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SOLAR SATELLITE PROJECT

INSTRUMENTATION AND FLIGHT PERFORMANCE OF HCO HIGH RESOLUTION WAVELENGTH SPECTROMETER

NASA AEROBEE 4.185 US
NASA CONTRACT NSR-22-007-067

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INSTRUMENTATION AND FLIGHT PERFORMANCE OF HCO HIGH RESOLUTION WAVELENGTH SPECTROMETER

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May 1969

REPORT ON INSTRUMENTATION AND FLIGHT PERFORMANCE
OF HCO-NASA AEROBEE 4.185 US
HIGH RESOLUTION WAVELENGTH SPECTROMETER

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1.0 INTRODUCTION

This report investigates and analyzes the performance of the HCO High Resolution Wavelength Spectrometer and the BBRC SPC 324 D/B Solar Pointing Control on NASA Aerobee Flight 4.185 US. Flight evaluation indicates the only system failure to have been in the pointing control. The reasons for this failure are discussed. It is possible, study shows, to prevent future failures of this nature with improved reliability control and more clearly defined lines of authority between Harvard and its subcontractors. An outline of suggested new procedures is enclosed.

2.0 HISTORY

The Aerobee Flight 4.185 US was launched at 16:31 hours UT on September 24, 1968, at White Sands Missile Range. The payload contained the HCO (Harvard College Observatory) high resolution wavelength spectrometer, which utilized the BBRC (Ball Brothers Research Corporation) SPC 324 D/B series solar pointing control (SPC).

3.0 FLIGHT PERFORMANCE

The initial phases of the flight appeared normal with azimuth coarse acquisition as expected. When the nose cone was raised and the instrument was released, it was observed that the pointing accuracy was out of limits, with excursions in both azimuth and elevation great enough to cause the SPC coarse eye system to be alternately enabled and disabled throughout the flight.

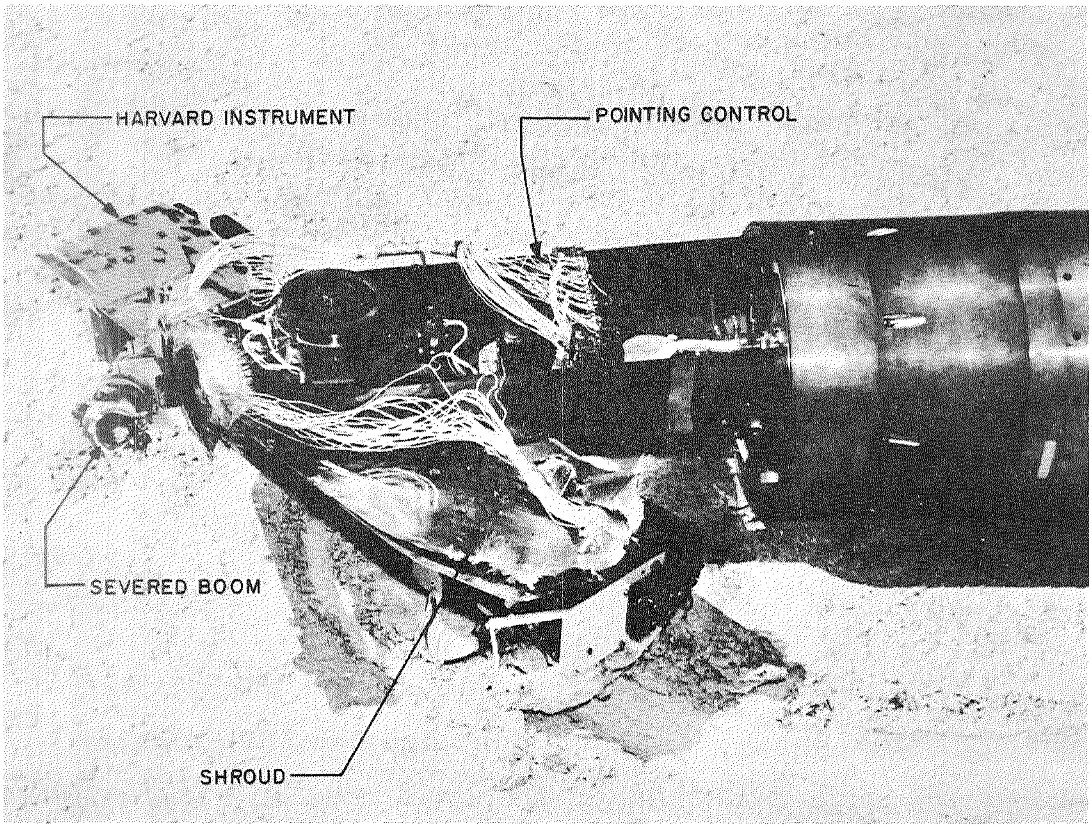
All data indicate perfect operation of the scientific instrumentation. Data was obtained when the pointing control was properly pointing in the "fine eye" mode, that is when the pointing error in elevation was within two arc minutes peak-to-peak (one arc minute either side of the center of the solar disc) and within eight arc minutes peak-to-peak (four arc minutes either side of the center of the solar disc) in the azimuth axis. (cf.

Appendix I for a description of the data collected.)

At the command to restow the instrument and return the nose cone to a down and locked condition, the instrument stowed, but the cone did not drive down.

4.0 INSTRUMENT RECOVERY

The instrument had broken out of the stowed position during reentry, probably on parachute deployment. Because of this, and because the nose cone did not come down, the instrument was subjected to surface heating, buffeting, and desert contamination. The fiberglass thermal shield was burned and ripped away, but the rest of the instrument exhibited very little damage when it was brought back to the Navy Headquarters building after the shot. The instrument will be refurbished and relaunched. (Figure 1 shows two views of the instrument at the recovery site.)



