102.6	35.8	-11.7
Hold vehicle attitude	14, 540.139	703, 458	-22.850	113.624	25, 626.007	0.061	67.382	559.0	16, 819	-102.6	35.8	-11.7
Set maximum deadband to 5 degrees	14, 540.140	703, 458	-22.850	113.624	25, 626.007	0.061	67.382	559.0	16, 819	-102.6	35.8	-11.7

Run 10 Phase Summary; DPS1 Burn

Phase	Unit	Value	GET (sec)
ATTITUDE MANEUVER SUMMARY			
RCS jet firings		39	
RCS jet firing on-times	sec	8.703	
RCS fuel consumption	lb	3.7406	
Maximum body rates	deg/sec	-0.0619, yaw	14,142.537
		-1.1216, pitch	14,142.537
		5.1188, roll	14,142.537
Total time of maneuver	sec	13.734	
BURN SUMMARY			
Start of ullage maneuver			14,394.407
Time duration of ullage maneuver	sec	8.010	
Start of burn			14,401.917
Length of burn	sec	42.127	
Thrust maximum	lb	9,885.20	14,440.090
Thrust minimum	lb	1,283.00	14,404.047
Maximum acceleration	fps/sec	10.3461	14,440.090
Main engine fuel consumption	lb	494.25	
RCS fuel consumption	lb	18.3	
Time of engine off command			14,440.086
Time after engine off to DV monitor detects zero thrust	sec	3.957	

Run 10 Phase Summary; DPS1 Burn (Continued)

Phase	Unit	Value	GET (sec)
Maximum body rates	deg/sec	-0.0388, yaw -3.9190, pitch -0.9453, roll	
Position vector at thrust termination (ECI)	ft	-19,157,106, yaw -4,039,265, pitch -9,165,628, roll	
Velocity vector at thrust termination (ECI)	fps	1,346.064, yaw -24,340.507, pitch 7,902.623, roll	
Maximum torque on vehicle	ft-lb	1,678.6059	14,427.919
Initial gimbal angles of main engine	deg	-2.3177, pitch 4.3151, roll	
Final gimbal angles of main engine	deg	-1.343, pitch 3.125, roll	

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RUN 11 TEST RESULTS SUMMARY

Test Run Description

A DPS1 burn with an initial nozzle offset in roll only.

Test Run Objectives

To demonstrate the capability of steering and attitude control with an initial nozzle offset for the DPS1 burn.

Summary of Test Results

The LGC steering and attitude control performed satisfactorily as compared to the nominal run (run 4) for the perturbations caused by an initial nozzle offset of 0.5 degree in the roll axis.

Discussion of Test Results

The RCS ullage overlap problem discussed under nominal run 4 in Reference 1 was exhibited in this run. The attitude maneuver prior to thrusting was nominal requiring 13.7 seconds and 3.7 seconds of RCS fuel to complete. The initial roll nozzle offset of 0.5 degree caused the CDUY value to go from 43.23 to 26.70 compared to the nominal values of 36.99 to 34.42. The CDUX and CDUZ values were near the nominal values. The RCS firings increased from the nominal value of 32 to 53 with a total on-time of 18.30 seconds using 7.58 pounds of RCS fuel. This compares to the nominal on-time of 8.46 seconds and 3.58 pounds of RCS fuel. The target apogee altitude was achieved at the DPS1 cutoff conditions with a 0.08 nautical-mile deviation from the nominal.

RUN 11 TRAJECTORY SUMMARY

The following are the trajectory deviations observed with respect to the nominal DPS1 (run 4) parameters evaluated at DPS1 guidance engine off command:

Altitude	3.0 ft
Latitude	0.0 deg
Longitude	0.0 deg
Inertial velocity	0.14 fps
Inertial flight-path angle	0.0 deg
Inertial azimuth	0.004 deg
Apogee	0.08 n mi
Perigee	0.03 n mi

The LGC state vector deviation from the environment in ECI at DPS1 guidance engine off command is as follows:

ΔX	19 ft
ΔY	40 ft
ΔZ	33 ft
$\Delta \dot{X}$	0.031 fps
$\Delta \dot{Y}$	0.025 fps
$\Delta \dot{Z}$	0.098 fps

Run 11 Event Summary; DPS1 Burn

Mission Event	GET (sec)	Altitude (ft)	Geodetic Latitude (deg)	Longitude (deg)	Inertial Velocity (fps)	Inertial Flight-path Angle (deg)	Inertial Azimuth Angle (deg)	RCS Fuel (lb)	DPS Fuel (lb)	OGA (deg)	IGA (deg)	MGA (deg)
Simulation initialized	14,100.000	726,525	-30.911	83.251	25,464.957	-0.074	82.245	585.0	17,314	-113.1	-25.9	-5.5
Hold vehicle attitude	14,100.032	726,523	-30.910	83.253	25,464.958	-0.075	82.244	585.0	17,314	-113.1	-25.9	-5.5
Start DAP	14,105.031	726.306	-30.864	83.621	25,465.183	-0.076	82.045	585.0	17,314	-113.1	-25.9	-5.5
Hold vehicle attitude	14,105.032	726.306	-30.864	83.621	25,465.183	-0.076	82.045	585.0	17,314	-113.1	-25.9	-5.5
Start MP9	14,126.043	725,351	-30.657	85.162	25,466.170	-0.081	81.214	585.0	17,314	-113.1	-25.9	-5.5
Enter program 31 pre-DPS1 burn	14,126.045	725,351	-30.657	85.162	25,466.171	-0.081	81.214	585.0	17,314	-113.1	-25.9	-5.5
Finish orbital integration	14,128.659	725,227	-30.630	85.353	25,466.298	-0.082	81.111	585.0	17,314	-113.1	-25.9	-5.5
Begin attitude maneuver	14,128.803	725,220	-30.628	85.364	25,466.305	-0.082	81.105	585.0	17,314	-113.1	-25.9	-5.5
Complete attitude maneuver	14,142.547	724,558	-30.480	86.368	25,466.887	-0.084	80.569	581.3	17,314	-102.2	36.9	-12.7
Enter program 41 DPS1 burn	14,335,908	712,184	-27.526	100.084	25,479.640	-0.131	73.512	577.6	17,314	-102.0	37.8	-12.6
Finish orbital integration	14,341.117	711,780	-27.426	100.442	25,480.054	-0.132	73.338	577.6	17,314	-102.1	37.7	-12.6
Start reading PIPA's	14,371.906	709,316	-26.809	102.542	25,482.578	-0.138	72.325	577.5	17,314	-101.9	37.4	-12.5
Command +X translation - RCS ullage	14,394.407	707,443	-26.337	104.061	25,484.499	-0.143	71.605	577.5	17,314	-101.6	37.5	-12.5
Command DPS engine on	14,401.907	706,809	-26.176	104.565	25,487.166	-0.143	71.369	567.9	17,314	-102.1	36.7	-13.5
Command +X translation off	14,402.407	706,766	-26.165	104.598	25,487.381	-0.143	71.353	567.2	17,314	-102.1	36.7	-13.5
Increase throttle to maximum	14,427.908	704,747	-25.600	106.300	25,518.028	-0.114	70.568	561.9	17,206	-104.9	29.7	-14.2
Disable DAP trim gimbal control	14,427.915	704,747	-25.600	106.301	25,518.037	-0.114	70.568	561.9	17,206	-104.9	29.7	-14.2
Enable DAP trim gimbal control	14,429.866	704,609	-25.556	106.431	25,530.282	-0.102	70.508	561.1	17,162	-103.2	37.1	-13.7
Command DPS engine off	14,440.096	704,170	-25.322	107.110	25,624.531	0.007	70.203	560.4	16,827	-104.6	35.5	-11.1
Hold vehicle attitude	14,440.100	704,170	-25.322	107.110	25,624.566	0.007	70.203	560.4	16,826	-104.6	35.5	-11.1
DV monitor detects engine shutdown	14,448.040	704,035	-25.137	107.637	25,626.939	0.013	69.965	560.2	16,818	-105.6	34.7	-10.5
Set maximum deadband to 5 degrees	14,478.142	703,653	-24.421	109.612	25,626.973	0.029	69.087	560.0	16,818	-104.3	36.4	-11.7
LGC idling	14,540.149	703.503	-22.849	113.624	25,626.263	0.062	67.379	559.8	16,818	-101.3	39.6	-17.0
Hold vehicle attitude	14,540.153	703,503	-22.849	113.625	25,626.263	0.062	67.379	559.8	16,818	-101.3	39.6	-17.0
Set maximum deadband to 5 degrees	14,540.154	703,503	-22.849	113.625	25,626.263	0.062	67.379	559.8	16,818	-101.3	39.6	-17.0

Run 11 Phase Summary; DPS1 Burn

Phase	Unit	Value	GET (sec)
ATTITUDE MANEUVER SUMMARY			
RCS jet firings		38	
RCS jet firing on-times	sec	8.608	
RCS fuel consumption	lb	3.6943	
Maximum body rates	deg/sec	-0.0317, yaw -0.9410, pitch 5.0487, roll	14,142.547 14,142.547 14,142.547
Total time of maneuver	sec	13.744	
BURN SUMMARY			
Start of ullage maneuver			14,394.407
Time duration of ullage maneuver	sec	8.000	
Start of burn			14,401.907
Length of burn	sec	42.137	
Thrust maximum	lb	9,885.20	14,440.100
Thrust minimum	lb	1,283.00	14,404.056
Maximum acceleration	fps/sec	10.3465	14,440.096
Main engine fuel consumption	lb	495.28	
RCS fuel consumption	lb	17.1	
Time of engine off command			14,440.096
Time after engine off until DV monitor first detects zero thrust	sec	3.947	

Run 11 Phase Summary; DPS1 Burn (Continued)

Phase	Unit	Value	GET (sec)
Maximum body rates	deg/sec	-0.1076, yaw -0.8443, pitch 3.6586, roll	
Position vector at thrust termination (ECI)	ft	-19,157,114, yaw -4,039,266, pitch -9,165,610, roll	
Velocity vector at thrust termination (ECI)	fps	1,344.999, yaw -24,340.504, pitch 7,903.825, roll	
Maximum torque on vehicle	ft-lb	990.9507	14,429.866
Initial gimbal angles of main engine	deg	-0.3171, pitch 2.8151, roll	
Final gimbal angles of main engine	deg	-0.381, pitch 2.211, roll	

RUN 13 TEST RESULTS SUMMARY

Test Run Description

DPS1 targeted burn with a 10 percent moment of inertia discrepancy between the LGC and environment data.

Test Run Objectives

To investigate the sensitivity of the guidance dynamics to changes in the vehicle characteristics.

Summary of Test Results

The DPS1 burn and attitude control performance with 10 percent moment of inertia error was comparable to the nominal DPS1 burn (run 4). The main discrepancy between the perturbed and nominal was the 2-pound decrease in the RCS fuel used during the burn and the 0. 6-pound increase in RCS fuel required for the attitude maneuver.

Discussion of Test Results

The RCS ullage shutdown problem discussed under nominal run 4 was exhibited in this run. The attitude maneuver prior to thrusting was nominal in the time required to complete but used 0. 6 pound of RCS fuel more than the nominal. The RCS propellant used during the burn was 1. 62 pounds compared to the nominal of 3. 58 pounds but required 37 RCS firings for a total on-time of 3. 26 seconds compared to 32 firings and a total on-time of 8. 46 seconds for the nominal. The target apogee altitude evaluated at DPS1 cutoff was in error by 0. 83 nautical miles.

RUN 13 TRAJECTORY SUMMARY

The following are the trajectory deviations observed with respect to the nominal DPS1 (run 4) parameters evaluated at DPS1 guidance command engine off:

Altitude	19.0 ft
Latitude	0.0 deg
Longitude	0.0 deg
Inertial velocity	1.47 fps
Inertial flight-path angle	0.006 deg
Inertial azimuth	0.001 deg
Apogee	0.83 n mi
Perigee	0.001 n mi

The LGC state vector deviation from the environment in ECI at DPS1 guidance command engine off is as follows:

ΔX	20 ft
ΔY	40 ft
ΔZ	36 ft
$\Delta \dot{X}$	0.020 fps
$\Delta \dot{Y}$	0.056 fps
$\Delta \dot{Z}$	0.095 fps

Run 13 Event Summary; DPS1 Burn

Mission Event	GET (sec)	Altitude (ft)	Geodetic Latitude (deg)	Longitude (deg)	Inertial Velocity (fps)	Inertial Flight-path Angle (deg)	Inertial Azimuth Angle (deg)	RCS Fuel (lb)	DPS Fuel (lb)	OGA (deg)	IGA (deg)	MGA (deg)
Simulation initialized	14,100.000	726,525	-30.911	83.251	25,464.957	-0.074	82.245	585.0	17,314	-113.1	-25.9	-5.5
Hold vehicle attitude	14,100.032	726,523	-30.910	83.253	25,464.958	-0.075	82.244	585.0	17,314	-113.1	-25.9	-5.5
Start DAP	14,105.031	726,306	-30.864	83.621	25,465.183	-0.076	82.045	585.0	17,314	-113.1	-25.9	-5.5
Hold vehicle attitude	14,105.032	726,306	-30.864	83.621	25,465.183	-0.076	82.045	585.0	17,314	-113.1	-25.9	-5.5
Start MP9	14,126.043	725,351	-30.657	85.162	25,466.170	-0.081	81.214	585.0	17,314	-113.1	-25.9	-5.5
Enter program 31 pre-DPS1 burn	14,126.045	725,351	-30.657	85.162	25,466.171	-0.081	81.214	585.0	17,314	-113.1	-25.9	-5.5
Finish orbital integration	14,128.659	725,227	-30.630	85.353	25,466.298	-0.082	81.111	585.0	17,314	-113.1	-25.9	-5.5
Begin attitude maneuver	14,128.803	725,220	-30.628	85.364	25,466.305	-0.082	81.105	585.0	17,314	-113.1	-25.9	-5.5
Complete attitude maneuver	14,142.547	724,558	-30.480	86.368	25,466.888	-0.084	80.569	580.7	17,314	-102.3	36.8	-12.9
Enter program 41 DPS1 burn	14,335.908	712,185	-27.526	100.084	25,479.636	-0.131	73.512	576.4	17,314	-102.0	38.0	-12.7
Finish orbital integration	14,341.116	711,780	-27.426	100.442	25,480.051	-0.132	73.338	576.4	17,314	-102.1	37.9	-12.7
Start reading PIPA's	14,371.906	709,317	-26.809	102.542	25,482.576	-0.138	72.325	576.3	17,314	-101.8	37.7	-12.4
Command +X translation - RCS ullage	14,394.407	707,444	-26.337	104.061	25,484.497	-0.143	71.605	576.3	17,314	-101.6	37.5	-12.7
Command DPS engine on	14,401.907	706,809	-26.176	104.565	25,487.168	-0.143	71.369	566.7	17,314	-102.3	36.5	-13.1
Command +X translation off	14,402.407	706,767	-26.165	104.598	25,487.376	-0.143	71.353	565.9	17,314	-102.4	36.3	-13.1
Increase throttle to maximum	14,427.911	704,747	-25.600	106.301	25,518.267	-0.115	70.567	565.2	17,206	-104.2	35.8	-11.0
Disable DAP trim gimbal control	14,427.917	704,747	-25.600	106.301	25,518.275	-0.115	70.567	565.2	17,206	-104.2	35.8	-11.0
Enable DAP trim gimbal control	14,429.866	704,609	-25.556	106.431	25,530.632	-0.103	70.509	565.1	17,163	-104.4	35.3	-11.0
Command DPS engine off	14,440.096	704,148	-25.322	107.110	25,625.864	0.001	70.200	565.0	16,827	-104.8	36.0	-12.6
Hold vehicle attitude	14,440.100	704,148	-25.322	107.110	25,625.898	0.001	70.200	565.0	16,827	-104.8	36.0	-12.6
DV monitor detects engine shutdown	14,448.044	703,994	-25.137	107.637	25,628.281	0.008	69.962	565.0	16,818	-105.4	35.2	-11.9
Set maximum deadband to 5 degrees	14,478.047	703,543	-24.421	109.613	25,628.384	0.024	69.084	564.7	16,818	-105.1	36.4	-12.8
LGC idling	14,540.135	703,260	-22.849	113.624	25,627.825	0.057	67.376	564.7	16,818	-101.9	38.9	-16.8
Hold vehicle attitude	14,540.139	703,260	-22.849	113.624	25,627.825	0.057	67.376	564.7	16,818	-101.9	38.9	-16.8
Set maximum deadband to 5 degrees	14,540.140	703,260	-22.849	113.624	25,627.825	0.057	67.376	564.7	16,818	-101.9	38.9	-16.8

Run 13 Phase Summary; DPS1 Burn

Phase	Unit	Value	GET (sec)
ATTITUDE MANEUVER SUMMARY			
RCS jet firings		58	
RCS jet firing on-times	sec	9.766	
RCS fuel consumption	lb	4.3398	
Maximum body rates	deg/sec	-0.0589, yaw	14, 142.547
		-1.0292, pitch	14, 142.547
		4.7356, roll	14, 142.547
Total time of maneuver	sec	13.744	
BURN SUMMARY			
Start of ullage maneuver			14, 394.407
Time duration of ullage maneuver	sec	8.000	
Start of burn			14, 401.907
Length of burn	sec	42.137	
Thrust maximum	lb	9, 885.20	14, 440.100
Thrust minimum	lb	1, 283.00	14, 404.054
Maximum acceleration	fps/sec	10.3435	14, 440.100
Main engine fuel consumption	lb	495.16	
RCS fuel consumption	lb	11.30	
Time of engine off command			14, 440.096
Time after engine off to DV monitor detects zero thrust	sec	3.947	

Run 13 Phase Summary; DPS1 Burn (Continued)

Phase	Unit	Value	GET (sec)
Maximum body rates	deg/sec	-0.0798, yaw 0.2853, pitch -0.2626, roll	
Position vector at thrust termination (ECI)	ft	-19,157,088, yaw -4,039,272, pitch -9,165,587, roll	
Velocity vector at thrust termination (ECI)	fps	1,346.627, yaw -24,341.024, pitch 7,906.215, roll	
Velocity as a result of tailoff	fps	45.95	
Maximum torque on vehicle	ft-lb	647.1384	14,401.907
Initial gimbal angles of main engine	deg	-0.3171, pitch 2.3151, roll	
Final gimbal angles of main engine	deg	-0.467, pitch 2.216, roll	

RUN 14 TEST RESULTS SUMMARY

Test Run Description

DPS1 (Hohmann DOI) burn with a 20 percent discrepancy between the LGC and environment gimbal drive rate data.

