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SUPPORT SERVICES FOR I. R. ROCKET PAYLOADS

Oklahoma State University

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This report summarizes services supplied in support of a series of Infrared payload instruments, launched aboard upper air research rockets by the Air Force Cambridge Research Laboratories. Circuit details are presented for a number of specific payload support packages which combined telemetry and trajectory electronics. Special ground support equipment provided in connection with the support is also described, with comments on operational experience gained in Field Services, both within the United States and abroad.

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SUMMARY

This report documents a continuing series of services which were supplied under contract to the Air Force Cambridge Research Laboratories. The services were supplied as direct support for a group of rocket-borne instruments designed to obtain data in the infrared region, launched from sites in the southwestern United States and southern Australia. Airborne support packages were developed and built to provide the required combination of data transmission from rocket to ground and associated tracking equipment, through which trajectory elements for the flight path could also be determined. Each such support package was tailored to the invididual mission requirements with respect to both the radio telemetry subsystem and the radar beacon subsystem employed; mechanical configurations were chosen for compatibility with adjacent portions of the overall payload structure. After local tests to confirm subsystem operation, each package was delivered to the AFCRL facility, where integration tests were performed to verify overall payload operation when assmbled in flight configuration. After shipment to the chosen launch site, the payload is reassembled and a program of prelaunch tests conducted in order to confirm flight-readiness of all elements of the flight system. Finally, both airborne and ground equipment are operated during flight of the rocket carrying the payload in order to receive and record the data from the scientific instrument for later analysis and interpretation.

Both personnel and equipment are provided as a part of these services. The equipment includes not only the airborne support package, but also a complete ground station which is capable of receiving and recording all data. The ground station capability is also matched to the characteristics of the particular mission, and usually includes a rather complex array of decoding equipment in order to permit quick-look analysis of overall payload performance. In this program, the ground station capability included an autotracking S-band antenna system and wideband magnetic tape recording equipment. In order to analyze system performance, analog telemetry systems required auxiliary FM discriminators and oscillograph recorders. Special purpose PAM and PCM decoders were also provided for the digital telemetry

systems, also driving appropriate oscillograph recorders through digital-to-analog converters for convenient quick-look evaluation. The digital PCM decoders also included provision for digital record printout.

In anticipation of a remote mission in Brazil, the ground equipment was expanded to include an auxiliary ranging loop with a unique PCM-coded signal compatible with the telemetry subsystem. This ranging subsystem, when operated in conjunction with the autotrack antenna, permitted trajectory data acquisition in spherical coordinate form. The trajectory data, encoded in serial PCM form, was then recorded together with the telemetry data.

ACKNOWLEDGMENT

The work discussed in this report has been made possible through the sponsorship, encouragement, and cooperation provided jointly by both the Optical Physics Laboratory and the Aerospace Instrumentation Laboratory of the Air Force Cambridge Research Laboratories. Special gratitude is due Dr. Russell G. Walker/OPI and Mr. Charles H. Reynolds/LCS, both of whom provided guidance and coordination for the orderly development of the required support services for this complex program.

We also express our thanks to all the other personnel from both Laboratories who lent their assistance and cooperation in order to maintain a constant flow of up-to-date technical coordination, so that the support provided under this contract might be properly responsive to the changing and complex requirements of the overall program.

Appreciation is also expressed to all those individuals from other agencies who participated in this program, without whose contributions much of the work reported herein would have presented a number of problems difficult to resolve satisfactorily. In particular, we wish to acknowledge the support provided at the various launch sites by responsible individuals at both the White Sands Missile Range in New Mexico and the Weapons Research Establishment in Woomera, South Australia.

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The following staff members from the Oklahoma State University Research Foundation Electronics Laboratory have contributed to the work described in this report. Names are listed alphabetically:

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TABLE OF CONTENTS

SUPPORT SERVICES FOR I.R. ROCKET PAYLOADS

LIST OF ILLUSTRATIONS

1.0 INTRODUCTION

1.1 Brief History of Contract

1.1.1 The services which have been provided under this contract have been in support of a series of research rockets, launched in a special measurement program by the Air Force Cambridge Research Laboratories. This particular program was actually initiated as one phase of work under an earlier contract, F19628-70-C-0147, in which a group of airborne support systems (which combined both analog and digital telemetry subsystems with radar beacons for trajectory information) were built up for use in support of an infra-red measurement program, and for which engineering support services were supplied during system tests and for a series of rocket launches at the White Sands Missile Range in New Mexico. As the termination date of the earlier contract (in the beginning months of 1972) approached, it was evident that the special measurement program was not only continuing, but of sufficient scope to warrant increased support services under a separate contractual document. The contract reported herein continued the support program for nearly four additional years. Concurrently, many other tasks previously performed under F19628-70-C-0147 were also continued, but under sister contract F19628-72-C-0139. Although these other tasks were not in direct support of the mission of this particular program, much of the work was indirectly related through common needs and objectives. As this contract and the sister contract in turn expire, the services will continue under the following contract F19628-75-C-0084.

1.1.2 The nature of the services provided have varied in accord with the needs of the program. In general, they may be divided into two broad classes: development and fabrication of necessary electronic instrumentation equipment in the home laboratory, and engineering field services which are provided during assembly, test, operation, and launch of the research rockets at remote sites. Both classes of services embrace both airborne subsystems and associated ground support equipment. The airborne equipment is designed to provide the telemetry links through which data is transmitted from the rocket-borne instruments to the ground-based recording sites, and also includes equipment for determination of the trajectory of the rocket-borne instrumentation. The ground support equipment includes the capability of providing adequate facilities to test and verify the proper operation of the airborne equipment, as well as providing data reception and recording during tests and flight. In addition, for some types of trajectory determination, the ground-based equipment also provides and records data elements for determination of the trajectory as a function of flight time.

1.1.3 The basic contract for all services provided under contract F19628-72-C-0172 was executed in response to RFQ F19628-72-Q-0128. The initial contract, executed in February of 1972, called for one year of services, in support of four research rockets, commencing on 17 May 1972. This initial program, meant to utilize the Aerobee 350 vehicle to carry the payload, encountered a number of delays due to difficulty in obtaining the desired capability in the associated instrument; when the first round (A35.191-2) was eventually launched, vehicle performance was below that anticipated and more delays were encountered. Personnel were diverted to other projects during these delays in order to conserve funds, allowing a considerable time extension with no additional funding required. In the meantime, it became evident that considerably greater ground support equipment capability was needed, and a new task directed toward this objective was added to the original work. During the delays in the Hi Hi Star program, other alternate payloads were added to the overall program. An independent capability for deployment of an auto-tracking S-band antenna for support without compromise to equipment availability for other AFCRL launches was added to the PCM ground support equipment requirements. A series of subsequent amendments were eventually negotiated, extending the scope of the services, the number of rockets, and the time of performance. A notable addition was the requirement for trajectory determination at remote sites such as Brazil, adding more requirements for ground support capability and station maintenance. Completion date for all services (other than the final report) was extended to 31 December 1975, and total available funding increased to $317,777.00, with corresponding changes in the Statement of Work.

1.2 Contract Objectives

1.2.1 The detailed specification of the work to be performed under this contract was presented in Part II, Section F of the contract. The Statement of Work, describing the contract objectives, was modified by amendments from time to time and called for supply of personnel, facilities, services, and material to accomplish the tasks below, quoted from the contractual document:

"Line Item 0001 - Provide telemetry components, fabricate, test, and install telemetry systems in research rockets at field sites and maintain and operate ground-based data and recovery equipment. Perform the necessary services to instrument seven (7) research rockets for data transmission and reception and trajectory determination in accordance with the following:

[Sub-line Item 0001AA] - Provide telemetry components for five (5) research rockets as required.

[Sub-Line Item 0001AB] - Fabricate, test, and calibrate five (5) telemetry systems (fabricated from components under [Sub-Line Item 0001AA]) for use in rockets in support of the upper air research program.

[Sub-Line Item 0001AC] - Provide engineering services to transport, integrate and operate seven (7) telemetry systems during test at AFCRL and during test and launch at WSMR, New Mexico; Natal, Brazil; and Woomera, Australia.

[Sub-Line Item 0001AD] - Provide engineering services to transport and operate ground based data reception and recording equipment during test and launch of four (4) rockets at WSMR, New Mexico, one (1) rocket at Natal, Brazil and two (2) rockets at Woomera, Australia.

[Sub-Line Item 0001AE] - Refurbish, test, and provide field services for two (2) telemetry systems flown on previous rocket flights under F19628-70-C-0147 at Woomera, Australia.

[Line Item 0002] - Reports are required hereunder....."

1.2.2 Concurrent with the work performed under this contract, similar support services were also supplied to AFCRL for other rocket programs under F19628-72-C-0139, and under F19628-75-C-0084. In particular, PCM telemetry systems and associated equipment were developed with applicability to this project, and development of S-band autotrack antenna systems and associated PCM ranging equipment which were later utilized in build-up of additional ground support equipment under this project (to provide trajectory determination capability) should also be given credit for development under the above-cited sister contracts with the Air F rce Cambridge Research Laboratories.

1.2.3 Work is reported herein in preparation for the launch of a special Castor/Lance rocket from Natal, Brazil. This launch was postponed in the closing months of activity under F19628-72-C-0172; support activities, when rescheduled, will be conducted under following contract F19628-75-C-0084.

2.0 FIELD SUPPORT AND CONFERENCE ACTIVITIES

Services supplied under this contract have involved a number of activities which required that personnel and equipment be supplied for work at locations other than the home laboratory in Stillwater, Oklahoma. Some of this work was for purposes of technical coordination required to define services; in addition to discussions held at other locations, forty-four man days were required in attendance at meetings with personnel from other agencies which were held in Oklahoma. The remainder of the field services required a total of two-hundred fifty-three additional man days of effort. This field work involved several different tasks: technical coordination and training, assistance in integration tests which were performed to verify system performance prior to assembly at the launch site, pre-launch tests performed at the launch site, support in the form of equipment operation and data retrieval and recording during the actual launch sequence, and tests and evaluations of developmental equipment which were performed under typical launch conditions, generally so scheduled as to occur in conjunction with some operational launch activities required on some other task.

2.1 Coordination Meetings

2.1.1 Technical coordination meetings at the AFCRL facility were, wherever possible, scheduled for periods when the personnel involved were required to be present at the Cambridge laboratory for other tests, in order to reduce travel costs. In general, these meetings occurred during available free time in the course of integration test activities and thus the man-hours and travel were absorbed in the integration test activities.

(a) One exception to this arrangement was the August 1975 meeting, which was specifically arranged for coordination in connection with the upcoming launch at Natal, Brazil. One man was supplied at AFCRL for six days; the discussions and work were concerned with both the logistics and technical aspects of supplying independent electrical power at the proposed launch site by use of a diesel electric generator.

(b) Remaining coordination meetings concerning this Brazilian mission were held either in the Stillwater Laboratory, or at AFCRL in connection with other scheduled integration tests. The first discussions were held in the 15 May 1975 meeting, chaired by Mr. C. H. Reynolds of AFCRL, and conducted at the Stillwater Laboratory. The general anticipated support requirements from OSU were discussed. In addition to provision of the required dual link S-band airborne package, two independent ground stations (each equipped with autotrack S-band receiving antennas and the requisite associated PCM ranging equipment) were foreseen as necessary for trajectory determination at the remote launch site, with a rather large commitment of manpower and logistic support requirements to this particular mission. Some procurement of supplies was initiated as a result of this meeting, and the decision was reached to proceed with the buildup of a second ranging system (TRADAT I) to go with the TRATEL I autotrack antenna, in order to supply the required support. The concept of a completely self-sufficient operation, with extensive local supplies of field spares for maintenance in Brazil, was also developed.

(c) The next meeting to discuss this project was held at AFCRL in July of 1975, in connection with integration tests for a different payload. An interim status report was presented, and a following conference at the Oklahoma Laboratory scheduled for the month of August.

(d) Mr. Jack Griffin of AFCRL chaired the next meeting, held in Stillwater on 11 August 1975. The discussions were directed primarily to a review of progress and future plans for development and fabrication of the auxiliary ground support equipment for tracking and trajectory determination for the Brazilian mission.

(e) A following technical conference was also chaired by Mr. Griffin and held in the Oklahoma Laboratory in the period of 20-22 August 1975.

This meeting continued the discussion of the technical details of the ground-based tracking and ranging equipment, including demonstrations of the developmental versions of the proposed equipment. The decision was made to schedule (in conjunction with another program, under sister contract F19628-75-C-0084) a series of field trials in which "piggyback" airborne equipment simulating the proposed Brazilian trajectory-determining equipment was to be launched aboard a series of small rockets; the new ground equipment to be used in Brazil was also scheduled to be operated by the personnel who would have the same responsibility at the Natal site later. This would provide both an evaluation of the system capability, and also an opportunity for training and experience under field conditions for the crew selected. During the same meeting, the anticipated logistic problems of transport and support of the men and equipment for the Brazilian operation were reviewed in some detail.

(f) The final technical meeting concerning planning for the Brazilian mission was also held in the Stillwater Laboratory in the period of 1-3 October 1975. Messrs. Jack Griffin and William Miller of AFCRL met with personnel from the Electronics Laboratory and reviewed specific details of the PCM telemetry link proposed, as well as continuing the discussions on logistic and tracking problems.

2.1.2 A number of technical coordination meetings were also held in the course of this contract in connection with the overseas mission to the Weapons Research Establishment (WRE) in Woomera, Australia, where three Aerobee 200 rockets were eventually launched under this contract.

(a) The first such meeting was held in the Oklahoma-based Laboratory on 7-8 December 1972, and chaired by Mr. Charles H. Reynolds of AFCRL. In addition to the planning discussions for the entire future program to be conducted under this contract, specific discussions were held in regard to plans for a series of three launches in 1974 from the Australian facility. Some long range procurement action was planned, and generalities of the future program discussed; in the absence of definitive technical details, further build-up of equipment was deferred until after an initial site visit by AFCRL personnel.

(b) After the return of AFCRL personnel from Australia, a following meeting was held in the Stillwater Laboratory for more detailed discussion of the field support requirements. Mr. Reynolds and Mr. Griffin again represented AFCRL at this meeting, which was held in the period of 23-24 August 1973. Both airborne and ground support equipment requirements were defined and a tentative timetable set up for implementation of the desired program. The major emphasis, however, was on logistic factors to be satisfied in successfully conducting the mission. A plan to coordinate equipment availability (combining AFCRL, OSU, and Australian facilities) for optimum support capability was developed, and procurement initiated for field spares and other necessary support equipment. Travel requirements were set up, costs estimated, and a tentative list of shipping requirements (weight and volume) prepared.

(c) The next following coordination meetings were conducted in conjunction with formal integration tests for the Australian payloads, during the week of 1-5 April 1974, at AFCRL. Technical data was reviewed and the schedule confirmed; shipping information was obtained and ground support capability reviewed again to insure that build-up of special items could be completed immediately. Special simulation tests were also arranged at the OSU Laboratory to verify acceptable operation of the proposed system, in which high bit-rate PCM techniques would be employed on a relatively low carrier (P-band) frequency transmitter. The receivers to be used in the field were modified for wide-band operation and one of the OSU PCM simulators used to provide modulation in the desired format. System loop checks were performed, receiving and tape-recording the simulated data with the equipment to be used in Australia. Magnetic tapes recorded in these tests were then played back through the OSU PCM and PAM decoding equipment to demonstrate the feasibility of the proposed system and also to provide operating experience for the crew members.

(d) The next meeting concerned with this mission occurred on 7 May 1974, also at the Stillwater Laboratory. Mr. Duane Cossey and Mr. Robert Birmingham, both from the Transportation Office of Tinker Air Force Base, Oklahoma City Air Material Area, visited our facility to assist in arranging the shipment of equipment to Australia. After inspecting the packing methods being used and reviewing the overall requirements, the necessary government forms to be required (DD-1149 and DD-1137) were provided, and arrangements were completed for shipment to the launch site.

(e) Mr. Reynolds of AFCRL next chaired still another conference at the OSU Laboratory, in which final plans for the Australian schedule and crew were confirmed, on 9 May 1974.

(f) In conjunction with a planning conference for a different mission conducted under this same contract, some brief additional discussions were held at AFCRL on 11 June 1974. The timetable for personnel arrival and transportation plans were revised to comply with a delay in the mission launch schedule.

(g) An additional technical conference which included discussions concerning this mission occurred at the OSU facility in the period of 6-8 August 1974. Mr. Jack Griffin and Mr. Warren Harding inspected the general features and applicability of OSU-developed equipment for tracking capability, and discussed specific details of ground station set-up and operation in Australia.

2.1.3 Some additional technical meetings, concerned with matters other than the two major overseas projects described above, were also held during the period covered by this report.

(a) The Oklahoma conferences of 7-8 December 1972 and 23-24 August 1973 which have been mentioned earlier also included discussion and review of activities to be conducted under both the Hi Star (using the Aerobee 170 vehicle) and Hi Hi Star (Aerobee 350 vehicle) which were scheduled for launch from the White Sands Missile Range (WSMR) in New Mexico. Design of the requisite support equipment and the schedules for the launch programs were reviewed in these meetings. The ensuing activities in field support and construction of equipment are detailed in other sections of this report.

(b) A special planning meeting was held at the AFCRL facility during the period of 10-12 June 1974. This meeting was for the purpose of defining the technical requirements for the Infrared Zodiacal Light Mission, eventually launched from the WSMR facility as rocket number A31.320-2, utilizing the Astrobee F vehicle. In attendance, in addition to those personnel from AFCRL and OSU to be involved, were representatives from Cornell University (representing the guest scientists), Pan-Monitor, Inc. (instrument subcontractor), and Space Vector Corporation (providing the attitude control system (ACS) to be used in pointing the instrument). Overall mission details were reviewed, and coordination of interface details arranged so as to permit construction of required portions of the overall payload. The equipment built at OSU for this mission is described in Section 3.1.2 of this report.

(c) The meeting at OSU on 15 May 1975 (which has been discussed previously in connection with overseas missions) also reviewed future plans for all other missions scheduled under this contract. Particular emphasis was placed upon review of the Hi Hi Star and Super Hi Star programs, scheduled later to use the Aerobee 350 vehicle from the WSMR facility in New Mexico.

(d) Two other meetings at the OSU Laboratory were held in connection with review of inventory and property accountability records for equipment procured and maintained for use on this contract. The first, held on 11 April 1973, was attended by Mr. Francis M. Lucas of the Office of Naval Research (ONR). The second, held on 9 July 1975, involved Mr. Martial W. Davoust, of the same office. Both were for the purpose of verifying records maintained under Facility Contracts negotiated between the Oklahoma State University and the Air Force, for which property administration has been delegated to the ONR office in Dallas, Texas. All government-owned equipment used in this contract was originally under Facility Contract F04701-69-C-0319 and reviewed at the first meeting. The Facility Contract was renegotiated as F04701-74-C-0271 effective 28 February 1974; the list of accountable equipment under this new contract was reviewed at the second meeting.

2.2 Integration Tests

As implied by the name, integration tests are performed for the purpose of integrating the various portions of a rocket payload into the final configuration to be employed in flight. As a general rule, these tests require travel and support in the form of personnel and equipment from the OSU laboratory at other physical locations. During these tests, portions of the payload which were constructed and tested locally are then mated to and tested with remaining portions, from other sources, to establish electrical and mechanical compatibility with the mission requirements. Not only operational flightworthy verification of the airborne equipment is involved; the tests also provide the opportunity to test the planned procedures and ground support equipment suitability prior to proceding with the actual field mission for the launch. Although occasionally performed elsewhere, most integration tests are performed at the AFCRL facility. In the course of this contract, forty-four man days of effort were devoted to this purpose.

2.2.1 The first integration test was conducted at the WSMR facility in preparation for the launch of Hi Star round A04.004-8. (The OSU-built subsystem had previously been delivered to AFCRL under preceding contract F19628-70-C-0147, and had already been through preliminary system checks at AFCRL prior to delivery to the launch site.) The period of 30 May through 4 June 1972 was devoted to these tests; tests were successful and verified both payload and ground system readiness for launch.

2.2.2 A similar system for Hi Star round A04.004-9 was started through full integration tests at the AFCRL facility in the period 23 October through 2 November 1972. After some initial difficulty with the operation of ground support equipment, which required some modification in order to decode the desired subcommutated PCM data, formal tests were begun. Prior to completion of the series of tests, a serious vacuum leak was detected in the instrument and the test series was postponed until repairs could be made. The test sequence was later completed at the WSMR facility during the period 13-17 November 1972.

2.2.3 Integration tests for the first Hi Hi Star flight, A35.191-2, were begun at AFCRL in the period 9 through 14 July 1973. Initial tests verified mechanical and electrical compatibility on this, the first of the new Aerobee 350 package designs. Although telemetry and beacon subsystems operated normally, difficulty was again encountered in the associated instrument, aborting this series of tests. The system was left at AFCRL for resumption of local tests there (without OSU participation) after repairs; testing by OSU personnel was later resumed at the launch site, WSMR, later in the year.

2.2.4 The Hi Star South series of Aerobee 200 payloads, A05.391-1, -2, and -3, were set up for integration tests during the week of 1-5 April 1974.

A two man crew was supplied from OSU and the ground support complex was a mixture of AFCRL and OSU equipment, assembled into the configuration proposed for use in Australia. Initial tests were concerned with the ground support complex, to verify that the desired support could be provided; test conditions were unusual in that airborne elements of the payload were in one physical area at AFCRL, with the ground station complex remotely located in a different physical facility, simulating the anticipated field conditions. Multipath propagation effects made tests of the high bit-rate PCM data over the low frequency P-band link rather difficult, but station operation was eventually verified after experimentation with antenna location. Although the first test was aborted by a premature stow sequence for the main instrument, the second test was successful and, even though magnetic tape quality was not up to the standards expected, playbacks were adequate to demonstrate satisfactory operation. The system was left in operating condition to permit later additional tests with the second instrument, and OSU members of the test crew were released for return to the home laboratory.

2.2.5 Integration tests for the Infrared Zodiacal Flight payload, A31.320-2, were conducted at the AFCRL facility in the period 21-25 July 1975. Modifications of the OSU-built support system, which had been completed a year earlier, were required to update the system and incorporate some additional requirements which had been added during the delay, partially due to a change from Aerobee 170 to Astrobee F for the launch vehicle, with a consequent change in mission requirements. Both static condition integration tests and vibration testing of the entire payload were accomplished during this same week; some damage occurred to the associated ACS and instrument sections during the vibration test, which eventually resulted in a delay in the later launch schedule from WSMR.

2.3 Launch Support Activities

Field support services at the launch site were responsible for the majority of the man-power efforts supplied at remote locations under this contract. Support of the launch mission, conducted at each selected launch site, required that both personnel and equipment from the home laboratory be committed to a series of operations in the field. The mission requires set-up and verification of satisfactory operation of both airborne and ground elements of the equipment. Prelaunch assembly and test operations may include a continuation of integration test activities commenced elsewhere, and usually include both formal "horizontal" and "vertical" series of tests before proceeding with the actual launch countdown. In "horizontal" tests, all payload elements are assembled into flight configuration and the anticipated operation is simulated, commencing with the normal prelaunch and test sequence and continuing through a simulated launch, with all systems operating on internal power in the same programmed event sequence planned during flight, with full data recording and playbacks of magnetic tape records to evaluate performance. This test is later followed by the "vertical" test, in which the vehicle and payload are assembled into actual flight configuration and installed in the launcher, ready for flight. A similar sequence is again followed for testing and evaluation to insure flight readiness. The actual launch sequence usually commences several hours before liftoff and consists of turn-on and verification of performance of all elements; it continues through the actual launch sequence with operation of the associated ground equipment for the purpose of receiving and recording data transmitted from the rocket payload during flight. Post-flight preparation of records (as desired for data analysis) is usually included, and services may also include tests conducted on the payload after recovery by parachute. Support was provided in connection with the launch of eight payloads from two different launch locations in the course of this contract; one-hundred and ninety-five man days of support in the field were required.

2.3.1 Launch support at the WSMR, New Mexico was provided in the period of 7 through 19 August 1972 in connection with the launch of A04.004-8, a continuation of the Hi Star Aerobee 170 sequence of missions begun earlier under contract F19628-70-C-0147. In common with other rockets launched in this series, a two-link telemetry system required dual ground station support (for both the eight-channel FM/FM analog system and also the 30-word digital PCM system). Following completion of initial system tests on 8-9 August, the horizontal test was successfully conducted on 11 August. After moving from the preparation area to the Aerobee 350 blockhouse, the vertical test was conducted on 15 August. The field crew ran through normal prelaunch tests, and successfully launched the payload at 0321 local time on 18 August 1972. Successful recovery was accomplished later the next day.

2.3.2 The next following round in the Hi Star series, A04.004-9, utilized a support section refurbished at OSU under this contract from the recovered payload which had been flown earlier on A04.004-7 (also under preceding contract F19628-70-C-0147). The launch support supplied involved two separate trips to the WSMR facility in New Mexico. The first trip, in the interval 13-17 November 1972, was actually considered as a continuation of the integration tests begun at AFCRL and interrupted by an instrument vacuum problem, as reported earlier in paragraph 2.2.2. Tests under room temperature conditions were performed on 15 November, and a second integration test with the payload cooled to operating temperature was conducted on 16 November. Support services were resumed on 27 November, with preliminary local tests completed on 28 November by a "horizontal" test in the preparation area. The system was then moved to the launch complex and the vertical test performed on 1 December, during which a problem with shutter control in the instrument was detected. After removal of the payload for repairs, it was reinstalled in flight configuration in the launcher and a short retest conducted on 3 December to verify flight readiness. Prelaunch countdown began early in the afternoon of 4 December, and successful launch occurred at 2120 hours local time the same day. Recovery was again accomplished on 5 December and the field support terminated.