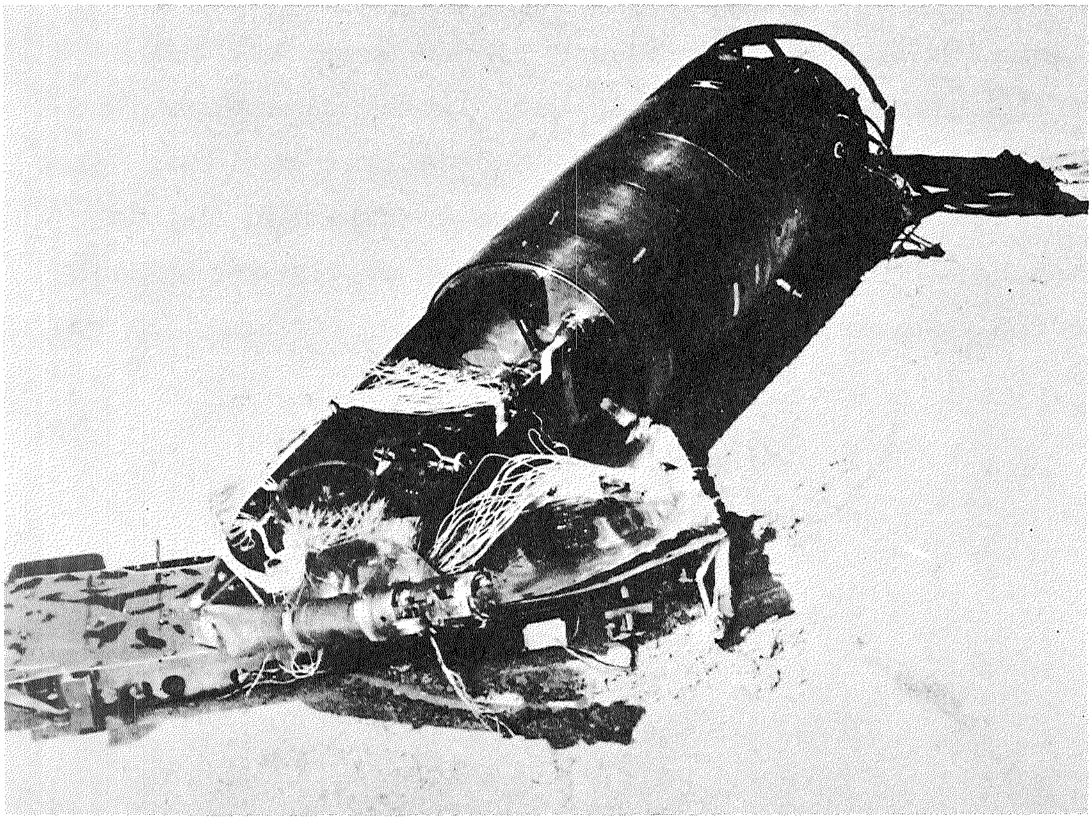


FIGURE 1 —INSTRUMENT AT RECOVERY

5.0 FAILURE ANALYSIS

Flight evaluation shows the only system failure to be in the pointing control. The cause of the failure was an improper assembly of the pointing control battery pack, which powers the control, when one cell was physically reversed.

The battery pack is composed of 20 Yardney HR-3 silvercells with a nominal battery voltage of 30 volts. With one cell reversed, the battery had a maximum voltage of 27 volts.

A review of the evidence indicates that the one cell was reversed after the horizontal test, and this reversal was not detected by the remaining preflight checks. During the horizontal test the battery pack is laid on its side making possible acid leakage. Therefore, after checks the battery cells are taken apart and the whole assembly cleaned. When the battery pack was reassembled it was not checked. The positive terminals should have been colored red, so than an obvious check could have been made.

The battery took a charge of 40.5 volts after the cleaning. It operated properly through the vertical checks, and was recharged. An open circuit check of voltage again read 40.5 volts. The battery pack plateau voltage is approximately 30 volts, and the peak "peroxide" level voltage is 37.5 volts. Thus the battery was overcharged.

The final preflight check of the battery was run at T-30 by the BBRC engineer. This check is made by recycling (i.e., charging and discharging) the battery for two minutes. The end voltage was read at 28 volts. (This is compared to a nominal battery voltage of 30 volts.) The engineer concluded that the battery acted like a "cold battery" and the pack was not inspected.

This conslusion was a mistake in judgment, since the rocket was in a controlled room at 60°F on the tower. In the past, before the controlled room was added, lower temperatures early in the morning were not usual, i.e., $\approx$ 30°F. An inspection of the battery pack should have been made at this point.

BBRC claims that the vibrations caused by the spin rate of the rocket affected the pointing control. Preflight ground tests had determined that the maximum nose cone motion, or its point of resonance, occurred with a rocket spin rate of 2.4 rps to 2.5 rps. The flight plan called for a spin rate between 1.8 to 2.0 rps.

Flight data show the rocket spin rate to have been 2.5 rps after burnout, 2.0 rps after yo-yo release, and finally 2.48 rps after the apron stage was despun. Therefore, near maximum nose cone motion was encountered.

However, had the battery been properly wired, the pointing control would have helped to damp the vibration of the cone. This would have improved the pointing.

BBRC indicates that another reason for the increased cone motion might have been the introduction of an offset between the vehicle spin axis and the payload. Performance tests at BBRC show that the major cause of offset has been misalignment between the payload sections aft of the pointing control. The responsibility for the alignment of the payload sections rests with NASA.

The servo-system's capacity to cope with the instrument's moment of inertia was questioned. Experiments indicated however, that the pointing control can handle the instrument.

The increased vibration, caused by the spin rate, loosened three yoke pins connecting the lift rod to the body of the upper section. Mr. Ralph Shook of BBRC believes that the nose cone would have restowed if the yoke pins had not loosened. This opinion is based on the fact that the restow mechanism will work for voltages as low as 15 volts. Two of the pins were driven out. The third pin was driven in so far that the lift rod came down on it when the command to restow was given. Therefore, it was impossible for the nose cone to restow.

6.0 CONCLUSIONS AND FUTURE PROCEDURES

The primary fault for the failure must lie with the technician responsible for assembling the battery pack following the horizontal test. However, the responsibility to prevent this kind of error lies with the overall organization.

The key problem was that the reliability control over the assembly of the pointing devices was not sufficient. It should have been at least equal to the reliability policy applied to the scientific instrument. Control for the instrument is with HCO, and BBRC should provide a similar independent control of the SPC system.

Analyses of the flight indicate that there were four major reasons for failures:

(1) The improper assembly and inspection of the pointing control;

(2) An inadequate procedure for checking systems;

(3) Excessive vibration caused by rocket spin rate;

(4) The loosening of three yoke pins.

In order to improve the chances for the success of future missions using the BBRC pointing control, these situations must be corrected. The following plans have been made to accomplish the necessary corrections:

1) To assure a proper assembly, an assembly check list has been agreed upon. At each step in the assembly operation the check list must be cosigned by two project technicians. This will provide a step by step reliability control over the assembly operation.

2) A new plan has been initiated for evaluating checks carried out after assembly is completed. During the horizontal and vertical tests, the values of all commutator points will be entered on a list. This list specifies the allowable limits for all values. If improper values appear, a fix will be made and the test run again. If the value remains unsatisfactory, the launch will be postponed. This procedure has the advantage of eliminating much of the human decision making at the launch.

3) A complete all-up check will be made at future launches. The payload will be taken out of doors and a complete test of all systems will be made under simulated flight conditions. (This will include vibration tests, in the three axes in flight configuration, conducted indoors.)

4) Excessive vibration caused by rocket spin rate proved a problem during the last flight. Therefore, a different yo-yo despin system will be used on the

next rocket in order to control the spin rate and the vibration. The 30% yo-yo system used on the last flight will be replaced by a 50% yo-yo system.

5) To prevent yoke pins from loosening, the yoke has been redesigned.

6) Lines of authority for the project must continue to be made clear. This will assure reliability control at all levels. Final decision making authority at the launch will rest with the project engineer. However, at all other times, personnel in other organizations, contracting to do work for HCO, will be responsible to the HCO engineers. The responsibility of the HCO engineering staff is to see that all work specifications established by Harvard are fulfilled.

APPENDIX I

Data Received on Aerobee Flight 4.185

A more detailed account of the results from this flight and their scientific implications will appear in papers published in Solar Physics (Parkinson and Reeves, 1969; Gingerich et al, 1969). An abbreviated version of them is presented here.

The output of the photomultiplier-amplifier system was measured both by rate meters and by a quasi-digital system. These outputs and the grating position, as indicated by a shaft encoder, were fed to the rocket telemetry and recorded with universal time at the ground stations at White Sands.