Test Run Objectives

To investigate the effect of discrepancies between actual (environment) and LGC predictions of DPS gimbal rates and to test DPS1 targeting and attitude control stability in the presence of these discrepancies.

Summary of Test Results

The DPS1 burn and associated attitude control were performed successfully in the presence of gimbal rate discrepancies.

Discussion of Test Results

The RCS ullage shutdown problem discussed under nominal run 4 was exhibited in this run. The attitude maneuver prior to thrusting was nominal. The RCS fuel used during the DPS1 burn was 2.57 pounds for a total of 40 firings with an on-time of 5.63 seconds. This compares to the nominal (run 4) values of 3.58 pounds for a total of 32 firings with 8.46 seconds of on-time. The CDU angle excursions compared to the nominal values to better than 1 degrees. The target apogee altitude evaluated at DPS1 cutoff was in error by 0.69 nautical miles.

RUN 14 TRAJECTORY SUMMARY

The following are the trajectory deviations observed with respect to the nominal DPS1 (run 4) parameters evaluated at DPS1 guidance command engine off:

Altitude	10. ft
Latitude	0. 0 deg
Longitude	0. 0 deg
Inertial velocity	1. 22 fps
Inertial flight-path angle	0. 005 deg
Inertial azimuth	0. 003 deg
Apogee	0. 69 n mi
Perigee	0. 001 n mi

The LGC state vector deviation from the environment in ECI at DPS1 guidance command engine off is as follows:

ΔX	19 ft
ΔY	40 ft
ΔZ	33 ft
$\Delta \dot{X}$	0. 046 fps
$\Delta \dot{Y}$	0. 053 fps
$\Delta \dot{Z}$	0. 087 fps

Run 14 Event Summary; DPS1 Burn

Mission Event	GET (sec)	Altitude (ft)	Geodetic Latitude (deg)	Longitude (deg)	Inertial Velocity (fps)	Inertial Flight-path Angle (deg)	Inertial Azimuth Angle (deg)	RCS Fuel (lb)	DPS Fuel (lb)	OGA (deg)	IGA (deg)	MGA (deg)
Simulation initialized	14, 100. 000	726, 525	-30. 911	83. 251	25, 464. 957	-0. 074	82. 245	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Hold vehicle attitude	14, 100. 032	726, 523	-30. 910	83. 253	25, 464. 958	-0. 075	82. 244	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Start DAP	14, 105. 031	726, 306	-30. 864	83. 621	25, 465. 183	-0. 076	82. 045	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Hold vehicle attitude	14, 105. 032	726, 306	-30. 864	83. 621	25, 465. 183	-0. 076	82. 045	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Start MP9	14, 126. 043	725, 351	-30. 657	85. 162	25, 466. 170	-0. 081	81. 214	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Enter program 31 pre-DPS1 burn	14, 126. 045	725, 351	-30. 657	85. 162	25, 466. 171	-0. 081	81. 214	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Finish orbital integration	14, 128. 659	725, 227	-30. 630	85. 353	25, 466. 298	-0. 082	81. 111	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Begin attitude maneuver	14, 128. 803	725, 220	-30. 628	85. 364	25, 466. 305	-0. 082	81. 105	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Complete attitude maneuver	14, 142. 547	724, 558	-30. 480	86. 368	25, 466. 887	-0. 084	80. 569	581. 3	17, 314	-102. 2	36. 9	-12. 7
Enter program 41 DPS1 burn	14, 335. 908	712, 184	-27. 526	100. 084	25, 479. 640	-0. 131	73. 512	577. 6	17, 314	-102. 0	37. 8	-12. 6
Finish orbital integration	14, 341. 116	711, 780	-27. 426	100. 442	25, 480. 054	-0. 132	73. 338	577. 6	17, 314	-102. 1	37. 7	-12. 6
Start reading PIPA's	14, 371. 906	709, 316	-26. 809	102. 542	25, 482. 578	-0. 138	72. 325	577. 5	17, 314	-101. 9	37. 4	-12. 5
Command +X translation -RCS ullage	14, 394. 407	707, 443	-26. 337	104. 061	25, 484. 499	-0. 143	71. 605	577. 5	17, 314	-101. 6	37. 5	-12. 5
Command DPS engine on	14, 401. 907	706, 809	-26. 176	104. 565	25, 487. 166	-0. 143	71. 369	568. 0	17, 314	-102. 1	36. 8	-13. 5
Command +X translation off	14, 402. 407	706, 767	-26. 165	104. 598	25, 487. 379	-0. 143	71. 353	567. 2	17, 314	-102. 1	36. 8	-13. 6
Increase throttle to maximum	14, 427. 911	704, 744	-25. 600	106. 301	25, 518. 246	-0. 115	70. 567	566. 1	17, 206	-103. 3	36. 8	-15. 0
Disable DAP trim gimbal control	14, 427. 918	704, 743	-25. 600	106. 301	25, 518. 254	-0. 115	70. 566	566. 1	17, 206	-103. 3	36. 8	-15. 0
Enable DAP trim gimbal control	14, 429. 866	704, 606	-25. 556	106. 431	25, 530. 256	-0. 101	70. 507	565. 7	17, 163	-103. 4	36. 9	-13. 7
Command DPS engine off	14, 440. 096	704, 157	-25. 322	107. 110	25, 625. 611	0. 002	70. 202	565. 4	16, 827	-104. 2	35. 1	-11. 6
Hold vehicle attitude	14, 440. 100	704, 157	-25. 322	107. 110	25, 625. 645	0. 002	70. 202	565. 4	16, 827	-104. 2	35. 1	-11. 6
DV monitor detects engine shutdown	14, 448. 044	704, 007	-25. 137	107. 637	25, 628. 037	0. 009	69. 964	565. 2	16, 818	-104. 8	34. 6	-12. 4
Set maximum deadband to 5 degrees	14, 478. 047	703, 568	-24. 421	109. 612	25, 628. 135	0. 025	69. 086	565. 2	16, 818	-105. 2	34. 3	-11. 3
LGC idling	14, 540. 130	703, 306	-22. 850	113. 623	25, 627. 551	0. 058	67. 378	565. 2	16, 818	-104. 8	33. 7	-9. 0
Hold vehicle attitude	14, 540. 139	703, 306	-22. 849	113. 624	25, 627. 551	0. 058	67. 378	565. 2	16, 818	-104. 8	33. 7	-9. 0
Set maximum deadband to 5 degrees	14, 540. 140	703, 306	-22. 849	113. 624	25, 627. 551	0. 058	67. 378	565. 2	16, 818	-104. 8	33. 7	-9. 0

Run 14 Phase Summary; DPS1 Burn

Phase	Unit	Value	GET (sec)
ATTITUDE MANEUVER SUMMARY			
RCS jet firings		38	
RCS jet firing on-times	sec	8.608	
RCS fuel consumption	lb	3.6943	
Maximum body rates	deg/sec	-0.0317, yaw	14,142.547
		-0.9410, pitch	14,142.547
		5.0487, roll	14,142.547
Total time of maneuver	sec	13.744	
BURN SUMMARY			
Start of ullage maneuver			14,394.407
Time duration of ullage maneuver	sec	8.000	
Start of burn			14,401.907
Length of burn	sec	42.137	
Thrust maximum	lb	9,885.20	14,440.100
Thrust minimum	lb	1,283.00	14,404.046
Maximum acceleration	fps/sec	10.3267	14,440.096
Main engine fuel consumption	lb	495.06	
RCS fuel consumption	lb	12.1	
Time of engine off command			14,440.096
Time after engine off to DV monitor detects zero thrust	sec	3.947	

Run 14 Phase Summary; DPS1 Burn (Continued)

Phase	Unit	Value	GET (sec)
Maximum body rates	deg/sec	-0.0613, yaw -0.9387, pitch -0.3028, roll	14,440.096 14,429.866 14,429.866
Position vector at thrust termination (ECI)	ft	-19,157,100, yaw -4,039,272, pitch -9,165,590, roll	
Velocity vector at thrust termination (ECI)	fps	1,346.467, yaw -24,341.022, pitch 7,905.490, roll	
Nominal Euler angles from REFSMAT	deg	1.7918 1.5722 -0.8702	
Initial Euler angles from TSI	deg	1.7918 1.5722 -0.8702	
Final Euler angles from TSI	deg	1.7918 1.5722 -0.8702	
Maximum torque on vehicle	ft-lb	403.1042	14,402.055
Initial gimbal angles of main engine	deg	-0.3171, pitch 2.3151, roll	
Final gimbal angles of main engine	deg	-0.331, pitch 2.278, roll	

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RUN 15 TEST RESULTS SUMMARY

Test Run Description

DPS1 thrust perturbation of nominal run 4; off-nominal LM thrust characteristics.

Test Run Objectives

To determine the effect of a $+3\sigma$ engine thrust perturbation on the guidance system performance.

Summary of Test Results

A comparative analysis between the perturbed run and nominal run 4 (DPS1 burn) revealed no significant problem areas resulting from the imposed perturbation.

Discussion of Test Results

The higher DPS thrust levels of the perturbed run resulted in an earlier thrust termination. This, of course, affected the ground elapsed time of a subsequent series of mission events keyed to the DPS thrust termination. At any common time dump, however, the discrepancy in the trajectory parameters was observed to be negligible. Attention is directed toward the LM-1 targeting parameter, apogee altitude, since the quantity represents a measure of the performance of the guidance program in light of the imposed perturbation. Upon completion of the DPS1 burn, the maximum deviation in the targeting parameter was observed never to have exceeded 0.115 nautical mile.

Similarly, the thrust perturbation resulted in a negligible change, approximately a 0.10 percent increase, in the total amount of propellant used during the run. The following tabulation shows the propellant used for comparison.

Propellant Used	Run 15 (lb)	Run 4 (lb)	Deviation (lb)
Total RCS	19.66	20.96	1.30
Total DPS	496.57	494.74	1.83
Total (RCS + DPS)	516.23	515.70	0.53

No attitude instabilities were observed to result from the thrust perturbation. The analysis did reveal, however, a minor perturbing effect upon the spacecraft attitude during the DPS1 burn. As a consequence, the desired (or commanded) CDU values following the burn phase differ somewhat from the respective nominal values. The initialization of the desired CDU values during post-DPS burn hold-vehicle-attitude maneuvers are listed below for comparison:

Hold-vehicle-attitude following command DPS engine off

Quantity	Run 15 (deg)	Run 4 (deg)	Deviation (deg)
XCDUD	-104.1830	-104.1060	0.0770
YCDUD	35.0903	34.7278	0.3625
ZCDUD	-11.6345	-11.8982	0.2637

Hold-vehicle-attitude following LGC idling

Quantity	Run 15 (deg)	Run 4 (deg)	Deviation (deg)
XCDUD	-104.3920	-106.3920	+2.0000
YCDUD	33.1018	36.2549	-3.1531
ZCDUD	-8.1848	-12.6563	+4.4715

RUN 15 TRAJECTORY SUMMARY

The parameters listed represent the trajectory deviations from the nominal at DPS1 guidance command engine off.

Parameter	DPS1 Engine Off
Time	0.750 sec (early)
Altitude	19 ft (high)
Geodetic latitude	0.0172 deg (south)
Geodetic longitude	0.0497 deg (west)
Inertial velocity	0.04 fps (high)
Inertial flight-path angle	0.0075 deg (low)
Inertial azimuth	0.0239 deg (north)
Inertial longitude	0.0528 deg (west)
Declination	0.0172 deg (high)
Radius vector magnitude	2 ft (high)
Apogee altitude (targeting parameter)	98 ft (high)
Perigee altitude	22 ft (high)

The following parameters represent the deviation in ECI coordinates between the LGC state vector estimates and the environment (for the perturbed run only) at DPS1 guidance command engine off:

ΔX	16 ft (high)
ΔY	95 ft (high)
ΔZ	52 ft (low)
$\Delta \dot{X}$	0.088 fps (high)
$\Delta \dot{Y}$	0.005 fps (high)
$\Delta \dot{Z}$	0.133 fps (high)

Run 15 Event Summary; DPS1 Burn

Mission Event	GET (sec)	Altitude (ft)	Geodetic Latitude (deg)	Longitude (deg)	Inertial Velocity (fps)	Inertial Flight-path Angle (deg)	Inertial Azimuth Angle (deg)	RCS Fuel (lb)	DPS Fuel (lb)	OGA (deg)	IGA (deg)	MGA (deg)
Simulation initialized	14, 100. 000	726, 525	-30. 911	883. 251	25, 464. 957	-0. 074	82. 245	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Hold vehicle attitude	14, 100. 032	726, 523	-30. 910	83. 253	25, 464. 958	-0. 075	82. 244	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Start DAP	14, 105. 031	726, 306	-30. 864	83. 621	25, 465. 183	-0. 076	82. 045	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Hold vehicle attitude	14, 105. 032	726, 306	-30. 864	83. 621	25, 465. 183	-0. 076	82. 045	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Start MP9	14, 126. 043	725, 351	-30. 657	85. 162	25, 466. 170	-0. 081	81. 214	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Enter program 31 pre-DPS1 burn	14, 126. 045	725, 351	-30. 657	85. 162	25, 466. 171	-0. 081	81. 214	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Finish orbital integration	14, 128. 659	725, 227	-30. 630	85. 353	25, 466. 298	-0. 082	81. 111	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Begin attitude maneuver	14, 128. 803	725, 220	-30. 628	85. 364	25, 466. 305	-0. 082	81. 105	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Complete attitude maneuver	14, 142. 547	724, 558	-30. 480	86. 368	25, 466. 887	-0. 084	80. 569	581. 3	17, 314	-102. 2	36. 9	-12. 7
Enter program 41 DPS1 burn	14, 335. 908	712, 184	-27. 526	100. 084	25, 479. 640	-0. 131	73. 512	577. 6	17, 314	-102. 0	37. 8	-12. 6
Finish orbital integration	14, 341. 116	711, 780	-27. 426	100. 442	25, 480. 054	-0. 132	73. 338	577. 6	17, 314	-102. 1	37. 7	-12. 6
Start reading PIPA's	14, 371. 906	709, 316	-26. 809	102. 542	25, 482. 578	-0. 138	72. 325	577. 5	17, 314	-101. 9	37. 4	-12. 5
Command +X translation -RCS ullage	14, 394. 407	707, 443	-26. 337	104. 061	25, 484. 499	-0. 143	71. 605	577. 5	17, 314	-101. 6	37. 5	-12. 5
Command DPS engine on	14, 401. 907	706, 809	-26. 176	104. 565	25, 487. 166	-0. 143	71. 369	568. 0	17, 314	-102. 1	36. 8	-13. 5
Command +X translation off	14, 402. 407	706, 767	-26. 165	104. 598	25, 487. 379	-0. 143	71. 353	567. 2	17, 314	-102. 1	36. 8	-13. 6
Increase throttle to maximum	14, 427. 911	704, 744	-25. 600	106. 301	25, 518. 258	-0. 115	70. 567	566. 1	17, 206	-103. 3	36. 8	-14. 6
Disable DAP trim gimbal control	14, 427. 918	704, 743	-25. 600	106. 301	25, 518. 267	-0. 115	70. 566	566. 1	17, 206	-103. 3	36. 8	-14. 6
Enable DAP trim gimbal control	14, 429. 866	704, 605	-25. 556	106. 431	25, 530. 463	-0. 101	70. 507	565. 8	17, 162	-103. 4	36. 6	-13. 8
Command DPS engine off	14, 439. 336	704, 186	-25. 339	107. 060	25, 624. 417	-0. 000	70. 223	565. 7	16, 826	-104. 2	35. 1	-11. 7
Hold vehicle attitude	14, 439. 340	704, 186	-25. 339	107. 060	25, 624. 454	-0. 000	70. 223	565. 7	16, 826	-104. 2	35. 1	-11. 7
DV monitor detects engine shutdown	14, 446. 044	704, 050	-25. 184	107. 505	25, 627. 008	0. 006	70. 022	565. 6	16, 817	-104. 3	36. 1	-12. 1
Set maximum deadband to 5 degrees	14, 476. 047	703, 567	-24. 470	109. 482	25, 627. 158	0. 022	69. 141	565. 3	16, 817	-105. 0	34. 7	-11. 8
LGC idling	14, 538. 127	703, 206	-22. 902	113. 495	25, 626. 691	0. 054	67. 429	565. 3	16, 817	-104. 4	33. 1	-8. 2
Hold vehicle attitude	14, 538. 132	703. 206	-22. 902	113. 496	25, 626. 691	0. 054	67. 429	565. 3	16, 817	-104. 4	33. 1	-8. 2
Set maximum deadband to 5 degrees	14, 538. 133	703, 206	-22. 902	113. 496	25, 626. 691	0. 054	67. 429	565. 3	16, 817	-104. 4	33. 1	-8. 2

Run 15 Phase Summary; DPS1 Burn

Phase	Unit	Value	GET (sec)
ATTITUDE MANEUVER SUMMARY			
RCS jet firings		38	
RCS jet firing on-times	sec	8.608	
RCS fuel consumption	lb	3.6943	
Maximum body rates	deg/sec	0.0436, yaw -1.9074, pitch 6.5537, roll	
Total time of maneuver	sec	13.744	
BURN SUMMARY			
Start of ullage maneuver			14, 394.407
Time duration of ullage maneuver	sec	8.000	
Start of burn			14, 401.907
Length of burn	sec	40.138	
Thrust maximum at 92.5 percent throttle setting	lb	10, 500.00	14, 439.336
Thrust minimum at 10 percent throttle setting	lb	1, 283.00	14, 404.046
Maximum acceleration	fps/sec	10.9675	14, 439.340
Main engine fuel consumption	lb	496.57	
RCS fuel consumption	lb	11.835	
Time of engine off command			14, 439.336

Run 15 Phase Summary; DPS1 Burn (Continued)

Phase	Unit	Value	GET (sec)
Time after engine off until DV monitor first detects shutdown	sec	2.708	
Maximum body rates	deg/sec	-0.0629, yaw 0.6183, pitch -0.4019, roll	
Position vector at thrust termination (ECI)	ft	-19,159,748, yaw -3,990,636, pitch -9,181,356, roll	
Velocity vector at thrust termination (ECI)	fps	1,293.616, yaw -24,350.857, pitch 7,880.575, roll	
Maximum torque on vehicle	ft-lb	950.4045	14,403.906
Initial gimbal angles of main engine	deg	-0.3171, pitch 2.3151, roll	
Final gimbal angles of main engine	deg	-0.473, pitch 2.246, roll	

RUN 16 TEST RESULTS SUMMARY

Test Run Description

DPS1 specific impulse perturbation of nominal run 4; off-nominal LM ISP engine characteristics.

Test Run Objectives

To determine the effect of a $+3\sigma$ ISP perturbation on the guidance system performance.