2.3.3 Relatively lengthy field services, involving the expenditure of 34 man days of support in three different trips to the WSMR launch facility, were involved in the support provided in connection with the launch of A35.191-2. This was the first of a proposed series of Aerobee 350 vehicles, carrying large infra-red payloads in the Hi Hi Star program. The first services were supplied in the period of 1 through 16 October 1973. A single S-band PCM link was provided for digital telemetry, with an associated C-band beacon to provide trajectory data. The use of high bit-rate PCM with a seventy word frame length and sixty-frame major frame length, using both non-synchronous PAM commutation of three main frame words, coupled with a complex synchronized subcommutation scheme within the PCM format, required a relatively elaborate ground support complex for data retrieval. After set-up of the ground station and operational verification of performance, local tests on 4 October were followed by a horizontal test with the instrument cooled on 5 October. Results appeared normal and preparations continued. After moving all equipment from the preparation area to the launch complex on 10 October, difficulty was encountered with a gasket seal in the instrument, delaying the vertical tests which had been scheduled for 12 October. Extensive repairs proved impractical under field conditions, causing a postponement, and services were terminated on 16 October, after disassembling and storing support equipment

Activities resumed and the second services were supplied in the period of 14-27 January 1974. After reinstallation of the support equipment and verification of telemetry beacon operation on 15 January, local tests were begun. A noisy stellar aspect sensor and delay in installation of the star-mapper caused postponement of the horizontal tests originally scheduled for 17 January, and local operations continued with support, pending re-schedule of the horizontal test for 23 January. These tests indicated questionable instrument performance. After further tests, it proved impossible to obtain use of the launcher and range on 26 January as desired, and the mission was again postponed; support services were terminated on 27 January.

The third field services were supplied in the period of 8-17 February 1974. The ground support complex was moved to the launch complex and, after local tests were successfully accomplished on 9 February, the services continued through the normal vertical test sequence on 11 February. After some modification to the umbilical complex to reduce line noise, prelaunch countdown began the evening of 15 February and launch was accomplished on schedule at 0133 hours local time on 16 February 1974. After preparation of required playback records, the station was dismantled and field services terminated on 17 February.

2.3.4 Support services supplied in connection with the launch of the Hi Star South series of experiments from the WRE facility in Woomera, South Australia, were quite extensive and required 96 man days of effort in the field, including travel time to and from Australia. Although this series was to include three Aerobee 200 launches, round numbers A05.391-1 through -3, only two sets of flight equipment were involved because the system recovered by parachute from the launch of A05.391-1 was refurbished in the field and reflown as round A05.391-3 later. The airborne system utilized a digital PCM system on a P-band carrier link; a C-band beacon was included for trajectory determination. Because of limitations on available compatible support facilities at the Australian launch range, an extensive ground station was assembled from both OSU and AFCRL equipment; eventually two separate ground stations, separated by several kilometers, were set up for flight coverage. Use of a 600 kilobit PCM system in a thirty word frame, with a 16 frame/main frame subcommutated data format and two PAM commutated main frame words running asynchronously, complicated the ground station requirements. All tests required magnetic tape recording in real time, with extensive tape playbacks required in order to decode the desired information into usable form with the limited field facilities available.

Field services occupied two men continuously throughout the period 9 August - 26 September 1974. All equipment was shipped to Australia well in advance; the work area was an abandoned building which required a considerable amount of preparation prior to use. Although equipment was uncrated and assembled in the preparation area on 14 August, local electrical power was not available until 17 August to permit local tests. Unfortunately, a considerable amount of shipping damage had occurred in transporting equipment to Australia; several days were occupied in repairs and verification of ground station operation. On 21 August a simulated PCM test signal was arranged by use of the OSU PCM simulator to modulate the spare transmitter unit, radiating the signal from the blockhouse (approximately ten kilometers distant from the preparation site where the ground station was set up). Since line-of-sight conditions did not exist along this route, the signal was marginal, but usable, and it was estimated that an increase of approximately 30 db could be expected at launch.

Local tests on the payload equipment were begun on 22 August, with tests at room temperature for the payload to be flown on A05.391-1. Similar tests on the second payload, for A05.391-2, began on 23 August. Instrument operation was satisfactory, but valve leakage was noted on both of the associated ACS systems, necessitating repairs. Pending the completion of these repairs, the -1 payload was moved to the launch site to test system operation over the actual signal path to be used later, and magnetic test tapes were cut while remote operation of equipment through umbilical lines was verified, after which the payload was returned to the preparation area. ACS repairs were verified by room temperature tests on both payloads on 26 August. Following tests were then made on both payloads with the instruments cooled to operating temperature in the normal horizontal test procedure, simulating a launch mission. A05.391-2 was tested on 28 August, with a duplicate test for A05.391-1 on 29 August. Playbacks of decoded data from the magnetic tape records verified operation of both systems, so half of the compound dual ground station complex was moved to the blockhouse and set up there to permit local checks at both sites. A "dry-run" vertical test was finally completed at the blockhouse with A05.391-2 on [illegible] September, after some trouble with recording quality at the high bit rates involved. A similar test was completed with the A05.391-1 payload on the launcher on 4 September, after which the normal countdown sequence proceeded, culminating in launch at 1954 hours local time on 4 September 1974. Recovery was accomplished satisfactorily. Playbacks were made as required to evaluate the flight results in the period of 5-9 September, at which time a changeover in station set-up was made to facilitate continuation of the prelaunch tests on A05.391-2.

Preflight test sequences were initiated on 10 September for A05.391-2; the countdown proceeded and launch occurred on schedule at 2255 hours local time on 11 September 1974. Parachute deployment was unsuccessful, however, and the payload was eventually recovered in very poor condition on 12 September. Playback of tape records was again required for flight data evaluation, and these were completed on 14 September 1974.

Since only the first payload was in suitable condition for reflight, the components recovered were tested and supplemented by spare parts where required in refurbishing the airborne equipment for use as the A05.391-3 system. Build-up had begun on 11 September; initial tests under room temperature conditions on 12 and 13 September verified the condition of all equipment. A formal "horizontal" test under cold conditions was completed successfully on 14 September. Preparations continued for flight, with the countdown initiated on 17 September; launch occurred on schedule at 2334 hours local time 17 September 1974. Parachute operation was again successful, and recovery accomplished the next day.

After completion of all required data playbacks, equipment disassembly and crating for return to the United States began on 19 September. Field services were finally concluded with return of the field crew to the home station on 26 September. However, follow-up activities in the OSU laboratory were required later to repair extensive shipping damage to the ground support equipment after receipt of the returned items on 4 November 1974.

2.3.5 Field support services for the Infrared Zodiacal Light launch required two men and occupied the time period of 5-15 October 1975. This support package, launched on an Astrobee F vehicle, A31.320-2, used a twelve-channel FM/FM analog telemetry system with the carrier frequency at S-band; a C-band radar beacon was included for trajectory determination. Three of the channels carried PAM commutation in order to multiplex data, using two different formats. A fourth channel was modulated by a digital PCM format to multiplex high-resolution position data from the ACS system used to provide control of the instrument scanning. As a result, the ground station complex which was required for tests and data analysis became relatively complicated, and required tape recording and playback sequences for all tests.

Preliminary local tests on 6-7 October verified performance of both airborne and ground elements of the system, and the formal horizontal test was conducted successfully on 8 October. Some difficulty was encountered in decommutation of PAM signals initially, but adjustments in the ground equipment permitted restoration of normal operation. After calibration of the instrument when cooled to operating temperature, all equipment was moved to the launch complex on 10 October and the formal vertical test was run on schedule on 11 October. The test was unsucccessful, as no data was obtained from the detector array channel. The modified 10x30 NRZ commutator which multiplexed this data within the instrument was found to be defective and was replaced. A second post-vertical test was conducted successfully on 13 October verifying flight readiness, and the prelaunch countdown sequence was begun at midnight on the same date. Launch occurred on schedule at

0430 hours local time on 14 October 1975. Recovery was accomplished a few hours later; the instrument had sustained mechanical damage at impact, but all other equipment was found still operative and in excellent condition. After preparing the desired post-flight records, equipment was repacked for storage and field services terminated on 15 October.

2.3.6 Field services supplied in connection with the launch of the Super Hi Star vehicle required eighteen man days of support during the period of 23 November through 5 December 1975. This payload, flown as round A35.191-1 on an Aerobee 350 vehicle at the WSMR facility, was a later modification from the Hi Hi Star program, using the same instrument intended for later launch on the Castor-Lance vehicle from the Natal, Brazil site. The airborne support system, while utilizing many components which were procured under this contract, was assembled elsewhere. The telemetry was digital in nature, again using PCM/FM modulation of an S-band carrier for data transmission, with an added C-band radar transponder for trajectory determination. The bit stream, at 800 kilobits per second, consisted of a total of 28 words fourteen-bits in length; two of the words were subdivided into seven bit words with a thirty-two subframe repeat cycle for digital subcommutation of two channels of housekeeping data (and the associated subframe identification word). The remaining seven-bit "half-word" for subframe number 10B was used to carry ACS information , and was modulated by a non-synchronous PAM commutator in a standard 5x30 RZ format. The ground station was similar to that required in the Hi Star South program, again requiring high bit-rate magnetic data recording and the use of both PCM and PAM decoding equipment to retrieve the data. In addition, the tracking and trajectory determination equipment built up for support in Brazil was deployed in the field during this launch period for the field trials described in Section 2.4 following; although the PCM ranging equipment was not included in this payload and so the TRADAT portion of the system was unusable on this round, the TRATEL portion was used to track the payload automatically in flight and to provide additional operator experience while recording the azimuth and elevation angular position data.

Support services began on 23 November in the preparation area at LC-37. After set-up and minor repairs to establish ground station operation, cold tests on the payload were conducted on 24 November. Some ACS difficulties were noted during the test and repairs were necessary to establish the desired operation. A retest was required on 25 November to accomplish a successful horizontal test. After completing playback data stripout from the two horizontal tests, the entire ground station complex was moved to the launch area. The TRATEL tracking system was added, and station readiness verified by local checks on 28 November. The formal vertical test was conducted on 29 November, with the rocket and payload assembled in the launch tower and instrument cooled to operating temperature. The first scheduled test was aborted by a local power failure in the blockhouse at T-3 minutes. A second test was hurriedly run when power was restored, but difficulty was encountered with the quality of the magnetic tape record and playbacks to verify test success were eventually managed from the poor record by processing the distorted NRZ-S video signal from the tape through the EMR-2720 bit synchronizer, converting to NRZ-M coding, and readjusting the ground station to decode this reconstructed data. The playback sequence was finally concluded on 30 November. The prelaunch test sequence was initiated on 1 December and countdown toward an initial predicted launch time of 2030 hours local time was interrupted several times by weather delays, recycling to T-5 minutes each time. Eventually the flight was cancelled due to upper wind conditions at 2108 hours, because the launch window with respect to desired astronomical conditions had expired. The tests were resumed in the prelaunch test sequence on 3 December and countdown proceeded with launch at 2022 hours local time. Recovery of all support systems by parachute was accomplished, but an abnormal recovery sequence caused the payload to break into two sections at the interface between the instrument and supporting electronics; the resultant loss of the instrument section in turn resulted in cancellation of the following launch from the site in Natal, Brazil. All equipment was crated for return, and field services terminated on 5 December 1975.

2.4 Field Tests for Training and Evaluation

Field tests conducted for purposes of training or equipment evaluation during the period of this contract were conducted in association with developmental activities which were primarily sponsored and funded by two sister contracts with the Air Force Cambridge Research Laboratories: Contract number F19628-72-C-0139 (in the period prior to 31 March 1975), and F19628-75-C-0084 (in the period since 1 February 1975). The statement of work for both of these contracts called for development of support equipment which was applicable to the needs of this contract. In general, prototype circuitry has been developed and tested under these other contracts. When applicable support equipment so developed has been needed for use under this contract, it has been built up as described in later sections of this report. Field tests and evaluations have therefore usually been accomplished under the sister contracts, in conjunction with regularly scheduled activities under the contract which funded the development, and are properly reported under the sponsoring contract.

2.4.1 The development of prototype equipment which led to construction of the TRATEL and TRADAT systems was previously discussed in the final report prepared at the conclusion of services under F19628-72-C-0139. (Field trials and tests for the original tracking and ranging systems which were later used in this project are described in Section 5 of the above cited report.) In particular, the tests discussed in paragraph 5.3.4 of that final report were for the TRATEL I tracker which was constructed for support on this contract, used in conjunction with the PCM ranging system. (This was the prototype unit preceding the TRADAT I trajectory system later built up for support of this contract.)

2.4.2 Further tests and evaluation of the performance of the TRATEL I/TRADAT I system were scheduled as a field test of the ground support equipment to be deployed in Brazil under this contract. In addition, the availability of six rockets with the capability of carrying "piggyback" PCM ranging experiments (which simulated the system proposed for Brazil) under sister contract F19628-75-C-0084 offered a unique opportunity to provide training and field experience for the personnel to be used during the Brazilian mission. The six rockets, all Astrobee D vehicles, were also scheduled for launch from the WSMR facility at approximately the same time as the Super Hi Star, A35.191-1. As a result, the TRATEL and TRADAT equipment was deployed for use with the joint objective of providing additional operator field experience under this contract and also to obtain additional data for evaluation under concurrent contract F19628-75-C-0084. Twenty-seven man-days of field effort were involved overall, beyond the eighteen man days earlier ascribed to support of the Super Hi Star experiment. Eight man days of this additional effort have been arbitrarily classed as training under this contract. (Because two separate groups of personnel from this organization were in the field simultaneously, operating shared ground station facilities in support of seven different rockets, an exact accounting of the time allocated to each test by each man is virtually impossible.)

Support services for the ranging test series actually began with initial set up of part of the tracker equipment on 24-25 November 1975, but did not reach operational status until additional personnel arrived on 28 November, when station checks began with informal tests from the TRATEL I/TRADAT I complex in the Aerobee blockhouse to all six Astrobee D ranging payloads, successively operated from the ARIES launcher at an adjacent site. After orientation checks of the tracker and calibration of the PCM range coding, a second set of checks was conducted with all six payloads and satisfactory ranging lock was achieved with each. A balloon sonde was tracked successfully after launch on 30 November, and the system judged ready for operational use. After tests with the Astrobee D payloads on the morning of 1 December, the TRATEL system was committed to support of the Super Hi Star mission. The aborted test due to blockhouse power failure (described in paragraph 2.3.5 above) also resulted in disabling the TRATEL and TRADAT equipment, which required minor repairs, accomplished prior to the eventual cancellation of A35.191-1 later that night. Early the next morning equipment was recommitted to the Astrobee D ranging tests, and a series of interleaved tests and launch sequences began. A30.311-8 was launched at 0556 hours, followed by A30.311-5 at 0650 hours and A30.311-7 at 0900 hours local time on 2 December 1975. Although good tracking was accomplished for angular data on all three flights, PCM ranging data was only partially available. After some modificiations to the ground station complex, the count was resumed for the remainder of the series. A30.413-5 was launched at 1735 hours, followed by A30.205-7 at 1759 hours and A30.413-4 at 1900 hours. Again, tracking performance was quite good, and all telemetry data was recovered, but only partial TRADAT I data received. Study of the test and data analysis are now being continued under F19628-75-C-0084; the desired operator training was accomplished.

2.4.3 The TRATEL I antenna and associated ground station complex was recommitted to the Super Hi Star vehicle on 3 December. As described earlier, successful launch occurred at 2022 hours local time on 3 December 1975 and a good track was accomplished, with additional operator training provided. The lack of associated PCM ranging circuitry on A35.191-1 prohibited further tests of the TRADAT I equipment during this test.

3.0 AIRBORNE EQUIPMENT: DESIGN AND CONSTRUCTION

The contractual requirement for supply of a number of airborne payload support system was specifically detailed in the original statement of work. However, the general description offered permitted a great deal of flexibility in the design of the actual subsystems which resulted. In general, they may all be characterized by the following features:

(a) A telemetry system, compatible with requirements of the instrument and associated payload, capable of relaying data from the vehicle to the ground.

(b) A radar transponder, included for purposes of providing trajectory elements back from the vehicle in conjunction with ground based radar.

(c) Power and control circuitry suitable for the individual mission requirements.

It was necessary in the course of the contract period covered herein both to refurbish existing payloads from preceding contract F19628-70-C-0147 (updating circuitry and adding components to meet later requirements in the program), to design and fabricate systems specifically for rounds which arose during the course of this program, and to procure components required to satisfy the specific requirements for support systems which were actually built up at the AFCRL laboratory, with general design and component selection provided from the OSU laboratory. In addition, certain items of auxiliary airborne apparatus which were useful in development of the ground-based tracking and trajectory determination equipment proposed for use in Brazil were also fabricated, based upon designs developed under sister AFCRL contracts F19628-70-C-0147 and F19628-72-C-0139.

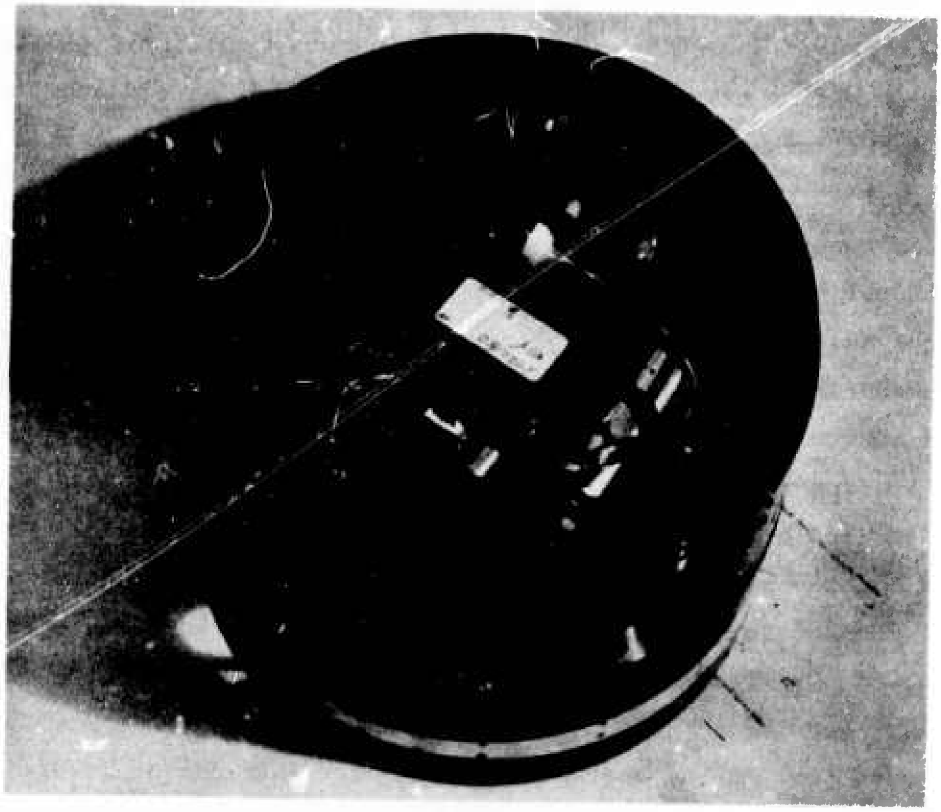

Figure 1. A31.320-2 Support Package

3.1 Analog System: Infrared Zodiacal Light (A31.320-2)

A special airborne support package was constructed for use on the A31.320-2 vehicle, launched for the purpose of infrared zodiacal light investigation. This system is shown in Figure 1, and was originally constructed for use on an Aerobee 170 vehicle. Interface mechanical features were laid out for compatibility with the standard Aerobee payload structure. Physically, the package consisted of a 2.6" high by 15" diameter ring antenna system which supported a disc plate, on which all electrical components were mounted. This internal structure was then enclosed by a 6" long x 15" diameter Aerobee section with standard mating screw hole pattern, for insertion between the associated control system and the instrument payload electronics forward. Electrical disconnect plugs were provided in both fore and aft directions for requisite mechanical interconnections. The 6" housing included a canted umbilical connector to provide means for external control and operation of this system, and within the umbilical mounting was an arming switch for the associated G-switch internal to the package. The basic electronics consisted of a 2 watt transmitting system, modulated by a 12 channel VCO complex in the conventional FM/FM mode. An OSU calibrator was included for preflight and inflight calibration, with the chassis on which the VCO and mixer-amplifier components were mounted. It also required a negative power supply as a bias source to the field effect transistors which are used to transfer from calibration to flight data transmission mode. The associated radar transponder used a C-band beacon, triggered by the ground radar, and sending back a reply pulse through an array of 3 cavity-backed helix antennas which were mounted in the skin of the outer housing. Power was supplied from an on-board nickel cadmium battery with provision for charging and monitor of battery condition through the umbilical. The control system permitted individual turn on and operation from either external or internal power sources for the telemetry subsystem and the beacon subsystem. In addition, a G-switch was included to sense acceleration at liftoff, thus closing a relay which gave a monitor of the fact liftoff had occurred and simultaneously steered control pulses to the associated power control relays to insure that all equipment was in the internal power mode during flight. Monitors as required were provided through the umbilical monitor, and in some cases, also as a portion of the telemetry reply signal. The main wiring harness not only accomplished the desired input connections to the telemetry subsystem, but also the interconnections between the attitude control system aft of the package and the forward portion of the instrument. Electrical details of the package are shown on Figure 2.

3.1.1 The analog telemetry system was built around purchased parts wherever possible. The main chassis, in which all SCO and mixer-amplifier components were mounted, the negative bias power supply, and the telemetry calibrator were all built within the OSU laboratory, based upon designs developed and described in earlier reports, cited in connection with the description of each component in the following test. The transmitter was

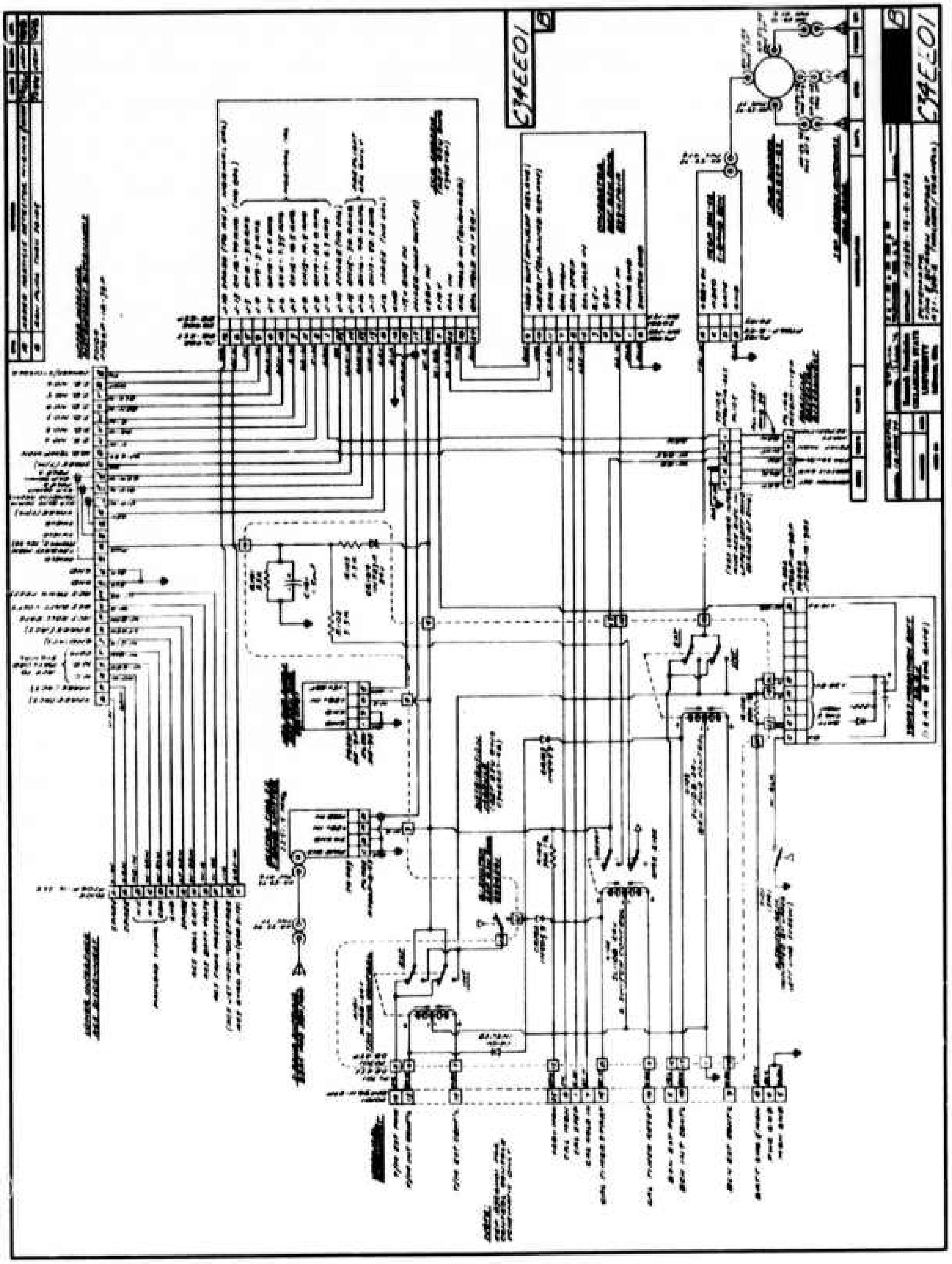

Figure 2. Wiring Schematic, A31.320-2

a nominal two watt power output S-band unit, Vector Model T102S, on a carrier frequency of 2251.5 MHz. Power was radiated by means of the antenna developed previously under contract F19628-70-C-0147 (Reference 1, Section 5.5), using the Ball Brothers Research Corporation Model SBA/100. Frequency modulation was accomplished with the mixed output of the VCO complex, as provided from the mixer-amplifier located on the telemetry subchassis. Primary power was at 28v dc from an onboard battery in flight.