As has been discussed in some length earlier in this report, the bi-axial pointing control operated only intermittently during the flight. However, the time response of the spectrometer detection system was more than sufficient to allow many intensity measurements to be made in the continuum throughout the wavelength range 1400Å to 1875Å from the central portion of the solar disc. In order to extract correct and unambiguous solar intensities from these records strict criteria were applied in selecting the data from the final flight records. These criteria were as follows:

1. The twenty arc minutes long by seven arc seconds wide slit was within ±3 arc minutes of the sun's center as estimated from the pointing control records.

2. An accurate wavelength scale was fitted to the complete record by applying laboratory observations which were taken during the preflight calibration. Intensity measurements were attempted only in regions where expected features could be clearly recognized by reference to the wavelength scale.

3. Data on or possibly involving the wings of emission lines were excluded from the final scientific analysis.

4. Whenever an absorption line was clearly recorded, an estimate was made of the continuum intensity at the top and bottom of the line.

5. Whenever necessary the intensity was corrected for atmospheric absorption by using the results of a computer program devised by Dr. G. Withbroe.

Since a period of 12 milliseconds represents a spectral scan of 0.06Å (1 resolution element) it was necessary to select regions when the pointing was satisfactory for a time sufficient to guarantee that enough good data points were obtained to insure that intensity measurements were not made in an absoprtion or emission line. Therefore, all continuum intensities reported represent regions in which the recorded intensity was approximately constant over at least 3 successive slit widths. As indicated above in Item 4, if an absorption profile was involved, both the maximum and minimum value of the continuum intensity is indicated.

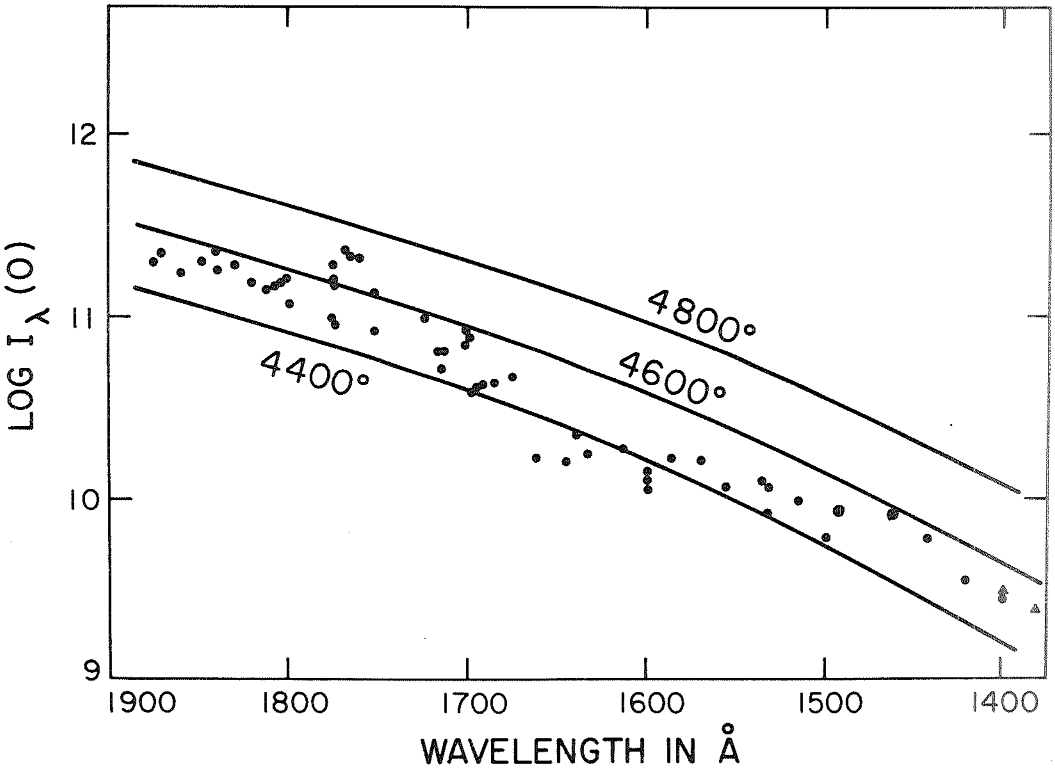


Figure A-1

Figure A-1 shows the data ($\log_{10}$ ergs/cm^2 sec cm steradian) plotted against wavelength. The solid curves represent the values obtained for an equivalent black body of temperature 4400°K, 4600°K, and 4800°K. Included on the graph are two values, indicated by triangles, from our OSO-IV spectrometer-spectroheliometer (Goldberg et al, 1969). It was indeed encouraging to note that at 1400Å, the intensities from both instruments are in substantial agreement.

There is clearly an as yet unexplained discrepancy between our observations and those of the NRL group. Our intensities are in general lower by a factor of 3 than the most current estimate by Whiting and Purcell (1969). In the region of the temperature minimum, this represents approximately 250°K. Corroborative observational evidence for the lower temperature minimum have been reported by Eddy, Lena, and MacQueen (1969). Their airborne observations made around 300 microns yield a brightness temperature of 4300°K.

As a result of these observations from widely separate portions of the solar spectrum, the new lower value for the temperature minimum has been accepted in the formulation of a new model of the Solar Atmosphere by Gingerich and others at Harvard and Smithsonian Observatories. The new model is known as the "Harvard-Smithsonian Reference Atmosphere."

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APPENDIX II

Thoughts on the Failure of Aerobee Flight 4.185

The only system that failed on this flight was the azimuth pointing control. The failure was caused by an improper assembly of the battery pack, which was not detected by the supervisory people in the pointing control group.

The technician responsible for assembling the batteries was newly transferred to the pointing control group. He should not have had the full confidence of his supervisors. Therefore, it is pointless to attribute to him any fault except the misasembly.

Fault for a lack of reliability procedures lies with the supervisory people of the pointing control group, and with the persons responsible for the overall organization of the project.

To some extent, it was Harvard's failure. HCO should have more clearly understood the lines of authority at BBRC for the integrated package (the instrument and the pointing control).

The two elements of the integrated package should have been under the authority of a single person. The reliability control of the instrument was superior to the reliability control of the production and assembly of the pointing control. If a great deal of effort goes into the testing, assembly, and general qualifications of the instrument, the same level of testing supervision of assembly and general qualifications should go into the pointing control. The pointing control group cannot be autonomous. It must be adjusted by the overall project manager to suit the level of sophistication decided upon by the management in conjunction with Harvard.

Harvard does supply the quality control for the instrument. HCO's calibration, determination of resolution, and witnessing of the noise level in the instrument under a variety of conditions are excellent measures of the instrument's reliability. However, HCO cannot serve as a reliability control for the pointing control device, since the HCO staff does not regularly work with servo-mechanisms.

BBRC should provide a person for independent reliability control of the pointing control group. He should report directly to the Project Engineer, who should be in charge of the integrated package. The pointing control group's internal reliability control has proven adequate in the past; however, it proved inadequate for this flight.

The reliability control person, associated with the pointing control should supervise the specifications and tests for the pointing control. The Project Engineer from BBRC, who supervises the whole project, must be at White Sands for the launching. He should reserve for himself that part of the authority which BBRC has in the launch determination. The engineer should be advised by the reliability control person just prior to launch as to whether there should be a hold of the launch.

The quality control person, who advises the Project Engineer, should be aloof from the general pressure of the launch preparations. There is a great deal of momentum built up in the hours and minutes and seconds before the launch. The momentum is very hard to frustrate for those who are immediately involved with the preparations and checks. A quality control person, who has maintained aloofness and objectivity, is in a better position to make the determination to stop that momentum than are the people involved in those preparations.