Summary of Test Results

A comparative analysis between the perturbed run and nominal run 4 (DPS1 burn) revealed no significant problem areas resulting from the imposed perturbation.

Discussion of Test Results

The imposed ISP perturbation resulted in a small saving, approximately a 1.24 percent decrease, in the total propellant required during the run. The propellant used is tabulated below for comparison:

Propellant Used	Run 16 (lb)	Run 4 (lb)	Deviation (lb)
Total RCS	19.59	20.96	1.37
Total DPS	489.69	494.74	5.05
Total (RCS + DPS)	509.28	515.70	6.42

The variation in the total mass of the LM caused by the ISP perturbation was less than 0.02 percent. Spacecraft acceleration levels experienced during the perturbed run were virtually identical to the nominal values. As a result, the trajectory conditions are virtually identical to the respective nominal values. Upon completion of the DPS1 burn, the maximum observed deviation in the LM-1 targeting parameter, apogee altitude, was 0.684 nautical mile (high). This corresponds to a 0.38 percent deviation with respect to the nominal value.

No attitude instabilities were observed to result from the ISP perturbation. Minor spacecraft attitude variations with respect to the nominal were observed. The variations resulted in the following deviations in the desired (or commanded) CDU values during post-DPS burn hold-vehicle-attitude maneuvers:

Hold-vehicle-attitude following command DPS engine off

Quantity	Run 16 (deg)	Run 4 (deg)	Deviation (deg)
XCDUD	-104.1830	-104.1060	-0.0770
YCDUD	35.3430	34.7278	0.6152
ZCDUD	-11.7114	-11.8982	0.1868

Hold-vehicle-attitude following LGC idling

Quantity	Run 16 (deg)	Run 4 (deg)	Deviation (deg)
XCDUD	-104.2820	-106.3920	2.1100
YCDUD	35.6067	36.2549	-0.6482
ZCDUD	-11.9971	-12.6563	0.6592

RUN 16 TRAJECTORY SUMMARY

The parameters listed below represent the trajectory deviations from the nominal at DPS1 guidance command engine off.

Parameter	DPS1 Engine Off
Time	0.005 sec (early)
Altitude	11 ft (low)
Geodetic latitude	0.0001 deg (south)
Geodetic longitude	0.0003 deg (west)
Inertial velocity	1.21 fps (high)
Inertial flight-path angle	0.0055 deg (low)
Inertial azimuth	0.0020 deg (north)
Inertial longitude	0.0003 deg (west)
Declination	0.0001 deg (high)
Radius vector magnitude	12 ft (low)
Apogee altitude (targeting parameter)	0.675 n mi (high)
Perigee altitude	7 ft (high)

The following parameters represent the deviation in ECI coordinates between the LGC state vector estimates and the environment (for the perturbed run only) at DPS1 guidance command engine off.

ΔX	19 ft (high)
ΔY	39 ft (high)
ΔZ	33 ft (low)
$\Delta \dot{X}$	0.022 fps (high)
$\Delta \dot{Y}$	0.037 fps (high)
$\Delta \dot{Z}$	0.107 fps (high)

Run 16 Event Summary; DPS1 Burn

Mission Event	GET (sec)	Altitude (ft)	Geodetic Latitude (deg)	Longitude (deg)	Inertial Velocity (fps)	Inertial Flight-path Angle (deg)	Inertial Azimuth Angle (deg)	RCS Fuel (lb)	DPS Fuel (lb)	OGA (deg)	IGA (deg)	MGA (deg)
Simulation initialized	14, 100. 000	726, 525	-30. 911	83. 251	25, 464. 957	-0. 074	82. 245	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Hold vehicle attitude	14, 100. 032	726, 523	-30. 910	83. 253	25, 464. 958	-0. 075	82. 244	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Start DAP	14, 105. 031	726, 306	-30. 864	83. 621	25, 465. 183	-0. 076	82. 045	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Hold vehicle attitude	14, 105. 032	726, 306	-30. 864	83. 621	25, 465. 183	-0. 076	82. 045	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Start MP9	14, 126. 043	725, 351	-30. 657	85. 162	25, 466. 170	-0. 081	81. 214	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Enter program 31 pre-DPS1 burn	14, 126. 045	725, 351	-30. 657	85. 162	25, 466. 171	-0. 081	81. 214	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Finish orbital integration	14, 128. 659	725, 227	-30. 630	85. 353	25, 466. 298	-0. 082	81. 111	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Begin attitude maneuver	14, 128. 803	725, 220	-30. 628	85. 364	25, 466. 305	-0. 082	81. 105	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Complete attitude maneuver	14, 142. 547	724, 558	-30. 480	86. 368	25, 466. 887	-0. 084	80. 569	581. 3	17, 314	-102. 2	36. 9	-12. 7
Enter program 41 DPS1 burn	14, 335. 908	712, 184	-27. 526	100. 084	25, 479. 640	-0. 131	73. 512	577. 6	17, 314	-102. 0	37. 8	-12. 6
Finish orbital integration	14, 341. 116	711, 780	-27. 426	100. 442	25, 480. 054	-0. 132	73. 338	577. 6	17, 314	-102. 1	37. 7	-12. 6
Start reading PIPA's	14, 371. 906	709, 316	-26. 809	102. 542	25, 482. 578	-0. 138	72. 325	577. 5	17, 314	-101. 9	37. 4	-12. 5
Command +X translation - RCS ullage	14, 394. 407	707, 443	-26. 337	104. 061	25, 484. 499	-0. 143	71. 605	577. 5	17, 314	-101. 6	37. 5	-12. 5
Command DPS engine on	14, 401. 907	706, 809	-26. 176	104. 565	25, 487. 166	-0. 143	71. 369	568. 0	17, 314	-102. 1	36. 8	-13. 5
Command +X translation off	14, 402. 407	706, 767	-26. 165	104. 598	25, 487. 379	-0. 143	71. 353	567. 2	17, 314	-102. 1	36. 8	-13. 6
Increase throttle to maximum	14, 427. 911	704, 744	-25. 600	106. 301	25, 518. 258	-0. 115	70. 567	566. 1	17, 207	-103. 3	36. 8	-14. 6
Disable DAP trim gimbal control	14, 427. 918	704, 743	-25. 600	106. 301	25, 518. 266	-0. 115	70. 566	566. 1	17, 207	-103. 3	36. 8	-14. 6
Enable DAP trim gimbal control	14, 429. 866	704, 605	-25. 556	106. 431	25, 530. 303	-0. 101	70. 507	565. 8	17, 164	-103. 4	36. 6	-13. 8
Command DPS engine off	14, 440. 081	704, 156	-25. 322	107. 109	25, 625. 585	0. 002	70. 201	565. 7	16, 832	-104. 2	35. 3	-11. 7
Hold vehicle attitude	14, 440. 084	704, 156	-25. 322	107. 109	25, 625. 620	0. 002	70. 201	565. 7	16, 832	-104. 2	35. 3	-11. 7
DV monitor detects engine shutdown	14, 448. 044	704, 003	-25. 137	107. 637	25, 628. 019	0. 008	69. 962	565. 7	16, 824	-104. 6	35. 7	-12. 8
Set maximum deadband to 5 degrees	14, 478. 047	703, 553	-24. 421	109. 612	25, 628. 141	0. 024	69. 084	565. 4	16, 824	-104. 9	36. 0	-12. 7
LGC idling	14, 540. 135	703, 270	-22. 849	113. 624	25, 627. 583	0. 057	67. 377	565. 4	16, 824	-104. 3	35. 6	-12. 0
Hold vehicle attitude	14, 540. 139	703, 270	-22. 849	113. 624	25, 627. 583	0. 057	67. 376	565. 4	16, 824	-104. 3	35. 6	-12. 0
Set maximum deadband to 5 degrees	14, 540. 140	703, 270	-22. 849	113. 624	25, 627. 583	0. 057	67. 376	565. 4	16, 824	-104. 3	35. 6	-12. 0

Run 16 Phase Summary; DPS1 Burn

Phase	Unit	Value	GET (sec)
ATTITUDE MANEUVER SUMMARY			
RCS jet firings		38	
RCS jet firing on-times	sec	8.608	
RCS fuel consumption	lb	3.6943	
Maximum body rates	deg/sec	0.0436, yaw	14, 132.000
		-1.2449, pitch	14, 132.000
		6.5537, roll	14, 132.000
Total time of maneuver	sec	13.744	
BURN SUMMARY			
Start of ullage maneuver			14, 394.407
Time duration of ullage maneuver	sec	8.000	
Start of burn			14, 401.907
Length of burn	sec	42.136	
Thrust maximum at 92.5 percent throttle setting	lb	9, 885.20	14, 440.084
Thrust minimum at 10.0 percent throttle setting	lb	1, 283.00	14, 404.046
Maximum acceleration	fps/sec	10.3309	14, 440.084
Main engine fuel consumption	lb	489.69	
RCS fuel consumption	lb	11.8264	
Time of engine off command			14, 440.081

Run 16 Phase Summary; DPS1 Burn (Continued)

Phase	Unit	Value	GET (sec)
Time after engine off until DV monitor first detects shutdown	sec	3.962	
Maximum body rates	deg/sec	-0.0633, yaw 0.6212, pitch -0.3737, roll	14,437.909 14,395.906 14,429.866
Position vector at thrust termination (ECI)	ft	-19,157,100, yaw -4,039,270, pitch -9,165,583, roll	
Velocity vector at thrust termination (ECI)	fps	1,346.537, yaw -24,340.812, pitch 7,906.035, roll	
Maximum torque on vehicle	ft-lb	988.7878	14,428.001
Initial gimbal angles of main engine	deg	-0.3171, pitch 2.3151, roll	
Final gimbal angles of main engine	deg	-0.4301, pitch 2.2046, roll	

RUN 17 TEST RESULTS SUMMARY

Test Run Description

Three-sigma IMU errors (three times the one-sigma uncertainties given in Table 7. 12 of Reference 9.) were modeled during the program P31 (pre-DPS1) and the program P41 (DPS1 burn), assuming a perfect state vector update prior to mission phase 9, and followed by an uplink state vector update after the DPS1 burn.

Test Run Objectives

To determine the effect of three-sigma IMU errors during mission phase 9 and to validate the uplink state vector update capability.

Summary of Test Results

The flight software for programs P31 and P41 has been validated for three-sigma IMU errors, with a perfect state vector update assumed prior to mission phase 9. The three-sigma IMU errors propagated from a perfect state vector update prior the start of mission phase 9 through the DPS1 burn does not significantly affect the final orbital trajectory after mission phase 9. The apogee was 0. 258 nautical miles higher than the nominal. The uplink state vector update capability following DPS1 has been verified.

Discussion of Test Results

The short duration of the DPS1 burn does not provide sufficient time for the three-sigma IMU errors to measurably affect the final orbital trajectory at the end of DPS1.

The orbital parameter deviations recorded at DPS1 engine off command are presented in the trajectory summary.

The guidance coordinates and the environment were initialized to be equal. At the end of the DPS1 burn, the deviations of the largest components were less than 90 feet in position and less than 1. 8 feet per second in velocity.

The Phase Summary contains detailed information regarding the attitude maneuver and the burn.

A state vector update of the LGC was achieved for 15,600.0 seconds GET when the following state vector was successfully uplinked within the resolution of the flight computer word length.

X = -2,834,403 ft

Y = -21,056,240 ft

Z = 4,689,081 ft

VX = 22,340.1 fps

VY = -489.3 fps

VZ = 12,226.7 fps

RUN 17 TRAJECTORY SUMMARY

The following are trajectory deviations with respect to the nominal test run number 4 at DPS1 guidance command engine-off:

Altitude	7 feet (high)
Latitude	0.00001 deg (north)
Longitude	0.00001 deg (west)
Inertial velocity	0.61 fps (high)
Inertial flight-path angle	0.0032 deg (high)
Inertial azimuth	0.0070 deg (north)
Apogee	0.258 n mi (high)
Perigee	0.003 n mi (high)
Declination	0.006 deg (low)
Longitude of ascending node	0.0095 deg (west)
Inclination	0.0035 deg (high)
Eccentricity	0.000035 (high)
True anomaly	0.3654 deg (west)
Semi-major axis	794 ft (high)

The following LGC state vector dispersions at the end of the DPS1 burn were observed with respect to the nominal test run (in ECI):

ΔX	177 ft
ΔY	-5 ft
ΔZ	402 ft
$\Delta \dot{X}$	3.0 fps
$\Delta \dot{Y}$	-0.2 fps
$\Delta \dot{Z}$	6.5 fps

The following environment dispersions resulting from erroneous guidance commands generated by the IMU errors were observed with respect to the nominal test case (in ECI):

ΔX	-14 ft
ΔY	35 ft
ΔZ	201 ft
$\Delta \dot{X}$	-0.059 fps
$\Delta \dot{Y}$	0.479 fps
$\Delta \dot{Z}$	3.378 fps

The following are LGC state vector deviations from the environment, due primarily to three-sigma IMU errors propagated through the DPS1 burn.

$\Delta X = 33.0$ ft
$\Delta Y = 50.0$ ft
$\Delta Z = 89.0$ ft
$\Delta \dot{X} = 1.638$ fps
$\Delta \dot{Y} = 0.340$ fps
$\Delta \dot{Z} = 1.776$ fps

Run 17 Event Summary; DPS1 Burn

Mission Event	GET (sec)	Altitude (ft)	Geodetic Latitude (deg)	Longitude (deg)	Inertial Velocity (ft/sec)	Inertial Flight-path Angle (deg)	Inertial Azimuth Angle (deg)	RCS Fuel (lb)	DPS Fuel (lb)	OGA (deg)	IGA (deg)	MGA (deg)
Simulation initialized	14, 100. 000	726, 525	-30. 911	83. 251	25, 464. 957	-0. 074	82. 245	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Hold vehicle attitude	14, 100. 032	726, 523	-30. 910	83. 253	25, 464. 958	-0. 075	82. 244	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Start DAP	14, 105. 031	726, 306	-30. 864	83. 621	25, 465. 183	-0. 076	82. 045	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Hold vehicle attitude	14, 105. 032	726, 306	-30. 864	83. 621	25, 465. 183	-0. 076	82. 045	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Start MP9	14, 126. 043	725, 351	-30. 657	85. 162	25, 466. 170	-0. 081	81. 214	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Enter program 31 pre-DPS1 burn	14, 126. 045	725, 351	-30. 657	85. 162	25, 466. 171	-0. 081	81. 214	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Finish orbital integration	14, 128. 659	725, 227	-30. 630	85. 353	25, 566. 298	-0. 082	81. 111	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Begin attitude maneuver	14, 128. 803	725, 220	-30. 628	85. 364	25, 466. 305	-0. 082	81. 105	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Complete attitude maneuver	14, 142. 547	724, 558	-30. 480	86. 368	25, 466. 877	-0. 084	80. 569	581. 2	17, 314	-102. 0	37. 0	-12. 7
Enter program 41 DPS1 burn	14, 335. 908	712, 184	-27. 526	100. 084	25, 479. 633	-0. 131	73. 512	576. 8	17, 314	-102. 0	37. 8	-12. 5
Finish orbital integration	14, 341. 149	711, 777	-27. 425	100. 444	25, 480. 058	-0. 132	73. 337	576. 5	17, 314	-102. 0	38. 0	-12. 6
Start reading PIPA's	14, 371. 906	709, 316	-26. 809	102. 542	25, 482. 574	-0. 138	72. 325	575. 9	17, 314	-101. 8	37. 8	-12. 9
Command +X translation - RCS ullage	14, 394. 407	707, 443	-26. 337	104. 061	25, 484. 495	-0. 143	71. 605	575. 7	17, 314	-101. 8	37. 3	-12. 9
Command DPS engine on	14, 401. 907	706, 809	-26. 176	104. 565	25, 487. 229	-0. 143	71. 369	565. 8	17, 314	-102. 4	36. 8	-13. 7
Command +X translation off	14, 402. 407	706, 766	-26. 165	104. 598	25, 487. 427	-0. 143	71. 353	565. 1	17, 314	-102. 5	36. 5	-13. 8
Increase throttle to maximum	14, 427. 911	704, 752	-25. 600	106. 301	25, 518. 029	-0. 113	70. 567	560. 2	17, 206	-100. 4	44. 5	-9. 8
Disable DAP trim gimbal control	14, 427. 918	704, 751	-25. 600	106. 301	25, 518. 037	-0. 113	70. 567	560. 2	17, 206	-100. 4	44. 5	-9. 9
Enable DAP trim gimbal control	14, 429. 866	704, 615	-25. 556	106. 431	25, 529. 829	-0. 099	70. 510	559. 8	17, 163	-101. 8	38. 3	-13. 9
Command DPS engine off	14, 440. 109	704, 175	-25. 322	107. 111	25, 624. 833	0. 004	70. 192	557. 6	16, 826	-102. 0	38. 2	-11. 5
Hold vehicle attitude	14, 440. 112	704, 175	-25. 321	107. 111	25, 624. 868	0. 004	70. 192	557. 6	16, 826	-102. 0	38. 2	-11. 5
DV monitor detects engine shutdown	14, 448. 052	704, 030	-25. 137	107. 638	25, 627. 419	0. 011	69. 953	556. 6	16, 818	-102. 2	37. 5	-11. 3
Set maximum deadband to 5 deg	14, 478. 047	703, 611	-24. 421	109. 612	25, 627. 463	0. 027	69. 076	556. 3	16, 818	-102. 3	38. 4	-12. 2
LGC idling	14, 540. 142	703, 388	-22. 848	113. 623	25, 626. 834	0. 059	67. 368	556. 3	16, 818	-102. 1	41. 9	-11. 8
Hold vehicle attitude	14, 540. 147	703, 388	-22. 848	113. 624	25, 626. 834	0. 059	67. 368	556. 3	16, 818	-102. 1	41. 9	-11. 8
Set maximum deadband to 5 deg	14, 540. 147	703, 388	-22. 848	113. 624	25, 626. 834	0. 059	67. 368	556. 3	16, 818	-102. 1	41. 9	-11. 8

Run 17 Phase Summary; DPS1 Burn

Phase	Unit	Value	GET (sec)
ATTITUDE MANEUVER SUMMARY			
RCS jet firings		41	
RCS jet firing on-times	sec	8.913	
RCS fuel consumption	lb	3.8414	
Maximum body rates	deg/sec	-0.0298, yaw	14,142.547
		-1.1017, pitch	14,142.547
		5.0942, roll	14,142.547
Total time of maneuver	sec	13.744	
BURN SUMMARY			
Start of ullage maneuver			14,394.407
Time duration of ullage maneuver	sec	8.000	
Start of burn			14,401.907
Length of burn	sec	42.144	
Thrust maximum	lb	9,885.23	14,440.112
Thrust minimum	lb	1,283.00	14,404.046
Maximum acceleration	fps	10.3176	14,440.109
Main engine fuel consumption	lb	495.49	

Run 17 Phase Summary; DPS1 Burn (Continued)

Phase	Unit	Value	GET (sec)
RCS fuel consumption	lb	18.1	
Time of engine-off command			14,440.109
Time after engine-off command until DV monitor first detects shutdown	sec	3.942	
Maximum body rates	deg/sec	-0.0524, yaw 2.6605, pitch -2.6402, roll	
Position vector at thrust termination (ECI)	ft	-19,157,120 -4,039,441 -9,165,522	
Velocity vector at thrust termination (ECI)	fps	1,343.981 -24,339.392 7,908.918	
Maximum torque on vehicle	ft-lb	979.3167	14,429.866
Initial gimbal angles of main engine	deg	-0.3171, yaw 2.3151, pitch	
Final gimbal angles of main engine	deg	-0.402, yaw 2.217, pitch	

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RUN 18 TEST RESULTS SUMMARY

Test Run Description

Three-sigma IMU errors (three times the one-sigma uncertainties given in Table 7. 12 of Reference 5) were modeled during programs P32, P42, P43, P44, and P74 assuming a perfect state vector update prior to mission phase 11, and followed by an uplink state vector update.