An array of 12 conventional IRIG voltage-controlled oscillators was used for data transmission. Channel 7 through 18 were involved in this package. All VCO units were commercially supplied (Sonex Model TEX-3005). Although the normal input data span for these units is 0 to +5v dc, those used for certain commutated data channels were readjusted to permit the insertion of a negative pedestal. A span from -1.25 to +5.00 volts was used for the 2.5 x 30 two-pole commutator which supplied PAM modulation to channels 15 and 16. The output of all VCO's was mixed and amplified in a commercial mixer amplifier, Dorsett Model MA-18K-1, and (after suitable adjustment for the desired deviation and modulation taper), applied directly as the input signal to modulate the transmitter. Each VCO was in turn modulated in frequency by variations in the data signal applied as input.

The chassis in which the VCO and mixer amplifier complex was mounted was per OSU drawing C34EV01; a Dorsett Model TMS-399-1 chassis was used, but had been specially modified for this mission by internal wiring changes designed to inhibit the calibration of the position in which channel 18 (carrying the PCM-coded gyro information) was located. The technical details of this mount have been described previously (Reference 1, paragraph 5.2.2). In brief, the chassis incorporated a number of field effect switches and was designed to permit transfer of the input to each individual VCO from the normal data bus to a step calibration signal generator located elsewhere in the payload. In addition to the FET-switched channels, three other positions were connected through relays in such a manner as to permit the calibration sequence to be accomplished only by umbilical control on the ground, rather than automatically in flight. This calibration mode was provided to permit set up and calibration of the VCO's used for commutated data, without the necessity of interrupting the commutated data stream in flight. This was possible because the commutators used were essentially self-calibrating by virtue of the formats employed. Proper operation of the FET switching required the addition of an OSU-built power supply, model B32AP01 (Reference 2, paragraph 3.1.3). A simple dc-to-dc converter is used in this circuit and the +28v power from the raw battery is converted to a -15 volt output, unregulated, which is then used as the hold-off bias for the field effect transistors.

The associated calibrator for the telemetry system was that shown in OSU drawing B99KF01A and has also been described previously. (Reference 2, paragraph 3.1.2). The basic design was that developed much earlier under contract AF 19(628)-4993, and has been discussed in some detail there (Reference 3, paragraph 3.1.1). It included a precision 5v regulator to provide reference signals for 2.5v and 5.00 calibration steps, as well as the ground reference. A ramp generator is used for timing, with a simple unijunction oscillator and ramp pick-off circuitry to give control through relay contact wiring, generating a repeated stairstep series of 0, 2.5, and 5 volts at predetermined intervals of time. In addition, the unit may be operated manually, in any one of the three steps, or cycled repeatedly through the steps, by means of an umbilical control system.

3.1.2 Data assignments for the VCO complex used in this telemetry subsystem was according to that shown in Table 1. The commutator segment assignments for the IRIG standard Pulse Amplitude Modulation (PAM) commutator (formatted 2.5 x 30, in a return-to-zero format) are shown in Table 2. These signals were applied as the two PAM-commutated monitor signals on channel 15 and 16 respectively. An electronic commutator in a different IRIG standard PAM format, 10 x 30 nonreturn-to-zero, was employed to provide the signal from the detector array flown as a piggyback instrument package in conjunction with this flight. Data channel assignments for this channel 17 signal are shown in Table 3.

3.1.3 The beacon subsystem was in a standard configuration and provided the ranging and trajectory data through interrogation of the Vega Model 302C-2 C-band transponder. Double pulse interrogation with a code spacing of 5 microseconds was used, and the pulsed reply signal returned back to the ground through the same array used for reception of the

TABLE 1. TELEMETRY DATA ASSIGNMENTS

Infrared Zodiacal Light - A31.320-2
(± 125 KHz Deviation on 2251.5 MHz Carrier, FM/FM)

IRIG Channel	Center Frequency	Band Width	Data Assignment	Notes
7	2.3 KHz	35 Hz	Mass Deposition Detector	1
8	3.0 KHz	45 Hz	Cornell Detector/Event Monitor	
9	3.9 KHz	59 Hz	Synchronous Det. No. 6	
10	5.4 KHz	81 Hz	Synchronous Det. No. 5	
11	7.35 KHz	110 Hz	Synchronous Det. No. 4	
12	10.5 KHz	160 Hz	Synchronous Det. No. 3	
13	14.5 KHz	220 Hz	Synchronous Det. No. 2	
14	22.0 KHz	330 Hz	Synchronous Det. No. 1	
15	30.0 KHz	450 Hz	Housekeeping Monitor Comm	2
16	40.0 KHz	600 Hz	Instrument Monitor Comm	2
17	52.5 KHz	790 Hz	Detector Array Comm	3
18	70.0 KHz	1050 Hz	Gyro Position (PCM)	4

1 Summed output of 16 channel detector array, with superimposed time of event monitors

2 IRIG 2½x30 RZ commutator; see Table 2 for data assignments.

3 IRIG 10x30 NRZ commutator; see Table 3 for data assignments.

4 NRZ-M PCM Train, 800 BPS, 4 ten-bit words.

Word 1 - Synch word (011 011 100 0)
Word 2 - Roll Gyro Position
Word 3 - Pitch Gyro Position
Word 4 - Yaw Gyro Position

TABLE 2. COMMUTATOR DATA ASSIGNMENTS

Infrared Zodiacal Light - A31.320-2
(IRIG Two-Pole 2½x30 RZ Format)

Segment	Pole 1 (Channel 15)	Pole 2 (Channel 16)
1	0 volt Calibration	0 volt Calibration
2	2.5 volt Calibration	2.5 volt Calibration
3	5.0 volt Calibration	5.0 volt Calibration
4	Rack Temperature	+34.5 volt Monitor
5	Top Ring Temperature	+21 volt Monitor
6	Inner Baffle Temperature	-21 volt Monitor
7	Outer Baffle Temperature	+28 volt MVR
8	Mirror Temperature	+28 volt CVR
9	Detector Temperature	+28 volt AVR
10	Mass. Dep. Temperature	Squib Altitude Switch
11	Synch Det. No. 1 Output	T-Zero Squib
12	Synch Det. No. 2 Output	G-Red Squib
13	Synch Det. No. 3 Output	Mirror Door Squib
14	Synch Det. No. 4 Output	Nose Cone Squib (Prime)
15	Synch Det. No. 5 Output	Nose Cone Squib (Back-up)
16	Synch Det. No. 6 Output	Helium Dump Squib
17	S.D. No. 1 Level Switch	Mirror Motor Monitor
18	S.D. No. 2 Level Switch	Mirror Deploy Monitor
19	S.D. No. 3 Level Switch	Nose Cone Off
20	S.D. No. 4 Level Switch	Marman Pin Monitor
21	S.D. No. 5 Level Switch	False Tip Eject
22	S.D. No. 6 Level Switch	Drain T.B. No. 1 Monitor
23	Dewar Vacuum	Drain T.B. No. 2 Monitor
24	Experiment Helium Pressure	Drain T.B. No. 3 Monitor
25	ACS Tank Pressure	Drain T.B. No. 4 Monitor
26	ACS Battery Volts	Drain T.B. No. 5 Monitor
27	ACS Roll Rate	Drain T.B. No. 6 Monitor
28	T/M Battery/G-switch	Cal Light "On" Monitor
29	+5v Synch	+5v Synch
30	+5v Synch	+5v Synch

TABLE 3. DETECTOR ARRAY DATA

Infrared Zodiacal Light - A31.320-2

Channel 17 Signal - IRIG 10x30 NRZ Format

Segment	Data Assignments
1	Detector No. 1 Output
2	Detector No. 2 Output
3	Detector No. 3 Output
4	Detector No. 4 Output
5	Detector No. 5 Output
6	Detector No. 6 Output
7	Detector No. 7 Output
8	Detector No. 8 Output
9	Detector No. 9 Output
10	Detector No. 10 Output
11	Detector No. 11 Output
12	Detector No. 12 Output
13	Detector No. 13 Output
14	Detector No. 15 Output
15	Detector No. 16 Output
16	Detector Summed Signal
17	Detector No. 2 Output
18	Detector No. 3 Output
19	Detector No. 4 Output
20	Detector No. 5 Output
21	Detector No. 6 Output
22	Detector No. 7 Output
23	F.E.T. Bias Monitor
24	Amplifier Bias Monitor
25	Detector Array Temperature
26	0 volt Calibration
27	5 volt Calibration
28	5 volt Calibration
29	5 volt Calibration
30	2.5 volt Calibration

interrogation pulse from the ground radar. An array of three Vega Model 820C cavity-backed helix antennas were used, with a Vega Model 854-C3 power divider to distribute this signal to the common RF connector on the C-band beacon.

3.1.4 Power at a nominal voltage of 28.8 volts for the entire system was provided from a single nickel-cadmium battery, rated 1.2 ampere hours in capacity at 5 hour discharge rate. Marathon P/N 39093 was selected for this purpose. This battery is encapsulated in a rectangular metal canister with a common power connector; provision is included within the canister for battery charging, with a blocking diode to prohibit inadvertent application of the wrong polarity signal from the charging source. The negative common reference, a tap at +14.4v and output power at +28.8v are provided through the same connector.

3.1.5 Control and monitor circuitry are more or less conventional within this package. A series of Potter & Brumfield latch-type relays were used, and all power control relays were wired with redundant contact configuration by parallel connecting both halves of the double-pole double-throw configuration. The common arm was connected to the unit to be powered, one set of contacts brought out through the umbilical, and the second set of contacts was internally connected to the +28v battery supply terminal. The external power for the test mode of operation was provided through the umbilical by the power source in the blockhouse, and subsystem turn-off was accomplished by returning each relay to the "external power" mode, then shutting off the external power. Control of the relays is provided by a similar system in which the two relay coil terminals were operated against a common negative reference. Pulse application of a positive voltage to one coil is sufficient to latch each individual relay into the desired mode of operation. One relay controls power to the entire FM/FM telemetry subsystem and simultaneously energizes the remotely located mass particle detector circuitry through an aft disconnect plug. A second identical relay is used for independent control of the C-band radar transponder.

A monitor of battery condition is provided through the same lead used for battery charge and service by a blocking diode, with a precision multiplier resistor wired in parallel, brought into the console and associated switching circuitry. A similar multiplier resistor is brought from the common telemetry supply bus back through the umbilical to blockhouse console, and permits monitor of the actual bus voltage within the package in either external or internal power modes. For inflight monitor of battery condition, a zener-offset voltage divider is built within the distribution box which houses the associated control relays, and is so arranged as to provide a voltage proportional to the actual bus voltage which is applied to the equipment. (The monitor point utilized for this purpose also serves as a liftoff monitor, by indicating the status of the G-switch controlled relay described below).

Combination monitor of the condition of the relay controlled by the G-switch and a backup transfer signal to place the control relays in the "internal power" mode is provided by standard OSU circuitry which has been described previously (Reference 2, Section 3.2). Diode steering of raw battery power through the contacts of a normally open switch, which is mass loaded in such a manner as to permit the contacts to close when the acceleration force in the direction of normal flight exceeds approximately 7 G's, is used to apply a pulse of 28v dc power to one coil terminal of each of three double-pole double-throw relays included within the package. (Two of these relays control power source to the telemetry subsystem and the beacon subsystem, as previously described). The third relay, K102 of Figure 2, has one set of contacts so wired as to apply 28v power to the OSU calibrator, initiating the timing sequence and generation of 0, 2.5, 5v cal steps in the associated telemetry subsystem. A second pair of contacts of the same relay is so wired as to parallel a resistor in the bus monitor voltage; this causes a shift in the calibration curve, indicating liftoff by an abrupt discontinunity in the telemetry battery monitor on a commutated signal supplied through the segment 28 signal of ch 15. Wiring is such that when the G-switch is cocked and the system is in the standby condition, lower voltages are obtained (roughly one-half the level which will exist in flight). Immediately upon energizing the G-switch control relay, this shunt is removed, permitting utilization of full 0 to 5v span as a monitor of telemetry voltage over a region of approximately 24 to 32 volts. Both control coils of the G-switch control relay are also brought through the umbilical back to the associated control console. This permits control of the G-switch relay without mechanically actuating the G-switch. This mode of operation is utilized to provide simulated liftoff for flight tests, and also to permit reset in the event the G-switch is inadvertently tripped in handling.

In order to eliminate discharge of the battery in shipping or handling by inadvertent actuation of the G-switch, the negative side of the internal flight battery is returned to ground through a microswitch interlock. Opening this microswitch will disable internal power, rendering the system safe to handle. For convenience in arming for flight, the microswitch is arranged on the umbilical mounting block in such a way that an external Allen head screw may be tightened while the rocket is in tower to arm the switch, or loosened to disarm the system for safe handling.

3.2 Hybrid Systems; Hi Star Series (A04.004-8 & -9)

Two airborne support packages were supplied in conjunction with the continuation of the program begun under the preceding contract F19628-70-C-0147. The packages were, however, refurbished and somewhat modernized for application in this series. General design features of the package have been described previously (Reference 1, paragraph 3.3.2). The same concept was continued with two packages, alternately used in the program, and a third package was continuously updated to the current configuration, then held in reserve as a field spare. The physical configuration is shown in Figure 3, and was built on the same base as the earlier package, a disc platform supported by the S-band antenna. The components projected into an Aerobee extension forward, in which interface components were also mounted. The support package continues to include a C-band transponder subsystem and two separate S-band telemetry data links. A PCM-coded digital link is provided on one S-band transmitter, while an 8-channel analog system using an FM/FM system is provided on a second adjacent carrier frequency; the two different transmitter models have approximately two watts power output. The C-band transponder is again included for trajectory determination, and the module containing the control and monitor electronics remains essentially as described before. Power is from two separate nickel-cadmium battery packs, but the switching circuit is more complex than described in connection with the infrared zodiacal light

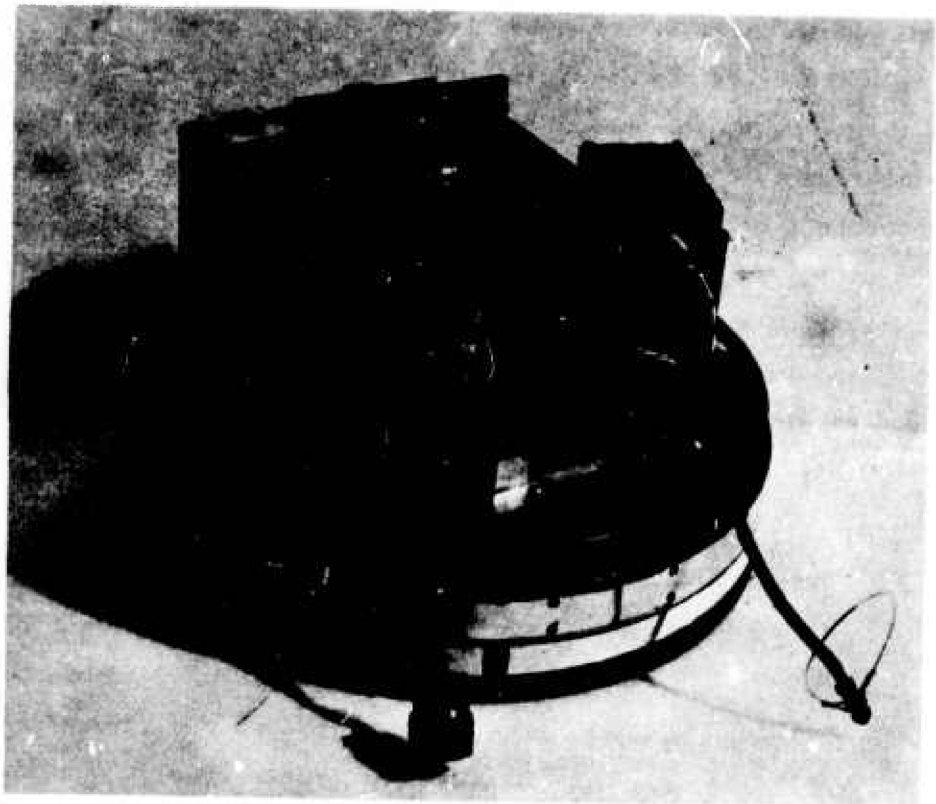

Figure 3. Hi Star Series Support Package

package. In order to facilitate tests of the high speed PCM system, a coaxial relay is included within the payload, permitting transfer from the flight antenna to an external connector on the surface of the vehicle. This permits operation into a dummy load or a "cheater" antenna system while the system is undergoing checks. Wiring details of the two packages prepared for support purposes under this flight are shown in Figure 4.

3.2.1 The analog telemetry system used a Conic Model CTM-UHF-402 transmitter on a carrier frequency of 2251.5 MHz. Standard FM/FM modulation techniques were employed, with modulation provided from the output of a mixer amplifier located on the VCO chassis. Transmitted power was radiated by means of a pair of New Mexico type PSL 6.017 quadraloop antennas, mounted diametrically opposed on the skin of a 25" long Aerobee

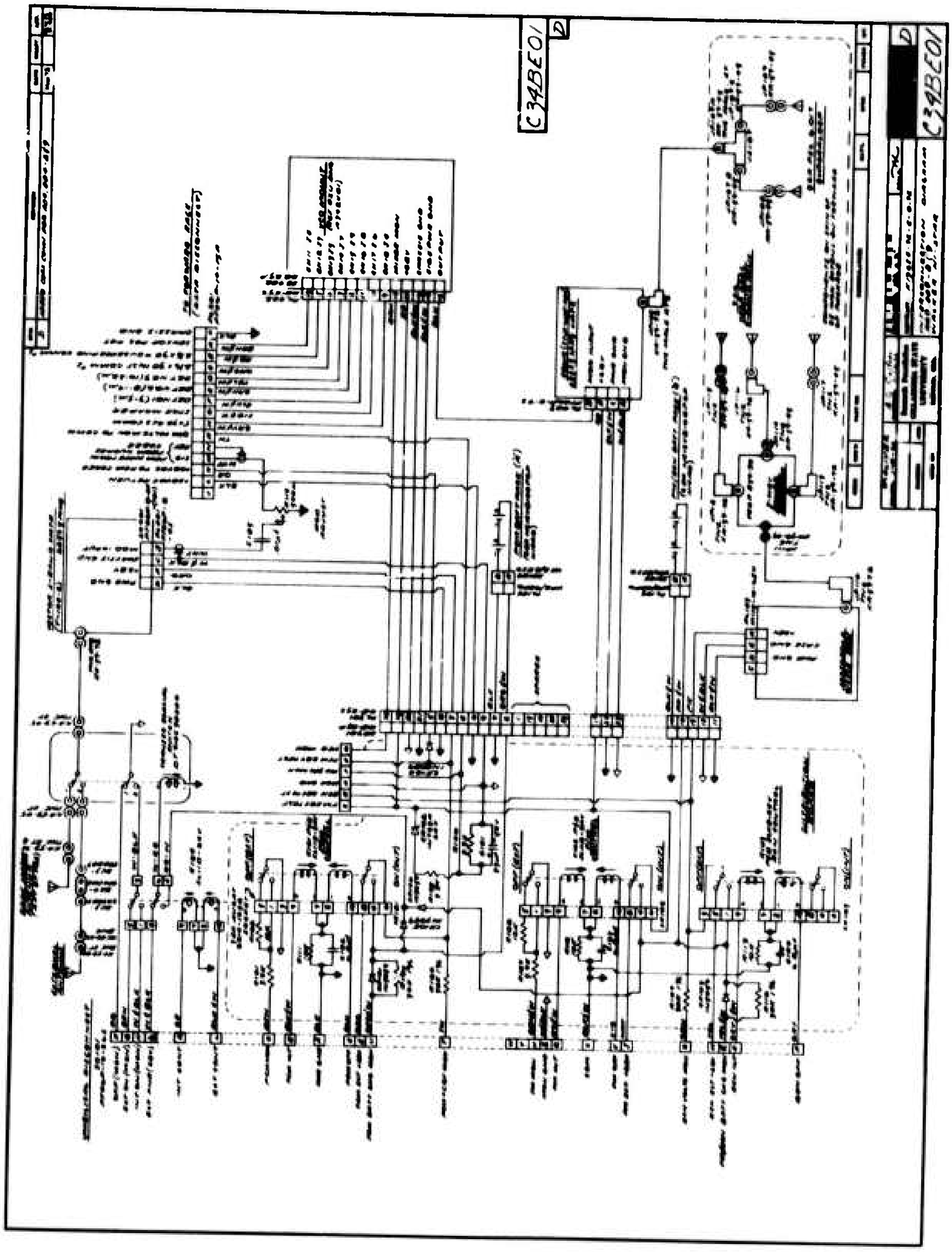

Figure 4. Wiring Schematic, A04.004-8

extension, 15" in diameter, and were physically located at the aft portion of the electronics interface package, which was immediately forward of the telemetry deck. The analog system was uncalibrated, so did not require either the calibrator or negative power supply described in the previous section of this report. A simple VCO mount accommodated eight VCO's and the mixer amplifier, all of which were plug-in units procured from Dorsett Electronics. VCO's were Model 0-18-K1; the mixer amplifier was model MA-18-K1. The chassis has been previously described (Reference 2, paragraph 3.1.1) and was a simple mechanical mount providing the necessary wiring to distribute power and input signals to the modules which were plugged in. The output of the mixer amplifier, adjusted to provide the proper modulation taper and deviation desired, was taken directly to the modulation input of the associated transmitter. The mixed VCO signal was brought from the chassis as a monitor into the associated distribution board module, where it appeared on one pin of a test plug. Assignment of data and VCO frequencies were as depicted in Table 4; channels 12 and 13 were in turn modulated by a standard IRIG 2.5x30 RZ commutator. Segment assignments within this commutator are shown in Table 5. A third channel within the complex, channel 18, was used for multiplexed transmission of information from the associated ACS system, which included an internal single pole 5x30 commutator. Data assignments within this commutator are also depicted in Table 5.

3.2.2 The high speed PCM data link required an external PCM coder which was physically mounted in the surrounding extension in such a manner as to provide a short input lead to the OSU package. The format for this PCM coder is as portrayed in Table 6. The digital multiplexed output signal from the PCM coder was taken through a small potentiometer, R114, to permit adjustment of the desired deviation of the associated transmitter. A Vector Model T102S transmitter, frequency modulated by the bit stream on a carrier frequency of 2259.5 MHz, was used to relay this information to the ground. Power from the transmitter was fed through a coaxial relay, Transco Model DT910C30200. This relay was wired so that in the relaxed position power was fed to the normal flight antenna, Ball Brothers Research Corporation Model SBA/100, as described in conjunction with the infrared

TABLE 4. TELEMETRY DATA ASSIGNMENTS
HI STAR SERIES - A04.004-8

ANALOG SYSTEM - LINK I
(± 125 KHz Deviation on 2251.5 MHz Carrier, FM/FM)

IRIG Channel	Center Frequency	Band Width	Data Assignments	Notes
11	7.35 KHz	110 Hz	Sensor Position Pot	
12	10.5 KHz	330 Hz	Instrument Comm #1	1
13	14.5 KHz	330 Hz	Housekeeping Comm #2	1
14	22 KHz	330 Hz	Inst. Channel #3 (Long)	2
15	30 KHz	430 Hz	Inst. Channel #2 (Medium)	2
16	40 KHz	600 Hz	Inst. Channel #1 (Short)	2
17	52.5 KHz	790 Hz	Star Mapper	
18	70 KHz	660 Hz	ACS Commutator	3

Notes:
1. IRIG 2½x30 RZ commutator; see Table 5 for data assignments (Also repeated in PCM assignment, words 26 and 27.)
2. Pulsed signals, riding on 2.5v bias level.
3. IRIG 5x30 RZ commutator; see Table 5 for data assignments. (Also repeated in PCM assignment, word 25.)

TABLE 5. COMMUTATOR DATA ASSIGNMENTS
HI STAR SERIES - A04.004-8

(PAM Data; Used on both FM/FM and PCM Links)

Segment	Pole 1 2½x30 RZ Ch 12 + Word 26	Pole 2 2½x30 RZ Ch 12 + Word 27	ACS 5x30 RZ Ch 18 + Word 25
1	0v Ref. Cal	0v Ref. Cal	0v Ref. Cal
2	2.5 volt Cal	2.5 volt Cal	5.0 volt Cal
3	5.0 volt Cal	5.0 volt Cal	Roll Position
4	Rad Door Pos	Support Battery	Pitch Position
5	Squib Relay Mon	PCM Battery	Yaw Position
6	Starmap Door/Tip	FM/FM Battery	Program Start
7	Rad Shield Temp 2	Dig. Timer 1	Roll Valves
8	Off Gimbal Temp	Dig. Timer 2	Pitch Valves
9	Detector Temp	Support Skin Temp	Yaw Valves
10	On Gimbal Temp	Load Address	Despin Mon
11	Rad Shield Temp 1	Rad Cap Pos	Roll Rate (Offset)
12	Cap Pressure	Rad Motor/Brake	Pitch Rate
13	Optics Temp	Rad Pos Pot	Yaw Rate
14	Rad Pos Bit 8	Shutter Power	ACS Hold
15	Rad Pos Bit 9	Logic Volts	+28v Bus Mon
16	Rad Pos Bit 10	Rad Pos MSB (1)	Capt/Roll Capt
17	Rad Pos Bit 11	Rad Pos Bit 2	Star Magnitude
18	Rad Pos Bit 12	Rad Pos Bit 3	Fine Capture
19	Rad Pos Bit 13	Rad Pos Bit 4	ACS Mode
20	Cone Skin Temp	Rad Pos Bit 5	Turn Pulse
21	+18 volt Mon	Rad Pos Bit 6	HV/Star Presence
22	-18 volt Mon	Rad Pos Bit 7	Fine Pitch Pos
23	Starmap HV Mon	Rad Pos Bit 8	Fine Yaw Pos
24	Cap Motor	Rad Pos Bit 9	Blank
25	Rad Motor/Brake	Rad Pos Bit 10	Gas Pressure
26	Rad Pos Pot	Rad Pos Bit 11	Program Pos
27	Shutter Power	Rad Pos Bit 12	Fuel/Ox Valve
28	Logic Volt Mon	Rad Pos LSB 13	Separation Mon
29	+5v Synch	+5v Synch	+5v Synch
30	+5v Synch	+5v Synch	+5v Synch

TABLE 6. HI STAR TELEMETRY FORMAT (A04.004-8)
DIGITAL SYSTEM - LINK II

($\pm$ 380 KHz Deviation on 2259.5 MHz Carrier, FM/FM)

NRZ-M format at 855 KBPS, 30 10-bit words per frame, subcomm at 16 frames/ major frame. Frame synch = 110 111 0000. Subframe ID in first 4 bits of subframe word, all data MSB first.