APPENDIX III

A letter report on instrumentation and flight performance of the Solar Pointing Control SPC 324 D/B, Telemetry System TEL 333, and NASA Aerobee Flight 4.185 US. This report was prepared by Ball Brothers Research Corporation, and has been reprinted here for reference purposes.

November 22, 1968

INTRODUCTION

The Ball Brothers Model SPC 300 D/B solar pointing control was designed and built to provide accurate orientation of scientific instrumentation toward the center of the solar disc during the upper atmospheric portion of an Aerobee sounding rocket flight. This model pointing control provides for maximum instrument protection during reentry and landing by retaining the nose cone in a raised position during instrumentation data acquisition and returning the instrument and nose cone to locked conditions upon completion of data acquisition.

The Ball Brothers Model TEL 300 telemetry system provides FM/FM radio transmission of instrument electronic data outputs, solar pointing control performance data outputs, and vehicle performance data outputs during the rocket flight.

The primary objective of the scientific instrument on board was to obtain solar spectral data in the region of 1400Å to 1900Å using a high resolution Ebert spectrometer in conjunction with an off axis collecting telescope and a continuously scanning grating. The spectral data from the photomultiplier tube was fed through a hybrid digital-analog data system and transmitted to ground receivers via the telemetry system.

HISTORY

Solar Pointing Control SPC 324 D/B and Telemetry System TEL 333 were fabricated and delivered in accordance with Harvard College Observatory purchase order Z-88881 on May 16, 1967.

SYSTEM INTEGRATION

Preliminary integration tests of SPC 324 D/B and TEL 333 with the flight instrument were begun on May 1, 1967.

On May 1st, the eyeblock was fitted to the instrument and the instrument then mated to the pointing control. At this point necessary mechanical adjustments were made to provide proper clearances between the instrument and nose cone. The routing of the interface cabling between the eyeblock, instrument and pointing control was determined and the fabrication of these cables was begun.

On May 2, 1967, the cable fabrication was completed and installed on the instrument. Initial electrical tests were begun with verification that the instrument was operating properly through the pointing control wiring. The pointing control was then operated through its normal sequence and the instrument monitored for any abnormal indications. During these tests it was discovered that excessive noise was introduced into the instrument through the instruments test input connector.

The remainder of the week was spent in isolating noise interference problems. It was finally decided that a means must be devised to open the test pulse input line to the instrument to eliminate the antenna effect of the line.

On May 8th, the pointing control, instrument and telemetry system were all operated to obtain records of the compatability between systems prior to calibration of the instrument. At this point, integration testing was terminated to allow for calibration of the instrument.

Integration testing resumed on August 22, 1968, with random vibration tests of the pointing control and telemetry system. These tests were conducted to fulfill the requirements set forth by the NASA Flight Readiness Review Board at NASA Goddard.

During the week of September 2, 1968, the instrument compartment assembly was attached to the nose cone evacuation system to determine ultimate pressures that could be obtained in the nose cone. These tests also served to remove as much trapped air as possible in the instrument and in general clean the entire instrument compartment and instrument.

On September 6, 1968, integration testing again resumed with a review of instrument, pointing control and telemetry system interfaces. At this time, additional modifications were made to incorporate the use of a yo-yo despin system.

On September 9th, the necessary modifications were completed and the pointing control and telemetry systems were checked to verify proper operation prior to connection of the flight instrument.

On September 10, 1968, the instrument was mated to the pointing control and mechanical interferences were rechecked to assure proper set of the instrument inside the nose cone. Interface cable routing was again checked to the satisfaction of all concerned.

The instrument was operated through the pointing control wiring and it was determined that the instrument was very quiet compared to the tests of May 1967.

On September 11, 1968, the instrument was operated with the pointing control also operating. All electrical interfaces checked properly and the instrument operation was very quiet with virtually no interference caused by the pointing control.

The pointing control was moved outside to run a pointing check and to align the eyeblock pointing axes with the instrument optical axis. Alignment was accomplished, by shimming the eyeblock mounting to an accuracy of better than one quarter arc minute.

The pointing control was moved back into the lab where three instrument restow sequences were run to insure that the instrument would be stowed in the proper position to allow the nose cone to return to the locked position prior to reentry.

On September 12, 1968, various pointing control checks were made which required the instrument. These checks include the determination of nose cone resonance frequency and the pointing control slewing speed. Azimuth coarse acquisition, response, and pointing stability were checked to determine the servo system gains necessary for flight. The afternoon was spent in running checks for noise interference in the instrument using the telemetry readouts, as in flight. Upon completion of these tests, it was determined that all systems were operating well and were ready for a flight simulated performance test.

The performance test was run at about 1100 hours on September 13. The pointing control and telemetry systems operated perfectly; however, it was discovered that the experiment test battery was dead and the instument did not function. It was decided to rerun the performance test at White Sands rather than delay the scheduled shipment that afternoon.

FIELD OPERATIONS

Field testing of solar pointing control SPC 324 D/B and telemetry system TEL 333 with the Harvard flight instrument began at White Sands Missile Range, New Mexico, on September 17, 1968.

The pointing control and telemetry system, with all associated field support equipment, were unpacked and checked for possible shipping damage. The pointing control was assembled, the instrument was installed, and a series of checks were run to assure that all systems were operating properly. The remainder of the day was spent potting various connectors and electronic subassemblies as they were checked for flight readiness.

On September 17th, the pointing control was moved outside on the patio of the Navy Headquarters building for outside pointing checks. These checks included pointing control sensing checks, final determination of the servo system flight gains, and a recheck of the alignment between the instrument optical axis and the eyeblock axis.

On September 18, 1968, additional pointing control and instrument interface tests were run with all systems operating normally. The telemetry system was checked using the NASA telemetry ground station at the Aerobee launch area. These pointing control checks were completed prior to securing each pointing control section for flight.

On September 19, 1968, the pointing control, telemetry system and associated launch support equipment were moved to the launch area for the final phases of testing. The integrated payload was assembled for a flight simulated performance test in the Aerobee prep building. This test was run at 2100 hours using a sun gun as the target.

Although the pointing control operated normally in all other respects, the elevation servo system failed to acquire the target. This problem was a function of the large instrument moment of inertia and the relatively narrow beam width of the gun. Time was allocated for further elevation servo tests the following day to confirm proper operation and the payload was prepared for the horizontal interference test.

The horizontal test was run at about noon on September 20. Initial acquisition of the sun gun was normal in all respects but the elevation servo could be forced into the oscillatory mode of the previous evening by manually forcing the instrument off target at a high rate.

Rocket and payload weight and balance measurements, and payload moment of inertia measurements were made while the horizontal telemetry record was being reviewed for proper operation. The telemetry record disclosed what appeared to be discriminator signal lock loss of the 70 KHz subcarrier oscillator. Since the pointing control was already being prepared for outside pointing tests of the elevation system, the investigation of this telemetry problem was delayed until these checks were complete.

The payload, on the spin table, was wheeled outside for the elevation acquisition tests. With the instrument properly balanced, several normal acquisitions were achieved. After finding it impossible to force the elevation system into the oscillatory mode, all present agreed that the pointing control was operating properly with the real sun.