Test Run Objectives

To determine the effect of three-sigma IMU errors during mission phase 11 and to validate the uplink state vector update capability.

Summary of Test Results

The flight software for programs P32, P42, P43, P44, and P74 has been validated for three-sigma IMU errors with a perfect state vector update assumed prior to mission phase 11. Even with a perfect state vector update prior to mission phase 11, the errors propagated through the DPS2/FITH/APS1 burn affect the trajectory. The perigee and the apogee of the orbit following mission phase 11 are 2. 3 nautical miles lower and 8. 1 nautical miles, respectively, higher than the nominal. The uplink state vector update capability following APS1 has been verified.

Discussion of Test Results

The duration of the DPS2/FITH/APS1 burn is approximately 739 seconds. Three-sigma IMU errors propagated through the burn, assuming a perfect state vector update prior to mission phase 11, produce large state vector deviations in the LGC. The guidance coordinate errors at the end of mission phase 11 as compared with the environment have components in excess of 130, 000 feet in position and 200 feet per second in velocity.

These errors produce the orbital parameter deviations defined in the Trajectory Summary with respect to the nominal test run.

The results of this test case show that even with a perfect state vector update prior to mission phase 11, the IMU errors propagated through DPS2/FITH/APS1 burn create trajectory errors that produce apogee and perigee deviations of 8. 1 nautical miles and 2. 3 nautical miles, respectively.

The Phase Summary contains detailed information pertaining to the attitude maneuver and the burn.

A state vector update of the LGC was achieved for 18,540.0 seconds GET when the following state vector was successfully uplinked within the resolutions of the flight computer word length.

X = -5,005,209.0 ft

Y = 21,235,575.0 ft

Z = -2,322,481.0 ft

VX = -21,482.6 fps

VY = -6,327.9 fps

VZ = -11,899.5 fps

RUN 18 TRAJECTORY SUMMARY

The following are trajectory deviations with respect to the nominal test run at APS guidance command engine-off:

Time	0.000 sec
Altitude	9,585. ft (low)
Latitude	0.0077 deg (south)
Longitude	0.0150 deg (west)
Inertial velocity	21.16 fps (high)
Inertial flight-path angle	0.0448 deg (low)
Inertial azimuth	0.0182 deg (south)
Apogee	8.108 n mi (high)
Perigee	2.309 n mi (low)
Declination	0.0078 deg (low)
Longitude of ascending node	0.0262 deg (west)
Inclination	0.0004 deg (high)
Eccentricity	0.001437 (high)
True anomaly	5.3455 deg (west)
Semi-major axis	17,619 ft (high)

The following LGC state vector dispersions at the end of mission phase 11 were observed with respect to the nominal test run (in ECI):

ΔX	182 ft
ΔY	321 ft
ΔZ	63 ft
$\Delta \dot{X}$	1.50 fps
$\Delta \dot{Y}$	0.60 fps
$\Delta \dot{Z}$	0.02 fps

The following environment dispersions due to erroneous guidance commands generated by the IMU errors were observed with respect to the nominal test case (in ECI):

ΔX	8,708 ft
ΔY	940 ft
ΔZ	6,755 ft

$\Delta\dot{X}$	26 fps
$\Delta\dot{Y}$	2 fps
$\Delta\dot{Z}$	20 fps

The following are LGC state vector deviations from the environment, due primarily to the three-sigma IMU errors propagated through the DPS2/FITH/APS1 burn.

ΔX	67, 826 ft
ΔY	138, 469 ft
ΔZ	36, 311 ft
$\Delta\dot{X}$	199. 480 fps
$\Delta\dot{Y}$	71. 685 fps
$\Delta\dot{Z}$	33. 259 fps

Run 18 Event Summary; DPS2/FITH/APS1

Mission Event	GET (sec)	Altitude (ft)	Geodetic Latitude (deg)	Longitude (deg)	Inertial Velocity (ft/sec)	Inertial Flight-path Angle (deg)	Inertial Azimuth Angle (deg)	RCS Fuel (lb)	DPS Fuel (lb)	OGA (deg)	IGA (deg)	MGA (deg)
Simulation initialized	16,402.283	1,001,109	30.977	-135.756	25,287.521	0.345	82.556	585.0	16,756	129.4	34.4	-7.2
Command DPS engine off	16,402.395	1,001,111	30.977	-135.755	25,287.518	0.345	82.557	585.0	16,756	129.4	34.4	-7.2
Schedule MP11	16,402.403	1,001,112	30.977	-135.754	25,287.517	0.345	82.557	585.0	16,756	129.4	34.4	-7.2
Turn DAP on	16,407.414	1,001,920	31.020	-135.392	25,286.608	0.344	82.754	585.0	16,756	129.4	34.4	-7.2
Start MP11	16,424.426	1,004,627	31.155	-134.162	25,283.562	0.338	83.424	585.0	16,756	129.4	34.4	-7.2
Enter major mode 32-2-pre-DPS2	16,424.428	1,004,627	31.155	-134.162	25,283.561	0.338	83.424	585.0	16,756	129.4	34.4	-7.2
Finish orbital integration	16,425.751	1,004,835	31.165	-134.066	25,283.327	0.337	83.477	585.0	16,756	129.4	34.4	-7.2
Begin attitude maneuver	16,440.537	1,007,136	31.272	-132.994	25,280.731	0.332	84.063	585.0	16,756	129.4	34.4	-7.2
Set minimum deadband	16,441.660	1,007,309	31.279	-132.912	25,280.536	0.332	84.108	585.0	16,756	129.4	34.4	-7.2
Complete attitude maneuver	16,460.240	1,010,127	31.398	-131.561	25,278.151	0.324	84.849	580.9	16,756	80.8	-63.9	-37.3
Enter major mode 42- DPS2 burn-braking	16,584.711	1,027,102	31.777	-122.457	25,257.958	0.277	89.886	576.6	16,756	79.6	-64.8	-37.4
Command DPS engine off	16,584.714	1,027,102	31.777	-122.457	25,257.957	0.277	89.886	576.6	16,756	79.6	-64.8	-37.4
Start reading PIPA's	16,601.419	1,029,113	31.773	-121.233	25,255.624	0.270	90.566	576.5	16,756	80.2	-64.4	-37.2
Command +X translation on (4 jet)	16,607.210	1,029,794	31.768	-120.809	25,254.833	0.268	90.801	576.5	16,756	80.3	-64.5	-37.2
Command DPS engine on	16,614.710	1,030,665	31.760	-120.259	25,253.970	0.264	91.101	566.8	16,756	80.4	-63.7	-36.6
Command +X translation off (4 jet)	16,615.210	1,030,723	31.760	-120.222	25,253.877	0.264	91.121	566.1	16,756	80.4	-63.6	-36.6
Command full throttle	16,640.709	1,033,580	31.712	-118.356	25,252.470	0.253	92.083	564.4	16,649	78.8	-65.9	-35.9
Throttle control regained	16,952.496	1,038,453	30.240	-95.755	25,254.272	-0.204	95.245	560.1	6,155	161.7	-57.4	-37.6
Enter major mode 43-DPS2 burn approach	17,095.596	1,024,158	29.159	-85.541	25,389.829	-0.193	97.691	559.6	3,583	-155.1	-46.5	-35.5
Enter major mode 44-random throttle	17,294.109	1,010.071	26.989	-71.668	25,374.602	-0.098	101.560	559.4	1,246	-110.2	-49.3	-34.2
Command APS engine on	17,346.719	1,007,113	26.260	-68.075	25,381.388	-0.093	102.399	556.8	0	-108.5	-47.1	-38.2
Command +X translation off (4 jet)	17,346.720	1,007,113	26.260	-68.075	25,381.388	-0.093	102.399	556.8	0	-108.5	-47.1	-38.2
Enter major mode 74-FITH/APS1	17,346.751	1,007,111	26.260	-68.073	25,281.390	-0.093	102.400	556.8	0	-108.5	-47.1	-38.2
DPS engine arm off	17,347.749	1,007,056	26.245	-68.005	25,382.362	-0.091	102.414	556.4	0	-110.8	-50.7	-37.7
Command APS engine off	17,351.750	1,006,842	26.188	-67.733	25,384.725	-0.087	102.442	555.3	0	-108.8	-47.5	-37.5
Command DPS engine off	17,351.752	1,006.842	26.188	-67.733	25,384.726	-0.087	102.442	555.3	0	-108.8	-47.5	-37.5
DV monitor detects engine shutdown	17,357.563	1,006,537	26.104	-67.338	25,385.031	-0.086	102.622	555.0	0	-108.0	-46.1	-38.2
Terminate average g routine	17,387.571	1,004,991	25.651	-65.310	25,386.541	-0.081	103.560	554.8	0	-108.5	-46.7	-37.4
Set maximum deadband	17,387.571	1,004,991	25.651	-65.310	25,386.541	-0.081	103.560	554.8	0	-108.5	-46.7	-37.4
Schedule MP13	17,387.573	1,004,991	25.651	-65.310	25,386.541	-0.081	103.560	554.8	0	-108.5	-46.7	-37.4
Enter major mode 0-LGC idling	17,389.646	1,004,886	25.619	-65.171	25,386.643	-0.080	103.624	554.8	0	-108.4	-46.5	-37.4
Set maximum deadband	17,389.651	1,004,885	25.619	-65.170	25,386.643	-0.080	103.624	554.8	0	-108.4	-46.5	-37.4

Run 18 Phase Summary; DPS2/FITH/APS1 Burn

Phase	Unit	Value	GET (sec)
ATTITUDE MANEUVER SUMMARY			
RCS jet firings		68	
RCS jet firing on-times	sec	8.937	
RCS fuel consumption	lb	4.1207	
Maximum body rates	deg/sec	0.327, yaw 0.0803, pitch 4.9063, roll	16,460.240 16,460.240 16,460.240
Total time of maneuver	sec	19.703	
BURN SUMMARY			
Start of ullage maneuver	sec	16,607.210	
Time duration of ullage maneuver	sec	8.000	
Start of burn	sec	16,614.710	
Length of burn	sec	738.852	
Thrust maximum	lb	10,310.34	16,952.496
Thrust minimum	lb	0.00	17,346.719
Maximum acceleration	fps/sec	16.4813	16,952.496
Main engine fuel consumption	lb	16,756.13	
RCS fuel consumption	lb	21.2	

Run 18 Phase Summary; DPS2/FITH/APS1 Burn (Continued)

Phase	Unit	Value	GET (sec)
Time of engine-off command			17, 351. 750
Time after engine-off command until DV monitor detects shutdown	sec	1. 812	
Maximum body rates	deg/sec	0. 2787, yaw 1. 1186, pitch -5. 7772, roll	
Position vector at thrust termination (ECI)	ft	17, 214, 976 9, 574, 093 9, 614, 456	
Velocity vector at thrust termination (ECI)	fps	-9, 970. 591 22, 813. 287 -4, 952. 831	
Maximum torque on vehicle	ft-lb	1, 630. 1997	17, 347. 749
Initial gimbal angles of main engine	deg	-0. 3177, yaw 2. 3151, pitch	
Final gimbal angles of main engine	deg	-0. 446, yaw 2. 426, pitch	

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RUN 20 TEST RESULTS SUMMARY

Test Run Description

Simulation of APS2 burn with a dispersed initial trajectory state vector.

Test Run Objectives

To demonstrate ascent guidance performance in a dispersed trajectory condition.

Summary of Test Results

The flight software has been exercised in mission phase 13 using the following deviations in the initial state vector:

ΔX = -8,700 ft	$\Delta \dot{X}$ = -600 fps
ΔY = 488,800 ft	$\Delta \dot{Y}$ = 48 fps
ΔZ = 91,000 ft	$\Delta \dot{Z}$ = 15.5 fps

The resulting target miss at the intercept point was 10.6 nautical miles.

Discussion of Test Results

With the perturbed initial state vector, guidance cutoff was achieved approximately 18.5 seconds earlier than nominal and with 239 pounds of fuel remaining. The shorter burn time and lower fuel consumption implies that the initial state vector perturbations were such that less energy and time were required to achieve the required to achieve the required end conditions.

At the conclusion of the burn, the perturbed trajectory was 16.5 nautical miles low at perigee, and 5.1 nautical miles high at apogee compared to the nominal ICS trajectory at nominal cutoff.

The resulting target miss was 10.6 nautical miles which compares well with 10.3 nautical miles for the nominal.

RUN 20 TRAJECTORY SUMMARY

The following are trajectory deviations with respect to the nominal ICS test run number 7 at commanded APS engine off (22, 836. 4 seconds GET)

Trajectory Parameters	Dispersion from ICS Nominal at Engine Cutoff
Altitude	219 ft
Latitude	-0. 81 deg
Longitude	0. 79 deg
Inertial Velocity	-21 fps
Inertial flight-path angle	0. 2 deg
Inertial azimuth	0. 25 deg
Apogee	5. 1 n mi
Perigee	-16. 5 n mi

The following are the deviations in the LGC state vector, and the environment state vector (ECI coordinates) of run 20 at APS engine off.

	LGC/ENV Deviations
ΔX	67
ΔY	-138
ΔZ	5
$\Delta \dot{X}$	0 fps
$\Delta \dot{Y}$	0 fps
$\Delta \dot{Z}$	0 fps

Run 20 Event Summary; APS2 Burn

Mission Event	GET (sec)	Altitude (ft)	Geodetic Latitude (deg)	Longitude (deg)	Inertial Velocity (fps)	Inertial Flight-path Angle (deg)	Inertial Azimuth Angle (deg)	RCS Fuel (lb)	APS Fuel (lb)	OGA (deg)	IGA (deg)	MGA (deg)
Simulation initialized	22,200.000	1,055,570	27.153	-132.006	25,336.113	-0.8	82.280	585.0	5,007	97.9	-43.8	-38.3
Hold vehicle attitude	22,200.031	1,055,568	27.153	-132.004	25,336.115	-0.8	82.281	585.0	5,007	97.9	-43.8	-38.3
Start MP13	22,245.059	1,052,630	27.515	-128.871	25,339.727	-0.4	83.802	585.0	5,007	97.9	-43.8	-38.3
Enter program 34 pre-APS2 burn	22,245.061	1,052,630	27.515	-128.870	25,339.727	-0.4	83.803	585.0	5,007	97.9	-43.8	-38.3
Begin attitude maneuver	22,251.044	1,052,240	27.557	-128.453	25,340.203	-0.3	84.007	585.0	5,007	97.9	-43.8	-38.3
Complete attitude maneuver	22,253.777	1,052,061	27.576	-128.262	25,339.976	-0.3	84.100	584.5	5,007	103.4	-34.5	-37.0
Enter program 46 APS2 burn	22,385.060	1,043,534	28.127	-119.021	25,350.589	-0.9	88.670	583.1	5,007	104.2	-33.8	-36.5
Start reading PIPA's	22,385.069	1,043,534	28.127	-119.020	25,350.590	-0.9	88.670	583.1	5,007	104.2	-33.8	-36.5
Command +X translation - RCS ullage	22,402.557	1,042,408	28.148	-117.784	25,351.907	-0.7	89.286	583.0	5,007	104.0	-33.7	-36.4
Command APS engine on	22,415.057	1,041,604	28.155	-116.899	25,350.708	-0.7	89.692	563.7	5,007	103.9	-33.5	-36.7
Command RCS ullage off	22,415.550	1,041,572	28.155	-116.860	25,350.500	-0.1	89.707	562.9	5,006	103.9	-33.3	-36.6
Command APS engine off	22,836.449	1,030,404	27.831	-87.317	25,244.987	0.2	90.035	508.7	239	111.2	-35.5	-35.9
Hold vehicle attitude	22,836.450	1,030,304	27.831	-87.317	25,244.989	0.2	90.035	508.7	239	111.2	-35.5	-35.9
End of tail-off	22,839.218	1,030,646	27.831	-87.122	25,245.228	0.1	90.124	508.5	237	111.5	-34.8	-36.9
Terminate reading PIPA's	22,873.216	1,034,699	27.803	-84.735	25,240.477	0.4	91.301	508.4	237	111.3	-32.7	-31.9
Hold vehicle attitude	22,875.293	1,034,937	27.800	-84.589	25,240.199	0.3	91.373	508.4	237	111.6	-32.1	-32.1

Run 20 Phase Summary; APS2 Burn

Phase	Unit	Value	GET (sec)
ATTITUDE MANEUVER SUMMARY			
RCS jet firings		10	
RCS jet firing on-times	sec	1.000	
RCS fuel consumption	lb	0.4849	
Maximum body rates	deg/sec	-0.1014, yaw 0.1430, pitch -4.9403, roll	22,253.777 22,253.777 22,253.777
Total time of maneuver	sec	2.732	
BURN SUMMARY			
Start of ullage maneuver			22,402.557
Time duration of ullage maneuver	sec	13.000	
Start of burn			22,415.057
Length of burn	sec	424.161	
Thrust maximum	lb	3,500.00	
Thrust minimum	lb	3,500.00	
Maximum acceleration	fps/sec	22.0443	22,836.450
Main engine fuel consumption	lb	4,769.65	
RCS fuel consumption	lb	74.3	
Time of engine off command			22,836.449
Maximum body rates	deg/sec	0.3336, yaw 6.1638, pitch 6.2604, roll	

RUN 21 TEST RESULTS SUMMARY

Test Run Description

Three-sigma errors (three times the one-sigma uncertainties given in Table 7.14 of Reference 9) are imposed on the IMU during the APS2 burn assuming a perfect state vector update prior to mission phase 13. The burn is followed by an uplink of a state vector update.