Word	Data	Notes
1 through 24	Radiometer 1 through 24 Outputs	
25	ACS Commutator, 5x30 RZ	1
26	Inst. Comm No. 1, $2\frac{1}{2}$x30 RZ	1
27	Housekeeping Comm, No. 2, $2\frac{1}{2}$x30 RZ	1
28	Star Mapper	
29	Subframe Data	2
30	Main Frame Synch Word	

Notes: 1 PAM commutator data, normally -1.25v to +5.0v span, compressed and offset to 0-5v range. See Table 5 for data assignments.

2 PCM subcommutation per assignment listed below. Data in last six bits only.

Subframe Data Format: (Duplicated in PAM, Table 5).

Word	ID	Data
1	0000	Optics Temperature
2	0001	Detector Temperature
3	0010	Rad Motor/Brake
4	0011	Rad Shield Temp. 1
5	0100	Rad Shield Temp. 2
6	0101	On Gimbal Temperature
7	0110	Off Gimbal Temperature
8	0111	Voltage Monitor
9	1000	Calibration Current
10	1001	Pressure
11 thru 16	1010 to 1111	Spare Words, Not Assigned

zodiacal light package above. Again, this antenna served as the mechanical structure on which the package was assembled. An aluminum disc mounted to this antenna provided physical mounting surface for all the components of the telemetry and beacon subsystems.

3.2.3 The radar transponder system was virtually identical to that described in the preceding section of this report. It differed only in the use of a Motorola Model WSMR-01 beacon, also double pulse coded with 5 microsecond spacing, in place of the Vega equipment previously described. The antenna system for the beacon consisted again of three each Vega Model 820C C-band helical antennas, flush mounted in the skin of Aerobee extension surrounding the package. A Vega Model 854-3C three-way power divider again was used between the beacon and the antenna array.

3.2.4 This system had two separate battery packs for power. A one ampere hour nickel-cadmium battery pack, constructed of two each Power Sources, Inc., Model NC12VB10JFGP, was used as power to the PCM subsystem. A second identical pack provided power for the combination of the analog FM/FM system and the associated radar transponder package. The battery pack which supplied power to the PCM subsystem also provided the power to the coaxial switch used to transfer RF power between the two usable antenna systems. Power is also supplied from this same bus through a blocking diode to the interface connector, where it served as the primary power for the PCM encoder in the associated interface electronics system.

3.2.5 The general function of the controls and monitors located within the distribution board module remain quite similar to those described previously. There are a total of three of the latch type power control relays: one for the beacon control, one for the FM telemetry control, and a third one for the PCM telemetry subsystem. Operation is as described previously, with the exception of the addition of a parallel combination of resistor and capacitor in series with the common return leg of each relay, in order that continuous application of power might not create an overheat problem in the coil of the associated relay. This feature was added because use of the systems in the tower with remote umbilical connections frequently leads to the use of voltages as high as 40 volts within the control console in order to provide external power at the desired level of 28v within the vehicle. Battery charge and monitor circuitry is as has been described previously, but the inflight monitor of battery performance is on this package confined to the battery and power supply bus used in conjunction with the analog telemetry system. In addition to the power control relays, a fourth double-pole-double-throw latch type relay is included in the circuitry for the coaxial switch. This feature was added so that the coaxial relay could be operated either by external power through the umbilical to transfer to the test antenna in a fail safe mode (whereby the relay would return to the flight antennas if the umbilicals were inadvertently removed during the test condition), or by means of the override provided by the control relay the system may be thrown into a test mode in which the relay can be energized from the internal battery. (This latter feature was an override feature permitting use of the external test antenna while tests are being performed in the internal power mode with the umbilical removed). The console is provided with suitable warnings to inhibit inadvertent operation and flight while in this external test antenna mode of operation on internal power. A set of monitor contacts on the coaxial switch relay are also wired to the umbilical and through one set of contacts on the control relay, K104, in such a manner as to energize one of three light bulbs in the associated console. A green light indicates that the system is in the flight antenna mode. An amber light indicates that the system is energized through the umbilical in the external power condition, and will immediately return from test antenna to flight antenna when the umbilical is removed. The third mode of operation is indicated by a red light, which indicates that the system has been latched in the test antenna mode of operation by the internal battery and must be reset by insertion of the umbilical and transfer of the relay back to the normal flight configuration. Transfer is indicated by the reappearance of the green light on the console.

3.3 PCM Systems: Hi Hi Star Series

A series of Aerobee 350 vehicle support packages originally planned for use on the Hi Hi Star series under designation A35.191-1 through -4 were designed around a single telemetry link with a high speed PCM modulation scheme for digital data, combined with a C-band transponder for

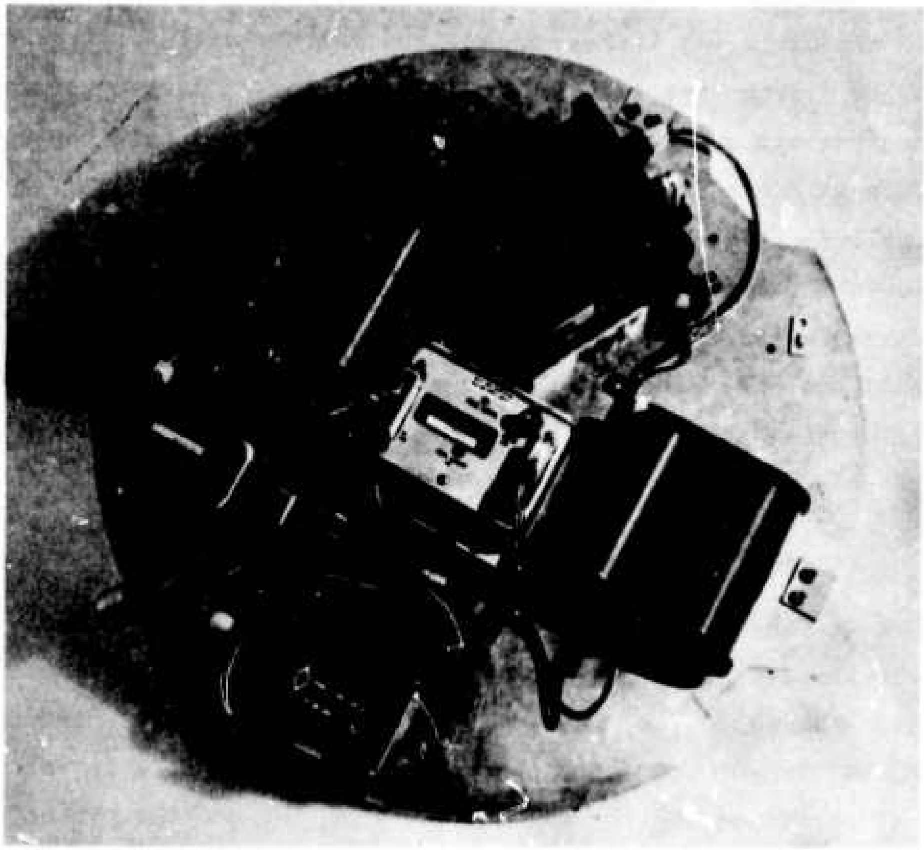

Figure 5. Hi Hi Star Support Package

trajectory information. The general design features were based upon an earlier development under contract F19628-70-C-0147 (Reference 1, paragraph 3.3.3). The mechanical package is shown in Figure 5, and was designed for compatibility with the Aerobee 350 vehicle. In order to conserve weight, the entire system is assembled on a single bond-o-ply disc 20.5" in diameter. The disc is provided with suitable holes for mating to the remainder of the internal vehicle structure. A total package height of only 4.5" is required for this application, in which all components are spread out in a low profile to utilize a thin shelf section at the end of an overall support package which is being fabricated elsewhere. All control and monitor circuitry is built within a single module, provided with one electrical disconnect to the associated umbilical and a second disconnect which serves as a main harness to distribute power to the remainder of the package. Modulation from the externally mounted PCM coder is fed to the transmitter, which radiates power from one section of a compound antenna system to be described later. As in the case of the Hi Star series, RF power is taken through a coaxial relay either to this flight antenna or to a connector on the side of the package to which an external test antenna may be attached. Power for the telemetry system is supplied from the same type of battery pack described previously. The associated C-band transponder is a Vega Model 302C-2 again, and control circuitry is essentially as has been described previously; antenna connections are into the same hybrid antenna utilized for the telemetry system. Power for the beacon transponder installation is identical to that described for the telemetry and used in previous packages. Control and monitor functions are similar to those which have been previously described and, in this system, include inflight monitors of condition of both beacon and telemetry battery packs. Umbilical controls again permit charge and monitor of battery condition through the umbilical system and a monitor is also provided for the actual bus voltage within the system, whether on external or internal power. Circuit details of the package which finally evolved in this series are shown in Figure 6.

Four of these packages were originally built under OSU drawing C34DE01B, without the feature of RF relay transfer or the associated G-switch for package turn-on and indication of liftoff signal. Both of these features were added to an intermediate version of the package prior to the launch of the first round in the series, A35.191-2, which has been described under field services. A second set of minor package changes was required after launch of the first round in order to provide a change in the type of radar transponder equipment flown, after phase out of Motorola type WSMR-01 beacon (flown on the first round) to the Vega 302C-2 equipment (now in use for following rounds of the same series).

3.3.1 The telemetry subsystem, because of the longer range anticipated with this rocket, is built around a higher-powered transmitter similar to that employed in the lower altitude Hi Star series. Vector Model T-105S equipment was selected, with a mechanical configuration virtually identical to the lower powered 2 watt nominal system, but with a

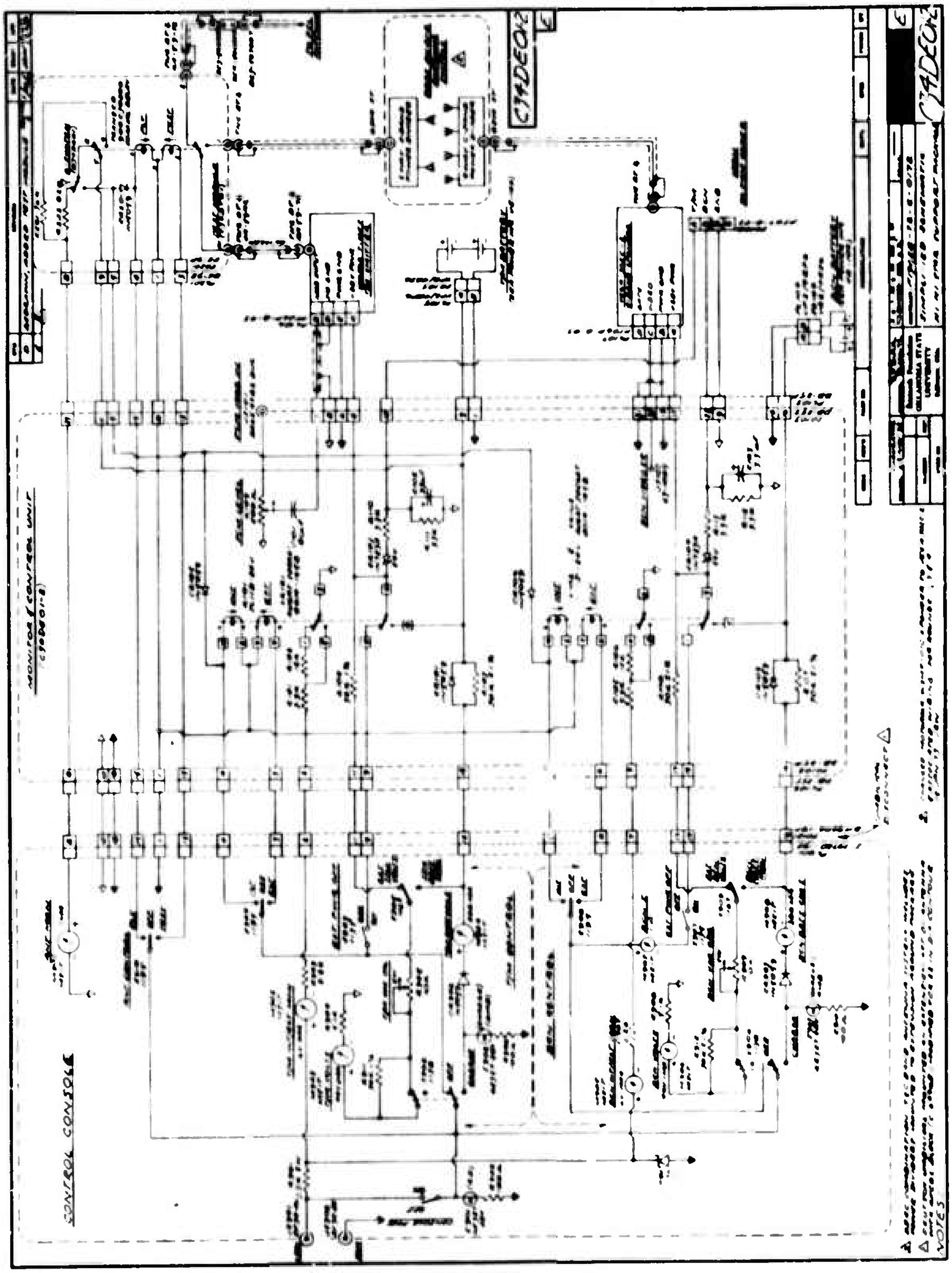

Figure 6. Wiring Schematic, A35.191-X Series

TABLE 7. HI HI STAR TELEMETRY FORMAT (A35.191-2)

($\pm$ 500 KHz Deviation on 2259.5 MHz Carrier, PCM/FM)

NRZ-M format at 245 KBPS, 70 10-bit words per frame, Subcomm at 60 frames/major frame. Data MSB first.
Frame Synch = 3 words long; 111 110 1011 110 011 0011 010 000 0000.

Word	Data	Word	Data
1	Stellar Aspect No. 1	36	Sensor Det 2-M11
2	Stellar Aspect No. 2	37	Sensor Det 1-S9
3	Housekeeping Comm. 1	38	Sensor Det 2-M12
4	Housekeeping Comm. 2	39	Sensor Det 2-M14
5	ACS Commutator	40	Sensor Det 2-M15
6	Spare Vehicle Data	41	Sensor Det 2-M16
7	Sensor Det 1-S1	42	Sensor Det 2-M17
8	Sensor Det 1-S2	43	Sensor Det 2-M18
9	Sensor Det 1-S3	44	Background, S.B.
10	Sensor Det 1-S4	45	Sensor Det 3-L1
11	Sensor Det 1-S5	46	Sensor Det 3-L2
12	Sensor Det 1-S6	47	Sensor Det 3-L3
13	Sensor Det 1-S7	48	Sensor Det 3-L4
14	Sensor Det 1-S8	49	Sensor Det 3-L5
15	Sensor Det 2-M7	50	Sensor Det 3-L6
16	Sensor Det 1-S10	51	Sensor Det 3-L7
17	Sensor Det 1-S11	52	Sensor Det 3-L8
18	Sensor Det 1-S12	53	Sensor Det 2-M8
19	Sensor Det 1-S13	54	Sensor Det 3-L10
20	Sensor Det 1-S14	55	Sensor Det 3-L11
21	Sensor Det 1-S15	56	Sensor Det 3-L12
22	Sensor Det 1-S16	57	Sensor Det 3-L13
23	Sensor Det 1-S17	58	Sensor Det 3-L14
24	Sensor Det 1-S18	59	Sensor Det 3-L15
25	Background, MB	60	Sensor Det 3-L16
26	Sensor Det 2-M1	61	Sensor Det 3-L17
27	Sensor Det 2-M2	62	Sensor Det 3-L18
28	Sensor Det 2-M3	63	Background, LB
29	Sensor Det 2-M4	64	Super Subcomm, Em.Dr. 1,3,5
30	Sensor Det 2-M5	65	Super Subcomm, Em.Dr. 2,4,6
31	Sensor Det 2-M6	66	Subcomm Data, Sensors
32	Sensor Det 2-M9	67	Sync Word 1
33	Sensor Det 2-L9	68	Sync Word 2
34	Sensor Det 2-M12	69	Sync Word 3
35	Sensor Det 2-M10	70	Subframe ID Word

specified minimum power output level of 5 watts and a somewhat increased dc input power demand. The modulation is supplied from the equipment which is mounted in the structure to which the telemetry disc shelf is attached. Modulated carrier signal is ra''ated from a special hybrid antenna system. A wraparound antenna is att... to the outer skin of the main vehicle. A two-way power divider provides the feed to a dual array in the S-band section of the antenna, for essentially omnidirectional pattern coverage for the telemetry signal. (The radar transponder is connected through a four-way power divider to an array of four elements tuned to the C-band frequencies used there.) This antenna was developed by Ball Brothers Research Corporation as their Model AN-21/A.

The format for the PCM signal is as chown in Table 7. Details of the actual word assignment for various rounds in this series will vary and are too lengthy to warrant inclusion in this report. The complete data information assigned in connection with the launch of A35.191-2 has been described previously (Reference 4). Besides the normal 10-bit digital words for sensor information, three words were assigned to externally-located PAM commutators in the assignment listed in Reference 4. In addition to these words and the lengthy series of "clear channel" words, word 66 was utilized in a complicated subframe system of digital commutation. The first few words of this subframe included binary monitors of a number of events in which specific bits within words 1 and 2 were used as binary monitors to indicate "go"-"no go" status of various equipment within the vehicle. Remaining subframes of word 66 were conventional data monitors until reaching the end of the data sequence. Words 64 and 65 were assigned in a super-subcommutated format in which 3 bits of information repeated in every third subframe of the sequence. Subframe identification was supplied in word 70, immediately following the 30 bit frame synchronizing signal, and refers to the number of the subframe which will follow. (Further details of this system are also disclosed in Reference 4.) Deviation of the transmitter modulated by this PCM signal was controlled by a variable resistor in the associated control module.

3.3.2 The subsystem for the radar tracking beacon has been described previously, and this particular installation di. not differ significantly from those reported earlier. Although initially all systems were wired for the Motorola WSMR-01 transponder, after the launch of the -2 round in the series all packages (including the recovered -2 round) were refurbished to incorporate proper wiring for installation of a later version Vega 302C-2. As indicated previously, the beacon antenna system was incorporated in the hybrid wrap-around array, BBRC Model AN-21/A.

3.3.3 Power was supplied by two identical nickel-cadmium battery packs. Each was built up of two series-connected Power, Incorporated batteries, Model VB-100. The two batteries are built into a pack supplying 28.8 volt power, with an integral Viking disconnect plug to facilitate service and installation in the harness without necessity for rewiring. (Even though batteries are serviced through the umbilical, it is frequently desirable to switch from test packs to a new battery pack for the launch configuration.) Each battery pack is capable of supplying one ampere of load current for a period of approximately 70 minutes; one battery pack will provide power for operation of the radar beacon for slightly in excess of 1 hour whereas life of the associated S-band transmitter is somewhat shortened because of the increased drain for the high powered unit and may be estimated as approximately 50 minutes in duration.

3.3.4 Control and monitor circuitry has been adequately described previously, and differs from earlier designs only by the addition of ohmmeter type monitors on one set of contacts for each of the two relays involved. K101, transferring power to the telemetry subsystem, has one set of contacts wired so as to switch the total resistance to ground from one pin of the umbilical; an ohmmeter type circuit within the associated control box detects which state the relay is in. Identical wiring is used on a second set of contacts of relay K102 in order to monitor condition of the latch relay which transfers power to the radar transponder equipment. A video test point from the beacon is brought out to a suitable connector on the surface of the monitor and control unit, and the potentiometer for adjustment of the PCM modulation level is also included within the same module. Zener offset voltage divider networks on the output bus for both telemetry power and transponder power are fed from this subsystem to the PCM coder through an interface disconnect plug, S0108.

A somewhat different version of the coaxial relay is used to transfer telemetry power from the normal flight antenna array to an external test antenna, through a disconnect plug in the surface of the vehicle. A Transco Model 900C30200 coaxial relay is used, and differs from the earlier version primarily through use of a two coil relay with latching capability, thus obviating the need for an external latch control relay. Twenty-eight volt power from the telemetry battery is taken through monitor contacts on this same relay and the G-switch contacts, back through the monitor unit to a meter in the control console. Calibration of the meter scale indicates by the deflection of this console meter whether the RF relay has been latched in the "fly" or "test" mode by switching between 82,000 and 36,000 ohm series resistors, used as multipliers to the monitor meter movement, M901. The G-switch, OSU Model B34DG01, is a mass-loaded, spring-return switch. The momentary closure of this switch steers power through a network of diodes (CR201, CR105, and CR106) to the internal power coils of both the RF relay (to transfer power to the flight antenna) and the control relays for both beacon and telemetry subsystem power. This insures that, if launch occurs while in the test mode, all relays will be automatically reset to the flight configuration.

3.4 PCM Support System: Hi Star South (A05.391-1 through A05.391-3)

The support systems used on the Hi Star South series were unique within this series of support systems. The combination of high bit rate PCM modulation, in conjunction with a lower P-band frequency transmitter, was used in order to adapt existing instrumentation to the requirements of the mission and still provide an RF carrier which was compatible with equipment availability at the Australian launch site. In order to increase the capability of ground data reception, using a relatively low-gain wide beamwidth ground receiving antenna, for tracking a high performance vehicle (the Aerobee 200), telemetry transmitter power was raised from the previous level of 2 watts to a nominal 5 watt minimum for this application. PCM encoders were provided by OSU for this application, as were many of the other components employed in the telemetry system, but the actual package was assembled at AFCRL in conjunction with build-up of other support equipment for the rounds. A C-band radar transponder beacon was included for trajectory determination, operating in conjunction with the Australian radar. Because of multipath propagation difficulties which had been experienced previously even with lower bit rate telemetry on this frequency, use of the high bit-rate system dictated a coaxial relay within the package again to permit transfer of power from the flight antenna to an external test antenna during ground checks. Circuitry used was similar to that which has been described previously. After procurement of the required components and local tests at OSU to verify compliance specifications, components were delivered to AFCRL for incorporation of the payloads. Actually, only two sets of components were purchased since round -3 of the series was to be refurbished after recovery from earlier flight of one of the first two systems.

3.4.1 The telemetry subsystem used 234.0 MHz for the RF carrier, and radiation at approximately 6 watt power level from Conic Model CTP-405 transmitters. Modulation was PCM/FM in nature, with a deviation of $\pm$ 300 KHz, in order to maintain compatibility with the high frequency pulse stream modulation which was used. Radiation in flight was from a pair of New Mexico State University quadraloop antennas, mounted on the outer skin of the extension in which the support electronics mounted. PCM coding and data multiplexing was provided by a Vector Model EMN-100 encoder. The data format for the PCM system is as shown in Table 8. Words 25 and 27 of the PCM format were modulated by PAM output signals, supplied by on-board IRIG commutators. All ACS data was multiplexed on word 25 by means of a 5x30 return-to-zero commutator, with housekeeping information supplied via word 27 using a 2.5x30 non-return-to-zero commutator. PAM commutator data segment assignments were as listed in Table 9. A conventional PCM subframe commutation system was also provided in word 29 as shown in Table 10. This subframe data included a 16 word repeat cycle and used 10-bit words, as did the major portion of the telemetry system. However, subframe identification was coded in the first four bits of each word, to identify words 1 through 16 by four digit binary notation. This created some difficulty initially in decommutation and also created intermittent problems in the field, since it was necessary to use a 4-bit delay in the associated PCM decoders in the

TABLE 8. PCM CODER FORMAT ASSIGNMENT
HI STAR SOUTH - A05.391-1 through -3

($\pm$ 300 KHz Deviation on 234.0 MHz Carrier, PCM/FM)

NRZ-S format at 600 KBPS, 30 10-bit words per frame, subcomm at 16 frames/major frame. Frame synch 110 111 0000, subframe ID on first 4 bits of subframe word. All data MSB first.

Word	Data	Notes
1	Radiometer Detector 1 Output	
2	Radiometer Detector 2 Output	
3	Radiometer Detector 3 Output	
4	Radiometer Detector 4 Output	
5	Radiometer Detector 5 Output	
6	Radiometer Detector 6 Output	
7	Radiometer Detector 7 Output	
8	Radiometer Detector 8 Output	
9	Radiometer Detector 9 Output	
10	Radiometer Detector 10 Output	
11	Radiometer Detector 11 Output	
12	Radiometer Detector 12 Output	
13	Radiometer Detector 13 Output	
14	Radiometer Detector 14 Output	
15	Radiometer Detector 15 Output	
16	Radiometer Detector 16 Output	
17	Radiometer Detector 17 Output	
18	Radiometer Detector 18 Output	
19	Radiometer Detector 19 Output	
20	Radiometer Detector 20 Output	
21	Radiometer Detector 21 Output	
22	Radiometer Detector 22 Output	
23	Radiometer Detector 23 Output	
24	Radiometer Detector 24 Output	
25	ACS Commutator, PAM @ 5x30 RZ	1
26	Radiometer Position Potentiometer	
27	Housekeeping Commutator, PAM @ 2.5x30 NRZ	
28	Star Mapper	
29	Subframe Data (16 Frame Repeat)	2
30	Synch Word	

Notes: 1 Compressed and offset to 0-5v span, see Table 9.

