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PROJECT VANGUARD REPORT NO. 5

PROGRESS THROUGH MAY 15, 1956

[UNCLASSIFIED TITLE]

Project Vanguard Staff

June 1956

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Previous Project Vanguard Reports

Project Vanguard Report No. 1, "Plans, Procedures, and Progress" by the Project Vanguard Staff, NRL Report 4700 (Secret), January 13, 1956

Project Vanguard Report No. 2, "Report of Progress" by the Project Vanguard Staff, NRL Report 4717 (Confidential), March 7, 1956

Project Vanguard Report No. 3, "Progress through March 15, 1956" by the Project Vanguard Staff, NRL Report 4728 (Confidential), March 29, 1956

Project Vanguard Report No. 4, "Progress through April 15, 1956" by the Project Vanguard Staff, NRL Report 4748 (Confidential), May 3, 1956

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PROBLEM STATUS

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

AUTHORIZATION

NRL Problem A02-18

Manuscript submitted May 25, 1956

PROJECT VANGUARD REPORT NO. 5

PROGRESS THROUGH MAY 15, 1956
[UNCLASSIFIED TITLE]

PREFACE

This report is intended as a general summary of the progress on Project Vanguard through 15 May 1956. Hence, minor phases of the work are not discussed to a great extent and technical detail is kept at a minimum. It is hoped that the information here provided will be of use to administrative and liaison personnel in coordinating and planning their activities, and as a guide to the current status of the project. Material of a more technical nature will be published from time to time in separate reports which will be announced in the subsequent monthly progress report.

COORDINATION WITH OTHER SERVICES

Army

The Minitrack site selection party, under sponsorship of the Office of the Chief of Engineers and with representatives from the Office of the Chief of the Signal Corps, the Naval Research Laboratory, and the National Academy of Sciences, left Washington on 26 March for Fort Clayton, Panama Canal Zone. At Fort Clayton, detailed discussions were held with the Commanding Officer of the Inter-American Geodetic Survey exploring the feasibility of obtaining the cooperation of the IAGS in the establishment of the satellite tracking network, thereby taking advantage of his existing relationship with the individual South and Latin American countries. It became quite apparent that, with certain augmentation in strength, the IAGS organization would be ideally suited for this mission.

The party left Panama for Quito, Ecuador, where, with the help of the local IAGS representatives and the Chief of the Ecúadorean Instituto Geographica Militar, a suitable site was located about 25 miles south of Quito on the Paromo of Mount Cotopaxi. The Chief of the Instituto Geographica Militar, Colonel Bolivar Zurita, agreed to handle the site acquisition problems under the existing agreement with the IAGS.

The next area visited was Lima, Peru. The President of the Peruvian International Geophysical Year Board of Directors, Dr. Jorge Broggi, along with the Chief of Peruvian Instituto Geographica Militar, Lt. Colonel Guillermo Barriga, and the local IAGS organization, assisted the party in locating a suitable site near Ancon, about 10 miles north of Lima.

Since the next two general site locations were in Chile, the party left Lima for Santiago, Chile, to obtain the necessary diplomatic clearances for that country. Personnel and official interest and full support was assured by the Chilean Minister of Defense, Admiral O'Ryan, the Commander in Chief of the Chilean Army, and the Commander in Chief of the Chilean Air Force, along with the Chief of the Chilean Instituto Geographica Militar, General Daniel Urra. Under this sponsorship and through the local IAGS organization a suitable site was obtained on the Peldehue Military Reservation about 12 miles north of Santiago. Under this same sponsorship the party left for Antofagasta, Chile, where a suitable site was located about 10 miles east of the city.

The party then returned to Panama. A suitable site for the Panama tracking station was located at Rio Hata, a U. S. Military reservation, about 80 miles southwest of Panama. The next area of interest was Havana where, with utmost cooperation from the Cuban Army and the local IAGS project, a suitable site was selected on Batista Air Field of the Cuban Army Air Force. The party then returned to the United States to select a site at Fort Stewart near Savannah, Georgia.

With the exception of the site near Quito, Ecuador, all South American and Cuban sites are on local government-controlled land and are expected to be made available for the satellite tracking mission.

A detailed trip report and cost estimate for the satellite tracking network is under preparation by the Office of the Chief of Engineers.

Air Force

Test Program

During the last month the Preliminary Vanguard Test Plan was revised and a specific test program developed.