Attention then shifted to the telemetry problem, which appeared to be random noise spikes with an amplitude that was not coincident with the discrete levels of the quasidigital data. These spikes were not discernable on the portable ground station recording but were evident on playbacks from the NASA "D" van video tape. The 70 KHz SCO bandedges were properly set for data inputs of 0 volts and 5 volts but the instrument quiescent data output was approximately 6 volts. This level was reduced to 5 volts and further telemetry checks showed that the problem was resolved.

It is very doubtful that the data output of 6 volts was solely responsible for the spikes evident on the record. The required data had passed through both the portable ground station and the BBRC ground station without any evidence of spikes. At this time we can only assume that some deficiency existed in the NASA "D" van 70 KHz link at the time of the horizontal recording.

Final pointing control tests and securing procedures were completed on September 21 and 22. The entire payload was installed aboard NASA Aerobee 4.185 US in Tower "B" on the afternoon of September 22, 1968. Pre-vertical checks of the pointing control, telemetry system and instrument were made and the payload was secured to begin the nose cone evacuation.

The vertical interference test was run at 0615 hours on September 23, 1968. All systems operated as expected and preliminary flight preparations were completed prior to final nose cone evacuation pumping for flight.

The BBRC field crew arrived at the launch area for the T-3 hour check at 0715 hours on September 23. Final flight preparations were completed and the launch tower was cleared by 0930 hours for an anticipated launch at 1030 hours.

The countdown progressed smoothly to the launch of NASA Aerobee 4.185 US with SPC 324 D/B, TEL 333 and the Harvard spectrometer at 10 hours, 30 minutes, 59.96 seconds MDT. The initial phases of flight appeared normal with azimuth coarse acquisitions as expected. When the nose cone was raised and the instrument was released, it was observed that the pointing accuracy was very much out of limits with excursions in both azimuth and elevation great enough to cause the coarse eye system to be alternately enabled and disabled throughout the flight. At the command to restow the instrument and return the nose cone to a down and locked condition, the instrument stowed, but the cone made no apparent attempt to drive down.

The telemetered data showed that the pointing control battery was very low, but at this point the cause was unknown.

The payload was quickly recovered and returned to the Navy Headquarters for a quick-look analysis.

FLIGHT PERFORMANCE DATA

The elevation of the flight data showed that the failure of the pointing control to maintain the expected pointing accuracy was due to a combination of circumstances. The major contributor to the failure was the low pointing control battery voltage, which under ideal conditions of rocket roll rate would have provided unstable pointing, but possibly not to the extent seen. Unfortunately, the rocket roll rate was very near the nose cone resonance frequency. This caused excessive forcing functions which, with a low battery, the pointing control could not overcome.

The following tabulated data compares the predicted flight performance parameters with the actual flight performance parameters:

Occurence	Predicted	Actual
Zenith Altitude	113.0 miles	112.0 miles
Roll Rate at Burnout	1.8 rps	2.6 rps
Yo-Yo Despin Initiation	60.0 seconds	59.7 seconds
SPC Servo Operation	73.0 seconds	73.0 seconds
SPC Nose Cone Life	92.0 seconds	91.4 seconds
SPC Restow Command	357.0 seconds	359.2 seconds
First Severance	370.0 seconds	371.2 seconds

The following graphs present information regarding pointing control operation and vehicle performance.

Graph No. 1 is a plot of the NASA accelerator output versus time from lift-off to T + 73 seconds. The data was on a shared telemetry channel which was switched at T + 73 seconds. The output is plotted as telemetered voltage since the transducer calibration was not available at BBRC. It should be also noted that the vehicle sustainer chamber pressure transducer did not operate properly during this flight and therefore no data are available.

Graph No. 2 is a plot of the vehicle roll rate versus time from T + 2.0 seconds to T + 90 seconds. The roll rate of the vehicle at sustainer burnout was 2.60 rps, which was maintained until Yo-Yo despin initiation occurred at T + 59.7 seconds, despinning the vehicle to 2.05 rps. The despin of the upper payload section then increased the vehicle roll rate to the final figure of 2.48 rps.

Graph No. 3 is a plot, contained on three sheets, of various solar pointing control parameters versus time. This graph shows that both azimuth and elevation coarse eyes were able to acquire the sun although the battery voltage was excessively low. The target eye signal intermittently dropped to zero throughout the flight. When the target eye signal is at zero the pointing error is greater than three degrees. At T + 371.2 seconds all telemetry signals were lost when the antenna line was severed with vehicle payload severance.

Graph No. 4 represents the instrument motion in the elevation axis with respect to time. The sinusoidal appearance of the plot is due to the precessional motion of the vehicle which had a cone half angle of 3 degrees and a period of 88 seconds. As the solar elevation angle at launch was 41 degrees, the plot indicates that the vehicle was very nearly aligned with local vertical throughout the flight.

Due to the wide excursions of the pointing control, especially in the azimuth axis, the following tabulated data were obtained showing the points in time, as referenced to launch, where the pointing control was pointing in the fine eye mode. These times are when the pointing error in elevation is within two minutes peak-to-peak (one minute either side of the center of the solar disc) and within eight minutes peak-to-peak (four minutes either side of the center of the solar disc) in the azimuth axis.

TABLE I

Time when pointing within prescribed limits		Duration of pointing in seconds
From	To	
138.48	138.58	0.10
179.51	179.66	0.15
202.47	202.55	0.08
219.01	219.09	0.08
220.51	220.57	0.06
220.62	220.69	0.07
255.62	255.66	0.04
255.71	255.77	0.06
255.90	256.03	0.13
256.32	256.42	0.10
264.29	264.38	0.09
267.16	267.24	0.08
283.13	283.18	0.05
291.06	291.27	0.21
306.55	305.60	0.05
306.73	306.79	0.06
322.31	322.36	0.05
346.50	346.55	0.05
346.69	346.71	0.12

POST FLIGHT ANALYSIS

The payload was located in the vicinity of 4Q Target and Northrup Strip about 40 miles north of the launch tower. The nose cone assembly was located approximately 200 yards east of the parachuted payload. All recovered sections were returned to the Navy Headquarters for post-flight inspection.

The following conditions of the payload were noted during the initial inspection:

A. The nose cone had not restowed and was separated from the pointing control prior to impact.

B. The heat shield on the instrument was missing.

C. The nose cone lift motor was missing

D. The lift support tube had been bent at its base about 70 degrees during reentry or on impact.

E. The instrument had broken out of the stowed position, probably on parachute deployment.

F. There was enough heating during reentry to melt some vinyl tubing, cable clamps, spot ties and soldered electrical connections.

G. There was no evidence of electrical arcing in the pointing control or instrument.

The payload was then moved into a lab for dissambly. The pointing control was taken apart between the electronics section and the agency compartment and the experiment control deck removed. The pointing control battery was removed from the electronics section and it was noted that the battery had boiled over and there was some corrosion in the electronics section due to battery electrolyte.

The battery was examined and one cell was found to be physically reversed. The battery pack is composed of 20 Yardney HR-3 Silvercels with a nominal battery voltage of 30 volts. With the one cell reversed, the battery pack had a maximum voltage of 27 volts. The battery pack had been disassembled and cleaned after the horizontal test due to electrolyte spillage. A review of all evidence and data indicates that one cell was reversed at that time and the reversed cell was not detected during the remaining pre-flight checks.