2 See Table 10 for assignments.

TABLE 9. PAM COMMUTATED DATA, HI STAR SOUTH
(A05.391-1 through A05.391-3)

Segment	Word 25 - 5x30 RZ (ACS Comm)	Word 27 - 2½x30 NRZ (Housekeeping Comm)
1	0% Data Reference	Support Battery Voltage
2	100% Data Reference	Squib Battery Voltage
3	Roll Position	Rad. LG-SM Door Position
4	Pitch Position	Starmap Door/Tip Position
5	Yaw Position	Squib Selector Relay Mon
6	Program Start	T/M Battery Voltage
7	Roll Valves	Support Skin Temperature
8	Pitch Valves	Load Address
9	Yaw Valves	Radiometer Cap Position
10	Despin Monitor	Squib Battery Voltage
11	Roll Rate	Cone Skin Temperature
12	Pitch Rate	Logic Voltage
13	Yaw Rate	Rad. Position, MSB 1
14	Hold Control	Rad. Position, Bit 2
15	+28v Bus Mon	Rad. Position, Bit 3
16	Capt./Roll Capture	Rad. Position, Bit 4
17	Star Magnitude	Rad. Position, Bit 5
18	Fine Capture	Rad. Position, Bit 6
19	ACS Mode	Rad. Position, Bit 7
20	Turn Pulse	Rad. Position, Bit 8
21	HV/Star Presence	Rad. Position, Bit 9
22	Fine Yaw Position	Rad. Position, Bit 10
23	Fine Pitch Position	Rad. Position, Bit 11
24	Blank	Rad. Position, Bit 12
25	Nitrogen Pressure	Rad. Position, LSB 13
26	ACS Program Position	0 volt Cal Ref.
27	Fuel/Ox Valve Mon	+5v Frame Synch
28	Payload Separation	+5v Frame Synch
29	+5v Synch	+5v Frame Synch
30	+5v Synch	+2.5v Cal Ref.

TABLE 10. SUBFRAME DATA, HI STAR SOUTH
(A05.391-1 through A05.391-3)

Digital Data Assignments, Word 29

Subframe Word	Ident.	Data	Note
1	0000	Optics Temperature	
2	0001	Detector Temperature	
3	0010	Rad Motor/Brake Monitor	1
4	0011	Rad Shield Temp. No. 1	
5	0100	Rad Shield Temp. No. 2	
6	0101	On Gimbal Electronics Temperature	
7	0110	Off Gimbal Electronics Temperature	
8	0111	Sensor Battery Voltage	
9	1000	Starmapper Hi Voltage Monitor	
10	1001	Radiometer Cap Pressure	
11	1010	Starmapper +18 volt Monitor	
12	1011	Starmapper -18 volt Monitor	
13	1100	Longitudinal Accelerometer	
14	1101	Rad Position Potentiometer	
15	1110	Digital Timer No. 1 Monitor	
16	1111	Digital Timer No. 2 Monitor	

Note: 1 Multicondition monitor voltage, as follows: (All voltages @ 28 volt supply voltage; proportional to exact voltage of support battery.)

Radiometer Deploy, Moving:	Hi Speed	2.6v
:	Lo Speed	1.25v
Fully Deployed:	At Rest	4.2v
while stepping		1.25v
Stow Cycle: Moving:	Hi Speed	1.5v
	Lo Speed	0.9v
Stowed:	Brake On	3.9v
	Brake Off	0v

OSU ground station in order to eliminate the identification bits from the data being decoded. Also because of the construction of the OSU decoding equipment, some care was necessary in choosing the desired format for the subframe sync word and determining settings of the associated subcommutator detectors, in order to abstract the desired subframe words from the bit stream. Initial attempts were to use word number 16 (SFID = 1111) as the subframe sync pattern. In doing this, the "selected words" position of the subframe decoder then needed to be set according to the word number list normally used in describing the format. However, field difficulties with synchronization with this pattern of four 1's led to attempts to pick a different word as the desired sync word. This technique proved feasible and somewhat better operation was achieved with 1000 as synchronization word; this mode of operation required an offset in word selection to compensate for the number of words between the selected SFID pattern used for synchronization and the word list of the data on which decoding was desired.

3.4.2 The radar beacon installation was essentially identical to that which has been described previously using the Vega Model 302C-2 transponder operated in a single pulse interrogation mode and with the conventional system of Vega Model 820C antennas located on the skin and appropriate power divider.

3.4.3 Other features of the package were also approximately as have been described for earlier packages in this series. Nickel-cadmium batteries were used for prime power, and switching control circuitry was chosen for compatibility with the existing control console using the same system of latch-relay transfer and external power control through the "off" mode. A Transco coaxial relay was again used to permit the telemetry system to operate either through the flight antenna array or (by means of a disconnect plug on the outer surface of the rocket) through the test antenna.

3.5 Special PCM System; Super Hi Star (A35.191-1)

The support system for this round was similar to the package described in connection with the Hi Star South series in the preceding section, in that it represented a joint effort of this laboratory and AFCRL. The round number used for the flight, A35.191-1, is bound to create some confusion in that this particular round number had been earlier assigned for one of the standard Hi Hi Star systems, of the type described in Section 3.3. However, an entirely different electrical and mechanical design was required for this payload, which consisted of an Aerobee 170 configuration, 15" in diameter, in the section forward of the ACS and recovery package, but used a conical transition package carrying a "piggy-back" gyro test system to adapt to the ACS and parachute sections, which were of the 22" diameter Aerobee 350 configuration. Since the telemetry and beacon subsystem was desired in the 15" diameter portion of the vehicle, the decision was made to remove components from the original 22" diameter disc package and, after conversion to the unique requirements of this particular round, repackage the subsystem in a 15" diameter configuration more similar to that used in the earlier rounds launched in this series, the original Aerobee 170 Hi Star program. The digital PCM telemetry system used the higher powered transmitter selected for the Hi Hi Star series on a frequency of 2259.5 MHz, with appropriate battery power and switching and a C-band transponder beacon again included for radar trajectory elements. Components supplied by OSU were assembled at the AFCRL facility in conjunction with build-up of other support equipment for the scientific instrument.

3.5.1 One of the Vector T105S transmitters, with a minimum of 5 watt power output on a carrier frequency of 2259.5 MHz, was used for the telemetry down link. Power from the transmitter was taken through the coaxial transfer relay system described previously, and in the flight mode, was radiated from one of the BBRC SBA/100 antennas which again served as the mechanical base for the package. Components, assembled atop a disc mounted to this base, were allowed to project forward into an extension which housed the remaining apparatus required for signal conditioning and support of the payload. The special PCM coder which was used to multiplex all the data into the required pulse train for modulation of this transmitter was built up at AFCRL. Format data for the PCM telemetry was as shown in Table 11. Standard word length was 14 bits; words 10 and 19 were subdivided into two words of 7 bits each in order to handle associated housekeeping data. PCM subcommutation in a 32 frame repeat format was used for words 10A, 19A, and 19B. Housekeeping monitors and word assignments

TABLE 11. SUPER HI STAR DATA FORMAT (A35.191-1)
(± 380 KHz Deviation on 2259.5 MHz Carrier, PCM/FM)

NRZ-S format at 800 KBPS rate, 28 14-bit words per frame. Subcomm at 32 frames/major frame, using half words of 7-bits as words 10A, 10B, 19A, and 19B. Subframe ID in first 5 bits of word 19B, binary notation. All data MSB first.

Word	Data	Notes
0	Frame Synch (111 001 101 000 00)	
1	Shaft Encoder Position	1
2	Radiometer Detector No. 1	
3	Radiometer Detector No. 2	
4	Radiometer Detector No. 3	
5	Radiometer Detector No. 4	
6	Radiometer Detector No. 5	
7	Radiometer Detector No. 6	
8	Radiometer Detector No. 7	
9	Radiometer Detector No. 8	
10A	Subframe No. 1 (Sensor Housekeeping)	2
10B	Subframe No. 2 (ACS Comm, 5x30 RZ)	3
11	Radiometer Detector No. 9	
12	Radiometer Detector No. 10	
13	Radiometer Detector No. 11	
14	Radiometer Detector No. 12	
15	Radiometer Detector No. 13	
16	Radiometer Detector No. 14	
17	Radiometer Detector No. 15	
18	Radiometer Detector No. 16	
19A	Subframe No. 3 (Support Housekeeping)	2
19B	Subframe Identification	2
20	Radiometer Detector No. 17	
21	Radiometer Detector No. 18	
22	Radiometer Detector No. 19	
23	Radiometer Detector No. 20	
24	Radiometer Detector No. 21	
25	Radiometer Detector No. 22	
26	Radiometer Detector No. 23	
27	Radiometer Detector No. 24	

Notes: 1 13-bit position data; last (14th) bit is Shutter Drive Monitor.

2 See Table 12 for detail assignment.

3 See Table 13 for PAM format data.

TABLE 12. SUBFRAME DATA ASSIGNMENT, SUPER HI STAR
(A35.191-1; words are 7-bit "Halfword" length)

Subframe Word No.	SF 10A (Sensor Housekeeping)	SF 19A (Support Housekeeping)		SF 19B (SF Ident.)
0	Tip & ST Door	Shutter Drive	1	00000 XX
1	Support Battery	Spare (Ov)		00001 XX
2	Cap Position	Spare (Ov)		00010 XX
3	Sensor Doors	Spare (Ov)		00011 XX
4	T/M Battery	Spare (Ov)		00100 XX
5	Rad Rotate/Brake	Spare (Ov)		00101 XX
6	FLSC/Droque Relay	Spare (Ov)		00110 XX
7	Scan or Chop	Spare (Ov)		00111 XX
8	Despin	Shutter Drive	1	01000 XX
9	Separation	OG-Whit 67-10	2	01001 XX
10	Spare (Ov)	IG-Whit 67-10	2	01010 XX
11	Logic Voltage	IG-Whit 67-2	2	01011 XX
12	Dig. Timer 1	OG-Whit 67-2	2	01100 XX
13	Dig. Timer 2	IG-Conrac 116	2	01101 XX
14	Acceleration	OG-Conrac 116	2	01110 XX
15	Accel B+	IG-El Spec	2	01111 XX
16	Tip Temperature	Shutter Drive	1	10000 XX
17	Skin Temperature	OG-El Spec	2	10001 XX
18	Pressure No. 1	Spare (Ov)		10010 XX
19	Pressure No. 2	Spare (Ov)		10011 XX
20	Pressure No. 3	Spare (Ov)		10100 XX
21	Pressure No. 4	Spare (Ov)		10101 XX
22	Fuel Valve Pos	On Gimbal Temp		10110 XX
23	Ox Valve Pos	(-) Sensor Power		10111 XX
24	Cap Discharge 1	Shutter Drive	1	11000 XX
25	Cap Discharge 2	(+) Sensor Power		11001 XX
26	Spare (Ov)	Cap Pressure		11010 XX
27	Spare (Ov)	Rad Shield Temp 2		11011 XX
28	Spare (Ov)	Rad Shield Temp 1		11100 XX
29	Spare (Ov)	Off Gimbal Temp		11101 XX
30	Spare (Ov)	Detector Temp		11110 XX
31	Spare (Ov)	Optics Temp		11111 XX

Notes: In word 19A Subcomm Format:

1 Shutter drive is on super subcomm format; sample rate 4X normal subcomm rate.

2 Outer and inner gimbal signals from set of 4 strap-down gyros; piggy-back test for ACS on this payload.

TABLE 13. PAM COMMUTATOR SCHEDULE, WORD 10B
SUPER HI STAR, A35.191-1
7-Bit Analog Data, ACS Commutator
(IRIG 5x30 RZ Format)

Segment	Data 1	Notes
1	0% Reference Level	
2	100% Reference Level	
3	Roll Position	1
4	Pitch Position	1
5	Yaw Position	1
6	Program Start	2
7	Roll Valves	2
8	Pitch Valves	2
9	Yaw Valves	2
10	Fine Capture (Roll axis)	2
11	Roll Rate	3
12	Pitch Rate	3
13	Yaw Rate	3
14	ACS Hold Control	2
15	+28 volt Bus Monitor	3
16	Capture/Roll Capture	2
17	Star Magnitude (P/Y)	3
18	Fine Capture (P/Y)	2
19	ACS Mode (P/Y)	2
20	Fine Roll Position	3
21	HV/Star Presence (P/Y)	2
22	Fine Yaw Position	3
23	Fine Pitch Position	3
24	ACS Model (Roll)	2
25	Nitrogen Pressure	3
26	Program Position	2
27	Star Magnitude (Roll)	3
28	HV/Star Presence (Roll)	2
29	+5v Synch	
30	+5v Synch	

Notes: 1 Dual-scale factor analog voltage; required cal curve.

2 Discrete levels indicate status and time of event.

3 Analog data; requires cal curve.

for the first 7 bits of words 10 and 19 are as listed in Table 12. Word 19B was utilized for subframe identification, using a straight binary coded indication of the first five bits to indicate subframe words 0 through 31 inclusive as listed in Table 12; synchronization was achieved by using the five consecutive ones as a subframe synchronizing word for decoding of this data. Again the choice of this system imposed some minor difficulties. Since subframe identification occurred in the latter part of the 19th word, but indicated what information was present in the first part of words 10 and 19, it was necessary to offset the decoding capability in order to select the proper words. This only required a change in operational procedure and did not inhibit operation of the equipment. Conventional PAM modulation with an IRIG 5x30 RZ commutator format in accordance with the data assignments shown in Table 13 provided the modulation to the second 7-bits of word 10, designated as word 10B.

3.5.2 The radar transponding signal was supplied by the normal double-pulse coded C-band transponder, Vega Model 302C-2. The beacon antenna system consisted of three equally spaced flush-mount antennas of the type previous described, and the Vega Model 854C3 power divider was again used to drive three of the Vega Model 820 antennas, all of which were mounted in the skin of the forward section which, after assembly, surrounded this support subsystem.

3.5.3 Other features of the package essentially duplicated the circuitry which has been described previously. The relay used for transfer of power from the telemetry system to the flight antenna (or, in the test mode, to a jack on the skin to which test equipment or external radiating antennas could be attached) was the same as used on the original Hi Star system, A04.004-8. The system was designed for compatibility with the same console used on this earlier program, and umbilical arrangements were identical to those which have been described previously except that the FM analog system was not included in the package. A spare package was not built for this round; spare components borrowed from the unflown packages in the Hi Hi Star program were supplied in the field as operating spares and parts changeout was necessary for service7

3.6 Auxiliary Apparatus: Airborne Items

3.6.1 As an accessory piece of equipment for use in evaluating performance of the S-band autotrack antenna and related equipment which was built up under this contract, six S-band sonde beacons were built up for balloon launch. The design was for an expendable unit for approximately $30 value, designed to be launched from a standard weather balloon with no recovery operation or no hazard to aircraft by using a light-weight jet engine ingestible configuration. These transmitters have been previously described in connection with their development under contract F19628-72-C-0139 (Reference 5). The design is documented on OSU drawing number C36MA07. A source of unmodulated RF carrier, tunable from 2200 to 2300 MHz in frequency, with approximately 50 milliwats power output and automatic shutoff at the end of 2 to 3 hours operation was provided, using expendable transistor radio type batteries. The RF source is actually a Hartley oscillator, using a single transistor and with direct coupling from the transistor to a short radiating antenna which forms one end of the mechanical housing. To maintain frequency stability, a simple degenerative voltage regulator was included, down-regulating the normal 18v power supply to approximately 12v; this stabilized the oscillator for temperature and input voltage variations. A combination battery monitor/shutoff circuit is included in each device; two transistors and the zener reference diode are used in such a way as to sense the battery voltage used to supply power to the unit, then shunt the battery with a 68 ohm load resistor as soon as the available potential drops below the zener reference, thus draining remaining power from battery very rapidly and turning the transmitter off. This provides a reversible type of circuitry in that no damage occurs and the transmitter can be reused by simply supplying new batteries. Each transmitter weighs approximately 55 grams when encapsulated in foam insulation and is of cylindrical configuration (1.7" in diameter by 3" in length), exclusive of the antenna at the oscillator end. In field operation, the unit has been found to be equally useful as a local reference "bore-sight" source and has frequently been used for this purpose, as well as a moving target for evaluating tracking performance.

3.6.2 Additional airborne equipment related to the work done on the contract in the course of this period has involved the procurement and modification of a number of airborne ranging receivers. These ranging receivers operated in the 400 MHz region, and were for the purpose of detecting the PCM ranging signal from the Tradat system (radiated from the tracking antenna up to the airborne system) and in turn provided the PCM output from the receiving section as a modulating signal to the telemetry aboard the vehicle, thus closing the loop for trajectory determination. No such receivers were directly flown in any of the payloads built in the course of this contract, but equipment was procured for use in the proposed Castor/Lance launch at Natal, Brazil. Some of the receivers were also used in piggyback packages in the ranging tests conducted during field operations, in evaluating the performance to be expected from the combination of the Tratel I/Tradat I equipment under field operating conditions. The actual airborne components for field trials were procured under sister contract F19628-72-C-0139 and were on hand prior to the decision to conduct the field trials. The ranging receivers were Aacom Model AR0900P, tuned to a frequency of 430 MHz. Seven of these units were selected for modification and use on the Astrobee D series of field trials. The noise-derived squelch circuitry and video amplifiers present in the original models (which were purchased for tone ranging systems) were inappropriate for use in the PCM ranging method utilized with a Tradat I equipment. As a result, the module concerning this circuitry was removed and new modules as shown in OSU drawing B95AA01 were built up as replacements. The actual development of this modification and construction of the circuitry was relatively simple. The basic 28v power bus within the receiver was down-regulated to a 12v level by a simple degenerative regulator with a diode reference and power transistor. The regulated 12v supply was then used as the reference voltage for a video amplifier and limiter circuitry in which a single transistor drove two cascaded inverting amplifiers on a microcircuit chip. The output then presented a swing in normal logic "0-1" format, and a voltage divider to ground across the output bus was used to set voltage levels such that the output PCM, reconstituted from the video transmitted up from the ground, was then put back in the same coded logic form for modulation, but at the desired 0-5v span for input to the associated VCO in the telemetry complex. The modified receivers were then shipped to Northeastern University for installation as the "piggyback" portion within some payloads being constructed for flight in the Astrobee D series. The actual field trials were a mixture of training experience and ground equipment operation from the viewpoint of this contract, but were conducted for acquisition and evaluation of data, under the objectives of sister contract F19628-75-C-0084.

3.6.3 One additional item was built as airborne equipment, under the relationship existing between this contract and a concurrent contract within the National Science Foundation, AURA subcontract 380-72. This was done as an investigation concerning recovery techniques for the infrared payloads. An experimental low voltage sensor unit was built up in the OSU laboratory and calibration curves prepared for the voltage levels at which it operated. The package prepared was actually a monitor package for a piggyback test flight only; the final experimental equipment was launched aboard Aerobee 170, round number KP 3.42, which was launched from the White Sands Missile Range on 12 January 1973 and supported under the above cited AURA subcontract. The intent of the program was to provide a test of a circuit capable of sensing the terminal voltage under load of the nickel-cadmium battery. In its final development form, the circuit was proposed for use as a control element within the payload, designed to disconnect the battery load and turnoff equipment at some predetermined end-point voltage for the battery. Two desired advantages would result: first, the associated transmitter in the support package would be shut off freeing the frequency for use by following missions; second, the battery would be preserved with a better probability of recycling for future use at a later time. For the piggyback module, the sensor circuitry was arranged to operate into a simple monitor network, allowing relay of data back to the ground by telemetry and this signal, in association with calibrated monitor of the battery condition on the same rocket, would permit evaluation of the point at which the circuit tripped an associated relay. In this instance, the relay, instead of turning off the equipment, actually provided an event monitor on telemetry and simultaneously reset itself for a repeated cycle of operation at a second trip point, thus providing two tests of the circuit during a given flight. The circuit was based upon that developed earlier for use on the Cannonball II satellite, as the low voltage sensor (LVS) element (Reference 1, paragraph 3.1.1.2). It consisted of a simple voltage comparator, switching control current into an RC ramp generator to provide a 3 second delay in action. A four-layer diode dumped energy from the timing capacitor into one or the other of a pair of latch relay coils, thus reversing the relay from one mode to the other each time the applied voltage from the battery bus dropped to the trip point for the voltage comparator. The equipment was installed and run through all of the normal calibration tests prior to launch of Aerobee KP 3.42. The monitor indicates that the system functioned in flight as desired, with the first trip point selected at 28.8v; this voltage was reached at approximately T+55 seconds when the automatic valve closing circuitry aboard the vehicle imposed a surge load upon the battery being monitored, thus dropping the bus voltage. After removal of the surge load, battery recovered and was still at 29.9v at T+460 seconds. The associated battery monitor during flight shows a drop which should have placed the circuit somewhere near the anticipated second trip of 28.3v at 461 seconds during reentry. In order to prevent premature cycling of the apparatus in this test flight, a deliberate time delay was employed so that the relay would not throw unless the threshold voltage had been encountered continuously for a period of 3 seconds. In this instance, the load which dropped the battery voltage is assumed to be part of vehicle break-up on the downward leg, as catastrophic failure occurred in many portions of the equipment approximately 1 second later. Amongst the failure effects were the loss of the forward section of the payload and all power to the PCM coding system used for the telemetry on Aerobee KP 3.42 only 1.3 seconds after the drop in voltage. Because of this, it was impossible to evaluate the final conditions for the circuitry; even though the telemetry carrier signal remained throughout flight, all coded modulation was lost and no further evaluation data can be abstracted for the remaining 600 seconds of the flight. (The voltage trip points were selected after examination of battery condition during similar Kitt Peak flights, and were anticipated to provide the first trip point at approximately T+60 seconds, followed by the second trip point at approximately T+550 seconds.) It is likely that the unit did function, but the absence of the telemetry monitor for the anticipated interval of time prevents further analysis of the flight data. In view of the low cost of batteries involved and the lack of interest in an automatic turn-off system, coupled with some uncertainity as to the compromise which might result to the scientific instrument if the system malfunctions and turned off telemetry during the useful portion of the flight, further investigation on this circuit was dropped.

4.0 GROUND SUPPORT EQUIPMENT

A major effort under the work performed under this contract has been maintenance, modification, and supply of ground support equipment required under the statement of work. This includes not only the equipment specified by Subline Item 0001AD, but also supply of the required services as called for in 0001AB, 0001AC, and 0001AE. The launch mission required special ground support equipment, but adequate tests and field services also consistently required a more elaborate ground station set-up than is normally the case for AFCRL contracts. Wherever possible, existing equipment was utilized for this purpose. However, this phase of our activity has also included both the build up of special items and the duplication of additional equipment, which had been developed under previous AFCRL contracts in suitable versions, so that equipment could be committed to this project without compromise to other on-going programs. In addition, modification of existing equipment for special purposes was occasionally involved and a number of items of commercial equipment were purchased specifically for this use. The empnasis on ground support equipment was largely due to the complexity of the payloads, with the attendant necessity for relatively complex ground stations to provide adequate operational evaluation, but which also indirectly led to the commitment of this complex ground equipment to support for much longer periods of time than is normally the case with the simpler payloads.

4.1 Test Consoles

One rather obvious requirement in providing airborne apparatus and the ensuing operation and test of this apparatus was the provision of a

Figure 7. Hi Hi Star Control Console

suitable console, for connection through the umbilical to the airborne support system which was to be tested. Small portable consoles, constructed within Halliburton equipment cases which permit stowing the associated cables and carrying as a self-contained suitcase, were built for two different versions of the airborne package; existing consoles from previous programs were also usable in some instances with minor modification and suitable adapter cables.

4.1.1 The Hi Hi Star series of Aerobee 350 rockets were provided with two identical consoles for convenience in test and operation. One console was retained by OSU; the other was delivered to AFCRL. A photograph of one of the consoles is shown in Figure 7. Circuit details are shown in the left of Figure 6, which depicted both the airborne package and the associated control system. Features of the console included the ability to turn on and operate the associated PCM subsystem in either internal or external power modes, and the simultaneous ability for independent control of the radar transponder from the same console. Each of the two control subsections included a monitor meter, which indicated by its reading whether the associated relay in the airborne package is in the "internal" or "external" mode of operation. A voltmeter was included, and which normally displays the bus voltage within the package, whether or not the external mode of operation is involved. This meter was capable of being switched to measure battery voltage within the package as well. Facilities were added for charging (through the umbilical) the associated battery which powered the equipment. A "charging meter" to monitor charging current is included, together with a blocking diode to eliminate the possibility of battery damage by application of a reverse voltage. A momentary center position "off" switch is used to select the "internal" or "external" mode of operation for the telemetry subsystem by latching in the appropriate coil of relay within the package. The condition of the relay is shown by an ohmmeter circuit, powered by a zener supply voltage which operates from the main 28v supply and which gives a different meter deflection for each mode of operation (by having switched, through relay contacts, the series resistor returned to the common ground within the package). When the package is in the "external" mode of operation, a separate switch permits power to be applied from the console power supply. Turn off is accomplished by placing the airborne package in the "external" mode of operation and turning "off" the external power within the console. A second section of the console incorporates an identical set of circuits for control and monitor of the associated transponding beacon.