Test Run Objectives

To determine the effect of three-sigma IMU errors during mission phase 13 and to validate the uplink capability of a state vector update to the LGC.

Summary of Test Results

The flight software for AS-206 programs 34 and 46 has been successfully exercised for three-sigma IMU errors in mission phase 13. An uplink of a state vector update has been successfully performed following the APS2 burn. The resulting intercept target miss was 14.7 nautical miles.

Discussion of Test Results

This perturbed case was run through the APS2 burn and a guidance cutoff was achieved with 28 pounds of APS propellant remaining. At the conclusion of the burn the three-sigma IMU perturbations of run 21 imposed errors of 1.01 nautical miles in apogee and 3.98 nautical miles in perigee compared to the nominal ICS trajectory. The minimum instaneous perigee occuring during the burn was 34 nautical miles. The resulting intercept miss was 14.7 nautical miles as compared to 10.3 nautical miles of the nominal.

The LGC/environment velocity error magnitude generated through mission phase 13 resulting from three-sigma IMU errors was 11.55 feet per second as compared with 0.01 feet per second in the nominal ICS run 7.

The mission phase 13 sequencing of run 21 follows the same format of the ICS nominal run 7.

A state vector update of the LGC was achieved for 24,000 seconds GET when the following state vector was successfully uplinked within the resolution of the flight computer word length.

X = -7596444.0 ft
Y = 20347340.0 ft
Z = 2584369.0 ft
VX = -21428.6 fps
VY = -6665.4 fps
VZ = -11774.2 fps

RUN 21 TRAJECTORY SUMMARY

The following are trajectory deviations with respect to the nominal ICS test run number 7 just after engine off at 22,860 seconds GET.

	Dispersion from ICS Nominal at Engine Cutoff
Altitude	-3519 ft
Latitude	0.0009 deg
Longitude	-0.003 deg
Inertial velocity	9.36 fps
Inertial flight-path angle	-0.0334 deg
Inertial azimuth	0.0043 deg
Apogee	-6142.0 ft 1.01 n mi (low)
Perigee	24228.0 ft 3.98 n mi (high)
Period	0.0559 min
Semi-major axis	9043 ft (high)
Inertial longitude of ascending node	-0.012 deg
Argument of perigee	-5.0973 deg
True anomaly	5.1051 deg
Inclination	0.0008 deg

The following are the deviations in the LGC state vector, and the environment state vector (ECI coordinates) of run 21 at the completion of mission phase 13.

	LGC/ENV Deviation
ΔX	3976 ft
ΔY	535 ft
ΔZ	3003 ft
$\Delta \dot{X}$	17 fps
$\Delta \dot{Y}$	1 fps
$\Delta \dot{Z}$	12 fps
ΔVMAG	11.55 fps

An uplink of a state vector update was achieved for the time 24,000 seconds GET.

Run 21 Event Summary; APS2 Burn

Mission Event	GET (sec)	Altitude (ft)	Geodetic Latitude (deg)	Longitude (deg)	Inertial Velocity (ft/sec)	Inertial Flight-path Angle (deg)	Inertial Azimuth Angle (deg)	RCS Fuel (lb)	DPS Fuel (lb)	OGA (deg)	IGA (deg)	MGA (deg)
Simulation initialized	22, 200. 000	1, 039, 264	27. 711	-132. 841	25, 341. 690	-0. 105	81. 618	585. 0	5, 007	97. 9	-43. 8	-38. 3
Hold vehicle attitude	22, 200. 031	1, 039, 263	27. 711	-132. 839	25, 341. 691	-0. 105	81. 620	585. 0	5, 007	97. 9	-43. 8	-38. 3
Start MP13	22, 245. 059	1, 037, 604	28. 107	-129. 691	25, 343. 857	-0. 102	83. 177	585. 0	5, 007	97. 9	-43. 8	-38. 3
Enter program 34 pre-APS2 burn	22, 245. 061	1, 037, 604	28. 107	-129. 690	25, 343. 857	-0. 102	83. 177	585. 0	5, 007	97. 9	-43. 8	-38. 3
Begin attitude maneuver	22, 250. 954	1, 037, 385	28. 153	-129. 277	25, 344. 138	-0. 102	83. 384	585. 0	5, 007	97. 9	-43. 8	-38. 3
Complete attitude maneuver	22, 253. 757	1, 037, 281	28. 174	-129. 080	25, 343. 855	-0. 101	83. 482	584. 4	5, 007	103. 6	-34. 2	-36. 3
Enter program 46 APS2 burn	22, 385. 060	1, 032, 320	28. 810	-119. 779	25, 350. 396	-0. 091	88. 177	582. 5	5, 007	103. 8	-33. 8	-35. 4
Start reading PIPA's	22, 385. 069	1, 032, 320	28. 810	-119. 778	25, 350. 397	-0. 091	88. 177	582. 5	5, 007	103. 8	-33. 8	-35. 4
Command +X translation RCS ullage	22, 402. 557	1, 031, 650	28. 841	-118. 533	25, 351. 205	-0. 090	88. 811	582. 2	5, 007	104. 0	-34. 1	-35. 7
Command APS engine on	22, 415. 057	1, 031, 170	28. 855	-117. 642	25, 349. 623	-0. 089	89. 230	562. 8	5, 007	104. 4	-33. 5	-35. 7
Command ullage off	22, 415. 557	1, 031, 151	28. 855	-177. 606	25, 349, 480	0. 089	89. 246	562. 1	5, 005	104. 4	-33. 4	-35. 7
Command APS engine off	22, 854. 899	1, 027, 637	28. 646	-86. 537	25, 274. 521	0. 051	89. 788	504. 4	30	127. 3	-32. 6	-39. 3
Hold vehicle attitude	22, 854. 900	1, 027, 637	28. 646	-86. 537	25, 274. 523	0. 051	89. 788	504. 4	30	127. 3	-32. 6	-39. 3
End of tail-off	22, 857. 212	1, 027, 688	28. 647	-86. 373	25, 275. 088	0. 049	89. 864	504. 2	28	127. 2	-32. 7	-38. 0
Terminate reading PIPA's	22, 891. 216	1, 028, 325	28. 628	-86. 962	25, 274. 314	0. 038	91. 085	504. 2	28	126. 5	-34. 5	-44. 8
Hold vehicle attitude	22, 893. 298	1, 028, 357	28. 626	-83. 814	25, 274. 275	0. 038	91. 160	504. 2	28	126. 9	-33. 9	-44. 9

Run 21 Phase Summary; APS2 Burn

Phase	Unit	Value	GET (sec)
ATTITUDE MANEUVER SUMMARY			
RCS jet firings		16	
RCS jet firing on-times	sec	1.140	
RCS fuel consumption	lb	0.5989	
Maximum body rates	deg/sec	-0.0771, yaw	22,253.757
		0.7985, pitch	22,253.757
		-4.6677, roll	22,253.757
Total time of maneuver	sec	2.803	
BURN SUMMARY			
Start of ullage maneuver			22,402.557
Time duration of ullage maneuver	sec	13.000	
Start of burn			22,415.057
Length of burn	sec	442.155	
Thrust maximum	lb	3,500.00	
Thrust minimum	lb	3,500.00	
Maximum acceleration	fps/sec	21.6170	22,854.900
Main engine fuel consumption	lb	4,978.63	

Run 21 Phase Summary; APS2 Burn (Continued)

Phase	Unit	Value	GET (sec)
RCS fuel consumption	lb	77.8	
Time of engine-off command	sec	22,854.899	
Maximum body rates	deg/sec	0.1018, yaw 0.8564, pitch -0.8738, roll	

RUN 22 TEST RESULTS SUMMARY

Test Run Description

Simulation of APS2 burn with an initial c. g. offset along the Y and Z axes.

Test Run Objectives

To demonstrate and test thrust vector and attitude control capabilities when the c. g. is offset initially.

Summary of Test Results

The flight software was exercised successfully in mission phase 13 using an initial c. g. offset during APS2. No significant body rates, trajectory deviations or fuel problems were noted.

Discussion of Test Results

With an initial c. g. offset ΔX = 1. 0 inch, ΔY = 0. 5 inch, and ΔZ = 0. 5 inch guidance cutoff was achieved approximately 1. 7 seconds earlier than nominal. APS fuel remaining at commanded engine cutoff was 49 pounds. The maximum body rates attained during the burn were -0. 0588, 0. 8021, and -4. 8310 degrees per second compared to the maximum body rates -0. 0559, 0. 8165, and 4. 7043 degrees per second, respectively, of the nominal run.

At the conclusion of the burn, the perturbed trajectory was approximately 0. 92 nautical miles low at perigee and 0. 5 nautical miles high at apogee. The RCS fuel consumption during the burn was 87. 1 pounds as compared to 58. 5 pounds for the nominal. The target miss was 9. 11 nautical miles compared to the nominal miss of 10. 3 nautical miles.

RUN 22 TRAJECTORY SUMMARY

The following are trajectory deviations with respect to the nominal ICS test run number 7 at commanded APS engine off (22, 858. 2 seconds GET).

Trajectory Parameters	Dispersion from ICS Nominal at Engine Cutoff
Altitude	63 ft
Latitude	0. 02 deg
Longitude	-0. 0 deg
Inertial velocity	-0. 5 fps
Inertial flight-path angle	0. 01 deg
Inertial azimuth	0. 05 deg
Apogee	0. 5 n mi
Perigee	-0. 9 n mi

The following are the deviations in the LGC state vector, and the environment state vector (ECI coordinates) of run 22 at APS engine off:

	LGC/ENV Deviations
ΔX	57 ft
ΔY	-134 ft
ΔZ	36 ft
$\Delta \dot{X}$	0 fps
$\Delta \dot{Y}$	0 fps
$\Delta \dot{Z}$	0 fps

Run 22 Event Summary; APS2 Burn

Mission Event	GET (sec)	Altitude (ft)	Geodetic Latitude (deg)	Longitude (deg)	Inertial Velocity (fps)	Inertial Flight-path Angle (deg)	Inertial Azimuth Angle (deg)	RCS Fuel (lb)	APS Fuel (lb)	OGA (deg)	IGA (deg)	MGA (deg)
Simulation initialized	22,200.000	1,039,264	27.711	-132.841	25,341.690	-0.105	81.618	585.0	5,007	97.9	-43.8	-38.3
Hold vehicle attitude	22,200.031	1,039,263	27.711	-132.839	25,341.691	-0.105	81.620	585.0	5,007	97.9	-43.8	-38.3
Start MP13	22,245.059	1,037,604	28.107	-129.690	25,343.857	-0.102	83.177	585.0	5,007	97.9	-43.8	-38.3
Enter program 34 pre-APS2 burn	22,245.061	1,037,604	28.107	-129.690	25,343.857	-0.102	83.177	585.0	5,007	97.9	-43.8	-38.3
Begin attitude maneuver	22,250.954	1,037,385	28.153	-129.277	25,344.138	-0.102	83.384	585.0	5,007	97.9	-43.8	-38.8
Complete attitude maneuver	22,253.757	1,037,281	28.174	-129.080	25,343.846	-0.101	83.482	584.5	5,007	103.6	-34.1	-35.8
Enter program 46 APS2 burn	22,385.060	1,032,320	28.810	-119.779	25,350.407	-0.091	88.177	582.4	5,007	103.9	-33.8	-35.3
Start reading PIPA's	22,385.069	1,032,320	28.810	-119.778	25,350.408	-0.091	88.177	582.4	5,007	103.9	-33.8	-35.3
Command +X translation - RCS ullage	22,402.557	1,031,650	28.841	-118.533	25,351.206	-0.090	88.811	582.4	5,007	103.7	-33.9	-35.5
Command APS engine on	22,415.057	1,031,170	28.855	-117.642	25,349.761	-0.089	89.230	562.9	5,007	103.6	-34.1	-35.9
Command RCS ullage off	22,415.555	1,031,151	28.855	-117.600	25,349.640	-0.889	89.246	562.1	5,006	103.5	-34.1	-35.8
Command APS engine off	22,853.230	1,031,148	28.662	-86.608	25,264.540	0.108	89.732	476.2	49	1.4	-30.5	-31.1
Hold vehicle attitude	22,853.230	1,031,148	28.662	-86.608	25,264.541	0.108	89.732	476.2	49	1.4	-30.5	-31.1
End of tail-off	22,855.219	1,031,244	28.663	-86.467	25,263.865	0.108	89.795	475.8	47	4.4	-24.0	-25.6
Terminate reading PIPA's	22,889.226	1,032,750	28.647	-84.057	25,262.759	0.095	91.017	475.2	47	12.5	-12.6	-15.4
Hold vehicle attitude	22,891.284	1,032,834	28.644	-83.911	25,262.660	0.095	91.091	475.2	47	12.2	-12.3	-15.0

Run 22 Phase Summary; APS2 Burn

Phase	Unit	Value	GET (sec)
ATTITUDE MANEUVER SUMMARY			
RCS jet firings		8	
RCS jet firing on-times	sec	1.131	
RCS fuel consumption	lb	0.5153	
Maximum body rates	deg/sec	-0.0588, yaw 0.8021, pitch -4.8310, roll	22,253.757 22,253.757 22,253.757
Total time of maneuver	sec	2.802	
BURN SUMMARY			
Start of ullage maneuver			22,402.557
Time duration of ullage maneuver	sec	13.001	
Start of burn			22,415.057
Length of burn	sec	440.162	
Thrust maximum	lb	3,500.00	
Thrust minimum	lb	3,500.00	
Maximum acceleration	fps/sec	21.4285	22,853.230
Main engine fuel consumption	lb	4,959.72	
RCS fuel consumption	lb	106.2	
Time of engine off command			22,853.230
Maximum body rates	deg/sec	0.3336, yaw 6.1638, pitch 6.2604, roll	

RUN 23 TEST RESULTS SUMMARY

Test Run Description

Simulation of APS2 burn with off-nominal thrust characteristics.

Test Run Objectives

To test APS guidance performance subjected to an off-nominal ascent engine thrust characteristic (thrust scale factor = 1.07).

Summary of Test Results

The flight software was exercised successfully in mission phase 13 using a higher than nominal thrust engine.

Discussion of Test Results

With the 7 percent above nominal thrust engine, guidance cutoff was achieved approximately 24.1 seconds earlier than nominal, as expected. The fuel was depleted at approximately 2.3 seconds before commanded APS engine off.

At cutoff, the perturbed trajectory was 5.3 nautical miles low at perigee and 0.3 nautical mile high at apogee compared to the nominal ICS trajectory at nominal cutoff.

The resulting target miss was 16.9 nautical mile. Nominal target miss was 10.3 nautical mile.

RUN 23 TRAJECTORY SUMMARY

The following are trajectory deviations with respect to the nominal ICS test run number 7 at commanded APS engine off (22, 830. 8 seconds GET).

Trajectory Parameters	Dispersion from ICS Nominal at Engine Cutoff
Altitude	277 ft
Latitude	0. 26 deg
Longitude	-1. 68 deg
Inertial velocity	-8. 6 fps
Inertial flight-path angle	0. 02 deg
Inertial azimuth	0. 1 deg
Apogee	0. 3 n mi
Perigee	-5. 3 n mi

The following are the deviations in the LGC state vector, and the environment state vector (ECI coordinates) of run 23 at APS engine off.

	LGC/ENV Deviations
ΔX	63 ft
ΔY	-138 ft
ΔZ	37 ft
$\Delta \dot{X}$	0 fps
$\Delta \dot{Y}$	0 fps
$\Delta \dot{Z}$	0 fps

Run 23 Event Summary; APS2 Burn

Mission Event	GET (sec)	Altitude (ft)	Geodetic Latitude (deg)	Longitude (deg)	Inertial Velocity (fps)	Inertial Flight-path Angle (deg)	Inertial Azimuth Angle (deg)	RCS Fuel (lb)	DPS Fuel (lb)	OGA (deg)	IGA (deg)	MGA (deg)
Simulation initialized	22, 200. 000	1, 039, 264	27. 711	-132. 841	25, 341. 690	-0. 105	8. 618	585. 0	5, 007	97. 9	-43. 8	-38. 3
Hold vehicle attitude	22, 200. 031	1, 039, 263	27. 711	-132. 839	25, 341. 691	-0. 105	8. 620	585. 0	5, 007	97. 9	-43. 8	-38. 3
Hold vehicle attitude	22, 205. 031	1, 039, 080	27. 759	-132. 491	25, 341. 933	-0. 105	8. 791	585. 0	5, 007	97. 9	-43. 8	-38. 3
Start MP13	22, 245. 059	1, 037, 604	25. 107	-129. 690	25, 343. 857	-0. 102	8. 177	585. 0	5, 007	97. 9	-43. 8	-38. 3
Enter program 34 pre-APS2 burn	22, 245. 061	1, 037, 604	28. 107	-129. 690	25, 343. 857	-0. 102	8. 177	585. 0	5, 007	97. 9	-43. 8	-38. 3
Begin attitude maneuver	22, 250. 955	1, 037, 385	28. 153	-129. 276	25, 344. 138	-0. 102	8. 384	585. 0	5, 007	97. 9	-43. 8	-38. 3
Complete attitude maneuver	22, 253. 767	1, 037, 280	28. 174	-129. 079	25, 343. 832	-0. 101	8. 482	584. 5	5, 007	103. 4	-34. 5	-35. 9
Enter program 46 APS2 burn	22, 385. 060	1, 032, 320	28. 810	-119. 779	25, 350. 405	-0. 091	8. 177	582. 7	5, 007	103. 4	-34. 1	-35. 2
Start reading PIPA's	22, 385. 069	1, 032, 320	28. 810	-119. 778	25, 350. 406	-0. 091	8. 177	582. 7	5, 007	103. 4	-34. 1	-35. 2
Command +X translation RCS ullage	22, 402. 557	1, 031, 650	28. 841	-118. 533	25, 351. 183	-0. 090	8. 811	582. 4	5, 007	103. 7	-34. 4	-35. 4
Command APS engine on	22, 415. 057	1, 031, 171	28. 855	-117. 642	25, 349. 628	-0. 089	8. 230	563. 0	5, 007	103. 7	-33. 6	-35. 6
Command RCS ullage off	22, 415. 588	1, 031, 152	28. 855	-117. 605	25, 349. 980	-0. 086	89. 245	562. 2	5, 006	103. 7	-33. 6	-35. 6
Command APS engine off	22, 830. 899	1, 031, 362	28. 905	-88. 209	25, 256. 451	0. 108	8. 838	503. 9	-0	78. 7	-31. 0	-37. 3
Hold vehicle attitude	22, 830. 900	1, 031, 362	28. 905	-88. 209	25, 256. 451	0. 108	8. 838	503. 9	-0	78. 7	-31. 0	-37. 3
End of tail-off	22, 831. 210	1, 031, 377	28. 906	-88. 187	25, 256. 433	0. 108	8. 850	503. 9	-0	79. 1	-30. 4	-37. 8
Terminate reading PIPA's	22, 865. 216	1, 032, 915	28. 927	-85. 771	25, 254. 655	0. 094	9. 083	503. 8	-0	73. 3	-34. 6	-32. 4
Hold vehicle attitude	22, 867. 283	1, 033, 000	28. 926	-85. 624	25, 254. 556	0. 093	9. 158	503. 8	-0	73. 3	-34. 4	-32. 1

Run 23 Phase Summary; APS2 Burn

Phase	Unit	Value	GET(sec)
ATTITUDE MANEUVER SUMMARY			
RCS jet firings		10	
RCS jet firing on-times	sec	1.159	
RCS fuel consumption	lb	0.5462	
Maximum body rates	deg/sec	-0.0608, yaw 0.849, pitch -4.9092, roll	22,253.767 22,253.767 22,253.767
Total time of maneuver	sec	2.812	
BURN SUMMARY			
Start of ullage maneuver			22,402.557
Time duration of ullage maneuver	sec	13.001	
Start of burn			22,415.057
Length of burn	sec	416.153	
Thrust maximum	lb	3,745.00	
Thrust minimum	lb	0.00	
Maximum acceleration	fps/sec	23.2269	22,828.003
Main engine fuel consumption	lb	5,007.50	
RCS fuel consumption	lb	20.2	
Time of engine off command			22,830.899
Maximum body rate	deg/sec	0.3336, yaw 6.1638, pitch 6.2604, roll	

RUN 24 TEST RESULTS SUMMARY

Test Run Description

Simulation of APS2 burn with an off-nominal ISP engine characteristic.