Examination of the nose cone assembly was made with two items very apparent. The first was that the joint between the lift tube and the upper nose cone casting was loose and the retaining roll pins had worked loose. This joint is assembled as a ring fit and the roll pins maintain position both laterally and longtidunally in the joint. The next point of examination was in the area of the upper casting on the lift support tube. This casting is a shrink fit to the support tube and is held in place with four steel dowel pins. The lift motor with its gear box and pinion gear is attached to this casting. The examination showed that this casting was loose on the support tube and two dowel pins were missing. One of the remaining dowel pins had moved far enough in toward the center of the casting to prevent passage of the nose cone tube when it attempted to drive down.

The nature of the damage and especially the loosening of the nose cone joint and the upper support tube joint showed that the nose cone must have been whipping violently while in the raised position. A correlating factor to this whipping motion was found in the flight data. It was determined during preflight ground tests that maximum nose cone motion, or its point of resonance, occurred with a rocket spin rate of 2.4 to 2.5 rps. From the flight data it was found that the rocket roll rate after the pointing control had acquired the sun was 2.48 rps. Hence, it could be expected that the nose cone motion due to vehicle roll rate was at the maximum.

Another model SPC 300 D/B was tested at White Sands Missile Range to determine the effect of low battery voltage while operating the pointing control at the nose cone resonance frequency. The pointing control behaved normally with a small increase in pointing error as the A+ voltage was dropped to 25 volts but below 25 volts the azimuth servo became marginally unstable. At 24 volts the system was oscillatory divergent and exhibited behavior very similar to SPC 324 D/B during flight. It was also observed during this test that nose cone motion was not materially affected when the pointing control was operated with an abnormally low battery voltage.

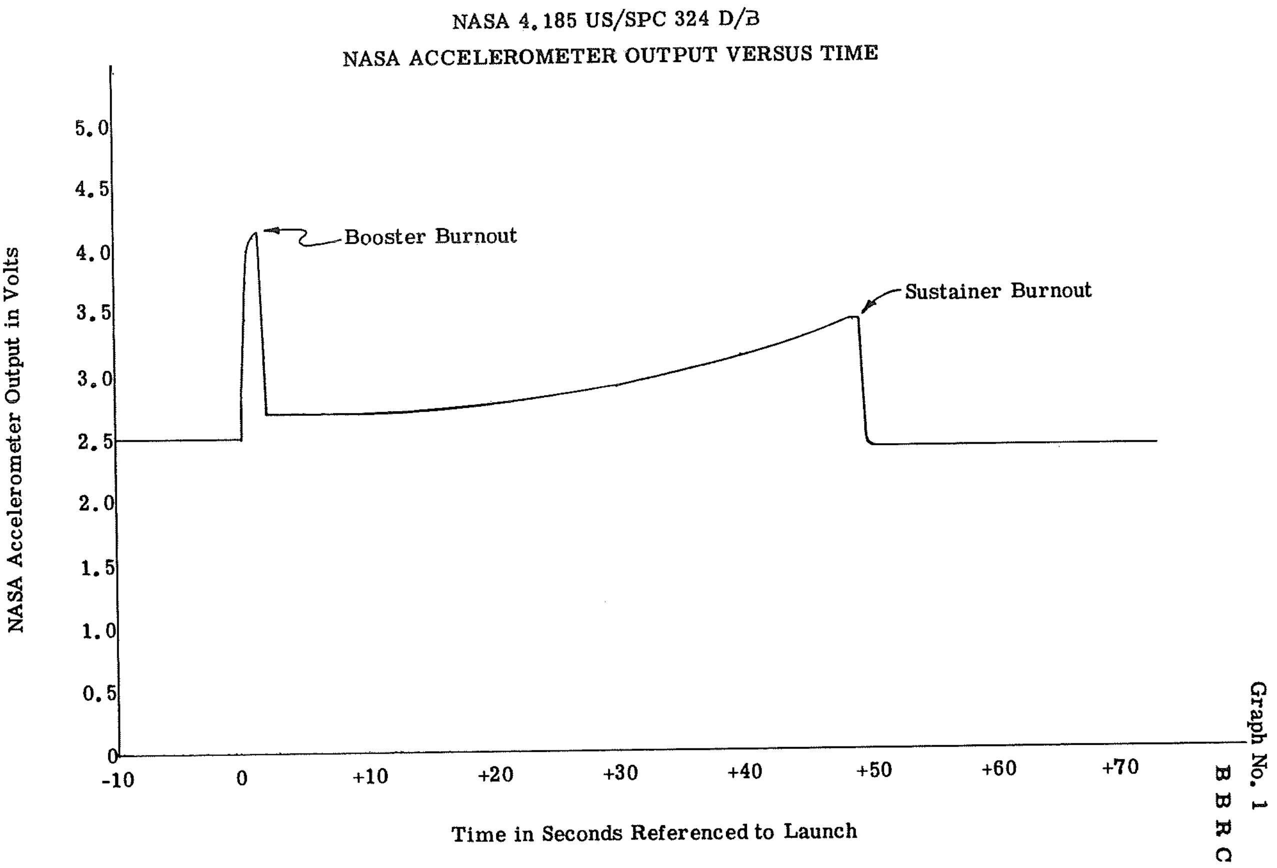
Past pointing control testing has shown that nose cone motion increases with the introduction of an offset between the vehicle spin axis and the pointing control azimuth axis. Two factors exerting an influence on this offset are dynamic unbalance and misalignment below the pointing azimuth joint. Past performance has indicated that misalignment has the greater influence on this offset and nose cone motion.

Further tests of the SPC 300 D/B have shown that the pointing control will operate, with some loss in pointing accuracy, at a spin rate equal to the nose cone resonance frequency but the introduction of an offset significantly increases nose cone motion, especially at the higher spin rates.