Because of the inclusion of the capability to operate the telemetry system either into the flight antenna or, at will, through a coaxial relay within the airborne package, to a test circuit, an auxiliary control section was added. A center position "off" switch permitted momentary application of power to either of two relay coils on the associated coaxial relay within the payload package. When the "fly" coil of the relay is

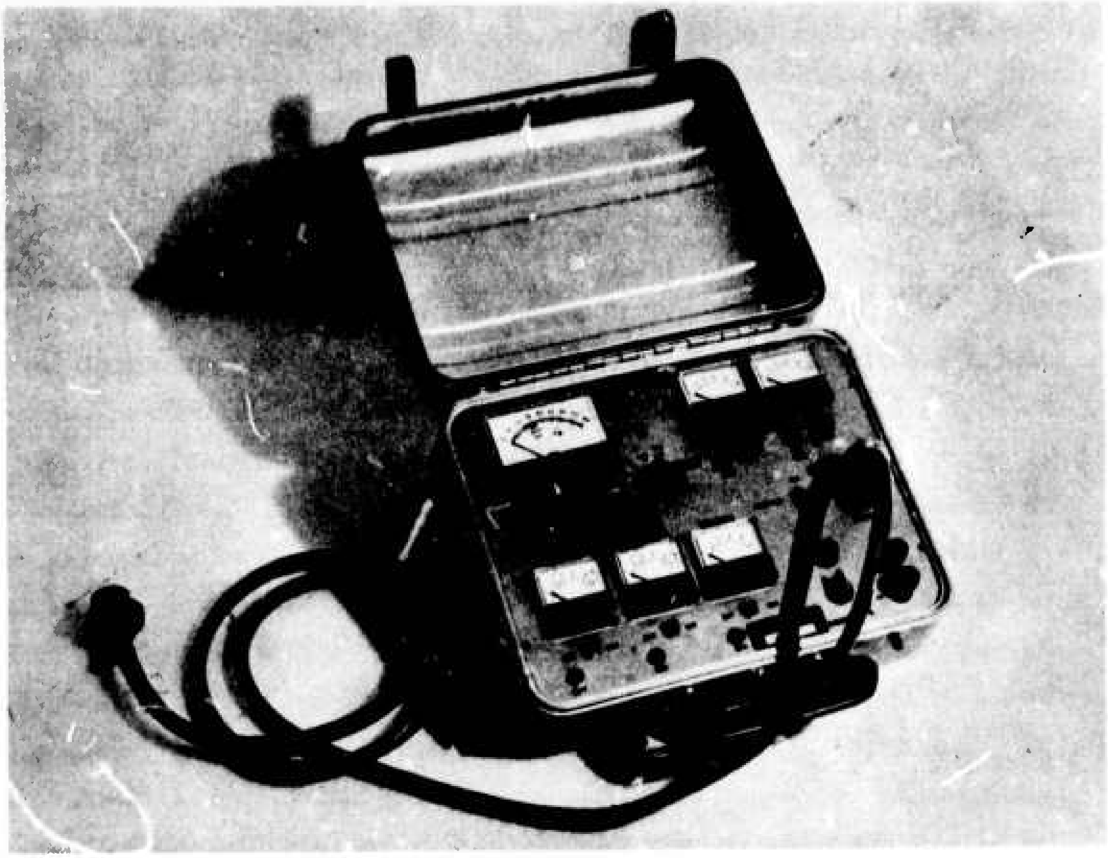

Figure 8. Hi Star Control Console

energized, radio frequency power from the transmitter was applied directly to the flight antenna. When the "test" coil within the payload is energized, the RF power was transferred to an external jack on the side of the missile vehicle, to which a test antenna or power measuring equipment could be attached. Auxiliary monitor contacts on the coaxial relay also returned the 28v power bus from the vehicle through one of two different resistors back through the umbilical to a monitor meter on the front panel. Two discrete meter readings indicated the state of the airborne relay as a panel monitor of the condition of the package.

4.1.2 A rather similar console was constructed in two different copies (one for AFCRL use and the second for local use at OSU), for operation of the Hi Star series of packages. A photograph of this unit, which superficially resembles that just described for the Hi Hi Star program, is shown in Figure 8. Figure 9 shows the circuitry used in this particular console. The control and monitor arrangement for the PCM telemetry subsystem and the transponder are as described above for the Hi Hi Star package. In addition, a third similar section was added for control of the second telemetry link (the FM/FM analog system), and it was built to use exactly the same type of switching circuitry. Monitor meters were provided for both the FM subsystem and the PCM subsystem, to indicate the condition of the relays within package. However, in this console, power for the monitor circuit was supplied by a battery within the console. A single voltmeter was included in the panel and this permitted measurement of the condition of the 5 volt battery within the console. Transfer of this meter by a selector switch allowed it to be used to check both of the 2 flight batteries, and bus voltage within the package for either PCM or the combination beacon and FM subsystems. Since two separate battery packs were involved, there were two separate facilities for battery charge, each with its own control switch and associated series charging current meter. In addition, a current meter in the external power mode of operation for the beacon package permitted observation of the current drawn by the transponding equipment. This allowed monitor of successful interrogation (by increase in the current demand as the airborne transponder was triggered). The arrangements for control of the coaxial relay and monitor arrangements are somewhat different for the Hi Star package and are shown in the upper left portion of Figure 9. Since the airborne package used a holding (rather than a latching type) coaxial relay, an auxiliary control relay within the package was required in order to latch power to the coaxial relay coil. This relay could be actuated for either "internal" or "external" control by switch S912. If the relay was placed in the "external" control mode, a separate switch permitted application or removal of external power to the coaxial relay coil from the console. This switch, S913, allowed transfer of the antenna when in the external mode by applying power to the coaxial relay coil through the control relay contacts at will. However, because there were conditions in the test program where it was desired to transfer the telemetry system to an external test antenna and then leave it on that antenna as the umbilical was removed in the test sequence, it was

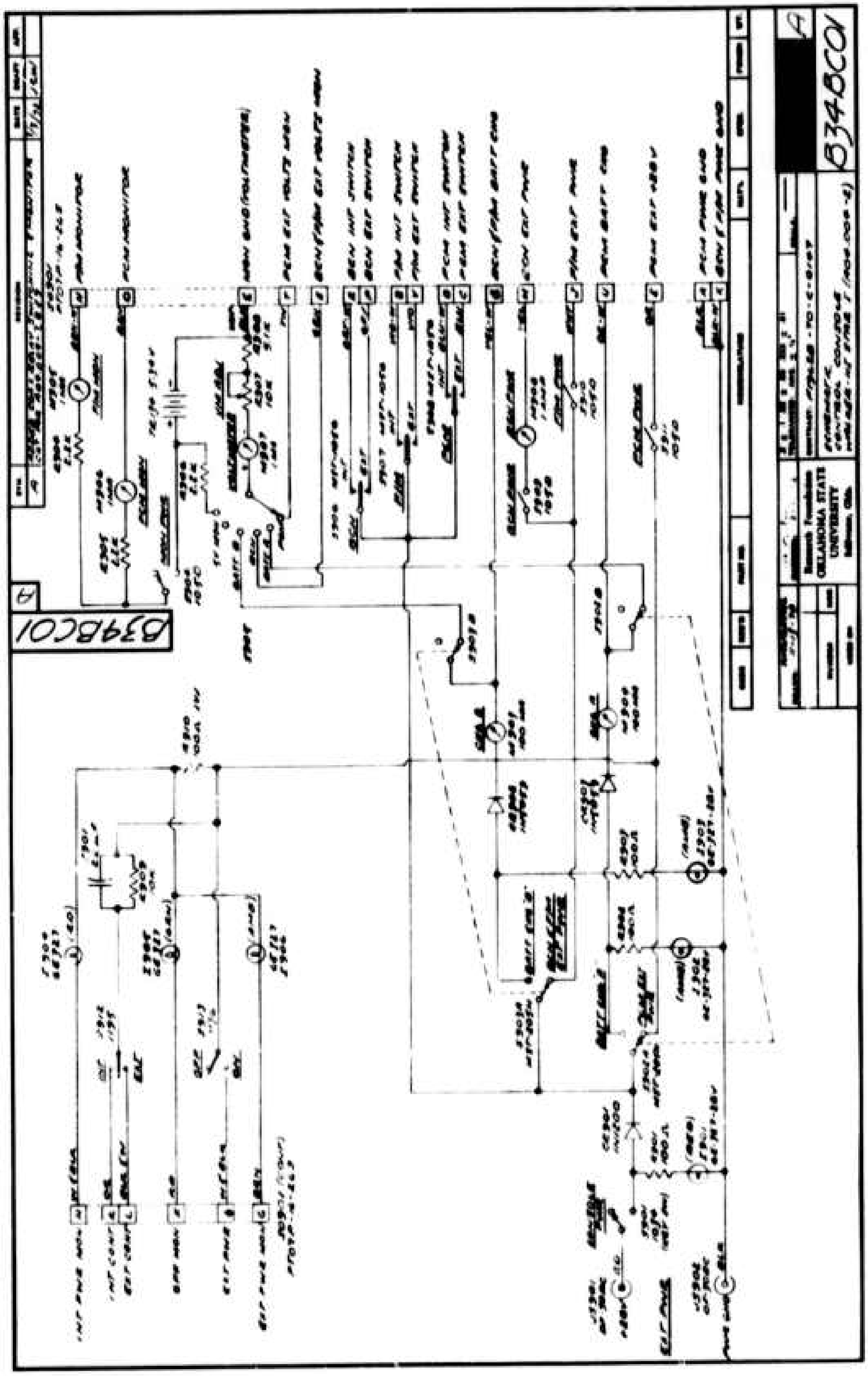

Figure 9. Wiring Schematic, Hi Star Console

necessary also to connect through the control relay "internal" contact a secondary lead from the battery power within the vehicle. When the "internal" power version of the test operation antenna transfer was desired, the RF relay was held energized by the internal battery power. In order to return to the "flight" mode, it was necessary to reinsert the umbilical and then apply power to the "external" control coil from the console. In order to monitor which mode of operation was in use at a given time, the 28v power from the console bus was taken through three different light bulbs to the payload by 3 wires of the umbilical circuit. Wiring within the payload was a conventional "tree" arrangement, such that one of the three light bulbs would always indicate the state of the control relay and whether or not the "external" mode of control was energized. A red light indicated that the payload was internally locked to the test antenna; an amber light indicated that the control relay was in the external mode position and power was applied from the console; in this mode of operation, removal of the umbilical would permit the system to revert back to the flight antenna A third green light was provided to indicate that the system was in the normal "flight" configuration, with the relay in the "external" control mode and no power applied.

4.1.3 Both the Super Hi Star and the Hi Star South series of payload systems were built for compatibility with the original Hi Star control console. Even though all console facilities were not required, suitable choice of umbilical pins and adapter cables between the console and the payload permitted the circuits which were desired to be used. Since both the Hi Star South and Super Hi Star packages contained PCM telemetry only, the secondary control and monitor for the auxiliary second analog link of the original Hi Star package was not used in this application.

4.1.4 The infrared zodiacal light series was so built as to utilize an existing console, residual from an earlier AFCRL contract. The console was originally built for use with the atomic oxygen payloads under contract F19628-67-C-0224, and has been previously described (Reference 6, Figure 6, and circuitry shown in Figure 7). Again, suitable choice of umbilical pins and console pins and wiring in the adapter harness between the control console and the payload umbilical permitted only those portions of the console which were desired and required in this application to be operational for this test series. Features are roughly the same as described previously, with the added feature of control of the on-board telemetry calibrator through the umbilical in a manner which has been described in detail previously (Reference 2, Section 4.1).

4.1.5 Associated with each class of payloads within the support systems built during the course of this contract were associated test cables for a number of purposes. Exact details of the designs are not pertinent nor within the scope of this report, but, in general, consisted of suitable cables to connect the console to the umbilical complex at the launch site, to adapt from the umbilical connector on the vehicle to the junction boxes within the launch facility, and for direct tests of the package, exclusive of the associated payload and normal umbilical apparatus. In addition, special test cables were supplied for convenience in working with the support systems, either for breakout of test points for measurement and wiring checks, or for special tests and operations done prior to integration test and assembly with the remainder of the payload.

4.2 PCM Equipment

The consistent use of pulse-code-modulated telemetry subsystems in the majority of this program made evident immediately the need for special PCM decoding equipment in order to evaluate system performance and permit adequate payload checks. Provision of such decoders was specifically designated in this contract under Section J, Special Provisions, Paragraph 9(a)-1, Special Test Equipment Requirements.

4.2.1 A photograph of a five-channel PCM decoder, of which two were built for use in this contract, is shown in Figure 10. The design, shown as OSU drawing B90RP21, was developed in connection with earlier contract F19628-70-C-0147 and has been described in complete detail. (Reference 1, Section 4.2.1.) The decoder permitted synchronization with the airborne package over a wide range of incoming PCM formats, and permitted both digital and analog displays of the data from selected portions of the format. The addition of five galvanometer current drivers within the decoder have also facilitated checks by permitting selected words to be displayed on stripcharts as a function of time, as well as allowing visual analysis on

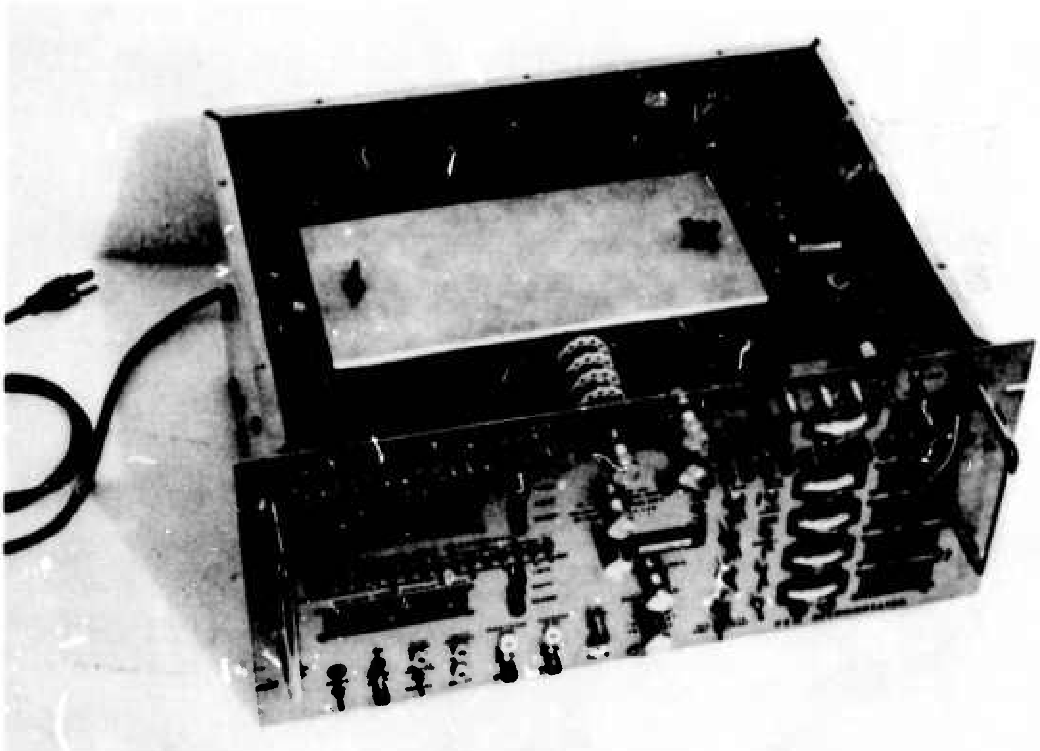

Figure 10. Five Channel PCM Encoder

the panel displays of the decoder. Of the two units built, one was retained at OSU for local and field operations; the second was shipped directly to AFCRL for use in payload checks at the AFCRL facility. Both units were later required for simultaneous operation in connection with the Hi Star South series at Woomera, Australia.

4.2.2 Also required by the contract under Section J, Special Provisions, Paragraph 9, Special Testing Equipment, Subparagraph a(1) was a PCM simulator. This unit also was developed under the same contract cited previously and has been fully described. (Reference 1, Section 4.2.4) Only one such simulator was built for use on this contract; two additional simulators were built under the previous contract F19628-70-C-0147 and provided the capability of simulation of several different formats when needed.

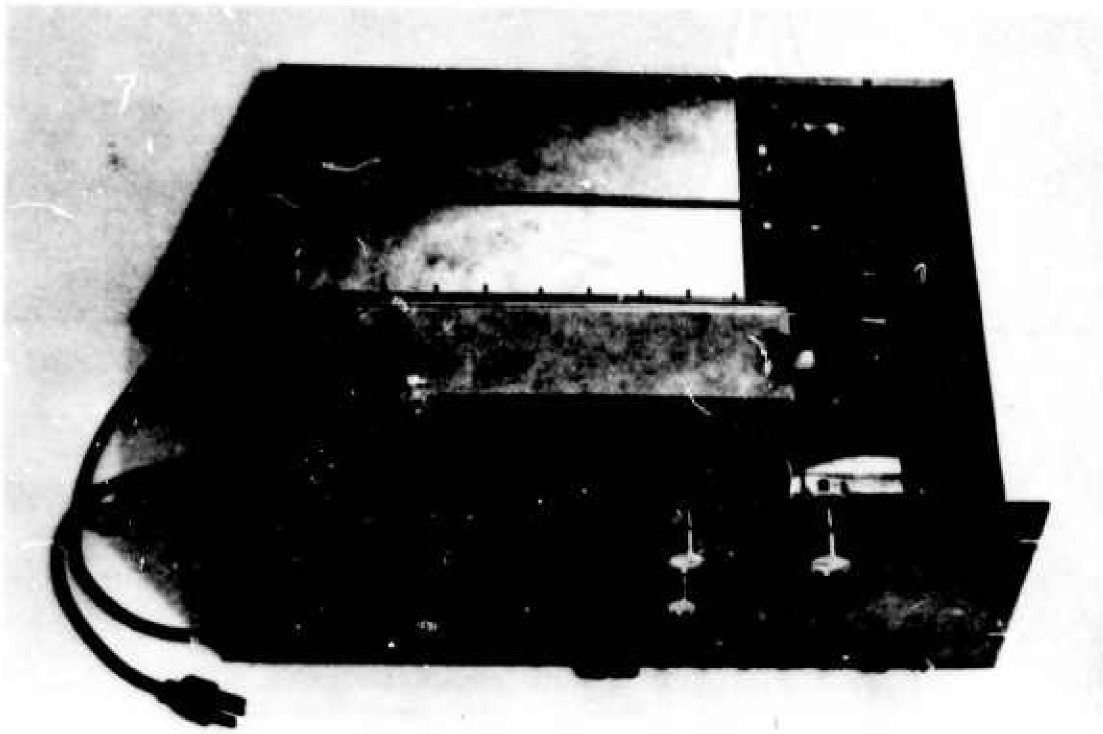

Figure 11. PCM Simulator

Details of the design were presented in the previous report (Reference 1) and may be summarized as follows: bit stream rates were variable continuously from approximately 30 bits per second to 1.2 megabit per second rates. Word lengths of up to 16 bits were available and could be selected from the front panel. Both main frame sync and subframe sync capability also existed, with panel programming switches. Frame lengths of up to 99 words could be provided, and the subframe capability permitted a subcommutated word to be inserted in any selected one of the total number of words chosen. An analog-to-digital converter was also included, with provision for switching it into any selected word within the frame. All other words in the frame displayed the coding of the "common word", also selected from the front panel and variable at will. A data blanking system permitted a number of words with no coding to be inserted immediately behind the frame synchronizing pulse, in order to test the capability of the associated decoder to operate with blank words within the format. Panel selection was provided for NRZ-L, NRZ-M, NRZ-S, RZ, bi-phase-L, bi-phase-M, or bi-phase-S coding of the PCM output.

4.2.3 Both versions of the 5 channel PCM decoder described in 4.2.1 above were originally provided with OSU-designed-and-built general purpose data conditioner cards, which incorporated a bit synchronizer of OSU design utilizing the phaselock technique. The original version was described in OSU drawing C90RP04A. Two custom-built replacement bit synchronizer cards were built up (interchangeable in either PCM decoder by direct substitution in the proper printed card slot) in the course of this contract. The Hi Star South mission in Australia, where difficulty was encountered with the high frequency bit stream and the relatively narrow bandwidth available for the radio frequency data transmission link, resulted in a requirement for an improved signal-to-noise ratio in abstracting the PCM data from the RF carrier. A commercial modular bit synchronizer, obtained from Correlation Industries of LaCanada, California, their series 113, was incorporated on a special printed circuit card for this application. The commercial module was installed on the card, together with an associated buffer amplifier and a one-shot for signal conditioning of the reconstructed data stream, and was so built as to utilize the bit rate adjustment control on the front panel of the PCM decommutator. However, the unit was hardwired into the desired configuration and thus could be used only with the NRZ-MARK bit stream. Threshold sensitivity for the overall ground station was improved by approximately 7 db through use of this bit synchronizer in place of the conventional data conditioner. However, its use was somewhat restricted in practice by the susceptibility of the bit synchronizer to interference effects in the presence of multipath propagation.

A second special-purpose bit synchronizer and data conditioner card was built up using the Data Control Systems Model 4903-101 bit synchronizer. Again a special printed circuit card was prepared, installing the commercial module with associated buffers, inverters, and a microcircuit one-shot, as described previously. This data conditioner card was also directly compatible with the main frame decoder wiring and could be inserted in the place of the standard OSU unit when desired. The panel controls for clock frequency were inoperational for this unit; selected components were installed on the surface of the card to provide the desired bit rate. Again, a slight improvement in the system operation was obtainable by use of this bit synchronizer under good data transmission conditions. The unit was usable for either NRZ-Mark or NRZ-Space code by changing a simple jumper connection on the face of the card. After return from the Hi Star South Mission, this card was modified for a higher frequency bit rate and served as an experimental data conditioner card in the Super Hi Star tests later.

4.2.4 The addition of Super-subcommutated data to the format of later rounds in the series of payloads covered by this contract led to a need for still more special purpose test apparatus. For proper decoding of super-subcommutated data formats, a change was developed. The system uses a minor modification to the 5-channel decoder (Reference 4.2.1 above) in order to provide this capability, when used in conjunction with an available earlier design single-channel PCM decoder (Reference 1, paragraph 4.2.3), to decode repeating subframe data, identified only by means of a separate identification word elsewhere in the main frame of the data stream. All words of super-commutated data within a given subframe can be decoded by the single channel decoder, provided only that the data falls at regular intervals throughout the subframe sequence.

This modification was provided by bringing out the bit clock, main frame synchronization, subframe synchronization, and main frame word clock from the 5-channel units through an auxiliary connector and a four-pole, double-throw switch as auxiliary inputs to the associated single channel unit. In the "super-subcomm" mode of operation, the bit counter of the single channel decoder is utilized to count minor frames. It may be programmed to reset itself at the desired repeat interval through use of "word length" switch on the front panel of the single channel decoder. The system remains synchronized with the subframe by "subrame sync" pulses, selected by the associated 5-channel decoder. (Note that subframe sync programmer of the 5 channel unit must be programmed to correspond with the format of the identification word which occurs just prior to the first appearance in a major frame of the desired subframe data.)

In this mode of operation, the single channel decoder receives a "word clock" pulse signal and reset for this function from the associated 5-channel unit. Because this word counter within the single channel unit normally serves as the frame length counter, unblanking to receive the frame sync pulse, and the system is designed to reset on the trailing edge of the word blanking pulse, the "frame length" switch of the single channel decoder must be set beyond the actual number of words in a minor frame in order to maintain proper operation in this auxiliary mode. Data input to the associated single channel decoder is parallel input from the second shift register of the associated 5-channel decoder, in order to remain synchronized with the frame sync detector of the main 5-channel unit. In the event the main frame sync format consisted of a multiple-length synch word, provision has been made on the 5-channel decoder unit to blank the word clock for up to four words following the first sync word. A thumbwheel switch marked "Synch" words on the main 5-channel unit is used to program the number of words in the main frame sync format. The blanked word clock is not applied to frame length counter or subcomm word counter as is normally done, and this must be considered when programming selector switches for the subcomm word desired. These switches must be programmed from the first sync word. (That is, the following extra words of a compound sync word are counted as word 1, word 2, word 3, etc., requiring an offset in selection of the subcommutated word to accommodate non-standard word lengths for the synchronizing format.)

4.3 PAM Equipment

Both single channel and 5-channel versions of PAM decommutation equipment had been developed by this laboratory under earlier contract F19628-67-C-0224. The circuitry for the units built up for AFCRL has been described in detail in the final report to that contract (Reference 6, paragraph 4.2 for the single channel unit and 4.3 for the five channel unit). Subsequently, under a following contract F19628-72-C-0139, a modification to improve operation of decommutation circuitry was developed and described in Scientific Report No. 1 to that contract (Reference 7). Because of the wide number of data formats which used PAM-modulation within the PCM format of the Hi Star and Hi Hi Star series of support systems, interest existed in updating the capability of this supporting ground equipment. As a result, both a 5-channel and a single-channel PAM decommutator were updated by the addition of this circuitry in preparation for further support of this contract.

4.3.1 Design changes were made in order to achieve several simultaneous objectives: addition of a phaselock clock circuit enhances the stability of the ground station equipment and permitted a better lock under conditions of a variable PAM frequency, particularly in those applications where the PAM format was running non-synchronously with respect to the PCM (which was generally the case in this series). In addition, the modification permitted decommutation of both 50 and 100 per cent duty cycle formats without the requirement of complicated circuitry within the PAM decommutator, and substituted a digital type frame synchronization decoder for the original analog pulse width discriminator (which required adjustment for individual variations in the IRIG PAM format). The modified cards were built up in such a manner as to permit direct substitution by replacement within the basic wiring of the PAM decommutators in which they were inserted.