Test Range Facilities

Instrumentation criteria for the tracking stations at Antigua, Mayaguana and Grand Turk islands have been completed by the range contractor. Additional detailed criteria are being formulated for each installation in order that construction may proceed.

A contract for the construction of the launching complex was awarded to the J. A. Jones Company on 24 April 1956, and the work is on schedule. The Vanguard assembly hangar requirement is being met by the assignment of hangar S to the project.

All information necessary for the flight safety plan of the first Vanguard test vehicle launching (TV-0) on 20 November 1956 has been provided AFMTC. Completion of the AFMTC range safety plan is expected by 1 July 1956.

THE LAUNCHING VEHICLE

Configuration and Design

The initial compression loading test on a first-stage propellant tank element has been conducted with water at an internal pressure of 9 psig. Buckling occurred in the lower skirt section at approximately 85 percent of the expected ultimate axial tank load. (Later calculations revealed that the loading had been considerably higher than the design load of the skirt, but less than the expected strength.) A second compression test was run on the repaired tank element with water at an internal pressure of 13 psig (the lowest expected in flight), and slight buckling occurred near the top dome at 106 percent of the design ultimate axial load. When the load was released the buckles virtually disappeared. A test with zero (internal) gage pressure is planned. Another tank element test with constant internal pressure of 13.2 psig, 100 percent design ultimate axial load, and increasing bending moments, resulted in buckling near the forward dome at 110 percent design ultimate moment as was expected. As a result of these test, consideration is being given to reduction of the skin thickness by 0.005 to 0.010 inch. The structural configuration of the tank dome has been changed to reflect the newly calculated and more severe pressures which result from the second-stage engine exhaust at ignition prior to separation.

The preliminary vibration analysis of the launching vehicle has been completed by digital computation. The results indicate that 6-10 cycles per second is the only range in which vehicle resonant frequencies do not occur. The results are being reviewed prior to entering the data into structural-feedback transfer functions.

The wiring diagram for TV-0 has been completed and released. In addition, the layout of components for the instrumented third-stage nose cone has been completed; it is presently planned to subcontract the installation of the nose cone temperature pickups.

Aerodynamics

Skin temperatures resulting from aerodynamic heating were computed on the following surfaces:

1. Nose cone; plastic, 0.040 inch thick

2. Nose cone; titanium, 0.020 inch thick

3. Second-stage skin adjacent to third stage; magnesium, 0.032 inch thick.

The maximum skin temperature four inches from the nose cone tip is expected to be 1360°F and 1320°F for titanium and plastic respectively, and occurs 148 seconds after launch. The maximum temperatures at the base of the cone 73.9 inches from the tip are 830°F (at 155 seconds) and 700°F (at 160 seconds), for titanium and plastic respectively. The maximum skin temperature expected on the second-stage magnesium skin adjacent to the third stage is 840°F. It is indicated that this can be reduced by approximately 15 percent through painting.

Consideration is being given to the effect of vibrational loading of the vehicle aft section on the launching stand due to the formation of the von Karman vortex trail in the presence of winds. This phenomenon, which can occur within a certain range of Reynolds numbers, is produced by the periodic shedding of vortices in the separated flow about a cylinder, resulting in oscillation in an unrestrained structure. In a low-speed wind tunnel test of a Vanguard model, this effect has been detected at an angle of attack of 90 degrees (the angle of the wind to the erected vehicle).

A crude estimate was made of the angles of attack required to reach ultimate loads for the launching vehicle at various altitudes. Above 125,000 feet and below 3000 feet, angles as great as 20 degrees might be required for self-destruction of the missile. At the intermediate altitudes, self-destruction might occur at angles between 5.8 and 20 degrees. The present design maximum angle of attack is 5.0 degrees.

Vehicle System Performance

The over-all performance and trajectory characteristics of the Vanguard vehicle system have been determined from the present estimates of the values of the basic performance parameters. The results are as follows:

Fundamental Parameters

	1st Stage	2nd Stage	3rd Stage
Mass Ratio*	0.885	0.766	0.823
Stage Ratio †	0.789	0.902	1
Specific Impulse (sec)	253.5	278	245
Weight Status and Goals			
Specification Weight (lb)	1782	973	89
Target Weight (lb)	1565	865	89
Current Weight (lb)	1532	870	82
Propulsion Parameters			
Nominal Thrust (lb)	27,835 (sea level)	7730 (altitude)	2350 (altitude)
Burning Time (sec)	141.6	116.5	41.5
Velocity Contribution			
Vertical	3927	1876	-
Horizontal	4579	10,126	13,687

The final projection velocity (at third-stage burnout) is 27,826 feet per second,‡ an excess of 2792 feet per second over the circular orbital velocity at 300 miles altitude.