CONCLUSIONS

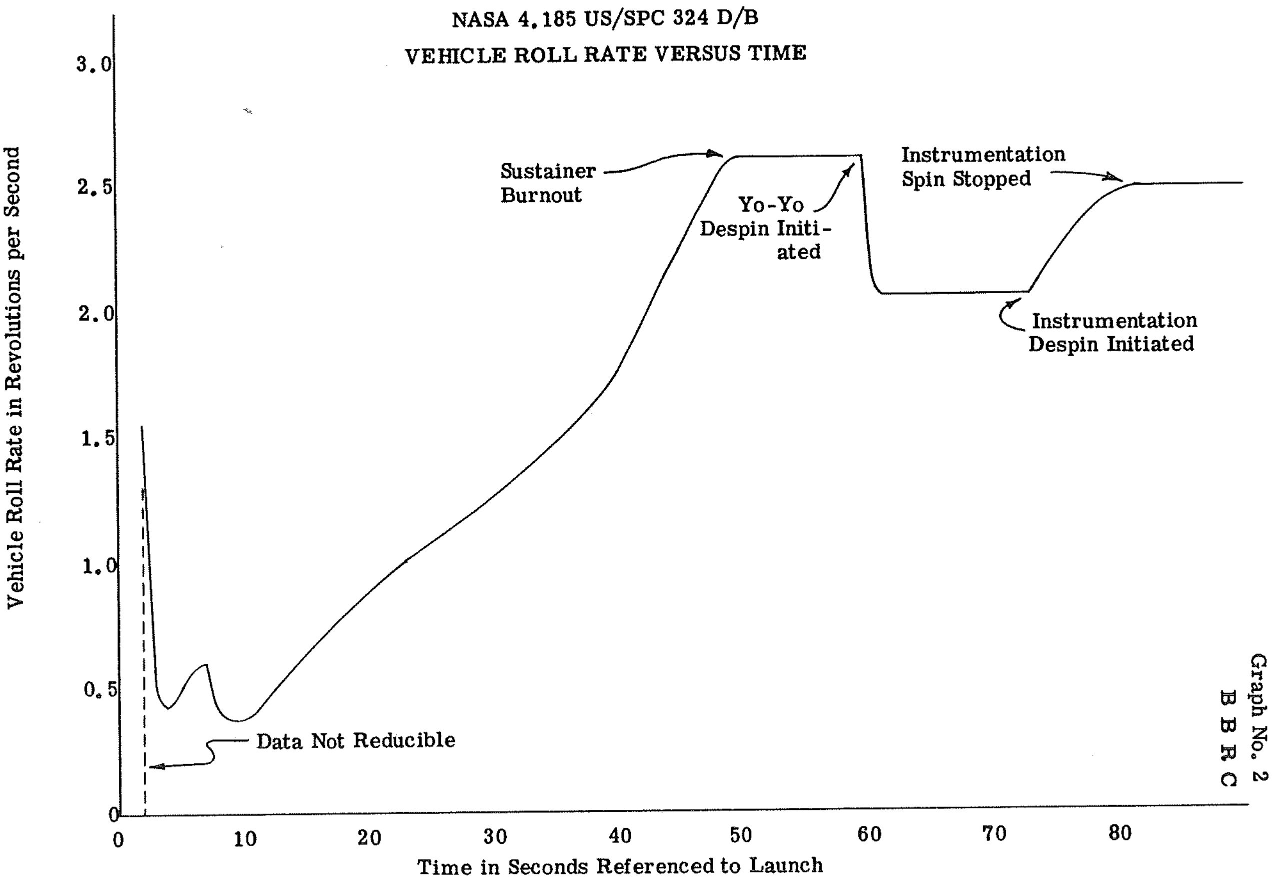
The failure of SPC 324 D/B to point within the anticipated accuracies was directly caused by the reversal of the one cell in the pointing control battery pack.

A secondary problem area which must be rectified concerns vehicle spin rate and misalignment between payload sections aft of the pointing control. It is mandatory that on all future flights more care be exercised to insure alignment between payload sections. Also the vehicle must be despun such that a roll rate of 2.00 rps or less is achieved after the upper section of the pointing control is despun.