4.3.2 An integrated circuit phaselock loop clock was added, and internal circuitry permitted doubling of the clock frequency automatically by clocking into a flipflop, one-half segment delayed by a one-shot multivibrator. VCO correction voltage was obtained through a phase detector with an "exclusive OR gate", gating the delayed data and clock data, with a lowpass filter to derive correction voltages. Circuitry added in this revision also had the desirable feature of simplifying operation in that the sample period duration and its location (sample aperture) within the segment was automatically adjusted to lie at about one-quarter of the channel width, near the center of the channel, for each segment. This is automatic with the logic used for development of the aperture gate. Frame synchronization operation was improved by clocking the data into a shift register in such a manner that "one's" could be entered in the register only for data pulses whose value was equivalent to 4.5v or greater on adjacent segments. Since the frame sync interval for a 100% duty cycle commutator is defined as consisting of a 0 amplitude level of duration T, followed by full amplitude level of duration 3T followed by one-half or less amplitude level of duration T again, the basic digital synchronization coding consists of a sequence of three one's with a zero on either side. The first five parallel outputs from an 8-bit shift register within this card are utilized to detect the presence of the frame synchronizing format through connecting the output of the shift register to an "AND" gate with bits 1 and 5 inverted to recognize a frame sync format in the digital notation of 01110. A blanking flipflop provides a sixth input to the frame sync detector gate, to reject false sync patterns when lock is achieved. When in the unblanked condition, the first recognized sync pattern will reset the counters and set up the blanking. Unblanking time is then selected from the counter decoder outputs at the desired time in the frame; manual reset is provided in the event false synchronization lock occurs. The unit is also usable with 50% duty cycle commutation with greater stability, since it is no longer necessary to count the intervening half-width pedestals between the data pulses. One of the advantages of including this modification is that clock frequency automatically adjusts the frame synchronization detector and sample aperture times, without the necessity for multiple ganged switches, as were previously employed. For this reason, a simple potentiometer-controlled variable clock frequency is sufficient to select any of the IRIG PAM formats. The two units in which the circuitry was installed were in use as ground support equipment throughout the duration of this particular contract.

4.4 Miscellaneous Ground Equipment Requirements

In connection with build-up of overseas facilities in connection with the launch of Hi Star South vehicles from Australia, it was necessary to provide not only a wide complement of field spares and components, but also to modify the associated oscillograph recorders (CEC Model 5-124), which were used for analog and data presentation during quick-look evaluation of tests and launch data. In order to conserve paper in the field operation, special motors were purchased and subassemblies built to permit three of these units to be operated at one-half of normal paper speed, thus permitting reduction of recording speed to 4" per second (instead of the normal 8 to 10" per second which has been utilized in the past). This permitted recognizable paper records with a reduction by 50% in the total amount of paper required for support at the field site. (Note that the original drive units were retained as back-up field spares, permitting their reinstallation if necessary to repair the equipment, with the added requirement of additional paper requirements in this mode of operation.) The validity of the concern for ability to maintain equipment in the field during the Australian mission was proven by the necessity for several days of repair for shipping damage occasioned in transporting the equipment to Australia well in advance of the launch sequence. Adequate field spares were procured and shipped to permit this to be accomplished without detriment to the program; a similar complement of field spares was built up in connection with plans for the launch of the Castor/Lance vehicle at Natal, Brazil and are available for use if this mission is rescheduled at a future date.

4.5 Ground Support Equipment Purchased Commercially

A number of items of special test equipment were purchased during the period of this contract in order to provide additional capability for self-sufficient tests under field conditions with the complicated payloads involved. Many of these items were specified in Section J, Special Provisions, Paragraph 9, Special Test Equipment, Subparagraph 2. Some of the items were simply purchased for use as intended by the original manufacturer as a convenience in field operation; other items were purchased specifically for incorporation within special purpose test apparatus being built up under this contract. Many of the latter items have since lost their identity as separate items of equipment, by incorporation and modification into a new subsystem. All property so acquired has now had accountability established under Oklahoma State University Facility Contract F07401-74-C-0271.

It should be noted that all of the equipment so purchased remains available for continuing support activities under ongoing AFCRL contract F19628-75-C-0084. In particular, those items which were initially desired for the mission in Natal, Brazil are of utility to the forthcoming schedule. Remote operations at the Alaska and Canada launch sites can make use of this gear, pending reschedule of the Brazilian mission.

TABLE 14. PURCHASED GROUND SUPPORT EQUIPMENT

USAF I.D. No.	Description	Cost	Notes
6802	Magnetic Tape Recorder, Sangamo Sabre III	$19,052	
6803	Telemetry Receiver, DEI TR-711	2,100	1
6804	S-band Tuner, DEI T-711-H	2,395	1
6805	Wideband Demodulator, DEI D-711-C	425	1
6806A	IF Filter, DEI I-711-E (300 KHz)	195	1
6806B	IF Filter, DEI I-711-G (750 KHz)	195	1
6807	Oscilloscope, Tektronix 326	1,739	
6808	Digital Printer, H-P 5050B	3,171	2
6809A	S-band Feed, S/A 72	7,000	3
6809B	Monopulse Comparator, S/A 80	500	3
6809C	Monopulse Comparator, S/A 80	500	3
6809D	Polarization Combiners, S/A 76	900	3
6809E	Monoscan Converter, S/A 251-2	2,500	3
6809F	Tracking Converter, S/A 3774	6,000	3
6809G	Scan Code Generator, S/A 3775A	3,500	3
6815A	Interval Counter, G-R 1192B	1,420	4
6815B	Time Code Generator, Datum 9300	2,045	4

Notes: 1 Components used to provide S-band receiver, for use alone or with TRATEL I system.

2 Used in conjunction with TRATEL I system.

3 Components used in converting existing AMSS antenna to TRATEL I S-band autotrack antenna.

4. Components incorporated in build-up of TRADAT I ranging/trajectory system.

6800 and 6801 were assigned to the 5-channel PCM decoders built locally and described in Section 4.2.1 of this report.

6810 through 6814 were assigned to equipment for sister contract F19628-75-C-0084.

(Final usage of the components listed in notes 1 through 4 above is described in connection with the TRATEL/TRADAT equipment under following Sections 4.6 and 4.7 of this report.)

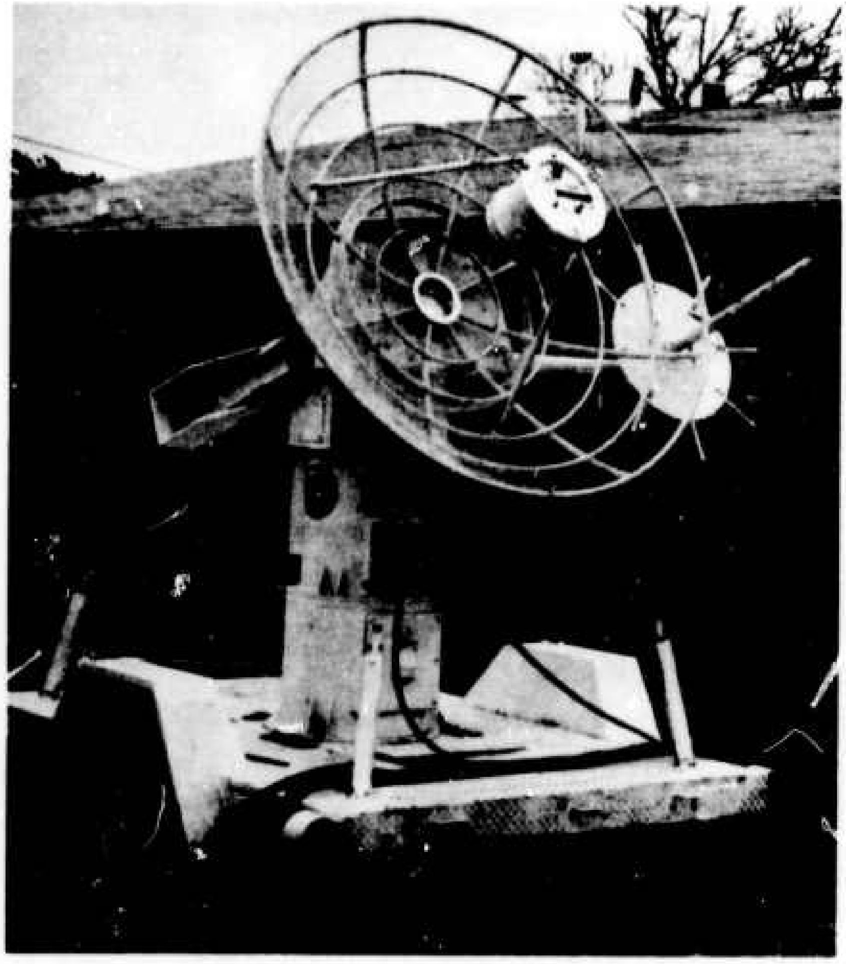

Figure 12. TRATEL I Autotrack Antenna

4.6 Autotrack Antenna System

S-band tracking systems developed by OSU in the past have included a modified AN/GMD-2 (Reference 2,3,6, and 7), and a modified T-9 fire control radar set (Reference 1 and 6). Both of these early trackers operated satisfactorily in field tests and provided excellent quality telemetry video recordings.

A new automatic tracking antenna system was later developed to provide reception of S-band telemetry signals from sounding rockets. This system may be used in conjunction with the TRADAT ranging system described in Section 4.7 to provide trajectory data as well as telemetry data; hence, the name TRATEL I for trajectory and telemetry. This tracking system was

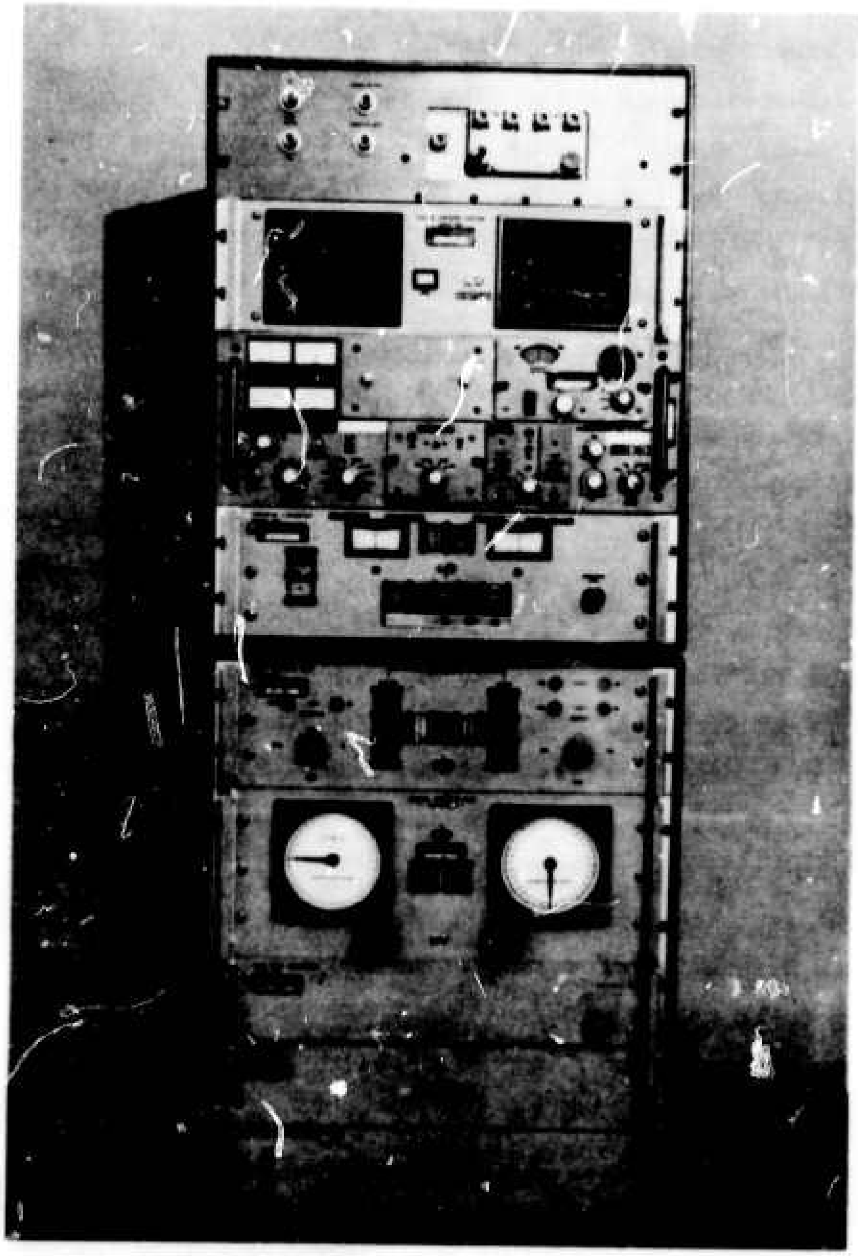

Figure 13. TRATEL I Control Console

developed and constructed under sister contract F19628-72-C-0139; details concerning its development and field testing may be found in the final report to that contract (Reference 2, Section 4.4, 5.1, 5.3, and Appendix A) and in Scientific Report No. 2 to the same contract (Reference 9). Another similar tracking system named TRATEL II was also developed under this sister contract. Both of these trackers are relatively inexpensive, small enough (87"W x 152"L x 105"H) to fit in a trailer van for shipment, and mobile (mounted on small, two-wheel trailers with a 2" ball hitch). These trackers were designed to be used for obtaining both trajectory and telemetry data from sounding rockets launched at remote launch sites (such as the Brazil mission under this contract mentioned in Section 1.2.3) where radar sets and S-band telemetry trackers are not available. Pictures of the TRATEL I trailer and its control console are shown in Figures 12 and 13.

4.6.1 TRATEL I was developed by modifying a government-furnished system called the Advanced Meteorological Sounding System (AMSS) (Reference 10). The TRATEL I system consists of a six foot parabolic reflector, monopulse RF feed, elevation-over-azimuth pedestal, trailer, 200' control cables, and portable control electronics. Most of the components were originally purchased from Scientific-Atlanta, Inc. The tracking converter unit, scan code generator, and RF feed (including its components) were purchased under this contract, and were listed in Section 4.5 of this report. Refer to Figure 14 for a functional diagram of TRATEL I.

A single channel monopulse autotrack system is used to allow good track of amplitude modulated RF signals such as those received from spin-stabilized sounding rockets. The azimuth and elevation axes of the tracker may each be operated independently in the autotrack, manual position, manual rate, slave, or standby modes from the control panel. An RF coaxial switch, operated by a lighted push-button switch on the control panel, was installed inside the RF feed ahead of the preamplifier so that in the "Cal" mode a signal strength calibration can be made through the preamp. In the "Operate" mode, the RF signal from the antenna is switched to the preamp for normal operation. Another lighted push-button switch on the control panel can select either the "Bypass" or "Operate" mode for the preamp; the "Bypass" mode is occasionally required in short range, high signal conditions to avoid preamplifier saturation. Also included at the tracker

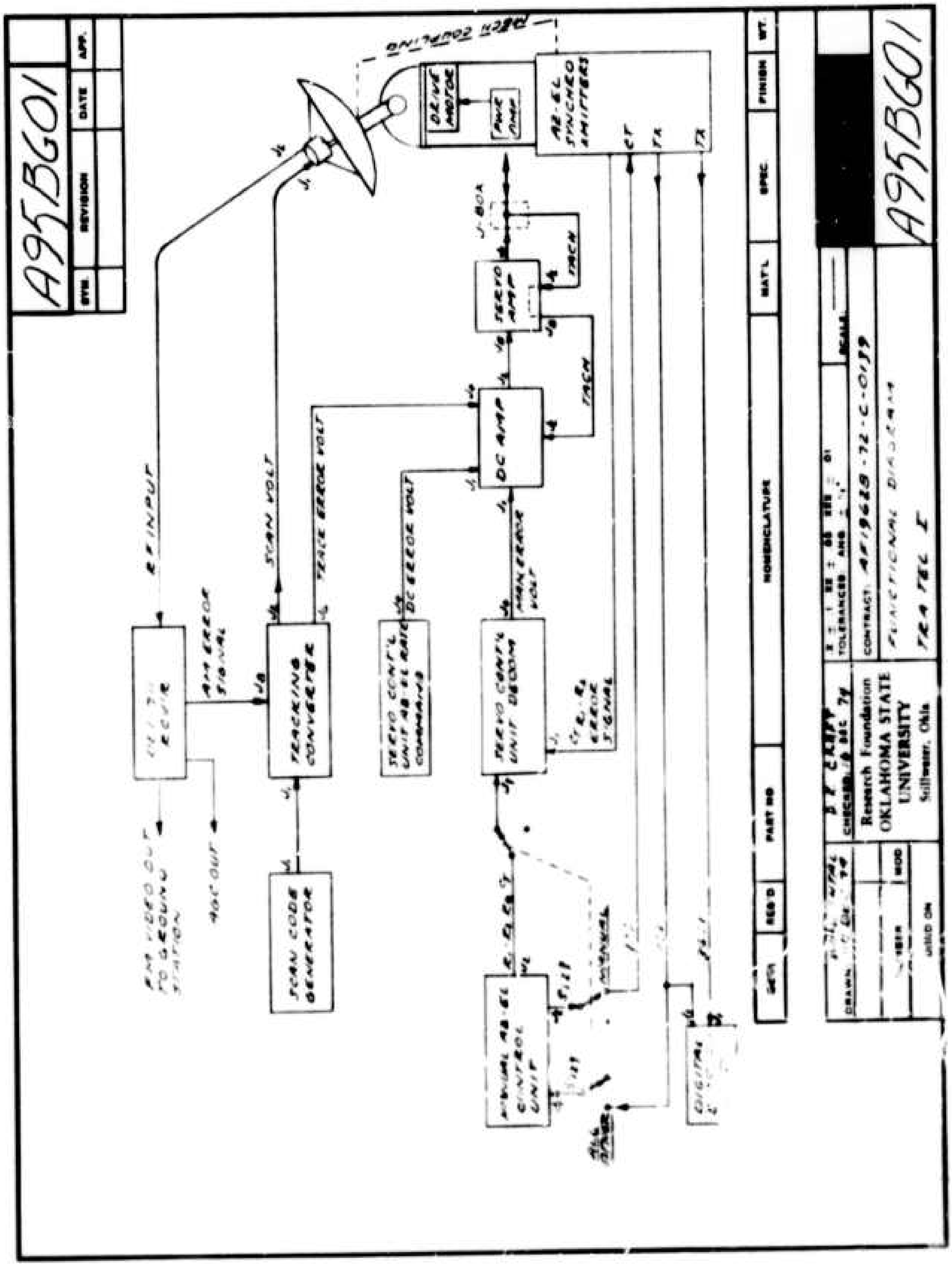

Figure 14. TRATEL I Functional Diagram

control console are Azimuth-Elevation digital readouts with BCD outputs, Azimuth-Elevation dial indicators, an OSU-built heater control for heating the pedestal during operation in cold climates such as Poker Flats Research Range, Alaska, and Ft. Churchill, Canada. A rigid trailer with leveling jacks was designed to provide a stable base. Bubble levels and a boresight telescope mount were added to the pedestal. A method for securing the dish and electronics components to the trailer for shipment was developed. For further information on specific tracker components, reference may be made to the appropriate Scientific-Atlanta, Inc. manuals for the following components:

Model No.	Component
3030/K448	Pedestal
3614	Servo Control Unit
3641	D.C. Amplifier
3621A	Servo Amplifier
3631	Power Amplifier
3734	Manual Command Unit
1841	Digital Synchro Display
72	S-band Tracking Feed
3774-4	Tracking Converter Unit
3775A	Scan Code Generator

Table 15 lists the TRATEL I pedestal technical characteristics. Autotrack and telemetry data recordings were provided using TRATEL I on a total of thirteen sounding rockets supported under sister contracts F19628-72-C-0139 and F19628-75-C-0084 during several missions at Poker Flats Research Range (PFRR), Alaska, and White Sands Missile Range, New Mexico (TRATEL II, which is similar to TRATEL I, was also used in this same general time period to provide autotrack and telemetry data recordings on a total of twenty-four sounding rockets during missions at Eglin AFB, Florida; Wallops Island, Virginia; Ft. Churchill, Canada; and White Sands Missile Range, New Mexico.) The TRATEL I system was deployed and successfully used in field support during the launch of A35.191-1 under this contract. The usage was in preparation for the planned Castor-Lance mission at Natal, Brazil, and has been mentioned previously in Section 2.4.3 of this report.

4.6.2 The autotrack and telemetry data recordings have been excellent during every mission except the ICE CAP 75A mission at PFRR. A new S-band tracking feed was being used to track rockets for the first time. Autotrack was very sporadic during this mission, but telemetry data was received by

TABLE 15. TRATEL I PEDESTAL TECHNICAL CHARACTERISTICS

Characteristic	Specification
Withstand Torque	500 lb - ft
Input Power Required	115V, 50/60-Hz, 1-phase
Drive Type	AC Servomotor, 2-phase
Compliance	1×10^{-5} Rad/ft-lb
Azimuth Bearing Dia	16 in
Azimuth Bearing Overturning Moment	16,000 ft-lb
Elevation Bearing Dia (two)	6 in
Max External Dead Weight Load	1000 lb
Orthogonality Tolerance	0.02°
Data Take-off Packages (Both Axes)	Size 23, 120V, 60-Hz synchro transmitters and control transformers
Electromechanical Brake Holding Torque	400 ft-lb
Pedestal System Accuracy (Typical)*	Static error, 1:1 speed 0.1° peak; 1:1 and 36:1 speed, 0.05°; velocity error, $0.003^\circ/^\circ$/s
Power Gearing Backlash	0.05°
Torque Sensitivity	10,000 ft-lb/$^\circ$
Pedestal Weight	350 lb (including antenna support structure)
Maximum Velocity	30°/s
Acceleration	30°/s/s
Delivered Torque	250 ft-lb
Motor Rating	200 watt
Gear Ratio	400:1 Elevation 476:1 Azimuth
Reflected Motor & Gear Train Inertia	156 SlFt^2 Azimuth 110 SlFt^2 Elevation

*Values are cumulative. Typical errors are listed. Values will vary depending on specific load conditions.

operating the tracker in the manual mode to orient the antenna toward the rocket. Post-mission analysis at OSU revealed that the manufacturer had made an error in cabling the semi-rigid coax in the RF feed. This error was such that it would not be apparent when the tracker was tracking a vertically polarized source, which just happened to be the polarization of the OSU boresight antenna. This explained why the feed appeared normal during tests at OSU while tracking the OSU vertically polarized source, but experienced difficulty in tracking the rockets, which had variable polarization.

4.6.3 Another problem encountered with the tracking feed was the malfunction of two of the Scientific-Atlanta "Monoscan" converters; one at OSU during tests and one during the ICE CAP 75A mission. Inspection revealed that several tiny pin diodes had failed. An explanation for these failures was never discovered. Another problem was solved when a bad solder joint in one of the Scientific-Atlanta polarization combiners was repaired. Due to these problems and the fact that Scientific-Atlanta could not repair the relatively expensive "Monoscan" converters, but would only replace them, an alternate source for a monopulse converter was sought. Vectronics Microwave Corporation built a monopulse converter to OSU specifications, as shown in Figure 15. The unit is very small (5.52" x 6.00" x 0.57") and replaces six components that were previously interconnected with semi-rigid coaxial cable. (The monopulse converter replaces the Scientific-Atlanta monopulse comparator, polarization combiner and "Monoscan" converter.) The prototype Vectronics unit cost less than half the price of the equivalent Scientific-Atlanta components, and future units will cost even less. The unit has a built-in driver such that TTL compatible square waves and ± 12 VDC are the only required inputs. This monopulse converter was first used in TRATEL II to track seven sounding rockets at WSMR, New Mexico. All tracking data was excellent. Further usage of this unit will be required under "field" conditions to adequately demonstrate its long term reliability.

4.6.4 The TRATEL system can also be used to track L-band signals (1680 MHz) with approximately a 7 db degradation in sensitivity with respect to normal S-band usage. A rocket with an L-band transmitter was tracked by TRATEL I during a test at WSMR in April, 1973. Several Super-Loki and

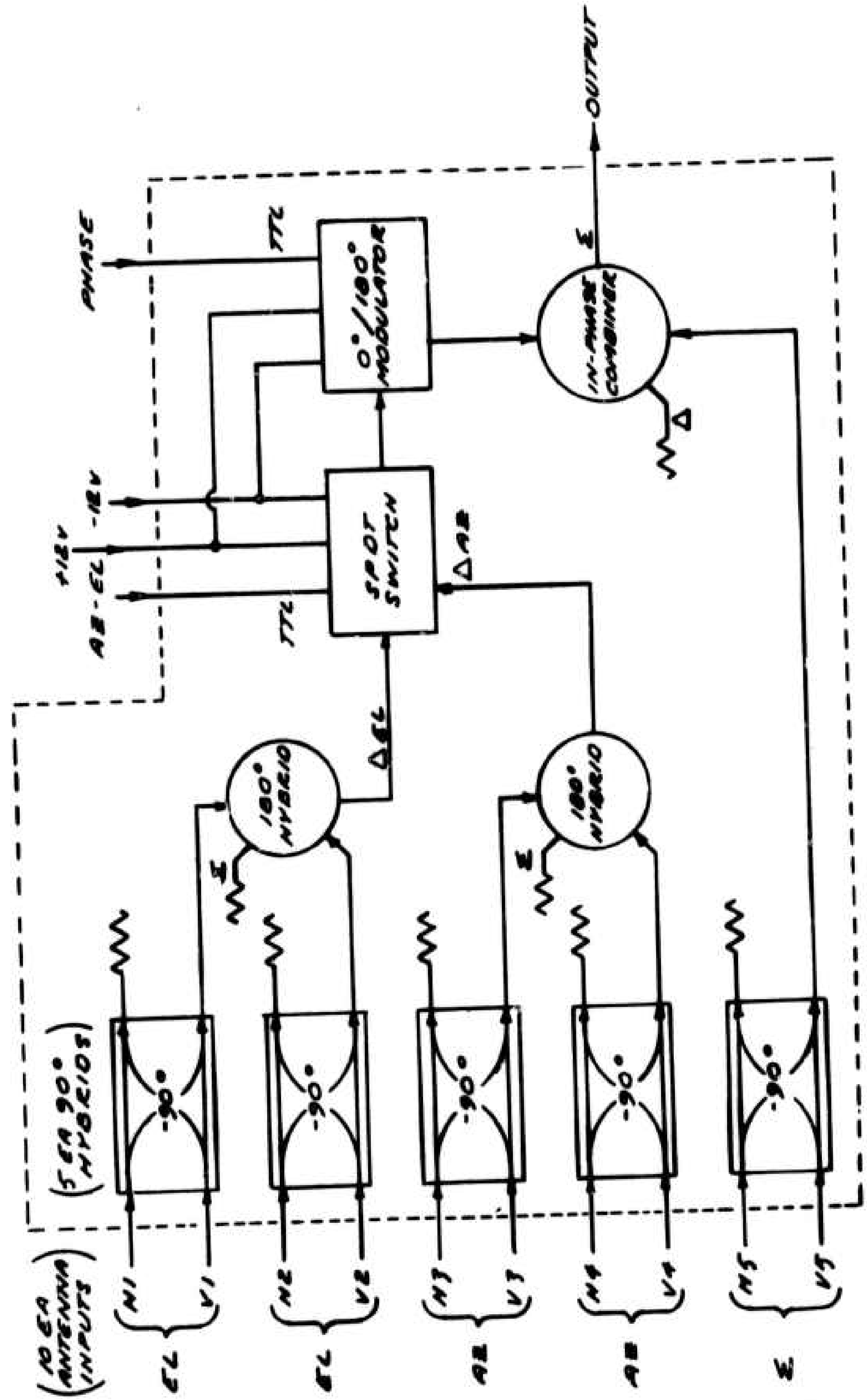

Figure 15. Vectronics Monopulse Converter

Super Arcas 1680 MHz telemetry packages were also tracked by TRATEL I during a mission to PFRR, Alaska, in February, 1975.