Test Run Objectives

To determine the effect of an ISP perturbation on the closed-loop APS2 guidance performance. (ISP Scale Factor = 1.03)

Summary of Test Results

The flight software was exercised successfully using an off-nominal LM ISP engine characteristic. The trajectory deviations from the nominal were negligible.

Discussion of Test Results

A 3 percent ISP perturbation caused very small deviations from the nominal trajectory. Burn time was approximately 2.2 seconds longer than nominal, and one more pound of main engine fuel was used. Apogee and perigee were nominal. The resulting target miss was nominal, 10.6 nautical miles.

RUN 24 TRAJECTORY SUMMARY

The following are trajectory deviations with respect to the nominal ICS test run number 7, at commanded APS engine off (22, 854.9 seconds GET).

Trajectory Parameters	Dispersion from ICS Nominal at Engine Cutoff
Altitude	1 ft
Latitude	0
Longitude	0
Inertial velocity	0
Inertial azimuth	0
Apogee	0
Perigee	0

The following are the deviations in the LGC state vector, and the environment state vector (ECI coordinates) of run 24 at APS engine off.

	LGC/ENV Deviations
ΔX	60 ft
ΔY	-113 ft
ΔZ	39 ft
$\Delta \dot{X}$	0 fps
$\Delta \dot{Y}$	0 fps
$\Delta \dot{Z}$	0 fps

Run 24 Event Summary; APS2 Burn

Mission Event	GET (sec)	Altitude (ft)	Geodetic Latitude (deg)	Longitude (deg)	Inertial Velocity (fps)	Inertial Flight-path Angle (deg)	Inertial Azimuth Angle (deg)	RCS Fuel (lb)	DPS Fuel (lb)	OGA (deg)	IGA (deg)	MGA (deg)
Simulation initialized	22, 200.000	1, 039, 264	27.711	-132.841	25, 341.690	-0.105	81.618	585.0	5, 007	97.9	-43.8	-38.3
Hold vehicle attitude	22, 200.031	1, 039, 263	27.711	-132.839	25, 341.961	-0.105	81.620	585.0	5, 007	97.9	-43.8	-38.3
Start MP13	22, 245.059	1, 037, 604	28.107	-129.690	25, 343.857	-0.102	83.177	585.0	5, 007	97.9	-43.8	-38.3
Enter program 34 pre-APS2 burn	22, 245.061	1, 037, 604	28.107	-129.690	25, 343.857	-0.102	83.177	585.0	5, 007	97.9	-43.8	-38.3
Begin attitude maneuver	22, 250.954	1, 037, 385	28.153	-129.277	25, 344.138	-0.102	83.384	585.0	5, 007	97.9	-43.8	-38.3
Complete attitude maneuver	22, 253.757	1, 037, 281	28.174	-129.080	25, 343.839	-0.101	83.482	584.5	5, 007	103.6	-34.1	-35.8
Enter program 46 APS2 burn	22, 385.060	1, 032, 320	28.810	-119.779	25, 350.408	-0.091	88.177	582.2	5, 007	103.6	-33.8	-35.7
Start reading PIPA's	22, 385.069	1, 032, 320	28.810	-119.778	25, 350.409	-0.091	88.177	582.2	5.007	103.6	-33.8	-35.7
Command +X translation RCS ullage	22, 402.557	1, 031, 650	28.841	-118.533	25, 351.191	-0.090	88.811	582.2	5, 007	104.0	-33.7	-35.2
Command APS engine on	22, 415.057	1, 031, 171	28.855	-117.642	25, 349.588	-0.089	89.230	562.9	5, 007	104.4	-33.5	-35.7
Command RCS ullage off	22. 415.555	1, 031, 151	28.855	-117.605	25, 349.440	-0.088	89.245	562.0	5, 006	104.4	-33.4	-35.7
Command APS engine off	22, 854.999	1, 031, 086	28.646	-86.529	25, 265.365	0.082	89.787	504.1	29	83.1	-29.6	-38.8
Hold vehicle attitude	22, 855.000	1, 031, 086	28.646	-86.529	25, 265.367	0.082	89.787	504.1	29	83.1	-29.6	-38.8
End of tail-off	22, 857.213	1, 031, 165	28.646	-86.372	25, 265.879	0.080	89.859	503.9	27	83.3	-28.9	-38.0
Terminate reading PIPA's	22, 891.216	1, 032, 259	28.628	-83.962	25, 264.547	0.068	91.079	503.8	27	81.9	-25.8	-42.7
Hold vehicle attitude	22, 893.283	1, 032, 318	28.625	-83.816	25, 264.477	0.067	91.154	503.8	27	82.0	-25.4	-42.6

Run 24 Phase Summary; APS2 Burn

Phase	Unit	Value	GET(sec)
ATTITUDE MANEUVER SUMMARY			
RCS jet firings		8	
RCS jet firing on-times	sec	1.132	
RCS fuel consumption	lb	0.5158	
Maximum body rates	deg/sec	-0.0587, yaw	22,253.757
		0.8122, pitch	22,253.757
		-4.8250, roll	22,253.757
Total time of maneuver	sec	2.802	
BURN SUMMARY			
Start of ullage maneuver			22,402.557
Time duration of ullage maneuver	sec	13.000	
Start of burn			22,415.057
Length of burn	sec	442.156	
Thrust maximum	lb	3,500.00	
Thrust minimum	lb	3,500.00	
Maximum acceleration	fps/sec	21.6182	22,855.000
Main engine fuel consumption	lb	4,979.77	
RCS fuel consumption	lb	78.1	
Time of engine off command			22,854.999
Maximum body rates	deg/sec	-0.1665, yaw	
		1.4595, pitch	
		-1.2567, roll	

RUN 43 TEST RESULTS SUMMARY

Test Run Description

Three-sigma IMU errors (same as run number 17) propagated to and through mission phase 9 with an uplink state vector update after the DPS1 burn.

Test Run Objectives

To determine the effect of the IMU errors on the DPS1 burn and to validate the uplink state vector update capability.

Summary of Test Results

The flight software for programs P31 and P41 has been validated for three-sigma IMU errors propagated through mission phase 9. Mission phase 9 was initialized with LGC state vectors dispersions defined in Reference 11. When the three-sigma IMU errors were propagated through mission phase 9, the altitude of the apogee following the DPS1 burn was 7.9 nautical miles higher than the nominal. Comparison of the results of this test case with run 17 indicates that a state vector update prior to mission phase 9 will significantly reduce trajectory errors at the end of the DPS1 burn.

Discussion of Test Results

The three-sigma IMU errors propagated from launch through mission phase 9 create the orbital trajectory errors defined in the Trajectory Summary.

The trajectory apogee is raised 7.775 nautical miles. The three-sigma IMU errors only affect the altitude of apogee (or perigee) in the targeting.

Comparison with the results of run 17 illustrate the reduction in errors at the end of the DPS1 burn with a state vector update prior to mission phase 9.

The Phase Summary contains detailed information pertaining to the attitude maneuver and the burn.

A state vector update of the LGC was achieved for 15, 600. 0 seconds when a state vector was successfully uplinked within the resolution of the flight computer word length.

RUN 43 TRAJECTORY SUMMARY

The following trajectory deviations were observed (with respect to the nominal) at DPS1 guidance command engine off:

Altitude	122 ft (high)
Latitude	0.001 deg (north)
Longitude	0.002 deg (west)
Inertial velocity	13.48 fps (high)
Inertial flight-path angle	0.015 deg (high)
Inertial azimuth	0.009 deg (south)
Apogee	7.775 n mi (high)
Perigee	0.005 n mi (low)
Declination	0.0006 deg (high)
Longitude of ascending node	0.0130 deg (east)
Inclination	0.0048 deg (low)
Eccentricity	0.001074 (high)
True anomaly	0.8280 deg (west)
Semi-major axis	23,608 ft (high)

The following state vector dispersions (difference between the LGC and environment) were observed during the AVERAGE-G integration:

	Begin AVERAGE-G	DPS1 Cutoff	Terminate AVERAGE-G
Time	14,372.	14,440.	14,536.
ΔX (ft)	15,059.	56,428.	1,118,116.
ΔY (ft)	534,823.	529,909.	517,016.
ΔZ (ft)	295,642.	320,352.	353,082.
$\Delta \dot{X}$ (fps)	613.	632.	651.
$\Delta \dot{Y}$ (fps)	41.	95.	73.
$\Delta \dot{Z}$ (fps)	373.	355.	326.

Run 43 Event Summary; DPS1 Burn

Mission Event	GET (sec)	Altitude (ft)	Geodetic Latitude (deg)	Longitude (deg)	Inertial Velocity (ft/sec)	Inertial Flight-path Angle (deg)	Inertial Azimuth Angle (deg)	RCS Fuel (lb)	DPS Fuel (lb)	OGA (deg)	IGA (deg)	MGA (deg)
Simulation initialized	14, 100. 000	726, 525	-30. 911	83. 251	25, 464. 957	-0. 074	82. 245	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Hold vehicle attitude	14, 100. 032	726, 523	-30. 910	83. 253	25, 464. 958	-0. 075	82. 244	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Start DAP	14, 105. 031	726, 306	-30. 864	83. 621	25, 465. 183	-0. 076	82. 045	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Hold vehicle attitude	14, 105. 032	726, 306	-30. 864	83. 621	25, 465. 183	-0. 076	82. 045	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Start MP9	14, 126. 043	725, 351	-30. 657	85. 162	25, 466. 170	-0. 081	81. 214	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Enter program 31 pre-DPS1 burn	14, 126. 045	725, 351	-30. 657	85. 162	25, 466. 171	-0. 081	81. 214	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Finish orbital integration	14, 128. 659	725, 227	-30. 630	85. 354	25, 466. 298	-0. 082	81. 111	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Begin attitude maneuver	14, 128. 804	725, 220	-30. 628	85. 364	25, 466. 305	-0. 082	81. 105	585. 0	17, 314	-113. 1	-25. 9	-5. 5
Complete attitude maneuver	14, 142. 437	724, 564	-30. 482	86. 360	25, 466. 876	-0. 084	80. 573	581. 0	17, 314	-102. 5	36. 5	-12. 7
Enter program 41 DPS1 burn	14, 334. 398	712, 301	-27. 555	99. 980	25, 479. 517	-0. 130	73. 563	577. 4	17, 314	-102. 1	37. 2	-12. 8
Finish orbital integration	14, 339. 752	711, 886	-27. 452	100. 348	25, 479. 941	-0. 131	73. 384	577. 4	17, 314	-102. 0	37. 3	-12. 7
Start reading PIPA's	14, 370. 396	709, 440	-26. 841	102. 439	25, 482. 450	-0. 138	72. 374	577. 3	17, 314	-102. 1	37. 4	-12. 2
Command +X translation -RCS ullage	14, 392. 897	707, 571	-26. 369	103. 960	25, 484. 367	-0. 143	71. 653	577. 3	17, 314	-102. 2	37. 1	-12. 2
Command DPS engine on	14, 400. 397	706, 938	-26. 208	104. 463	25, 487. 047	-0. 143	71. 416	567. 8	17, 314	-102. 5	36. 2	-13. 5
Command +X translation off	14, 400. 897	706, 895	-26. 198	104. 497	25, 487. 262	-0. 143	71. 401	567. 0	17, 314	-102. 6	36. 0	-13. 5
DV monitor detects engine shutdown	14, 402. 547	706, 756	-26. 162	104. 608	25, 487. 807	-0. 142	71. 349	566. 3	17, 312	-102. 7	35. 6	-13. 3
Increase throttle to maximum	14, 426. 405	704, 881	-25. 634	106. 201	25, 517. 847	-0. 114	70. 613	561. 9	17, 206	-101. 4	48. 2	-7. 5
Disable DAP trim gimbal control	14, 426. 413	704, 881	-25. 634	106. 201	25, 517. 860	-0. 114	70. 613	561. 9	17, 206	-101. 4	48. 2	-7. 5
Enable DAP trim gimbal control	14, 428. 356	704, 745	-25. 590	106. 330	25, 529. 742	-0. 099	70. 557	561. 0	17, 163	-102. 5	42. 3	-11. 6
Command DPS engine off	14, 440. 056	704, 289	-25. 323	107. 108	25, 637. 868	0. 022	70. 208	559. 3	16, 778	-105. 0	35. 8	-11. 1
Hold vehicle attitude	14, 440. 060	704, 289	-25. 323	107. 108	25, 637. 903	0. 022	70. 208	559. 3	16, 778	-105. 0	35. 8	-11. 1
Monitor detects engine shutdown	14, 446. 548	704, 223	-25. 172	107. 539	25, 640. 222	0. 028	70. 013	559. 3	16, 770	-105. 8	34. 7	-11. 2
Set maximum deadband to 5 deg	14, 476. 548	704, 058	-24. 457	109. 516	25, 639. 999	0. 046	69. 133	559. 1	16, 770	-105. 2	35. 6	-11. 9
LGC idling	14, 538. 639	704, 444	-22. 888	113. 532	25, 638. 654	0. 083	67. 421	559. 1	16, 770	-102. 5	38. 3	-11. 2
Hold vehicle attitude	14, 538. 643	704, 444	-22. 888	113. 532	25, 638. 654	0. 083	67. 421	559. 1	16, 770	-102. 5	38. 3	-11. 2
Set maximum deadband to 5 deg	14, 538. 644	704, 444	-22. 888	113. 532	25, 638. 654	0. 083	67. 421	559. 1	16, 770	-102. 5	38. 3	-11. 2

Run 43 Phase Summary; DPS1 Burn

Phase	Unit	Value	GET (sec)
ATTITUDE MANEUVER SUMMARY			
RCS jet firings		53	
RCS jet firing on-times	sec	9.128	
RCS fuel consumption	lb	4.0443	
Maximum body rates	deg/sec	-0.0620, yaw	14, 142.437
		-1.0885, pitch	14, 142.437
		5.198, roll	14, 142.437
Total time of maneuver	sec	13.633	
BURN SUMMARY			
Start of ullage maneuver			14, 392.897
Time duration of ullage maneuver	sec	8.000	
Start of burn			14, 400.397
Length of burn	sec	42.159	
Thrust maximum	lb	9887.34	14, 440.060
Thrust minimum	lb	1283.00	14, 402.547
Maximum acceleration	fps/sec	10.3585	14, 440.056
Main engine fuel consumption	lb	543.40	

Run 43 Phase Summary; DPS1 Burn (Continued)

Phase	Unit	Value	GET (sec)
RCS fuel consumption	lb	18.0	
Time of engine-off command			14,440.056
Time after engine-off command until DV monitor first detects shutdown	sec	2.499	
Maximum body rates	deg/sec	-0.0998, yaw 3.2474, pitch -3.0944, roll	
Position vector at thrust termination (ECI)	ft	-19,159,180 -4,003,300 -9,177,367	
Velocity vector at thrust termination (ECI)	fps/sec	1,300.851 -24,363.191 7,884.452	
Maximum torque on vehicle	ft-lb	1,384.4821	14,426.405
Initial gimbal angles of main engine	deg	-0.3177, yaw 2.3151, pitch	
Final gimbal angles of main engine	deg	-0.420, yaw 2.208, pitch	

RUN 44 TEST RESULTS SUMMARY

Test Run Description

Three-sigma IMU errors (same as run number 18) propagated to and through mission phase 11 with an uplink state vector update after the APS1 burn.

Test Run Objectives

To determine the effect of the propagated IMU errors on the DPS2/FITH/APS1 burn and to validate the uplink state vector update capability.

Summary of Test Results

The flight software for programs P32, P42, P43, P44 and P74 has been validated for three-sigma errors propagated through mission phase 11. Mission phase 11 was initialized with LGC state vector dispersions defined in Reference 11. For this test case, it was observed that the AVERAGE-G subroutine was started after the DPS2 burn had begun instead of approximately 6 seconds before ullage as performed in the nominal test case. With state vector errors of this magnitude, it is necessary to initiate mission phase 11 earlier. At least 149 seconds is required after the start of mission phase 11 before the AVERAGE-G subroutine is initiated. The time of mission phase enable in the OT is sufficient. The three-sigma errors propagated from launch through mission phase 11 create the following errors. The perigee and the apogee of the orbit following mission phase 11 are 6.3 nautical miles lower and 8.1 nautical miles higher than the nominal, respectively. These errors are not significantly different from those of run 18 with a perfect state vector update prior to mission phase 11. This indicates that a state vector update prior to mission phase 11 will not significantly reduce the orbital trajectory errors at the end of mission phase 11. The uplink state vector update capability after the APS1 burn has been verified.

Discussion of Test Results

Timing

One deviation in the timing, as compared with the OT, has been observed in this test case.

The "Start Reading PIPA's" and, therefore, state vector calculations using the AVERAGE-G subroutine is initiated approximately 1.0 second after the DPS engine is commanded on. This is illustrated in the Event Summary.