NASA 4.185 US/SPC 324 D/B

NASA ACCELEROMETER OUTPUT VERSUS TIME



NASA 4.185 US/SPC 324 D/B

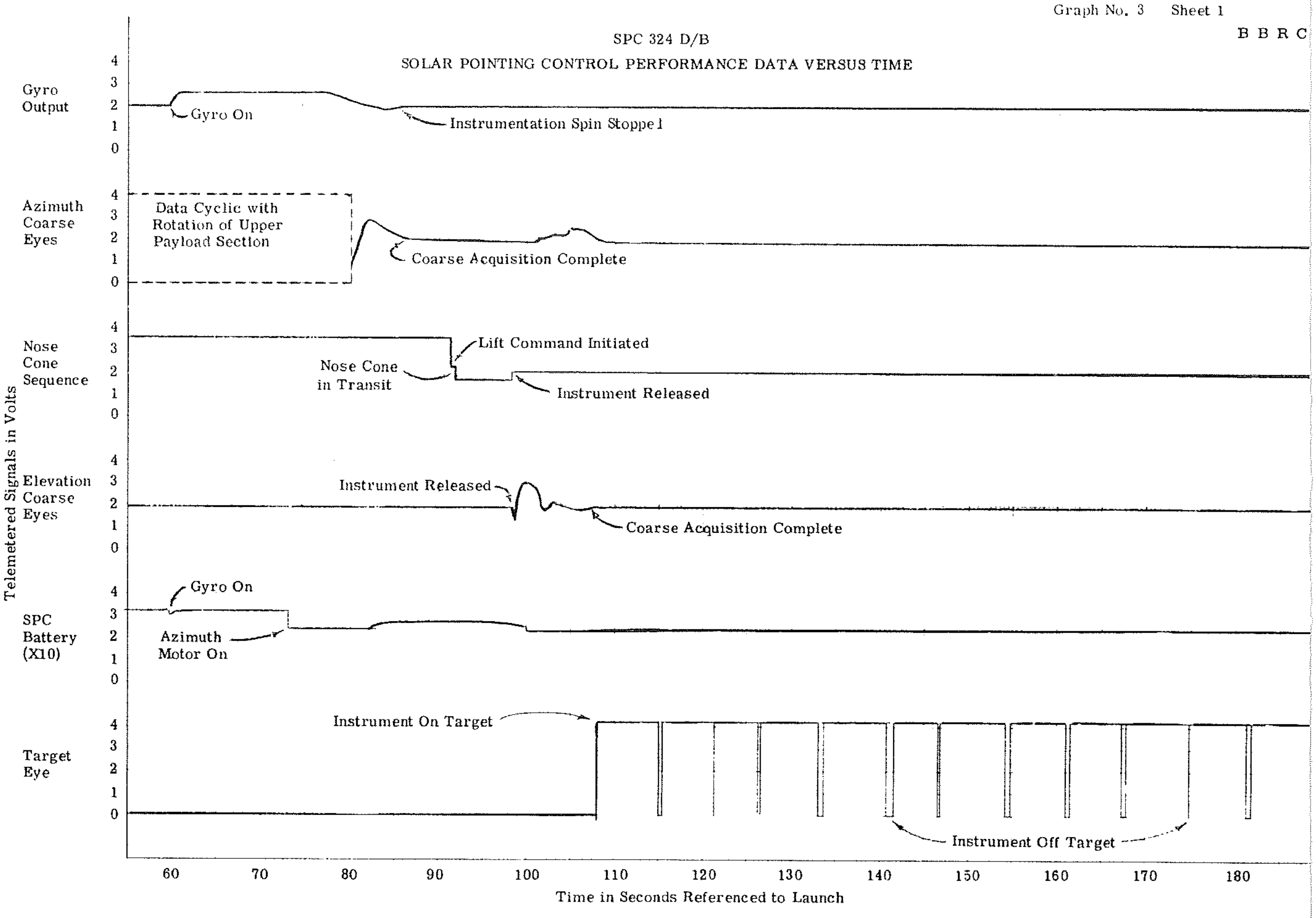
VEHICLE ROLL RATE VERSUS TIME

Graph No. 3 Sheet 1

B B R C

SPC 324 D/B

SOLAR POINTING CONTROL PERFORMANCE DATA VERSUS TIME

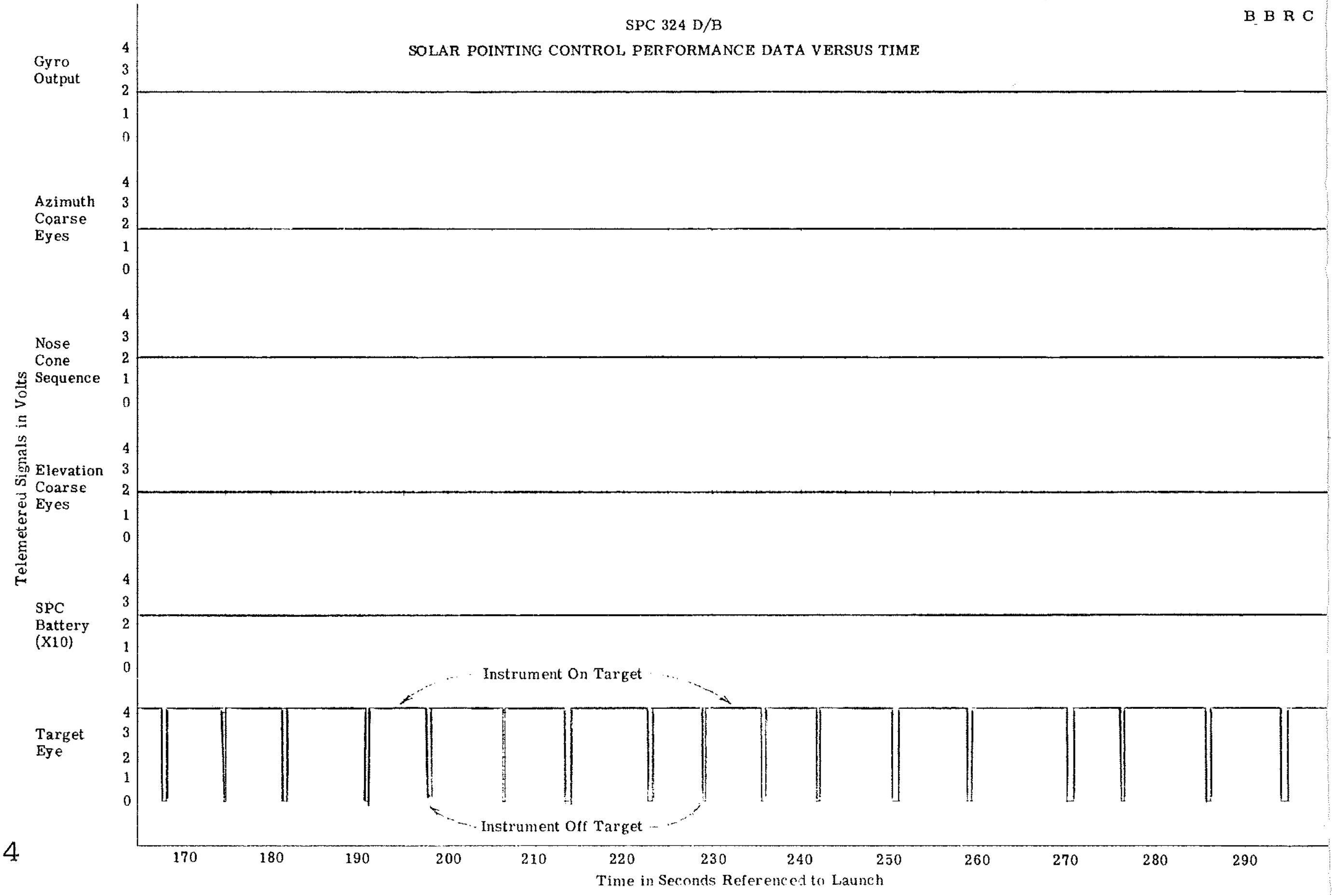


Graph No. 3 Sheet 2

B B R C

SPC 324 D/B

SOLAR POINTING CONTROL PERFORMANCE DATA VERSUS TIME

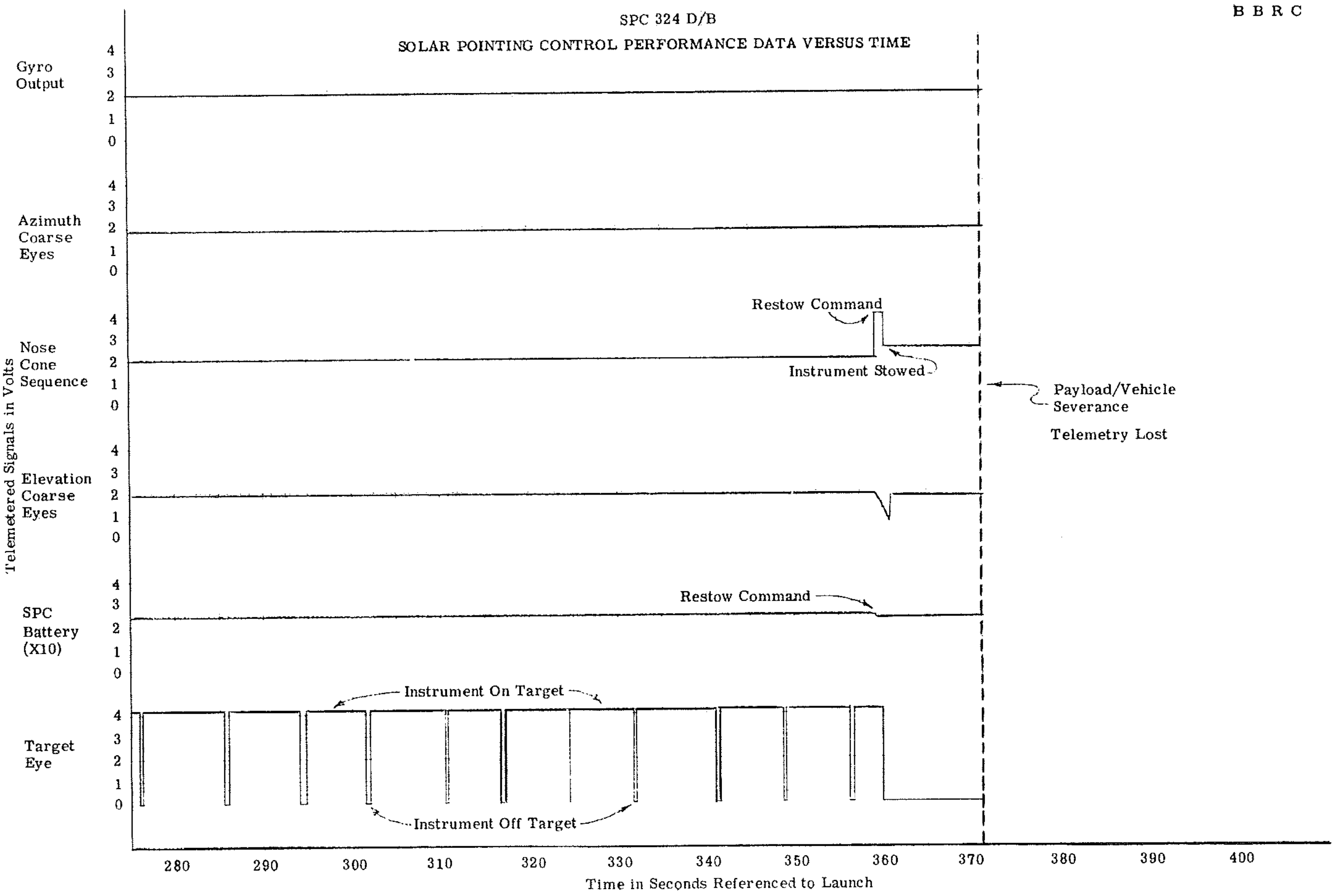


Graph No. 3 Sheet 3

B B R C

SPC 324 D/B

SOLAR POINTING CONTROL PERFORMANCE DATA VERSUS TIME



Graph No. 4

B B R C

SPC 324 D/B

INSTRUMENT ELEVATION ANGLE VERSUS TIME