4.6.5 During early tracker tests the pedestal was tilted 10^{o} to prevent the tracker from tracking in the "zone of confusion" that results from an overhead pass with an elevation-over-azimuth tracker. The pedestal must be tilted when used at sites such as Parker Station at WSMR, where the rockets pass nearly overhead. The rotation equations for reducing the tilted tracker azimuth, elevation, and slant range to X-Y-Z earth coordinates were derived and used to reduce the data for the early tracker tests. (See Reference 2, Section 5.1.3 for a derivation of the transformation equations). It was determined later that, with the tracker located in the general area of the launcher and blockhouse, adequate tracking could be achieved without tilting the pedestal. This results in slightly more jitter in the azimuth track during the first part of the flight, when the elevation angle is near 80^{o}. The advantages derived from keeping the pedestal level are:

(1) It is much easier initially to set up the angle readouts and level the pedestal.

(2) It is easier to know at the console where the tracker is actually pointing because the angle transformation calculations are not needed.

(3) It is easier to reduce the data.

Since trackers must be sited, oriented, and set up with the precision of a surveyor's transit when used to provide trajectory data, OSU has developed precise set-up and operation procedures. These procedures were described in detail in Appendix A of Reference 2.

4.6.6 The angular tracking accuracy of both TRATEL I and TRATEL II has proven to be about 0.1^{o} during the many field tests during the past several years. The azimuth angle tracking accuracy is somewhat worse than 0.1^{o} at elevation angles near 80^{o}, but better than 0.1^{o} at lower elevation angles. This is normal for an elevation-over-azimuth tracker. The elevation angle tracking accuracy averages better than 0.1^{o}. For a summary of tracking accuracy of these trackers during several sounding rocket missions, see References 2 and 9, prepared under AFCRL contract F19628-72-C-0139. Further analysis of recent tests is underway for forthcoming reports under sister contract F19628-75-C-0084.

4.7 TRADAT I Trajectory System

4.7.1 Several different ranging systems have been developed and tested by OSU in the past. Two early systems, developed in the 1960's, were:

(1) A system which involved computer integration of longitudinal acceleration data from rocket-borne accelerometers (References 11 and 12).

(2) A system which involved measurement of Doppler shifts due to motion of the airborne transmitters (References 3 and 8).

Another later system involved comparing the phases of high stability crystal-controlled oscillators on the ground and aboard the vehicle to determine the range (Reference 6, Section 4.2). A variation of this system involved using a PCM code at the oscillator frequency and deriving a start and stop pulse from the ground and airborne systems (References 1 and 6). Another ranging system involved use of a Vega 609C radar test set in conjunction with a wideband antenna and diplexer for simultaneous S- and C-band operation of the tracker, and deriving range as if the tracker were a low power radar set as well as a telemetry tracker (Reference 1, Section 3.2.4).

Several ranging systems were developed and tested on sister contract F19628-72-C-0139 during this contract period. These systems led directly to the construction of the TRADAT I ranging system. The first system used by OSU during this period was a government-furnished pseudo-noise (PN) system which was part of the Advanced Meteorological Sounding System (AMSS) developed by Motorola, Inc. (Reference 2, Section 5.2.1). The next step in development was the modification of the ground and flight portions of the PN system so that the ranging tone was at the standard IRIG channel 18 subcarrier frequency and the system could be used with a standard IRIG FM/FM airborne telemetry package (Reference 2, Section 5.2.1). A prototype pulse code modulation (PCM) system less complex than the PN system was then developed by OSU (Reference 2, Section 5.2.2). An upgraded version (Reference 2, Section 5.2.3) of the PCM trajectory system was the last system developed on the sister contract prior to TRADAT I. All of these systems were used in actual field tests, and trajectory results were cited in Reference 2, Section 5.3.

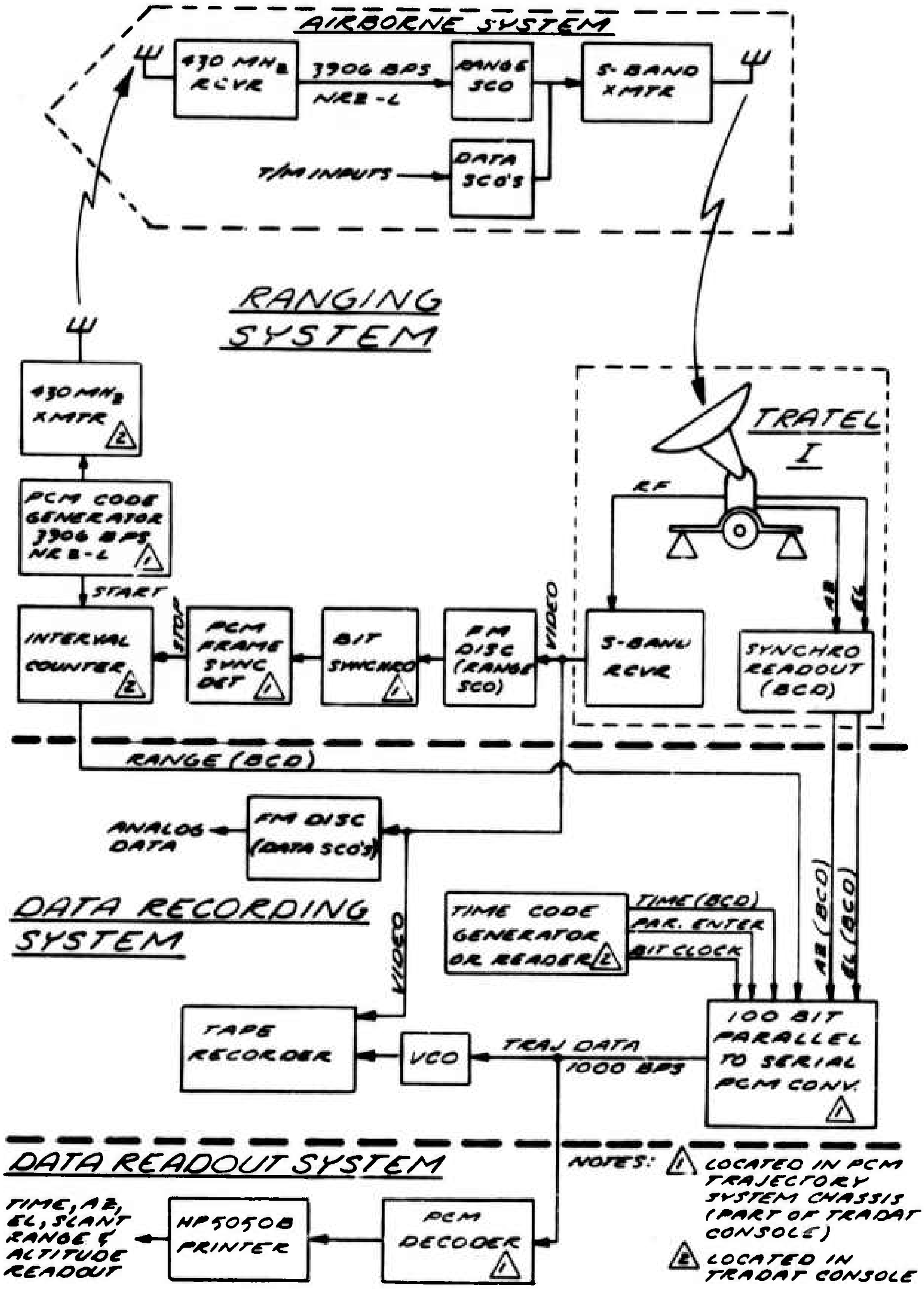

Figure 16. TRADAT I System Block Diagram

4.7.2 The TRADAT I trajectory system was constructed (using components purchased under this contract per notes in Section 4.5) because TRADAT I was to be used with the TRATEL I tracker to provide trajectory and telemetry data for the Brazil mission mentioned in Section 1.2.3. Since the funding for the development and construction of the circuits used in TRADAT I was provided by the sister contract, the reader is referred to sections of the final report (Reference 2) of the sister contract for details on specific circuits. Refer to Figure 16 for a block diagram of TRADAT I. This system involves the generation of a crystal-controlled 14-bit PCM code which is synchronized with the "start" pulse to a time interval counter. This code modulates a ranging transmitter, which transmits the code to the airborne receiver by means of a helix antenna, attached to and pointed by the S-band autotrack antenna. The code is detected in the airborne receiver and used to modulate a standard IRIG subcarrier (any channel above band 14 may be used). This subcarrier is mixed with the data-bearing subcarriers and used to modulate the airborne S-band telemetry transmitter. An S-band tracker (such as TRATEL) is normally used to receive the telemetry signal. The ranging code is retrieved from the telemetry data by a standard IRIG FM discriminator. The PCM code is stabilized and reshaped in an Aacom, Inc. bit synchronizer built to OSU specifications. The bit synchronizer reduces the code jitter to about 200 nanoseconds, which is equivalent to a range jitter of about 30 meters. The reconstructed received PCM code is decoded to produce a "stop" pulse to the interval counter. The General Radio Model 1192B counter was modified such that a new time base may be selected by a toggle switch, to give the range readout directly in kilometers to the nearest .01 kilometer. (The original time base may also be selected so that the counter may also be used in its original form as a general purpose counter for test purposes such as counting subcarrier oscillator frequencies.) The range is initialized with front panel switches and a fine adjust knob. A detailed description of the operation of the PCM code generator and decoder is given in Reference 2, Section 5.2.3.1.

4.7.3 TRADAT I was designed to record the trajectory data acquired during a rocket flight in a PCM format. The parallel BCD azimuth and

Range Time

```
Frame                      Hrs      Min      Sec      .1Sec    EL (Deg)
Sync        Spare          1   9    5   9    5   9    .9       8    9  .  9    7
11111011 0000 0000 0000   01 1001  101 1001  101 1001  1001   1000 1001 1001 0111
Bit      10          20              30          40              50         60
No. 1
```

Continued Frame

```
 Tracker
 Mon.     AZ (Deg)                          Range (KM)
 A   3   5    9  .  9    9    9    9    9  .  9    9
 01  11 0101 1001 1001 1001 1001 1001 1001 1001 1001
Bit No. 61      70         80             90         100
```

Figure 17a. Trajectory Data PCM Format

Print Hammers

```
            18 17 16 15 14 13 12 11 10  9  8  7  6  5  4  3  2  1
2nd Print    1  9  5  9  5  9. 9       8  9. 9  7     3  5  9. 9  9
                 Range Time             EL (Deg)        AZ (Deg)
                                        Spare           Range (KM)
1st Print    1  9  5  9  5  9. 9       0  0  0  A     9  9  9. 9  9
             Hr    Min    Sec          Tracker Mode
                                       of Operation
                                       Monitor
```

Figure 17b. Trajectory Data Printer Format

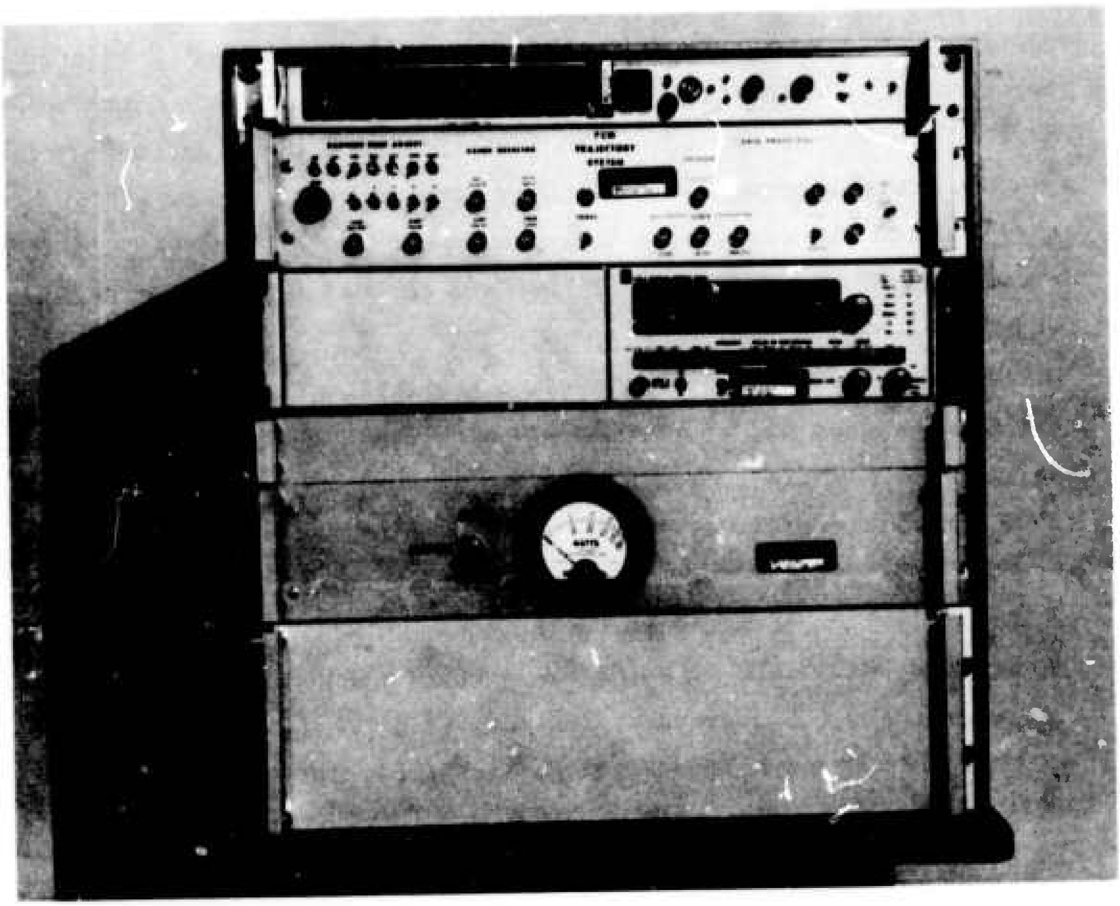

Figure 18. TRADAT I Console

elevation data from the tracker controls, range data from the interval counter, and time data (IRIG "B", in Universal Time) from a Datum, Inc., Model 9300 time code generator/reader are sampled simultaneously every tenth of a second. The data encoder converts all the above parallel data into a serial PCM data stream as shown in Figure 17a. The data uses an 8-bit frame synch (11111011). The bit rate (1000 BPS) and the frame rate (10 per second) are derived from the time code generator/reader, which is synchronized with the Universal Time, so that the trajectory data may be readily correlated to the scientific data and compared with other trajectory data. One of the data bits is used to indicate the tracker mode. The PCM data format was so chosen that the AFCRL computer center could reduce the OSU trajectory data directly from magnetic tapes. AFCRL has already reduced OSU trajectory data from three rocket launches. A detailed description of the operation of the data encoder is given in Reference 2, Section 5.2.3.2.

A special decoder is included to facilitate the prelaunch checks of the TRADAT system and to provide a "quick look" real time flight record of the flight. All trajectory data is printed by a Hewlett-Packard Model 5050B digital recorder at a selectable rate of one or two data sets per second. Two printout lines are required for one complete data set. Refer to Figure 17b for a sample of the printer format. A tracker mode monitor is provided such that, if an "A" is printed, both azimuth and elevation controls are in the autotrack mode and, if a "*" is printed, either or both controls are not in autotrack, so the angular data are not valid. A detailed description of this data decoder is given in Reference 2, Section 5.2.3.3.

4.7.4 The Aacom bit synchronizer, ranging code generator and decoder printed circuit card, data encoder card, and data decoder card are mounted in the PCM trajectory system chassis, which is located in the TRADAT I control console, along with the time code generator/reader, interval counter, and ranging transmitter, as shown in Figure 18. The lightweight TRADAT console is small (19½" rack height) and easily moved, with handles on the sides.

The ranging transmitter was redesigned under sister contract F19628-75-C-0084 and components for two transmitters (403 MHz and 430 MHz) were

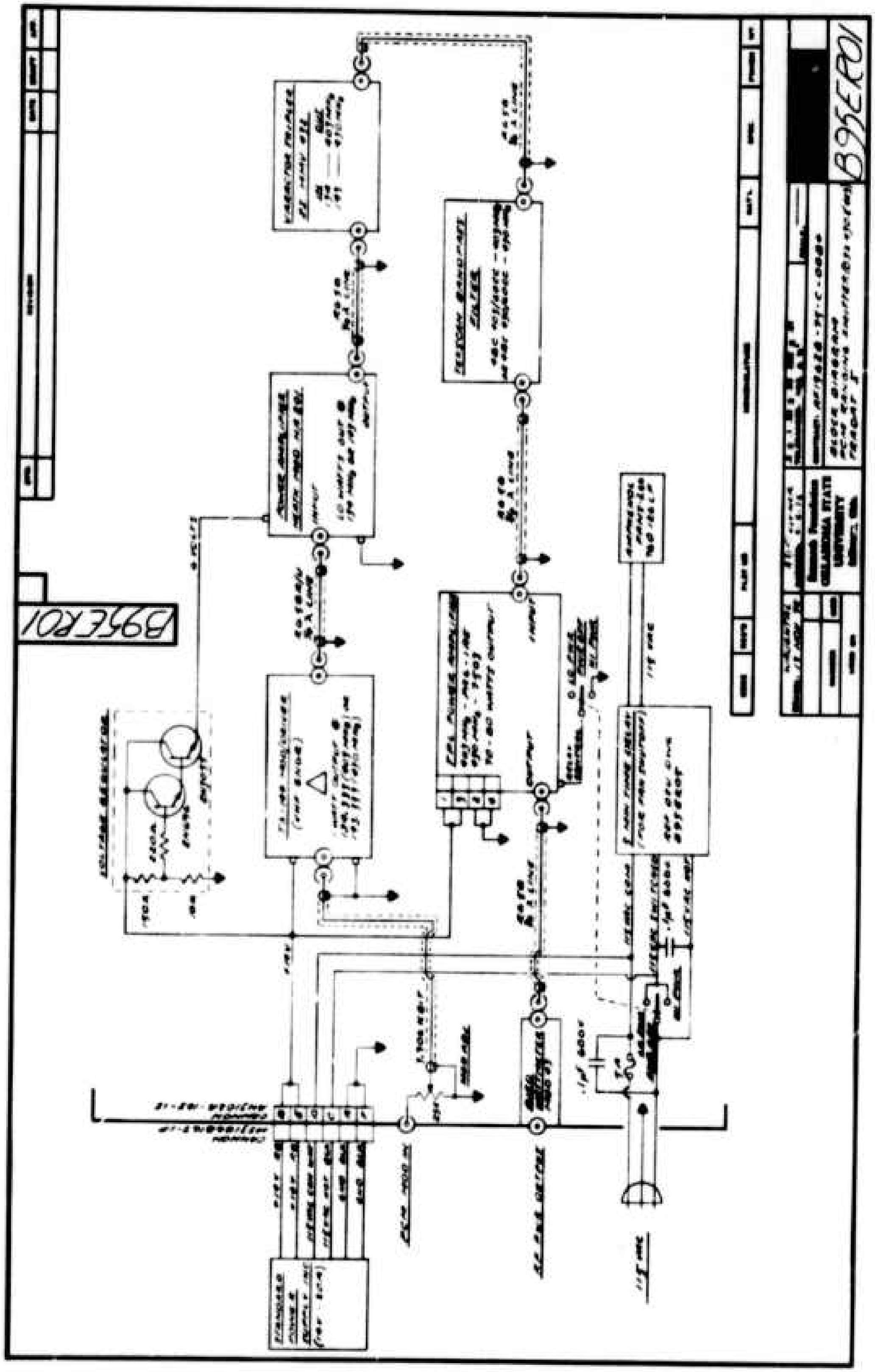

Figure 19. Ranging Transmitter Block Diagram

purchased under this contract. They were to be used for the Brazil mission mentioned in Section 1.2.3. One was to be used with TRADAT I and TRATEL I and the other was to be used with TRADAT II and TRATEL II. (The remaining components of TRADAT II were purchased under the sister contract.) The ranging transmitter is shown in block diagram form in Figure 19. Analysis of the power requirement for this transmitter involved the anticipated range, airborne receiver sensitivity, and 400 MHz band antenna gain. Details of the previous transmitter design are given in Reference 2, Section 5.2.3.4. These transmitters are called OSX 430 or OSX 403, depending on the frequency. They are small (3½" rack height), lightweight, and relatively inexpensive, as they were constructed primarily using modified amateur radio components. Since these units were developed under a different contract, specific circuit details can be found in forthcoming reports for that contract. However, its features include two selectable power outputs (3 watts or 75 watts), front panel wattmeter, and five-minute cooling fan shutoff delay to allow adequate cooling of the power amp after the transmitter itself is turned off.

4.7.5 Trajectory data from several rocket flights at several different launch sites has shown an average range deviation within 0.050 Km when compared with radar data. When the PCM trajectory system was used with the TRATEL tracker, altitude data averaging well within 0.10 Km of radar data was obtained. This data can be found in Reference 2, Section 5.3 and in upcoming reports being prepared under sister contract F19628-75-C-0084.

5.0 SUMMARY OF RESULTS

This contract was entered into for the fundamental objective of providing certain engineering support services to the Air Force Cambridge Research Laboratories. These services were a continuation of an effort which began earlier, under a preceding contract (F19628-70-C-0147) and were directed toward support of a program of infrared instrumentation aboard rocket vehicles at various launch sites. There have been a series of delays in this program; services have consequently been deferred in accord with schedule changes, extending the period of performance without a requirement for additional funds. The work will continue, with further scheduled activities supported under a following AFCRL contract F19628-75-C-0084. The varied nature of the services supplied over this prolonged time period have been such that a concise summary of results (or specific conclusion regarding the outcome of the program) is virtually impossible; only a number of generalities describing the various areas in which support was required appear possible. The services may be considered as covering three general areas: the supply of certain airborne apparatus, required for the support of the payload instrument in flight; the provision of ground support equipment, required to operate, test, and record data from the payload; and the supply of manpower for assistance in test operations, launch, and data retrieval from the flight of each payload.

5.1 Airborne Apparatus

Components and airborne subsystems were supplied, as required, for a total of eleven different payload applications during this period of time. Not all were actually launched; eight were flown and three others delivered for systems to be launched at a later date. Seven support packages were designed, built, tested, and delivered as completed subsystems, flight-ready. In four other cases, major components were supplied for subsystems assembled at AFCRL, in which this laboratory assisted in design, test, and eventual field support of the completed subsystems.

5.2 Ground Support Equipment

The complexity of the instrumentation involved in the infrared program was such as to involve relatively elaborate ground support systems, committed to unusually lengthy test and launch programs. As a result, to avoid compromise to other ongoing AFCRL programs, separate checkout and field support facilities were built up to provide an independent ground support capability, for primary usage under this contract, and with future applicability to a continued program of support under the following contract. Items of ground support equipment included both locally built and commercially purchased items; many of the latter were modified and/or incorporated into special ground support subsystems. The capability now includes the following: custom consoles for test and operation of the airborne subsystems, two five-channel PCM decoders, a PCM simulator, an autotracking S-band antenna with associated receiver and console (TRATEL I System), an auxiliary ranging system which adds trajectory determination capability to the autotrack capability (TRADAT I System), associated wideband magnetic tape recording and digital printer equipment, and a two-channel monitor oscilloscope. Of this equipment, the TRATEL I antenna and associated TRADAT I trajectory system, when combined with the wideband magnetic tape recorder and PCM decoder, are of special importance for remote sites where facilities for launch operations are limited: they offer a self-contained capability for simultaneously providing reception and recording of sophisticated PCM telemetry and evaluation of the vehicle trajectory.

5.3 Field Support Services

A considerable effort was devoted to field support services, in which personnel from this organization assisted AFCRL personnel and those of other agencies at locations away from the base laboratory in Oklahoma. A total of 298 man days were required for this phase of our activities. Technical coordination meetings in which the detailed requirements for eleven payload support systems were resolved required fifty-nine man days. Forty-four additional man days were occupied in conducting integration tests with the assembled payloads for eight launch missions, prior to proceeding with final operations at the selected launch sites. Assistance in the actual launch operation, including data retrieval and recording, accounted for the remaining 195 man days of effort in the field. In the course of this effort, five payloads were launched from the White Sands Missile Range in New Mexico, and three more from the Weapons Research Establishment in Woomera, South Australia. In addition, in preparation for a second overseas expedition to Natal, Brazil, personnel also participated in the launch of six additional rockets in a training and evaluation mission.

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