The PIPA's were not read during the ullage maneuver. However, this does not greatly affect the results of the DPS burn for this run, but a more adverse perturbation could create large errors if the PIPA's are turned on later in the mission. The program logic requires a minimum of 149 seconds before turning on AVERAGE-G. Therefore, mission phase 11 should be enabled at least 155 seconds before ullage. The OT provides mission phase 11 enable sufficiently early for three-sigma IMU perturbations.

A state vector update of the LGC was achieved at 18, 540.0 seconds when a state vector was successfully uplinked within the resolution of the flight computer work length.

Burn

The three-sigma IMU errors propagated from launch through mission phase 11 create the orbital trajectory errors defined in the Trajectory Summary.

The errors are not significantly different from those of run 18 with a perfect state vector update prior to mission phase 11. This indicates that a state vector update prior to mission phase 11 is of little effect in reducing the orbital trajectory errors at the end of the DPS2/FITH/APS1 burn.

Detailed information about the attitude maneuver for thrusting and the burn is contained in the Phase Summary.

RUN 44 TRAJECTORY SUMMARY

The following trajectory deviations were observed (with respect to the nominal) at APS1 guidance command engine off:

Time	27.740 sec (early)
Altitude	29,401. ft (low)
Latitude	0.9782 deg (north)
Longitude	1.4701 deg (west)
Inertial velocity	49.730 fps (high)
Inertial flight-path angle	0.0118 deg (high)
Inertial azimuth	0.6312 deg (north)
Apogee	8.106 n mi (high)
Perigee	6.323 n mi (low)
Declination	0.9742 deg (high)
Longitude of ascending node	0.3760 deg (east)
Inclination	0.6336 deg (high)
Eccentricity	0.001993 (high)
True anomaly	11.6271 deg (east)
Semi-major axis	5417 ft (high)

The following state vector dispersions (difference between the LGC and environment) were observed during the AVERAGE-G integration:

	Begin AVERAGE-G	FITH	APS1 Cutoff	Terminate AVERAGE-G
Time	16,575.	17,319.	17,324.	17,361.
ΔX (ft)	372,708.	88,263.	90,645.	113,000.
ΔY (ft)	635,936.	607,493.	606,069.	591,798.
ΔZ (ft)	4,536.	321,004.	322,210.	332,823.
$\Delta \dot{X}$ (fps)	557.	594.	593.	582.
$\Delta \dot{Y}$ (fps)	299.	358.	361.	389.
$\Delta \dot{Z}$ (fps)	23.	291.	289.	269.

Run 44 Event Summary; DPS2/FITH/APS1 Burn

Mission Event	GET (sec)	Altitude (ft)	Geodetic Latitude (deg)	Longitude (deg)	Inertial Velocity (ft/sec)	Inertial Flight-path Angle (deg)	Inertial Azimuth Angle (deg)	RCS Fuel (lb)	DPS Fuel (lb)	OGA (deg)	IGA (deg)	MGA (deg)
Simulation initialized	16,402.383	1,001,109	30.977	-135.756	25,287.521	0.345	82.556	585.0	16,756	129.4	34.4	-7.2
Command DPS engine off	16,402.395	1,001,111	30.977	-135.755	25,287.518	0.345	82.557	585.0	16,756	129.4	34.4	-7.2
Schedule MP11	16,402.403	1,001,112	30.977	-135.754	25,287.517	0.345	82.557	585.0	16,756	129.4	34.4	-7.2
Turn DAP on	16,407.414	1,001,920	31.020	-135.392	25,286.608	0.344	82.754	585.0	16,756	129.4	34.4	-7.2
Start MP11	16,424.426	1,004,627	31.155	-134.162	25,283.562	0.338	83.424	585.0	16,756	129.4	34.4	-7.2
Enter major mode 32 pre-DPS2	16,424.428	1,004,627	31.155	-134.162	25,283.561	0.338	83.424	585.0	16,756	129.4	34.4	-7.2
Finish orbital integration	16,425.752	1,004,835	31.165	-134.066	25,283.327	0.337	83.477	585.0	16,756	129.4	34.4	-7.2
Begin attitude maneuver	16,431.119	1,005,675	31.205	-133.677	25,282.379	0.336	83.689	585.0	16,756	129.4	34.4	-7.2
Set minimum deadband	16,432.240	1,005,850	31.213	-133.596	25,282.182	0.335	83.734	585.0	16,756	129.4	34.4	-7.2
Complete attitude maneuver	16,451.460	1,008,799	31.344	-132.200	25,279.649	0.328	84.498	580.9	16,756	59.1	-73.3	-50.0
Enter major mode 42 DPS2 burn-braking	16,542.481	1,021,726	31.730	-125.552	25,264.161	0.294	88.168	577.2	16,756	58.8	-73.8	-50.0
Command DPS engine off	16,542.484	1,021,727	31.730	-125.552	25,264.160	0.294	88.168	577.2	16,756	58.8	-73.8	-50.0
Command +X translation on (4 jet)	16,564.980	1,024,639	31.766	-123.904	25,260.818	0.285	89.083	577.1	16,756	58.8	-74.2	-49.6
Command DPS engine on	16,572.480	1,025,581	31.772	-123.354	25,259.863	0.281	89.383	567.5	16,756	60.3	-72.3	-49.0
Command +X translation off (4 jet)	16,572.980	1,025,644	31.773	-123.317	25,259.743	0.280	89.403	566.8	16,756	60.4	-72.0	-49.0
Start reading PIPA's	16,573.420	1,025,698	31.773	-123.285	25,259.673	0.280	89.421	566.5	16,756	60.6	-71.8	-49.0
Command full throttle	16,598.479	1,028,646	31.776	-121.448	25,257.981	0.253	90.369	565.5	16,649	58.9	-73.1	-47.8
Throttle control regained	16,950.480	1,003,823	30.685	-95.759	25,325.816	-0.238	94.570	561.8	5,427	93.5	-54.2	-39.7
Enter major mode 43 DPS2 burn approach	17,069.594	991,017	29.898	-87.156	25,425.369	-0.197	96.714	561.1	3,318	118.0	-41.7	-35.8
Enter major mode 44 random throttle	17,266.109	978,952	27.936	-73.229	25,409.337	-0.056	100.835	561.0	1,040	143.2	-45.1	-33.7
Command APS engine on	17,318.991	977,167	27.242	-69.564	25,415.574	-0.035	101.749	559.7	0	145.1	-41.8	-36.3
Command +X translation off (4 jet)	17,318.991	977,167	27.242	-69.564	25,415.573	-0.035	101.749	559.7	0	145.1	-41.8	-36.3
Enter major mode 74 FITH/APS1	17,319.012	977,166	27.242	-69.562	25,415.504	-0.035	101.749	559.7	0	145.1	-41.8	-36.3
DPS engine arm off	17,320.009	977,138	27.228	-69.494	25,414.904	-0.034	101.758	558.4	0	145.9	-40.5	-32.3
Command APS engine off	17,324.010	977,026	27.174	-69.218	25,413.293	-0.031	101.793	557.6	0	146.6	-40.4	-36.3
Command DPS engine off	17,324.012	977,026	27.174	-69.218	25,413.291	-0.030	101.793	557.6	0	146.6	-40.4	-36.3
DV monitor detects engine shutdown	17,329.559	976,876	27.098	-68.836	25,413.480	-0.029	101.974	557.2	0	145.3	-42.9	-36.9
Terminate AVERAGE-G routine	17,359.561	976,105	26.665	-66.779	25,414.121	-0.022	102.958	557.1	0	145.3	-40.8	-35.8
Set maximum deadband	17,359.561	976,105	26.665	-66.779	25,414.121	-0.022	102.958	557.1	0	145.3	-40.8	-35.8
Schedule MP13	17,359.564	976,105	26.665	-66.779	25,414.121	-0.022	102.958	557.1	0	145.3	-40.8	-35.8
Enter major mode 0 LGC idling	17,361.646	976.054	26.634	-66.637	25,414.161	-0.022	103.025	557.1	0	145.1	-40.9	-35.8
Set maximum deadband	17,361.651	976.054	26.634	-66.636	25,414.161	-0.022	103.025	557.1	0	145.1	-40.9	-35.8

Run 44 Phase Summary; DPS2/FITH/APS1 Burn

Phase	Unit	Value	GET (sec)
ATTITUDE MANEUVER SUMMARY			
RCS jet firings		57	
RCS jet firing on-times	sec	9.345	
RCS fuel consumption	lb	4.1678	
Maximum body rates	deg/sec	0.3233, yaw -1.0420, pitch 4.8245, roll	16,451.460 16,451.460 16,451.460
Total time of maneuver	sec	20.340	
BURN SUMMARY			
Start of ullage maneuver			16,564.980
Time duration of ullage maneuver	sec	8.000	
Start of burn			16,572.480
Length of burn	sec	753.076	
Thrust maximum	lb	10,093.74	16,757.599
Thrust minimum	lb	1283.00	16,575.557
Maximum acceleration	fps/sec	18.9895	17,319.012
Main engine fuel consumption	lb	16,756.13	

Run 44 Phase Summary; DPS2/FITH/APS1 Burn (Continued)

Phase	Unit	Value	GET (sec)
RCS fuel consumption	lb	19.5	
Time of engine-off command			17,324.101
Time after engine shutdown until DV monitor first shutdown	sec	1.546	
Maximum body rates	deg/sec	0.1679, yaw 2.1567, pitch -2.5801, roll	
Position vector at thrust termination (ECI)	ft	17,304,717 8,993,679 9,938,330	
Velocity vector at thrust termination (ECI)	fps	-9,380.085 23,156.328 -4,652.150	
Maximum torque on vehicle	ft-lb	3,908.5707	17,319.012
Initial gimbal angles of main engine	deg	-0.3177, yaw 2.3151, pitch	
Final gimbal angles of main engine	deg	-0.462, yaw 2.462, pitch	

RUN 45 TEST RESULTS SUMMARY

Test Run Description

The LGC state vector is perturbed from the nominal APS2 environment initialization (Ref 11) and combined with IMU errors (same as run 21), throughout mission phase 13. The burn is followed by an uplink of a state vector update.

Test Run Objectives

To determine the combined effect of state vector errors and IMU errors through APS2 and to verify a state vector update to the LGC.

Summary of Test Results

The flight software for LM-1 programs 34 and 46 has been successfully exercised for three-sigma IMU errors in mission phase 13 initialized with an LGC state vector error from the nominal. An uplink of a state vector update has been successfully performed following the APS2 burn.

Discussion of Test Results

The perturbed case was run through the APS2 burn and a guidance cutoff was acheived with 239 pounds of APS propellant remaining. At the conclusion of the burn the perturbation of run 45 imposed an error of 13.6 nautical miles in apogee and -33.0 nautical miles in perigee from the nominal ICS run 7. The minimum perigee during the burn was 43 nautical miles. The miss from the intercept target was 72.2 nautical miles. A target miss of this magnitude suggests that a state vector update prior to the APS 2 burn is very desirable.

A state vector update of the LGC was achieved for 24,000 seconds when a state vector was successfully uplinked within the resolution of the flight computer word length.

The errors generated through mission phase 13 resulting from the IMU errors and the initial state vector error resulted (as seen in the trajectory summary) in a LGC/environment velocity error of 30.16 feet per second as compared with 0.01 feet per second in the nominal ICS run 7.

RUN 45 TRAJECTORY SUMMARY

The following are trajectory deviations with respect to the nominal ICS test run 7 just after engine off at 22, 860 seconds GET.

	Dispersions from ICS Nominal after Engine Cutoff
Altitude	15, 574 ft
Latitude	-0. 0196 deg
Longitude	0. 0047 deg
Inertial velocity	-526 fps
Inertial flight-path angle	0. 3838 deg
Inertial azimuth	0. 9376 deg
Apogee	82, 634 ft 13. 6 n mi
Perigee	-200, 424 ft -33. 0 n mi
Period	-0. 3641 min
Semi-major axis	-58, 895 ft
Inertial longitude of ascending node	-1. 9615 deg
True anomaly	-27. 6239 deg
Inclination	-0. 0064 deg

The following are deviations in the LGC and environment state vector before and after the APS2 burn.

Parameter	Begin AVERAGE-G Before Burn	End AVERAGE-G After Burn
Time	22, 387 sec	22, 875 sec
ΔX	141, 106 ft	10, 432 ft
ΔY	-251, 385	215, 727 ft
ΔZ	-234, 201 ft	-277, 705 ft
$\Delta \dot{X}$	-247 fps	281 fps
$\Delta \dot{Y}$	8 fps	-152 fps
$\Delta \dot{Z}$	1 fps	18 fps
ΔVMAG	0. 27 fps	30. 16 fps

An uplink of a state vector update was achieved for the time 24, 000 seconds GET.

Run 45 Event Summary, APS1 Burn

Mission Event	GET (sec)	Altitude (ft)	Geodetic Latitude (deg)	Longitude (deg)	Inertial Velocity (ft/sec)	Inertial Flight-path Angle (deg)	Inertial Azimuth Angle (deg)	RCS Fuel (lb)	APS Fuel (lb)	OGA (deg)	IGA (deg)	MGA (deg)
Simulation initialized	22, 200. 000	1, 039, 264	27. 711	-132. 841	25, 341. 690	-0. 105	81. 618	585. 0	5, 007	97. 9	-43. 8	-38. 3
Hold vehicle attitude	22, 200. 031	1, 039, 263	27. 711	-132. 839	25, 341. 691	-0. 105	81. 620	585. 0	5, 007	97. 9	-43. 8	-38. 3
Hold vehicle attitude	22, 205. 031	1, 039, 080	27. 759	-132. 491	25, 341. 933	-0. 105	81. 791	585. 0	5, 007	97. 9	-43. 8	-38. 3
Start MP13	22, 245. 059	1, 037, 604	28. 107	-129. 691	25, 343. 857	-0. 102	83. 177	585. 0	5, 007	97. 9	-43. 8	-38. 3
Enter program 34 pre-APS2 burn	22, 245. 061	1, 037, 604	28. 107	-129. 690	25, 343. 857	-0. 102	83. 177	585. 0	5, 007	97. 9	-43. 8	-38. 3
Begin attitude maneuver	22, 251. 044	1, 037, 381	28. 154	-129. 270	25, 344. 143	-0. 102	83. 387	585. 0	5, 007	97. 9	-43. 8	-38. 3
Complete attitude maneuver	22, 253. 777	1, 037, 280	28. 174	-129. 078	25, 343. 830	-0. 101	83. 483	584. 5	5, 007	103. 4	-34. 5	-37. 0
Enter program 46 APS2 burn	22, 385. 060	1, 032, 320	28. 810	-119. 779	25, 350. 403	-0. 091	88. 177	582. 6	5, 007	103. 8	-33. 6	-36. 6
Start reading PIPA's	22, 385. 069	1, 032, 320	28. 810	-119. 778	25, 350. 403	-0. 091	88. 177	582. 6	5, 007	103. 8	-33. 6	-36. 6
Command +X translation RCS ullage	22, 402. 557	1, 031, 650	28. 841	-118. 533	25, 351. 204	-0. 090	88. 811	582. 4	5, 007	103. 7	-33. 9	-36. 7
Command APS engine on	22, 415. 057	1, 031, 169	28. 855	-117. 642	25, 349. 678	-0. 089	89. 230	563. 0	5, 007	104. 4	-33. 5	-36. 7
Command RCS ullage off	22, 415. 557	1, 031, 149	28. 855	-117. 606	25, 349. 54	0. 089	89. 246	562. 2	5, 005	104. 4	-33. 5	-36. 6
Command APS engine off	22, 836. 299	1, 041, 928	28. 640	-87. 843	25, 218. 519	0. 480	90. 057	508. 3	241	61. 8	-33. 6	-34. 1
Hold vehicle attitude	22, 836. 300	1, 041, 928	28. 640	-87. 843	25, 218. 520	0. 480	90. 057	508. 3	241	61. 8	-33. 6	-34. 1
End of tail-off	22, 839. 213	1, 042, 541	28. 639	-87. 637	25, 218. 092	0. 478	90. 154	508. 2	239	60. 7	-34. 7	-34. 6
Terminate reading PIPA's	22, 873. 219	1, 049, 508	28. 609	-85. 234	25, 209. 987	0. 458	91. 370	508. 0	239	69. 7	-26. 2	-31. 0
Hold vehicle attitude	22, 875. 310	1, 049, 925	28. 606	-85. 086	25, 209. 502	0. 456	91. 445	508. 0	239	69. 3	-26. 2	-31. 1

Run 45 Phase Summary; APS2 Burn

Phase	Unit	Value	GET (sec)
ATTITUDE MANEUVER SUMMARY			
RCS jet firings		10	
RCS jet firing on-times	sec	1.000	
RCS fuel consumption	lb	0.4849	
Maximum body rates	deg/sec	-0.1014, yaw	22,253.777
		0.1408, pitch	22,253.777
		-4.9408, roll	22,253.777
Total time of maneuver	sec	2.733	
BURN SUMMARY			
Start of ullage maneuver			22,402.557
Time duration of ullage maneuver	sec	13.000	
Start of burn			22,415.057
Length of burn	sec	424.156	
Thrust maximum	lb	3,500.00	
Thrust minimum	lb	3,500.00	
Maximum acceleration	fps/sec	20.7548	22,836.300
Main engine fuel consumption	lb	4,767.95	

Run 45 Phase Summary; APS2 Burn (Continued)

Phase	Unit	Value	GET (sec)
RCS fuel consumption	lb	74.1	
Time of engine-off command	sec	22,836.299	
Maximum body rates	deg/sec	-0.1890, yaw -0.3290, pitch 1.7982, roll	

RUN 53 TEST RESULTS SUMMARY

Test Run Description

A DPS1 burn simulation initialized with a trajectory state vector dispersion giving a low perigee.

Test Run Objectives

To test the guidance performance with a large dispersion in the initial orbit before the DPS1 burn. The initial perigee was 81. 9 nautical miles as opposed to the nominal of 95. 5 nautical miles.

Summary of Test Results

The DPS1 guidance equations were not able to attain the final desired apogee.

Discussion of Test Results

The final apogee was 2. 03 nautical miles higher than the nominal test case. The final perigee was 8. 02 nautical miles lower than the nominal test case.

RUN 53 TRAJECTORY SUMMARY

The following trajectory parameters were initialized for the nominal test case and for this trajectory dispersion test case:

Initialization	Nominal	Dispersed
Altitude	119.579 n mi	116.391 n mi
Latitude	-30.9106 deg	-30.842 deg
Longitude	83.2511 deg	83.386 deg
Inertial velocity	25,464.96 fps	25,467.809 fps
Inertial flight-path angle	-0.0745 deg	0.223 deg
Inertial azimuth	82.245 deg	82.000 deg
Apogee	121.226 n mi	121.5 n mi
Perigee	95.546 n mi	81.9 n mi

Following the DPS1 burn to raise the perigee of the orbit, the following trajectory parameters were observed:

Altitude	115.876 n mi	109.077 n mi
Latitude	-25.23 deg	-25.155 deg
Longitude	107.37 deg	107.238 deg
Inertial velocity	25,626.79 fps	25,661.961 fps
Inertial flight-path angle	0.0117 deg	0.006 deg
Inertial azimuth	70.0796 deg	70.007 deg
Apogee	179.029 n mi	177.0 n mi
Perigee	117.620 n mi	109.6 n mi

RUN 32A TEST RESULTS SUMMARY

Test Run Description

LGC Clock Alignment

1) Align the LGC clock to a specific value.

2) Increment the LGC clock by a specific amount.

3) Decrement the LGC clock by a specific amount.

This test was performed during the coast period of nominal run number 7 prior to initiating mission phase 13.

Test Run Objectives

To test the ability of the LGC to accept a specific value of uplink clock alignment and increment data.

Summary of Test Results

Test results show that the LGC is capable of accepting specific clock alignment data and is capable of being incremented and decremented via uplink.

Discussion of Test Results

The following table describes the results obtained during testing.

Test	GET (sec)	Action	LGC Clock at 22, 216. 00 Seconds GET	Error (sec)
Clock Alignment	22, 214. 30	Input 222. 20 sec LGC time at 22, 214. 30 simulation time	223. 89	-0. 01
Increment	22, 214. 00	+6. 00	22, 222. 00	0. 00
Decrement	22, 214. 00	-6. 00	22, 210. 00	0. 00

RUN 32B TEST RESULTS SUMMARY

Test Run Description

Testing of the DFI-TLM calibrate command.

Test Run Objectives

To test the ability to initiate the LGC DFI-TLM calibrate routine via uplink.

Summary of Test Results

Test results show that the LGC is capable of initiating the DFI-TLM calibrate routine when commanded via uplink.

Discussion of Test Results

Verb 66 ENTER was sent by uplink at 22, 213. 3 seconds GET, during the coast period prior to mission phase 13. At 22, 213. 3434 seconds GET, the LGC issued the LMP command for DFI-TLM calibrate on. At 22, 225. 3434 seconds GET, the LGC issued the LMP command for DFI-TLM calibrate off.

The following table describes the results obtained during the testing.

GET (sec)	Action	Comment
22, 213. 3	VERB66 ENTER	Uplink to initiate DFI-TLM calibrate routine
22, 213. 3434	LMP236	DFI TLM calibrate on
22, 225. 3434	LMP237	DFI TLM calibrate off
22, 225. 4634	LMP198	Master C&W alarm reset

RUN 32C TEST RESULTS SUMMARY

Test Run Description

Testing the uplink of LGC-LMP commands.

Test Run Objectives

To test the ability of the LGC to accept LMP commands via uplink.

Summary of Test Results

Test results showed that the LGC is capable of sending single LMP commands when ordered to do so via uplink.

Discussion of Test Results

Verb 67 ENTER 206 ENTER VERB 33 ENTER was sent via uplink at 22, 231. 1 seconds GET, during the coast period prior to mission phase 13. The LGC issued the LMP command 13410 (206_8) at 22, 231. 2234 seconds GET. The following table describes the results obtained during the testing.

GET (sec)	Action	Comment
22, 230. 3	VERB 67 ENTER	Single LMP command
22, 230. 7	206_8 ENTER	Engine select - APS arm
22, 231. 1	VERB 33 ENTER	Proceed
22, 231. 2234	LMP command 134_{10}	LMP $134_{10} = 206_8$

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RUN 32D/32E TEST RESULTS SUMMARY

Test Run Description

Update of mission timers and update of mission phase registers.

Test Run Objectives

To test the ability of the LGC to accept updates for mission phase registers and mission phase timer via uplink.

Summary of Test Results

The test showed that the mission phase to be run and the time when it is to start may be updated by use of uplink.

Discussion of Test Results

The following is the schedule of mission phase timer and mission phase register testing.

0	5	25	30	50	55	75	80	85	90	100	105	110	Time from Start of Test (sec)
T_0	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	

T_0 Schedule MP9 to occur in 10 seconds

T_1 Update mission timer with a DELTAT of 15 seconds via uplink

T_2 MP9 occurs, schedule MP11 to occur in 10 seconds

T_3 Update mission timer with a DELTAT of 15 seconds via uplink

T_4 MP11 occurs, schedule MP13 to occur in 10 seconds

T_5 Update mission timer with a DELTAT of 15 seconds via uplink

T_6 MP13 occurs, schedule MP9 to occur in 10 seconds

T_7 Update mission phase register via uplink to cause MP11 to occur

T_8 MP11 occurs, schedule MP13 to occur in 10 seconds

T_9 Update mission phase register via uplink to cause MP9 to occur

T_{10} MP9 occurs, schedule MP11 to occur in 10 seconds

T_{11} Update mission phase register via uplink to cause MP13 to occur

T_{12} MP13 occurs, end of test

RUN 32G TEST RESULTS SUMMARY

Test Run Description

Testing of Function Inhibit

This test was performed during the coast period prior to mission phase 8 (RCS cold soak), which was scheduled to start at 22, 215. 0 seconds GET.

Test Run Objectives

To test the ability of the LGC to respond to an inhibit function sent via uplink and to inhibit RCS cold soak.

Summary of Test Results

Test results show that the LGC is capable of inhibiting functions when commanded to do so via uplink.

Discussion of Test Results

The inhibit function (VERB73ENTER2ENTER) was sent via uplink at 22, 213. 9 seconds GET which resulted in mission phase 8 being inhibited.

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RUN 321 TEST RESULTS SUMMARY

Test Run Description

MP9, 11, and 13 Target Updates

Mission phase 13 was scheduled at a large ΔT so as to allow time to complete the update of all three sets of target parameters. Each set of target parameters was checked in EMEMORY to insure correct uplink.

Test Run Objectives

To test the ability of the LGC to accept target updates via uplink.

Summary of Test Results

Target update was successfully uplinked by using VERB75 along with the appropriate target update information.

Discussion of Test Results

The following numerical results were obtained in the test.

Initialization:

Mission Phase	GET (sec)	Parameter	E-Memory Value
MP9	22, 200.	RP	77777 77777
MP11	22, 200.	CPT6/2	77777 77777 77777 66666 77777 77777
MP13	22, 200.	R1VEC	75050 60775 72405 50143 76632 45240
		TINT	00227 12470
		RCO	06301 16557

Uplink:

Mission Phase	GET (sec)	Parameter	E-Memory Value	Uplink Value
MP9	22, 220.	RP	22222	22222
			44444	44444
MP11	22, 230.	CPT6/2	11111	11111
			33333	33333
			55555	55555
			77777	77777
			22222	22222
			44444	44444
MP13	22, 213.	R1VEC	74733	74733
			67377	67377
			72403	72403
			57777	57777
			77164	77164
			57577	57577
		TINT	00222	00222
			17400	17400
		RCO	06275	06275
			27000	27000

RUN 46 TEST RESULTS SUMMARY

Test Run Description

Open-loop simulation of S-IVB coast with a tumble rate greater than 3 degrees per second in mission phase 6, setting TUMBL bit for entrance to program P07 and continued through S-IVB separation.

Test Run Objectives

To validate S-IVB separation will occur with the TUMBL bit set indicating an excessive tumbling condition exists.

Summary of Test Results

The S-IVB separation discrete will be given during program P07 with an excessive tumbling rate; having the TUMBL bit set will not inhibit separation.

Discussion of Test Results

The TUMBL bit was initialized as one, indicating a tumble rate in excess of 3 degrees per second. The simulation was initialized at entrance to program P07. The TUMBL bit is set in mission phase 2 or the first 60 seconds of mission phase 6 in normal operation.

This test case verified that the S-IVB separation discrete will be given during program P07 with the TUMBL bit set to one, indicating a tumble rate in excess of 3 degrees per second prior to the start of mission phase 6 plus 60 seconds.

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RUN 47 TEST RESULTS SUMMARY

Test Run Description

Verb 74 uplink/orbital integration interaction

Test Run Objective

To verify a timing problem with the Verb 74 message.

Summary of Test Results

This run demonstrated an interface discrepancy between the orbital integration routine and the restart routines of the AS-206 flight program. The "enter" of a Verb 74 message, if received while a certain segment of the orbital integration routine is being processed, will result in terminating all succeeding state vector updates. A Verb 74 message was timed so that the problem would occur, and it was verified that the state vector was not updated after the Verb 74 message. A second Verb 74 message was received after determining that the state vector was not updated. This second Verb 74 message rectified the problem by restoring the 9-minute updates.

No problem resulted if the Verb 74 message was received when the orbital integration routine was not active.

Discussion of Test Results

The critical time interval referenced above is approximately 75 milliseconds long and recurs every 9 minutes, during the update of the state vector while in coast flight. The problem is a result of an entry made into group one of the restart table by the orbital integration routine. It is while this group is active that a Verb 74 message will cause a problem.

The "enter" character of the Verb 74 message was timed so that it was received when the instruction at location 07,2501 (BURST116 flight program) was being executed. The Verb 74 message caused a restart to be initiated, and the group one entry of the restart table was processed. The MMAINT routine, which in turn calls the orbital integration routine, was not recalled until a second Verb 74 message was received approximately 600 seconds later. A Verb 74 message was received approximately

30 milliseconds before the setting of the group one entry, and the MMAINT continued to be recalled every second. Failure to recall the MMAINT routine would result in no state vector update.

RUN 47 TRAJECTORY INITIALIZATION SUMMARY

The run was initialized prior to DPS1 during revolution 3.

1) Mission timer 2 initialized at 12,000 seconds.

2) AGC state vector initialized at 11,520 seconds from the AS-206 operational trajectory.

3) Environments state vector initialized from operational trajectory at 12,000 seconds.

4) AGC clock (TIME2) initialized at 12,000 seconds.

5) REFSMMAT computed from local vertical at 12,000 seconds.

6) MASS taken from operational trajectory.

RUN 47 EVENT SUMMARY

1) Program initialized to dump Erasable Memory every pass through routine MMAINT.

2) Orbital integration routine called for state vector update at 12,059.03 seconds.

3) Verb 74 message received at 12,061.63 seconds. Restart initiated.

4) MMAINT routine no longer recalled.

5) State vector not updated at next update time (12,601.63).

6) Verb 74 message at 12,661.0 seconds.

7) MMAINT routine recalled every second.

8) State vector updated at next update time (13,201.0).

9) Run terminated at 13,250.0 seconds.

RUN 49 TEST RESULTS SUMMARY

Test Run Description

Open-loop simulation of mission phase 2 (boost) with cycling through TUMTASK.

Test Run Objectives

To verify that the tumble flag is set correctly for tumble rates less than or greater than 3 degrees per second.

Summary of Test Results

TUMBL (bit 13 of FLAGWRD1) is set correctly to indicate whether or not the vehicle is tumbling about any axis in excess of 3 degrees per second. Sixteen separate angular rate combinations were imposed on the vehicle in this single run.

RUN 50 TEST RESULTS SUMMARY

Test Run Description

Open-loop simulation of mission phase 3 (suborbital abort) with a tumble rate greater than 3 degrees per second.

Test Run Objectives

To validate that separation during mission phase 3 will not be permitted with a tumble rate in excess of 3 degrees per second.

Summary of Test Results

Separation was inhibited during mission phase 3 with the tumble flag set to indicate a tumble rate in excess of 3 degrees per second.

RUN 51 TEST RESULTS SUMMARY

Test Run Description

Open-loop simulation of mission phase 4 (contingency orbital insertion) with a tumble rate greater than 3 degrees per second.

Test Run Objectives

To validate that separation during mission phase 4 will not be permitted with a tumble rate in excess of 3 degrees per second.

Summary of Test Results

Separation was inhibited during mission phase 4 with the tumble flag set to indicate a tumble rate in excess of 3 degrees per second.

RUN 52 TEST RESULTS SUMMARY

Test Run Description

Nominal DPS2/FITH/APS1 burn with a higher than nominal number of passes (100) through the DAP Kalman filter before the trim gimbal will relinquish control to the RCS jet control.

Test Run Objectives

To determine the effect of a larger than nominal value of COUNTBOX upon the DPS2/FITH/APS1 burn. The nominal value is 10.

Summary of Test Results

The sequencing of events from the program P32 (pre-DPS) through the program P74 (FITH/APS1) has been verified with the erasable load quantity (COUNTBOX = 100) ten times the nominal value. The most significant discrepancy was that the RCS fuel consumed was 160. 7 pounds while the nominal consumed only 28. 1 pounds.

Discussion of Test Results

The mission phase 11 event timeline varies only slightly from the nominal test case. However, the final orbit after APS1 has an apogee and perigee 19. 063 nautical miles higher and 0. 839 nautical miles lower than the nominal, respectively. The RCS fuel consumed was 160. 7 pounds compared to the nominal consumption of 28. 1 pounds.

Run 52 Event Summary; DPS2 Burn

Mission Event	GET (sec)	Altitude (ft)	Geodetic Latitude (deg)	Geodetic Longitude (deg)	Inertial Velocity (fps)	Inertial Flight-path Angle (deg)	Inertial Azimuth Angle (deg)	RCS Fuel (lb)	DPS Fuel (lb)	OGA (deg)	IGA (deg)	MGA (deg)
Simulation initialized	16,402.383	1,001,109	30.977	-135.746	25,287.521	0.345	82.556	858.0	16,756	129.4	34.4	-7.2
Command DPS engine off	16,402.395	1,001,111	30.977	-135.755	25,287.518	0.345	82.557	585.0	16,756	129.4	34.4	-7.2
Schedule MP11	16,402.403	1,001,112	30.977	-135.754	25,287.517	0.345	82.557	585.0	16,756	129.4	34.4	-7.2
Turn DAP on	16,407.414	1,001,920	31.020	-135.392	25,286.608	0.344	82.754	585.0	16,756	129.4	34.4	-7.2
Start MP11	16,424.426	1,004,627	31.155	-134.162	25,283.562	0.338	83.424	585.0	16,756	129.4	34.4	-7.2
Enter major mode 32 pre-DPS2	16,424.428	1,004,627	31.155	-134.162	25,283.561	0.338	83.424	585.0	16,756	129.4	34.4	-7.2
Finish orbital integration	16,425.751	1,004,835	31.165	-134.066	25,283.327	0.337	83.477	585.0	16,756	129.4	34.4	-7.2
Begin attitude maneuver	16,440.537	1,007,136	31.272	-132.994	25,280.731	0.332	84.063	585.0	16,756	129.4	34.4	-7.2
Set minimum deadband	16,441.660	1,007,309	31.279	-132.912	25,280.536	0.332	84.108	585.0	16,756	129.4	34.4	-7.4
Complete attitude maneuver	16,460.240	1,010,127	31.398	-131.561	25,278.182	0.324	84.849	581.1	16,756	80.4	-64.4	-37.3
Enter major mode 42 DPS2 burn-braking	16,584.721	1,027,103	31.777	-122.457	25,257.950	0.277	89.886	576.3	16,756	79.9	-65.1	-37.2
Command DPS engine off	16,584.724	1,027,104	31.777	-122.456	25,257.950	0.277	89.886	576.3	16,756	79.9	-65.1	-37.2
Start reading PIPA's	16,601.419	1,029,113	31.773	-121.233	25,255.623	0.270	90.566	576.3	16,756	79.8	-64.7	-37.5
Command +X translation on (4 jet)	16,607.220	1,029,795	31.768	-120.808	25,254.829	0.268	90.802	565.3	16,756	79.7	-64.6	-37.7
Command DPS engine on	16,614.720	1,030,666	31.760	-120.258	25,253.974	0.264	91.102	566.6	16,756	80.2	-63.8	-36.5
Command +X translation off (4 jet)	16,615.220	1,030,724	31.760	-120.222	25,253.873	0.264	91.121	565.9	16,756	80.3	-63.7	36.4
Command full throttle	16,640.719	1,033,578	31.712	-118.355	25,252.660	0.253	92.083	564.7	16,649	79.4	-65.6	-35.9
Throttle control regained	16,962.224	1,037,669	30.169	-95.074	25,213.173	-0.123	95.377	485.5	5,818	100.1	-60.7	-36.3
Enter major mode 43 DPS2 burn approach	17,093.578	1,028,578	29.175	-85.712	25,383.967	-0.162	97.606	482.1	3,477	133.0	-43.5	-34.7
Enter major mode 44 random throttle	17,292.169	1,018,522	27.025	-71.836	25,363.791	-0.033	101.471	435.5	1,123	132.1	-60.4	-29.9
Command APS engine on	17,344.729	1,016,909	26.302	-68.244	25,397.542	-0.035	102.295	426.3	0	137.2	-46.6	-37.8
Command +X translation off (4 jet)	17,344.730	1,016,909	26.302	-68.244	25,397.542	-0.035	102.295	426.3	0	137.2	-46.6	-37.8
Enter major mode 74 FITH/APS2	17,344.754	1,016,908	26.302	-68.243	25,397.542	-0.035	102.296	426.3	0	137.2	-46.6	-37.8
DPS engine arm off	17,345.749	1,016,879	26.288	-68.175	25,394.099	-0.034	102.309	426.0	0	138.5	-44.5	-35.3
Command APS engine off	17,349.750	1,016,767	26.231	-67.903	25,398.836	-0.030	102.377	424.7	0	138.0	-45.9	-38.0
Command DPS engine off	17,349.752	1,016,767	26.231	-67.903	25,398.837	-0.030	102.337	424.7	0	138.0	-45.9	-38.0
DV monitor detects engine shutdown	17,355.552	1,016,611	26.148	-67.508	25,399.221	-0.028	102.517	424.5	0	138.2	-46.3	-38.8
Terminate average g routine	17,385.550	1,015,858	25.698	-65.479	25,399.801	-0.020	103.457	424.3	0	137.0	-47.5	-37.2
Set maximum deadband	17,385.551	1,015,858	25.698	-65.479	25,399.801	-0.020	103.457	424.3	0	137.0	-47.5	-37.2
Schedule MP13	17,385.553	1,015,858	25.698	-65.479	25,399.801	-0.020	103.457	424.3	0	137.0	-47.5	-37.2
Schedule MP11	17,385.553	1,015,858	25.698	-65.479	25,399.801	-0.020	103.457	424.3	0	137.0	-47.5	-37.2
Enter major mode 0 LGC idling	17,387.642	1,015,809	25.666	-65.339	25,399.838	-0.019	103.521	424.3	0	137.0	-47.3	-37.5
Set maximum deadband	17,387.647	1,015,809	25.666	-65.338	5,399.858	-0.019	103.521	424.3	0	137.0	-47.3	-37.5

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