The specific impulses obtained in recent tests of the second-stage propulsion system¶ were lower than the specification value. In order to determine the consequences which would issue from a failure to attain the specification value, the over-all vehicle performance has been determined with an assumed second-stage specific impulse which was 5 percent less than the specification value. The resulting final projection velocity was 27,118 feet per second, an excess of 2084 feet per second over the circular orbital velocity at 300 miles altitude.

Trajectories for TV's 0-3 have been determined on the basis of range safety and tracking requirements which specified burnout and impact ranges and apogee altitudes; approximations of possible dispersion due to malfunctions on performance tolerances were calculated.

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*The propellant mass ratio of the given stage alone.

†Defined as the ratio of the weight of a given stage alone to the weight of the complete stage, including all the stages it carries.

‡The sum of the contributions of the separate stages, corrected to take into account such things as the earth's rotation.

¶See Propulsion section.

Propulsion

A summary of the servicing requirements for the propulsion system has been completed. The requirements were discussed with the servicing group at AFMTC and were revised in order to utilize more efficiently the equipment available at the base.

First Stage

During this report period the first General Electric X-405 demonstrator engine assemblies were completed (Fig. 1) and static firing tests were initiated. The effort has been approximately doubled on the testing of thrust chambers and other components.

Demonstrator engine No. 1, equipped with a heavy (nonflyable) thrust structure, was static fired for 30 seconds with normal start, operation, and shutdown. After several further attempts to start were thwarted by electrical malfunctions, another run was successfully initiated. Upon shutdown the hydrogen peroxide valve failed to close, causing overspeeding of the turbopump. At approximately 50,000 rpm (160 percent of the rates turbopump speed) a bearing seized, but there was no gross structural failure.

Ten propellant injectors of both aluminum and stainless steel have been tested with different injection-hole configurations. One stainless steel unit has a cumulative total of over 700 seconds test time. Studies of burned injectors have led to a more careful analysis of fabrication methods and evidence has been found of improper drilling of the injection nozzles. This condition has been rectified.

Fig. 1 - GE X-405 demonstrator first-stage powerplant (GE photo)

As a result of several weld failures in thrust chamber assemblies, the hydrostatic test procedure has been re-evaluated, and in order to simulate operating conditions more accurately a superimposed "water hammer" test has been incorporated; steps have been taken to insure better welding practices and better means of detecting faulty welds.

The first X-405 flyable turbopump (with a power take-off for the hydraulic pump) was received, installed for test, and operated with the hydraulic pump functioning. The hydrogen peroxide decomposer efficiencies have been about 99 percent, with the deviations not exceeding 1 percent. The first production prototypes have been received on schedule.

The first flyable thrust structure assembly has been received and tested on schedule. The gimbal ring assumed an undesirable set under loads of 30,000 pounds and over, necessitating a design change. Two other assemblies were received but required additional modification. A preliminary vibration test on the assembly with the thrust chamber installed revealed a structural resonance frequency of 24 cycles per second under load. Subsequent stiffening of this assembly increased this to 44 cycles per second which approaches the specification value.

Test pit No. 25 at the Malta test station, in which the Vanguard first-stage propellant tank configuration is roughly approximated, was put into operation during the report period with the firing of demonstrator engine No. 1 (Fig. 2). The propellant tank volume available is sufficient for runs of approximately 170 seconds duration.

Fig. 2 - Static firing of an X-405 development type thrust chamber (GE photo)

The delivery of valves, feed lines, and electrical equipment is proceeding on schedule. A mockup of the first-stage dynamic control system has been delivered (Fig. 3).

All components for the first-stage pressurization and propellant feed system with the exception of the lox vent and relief valve have been evaluated and selected, and procurement of the majority of these items has been initiated.

Second Stage

The basic design of the over-all AJ10-37 propulsion system for the second stage has not changed, but a revised breakdown of estimated second-stage weights, including heated

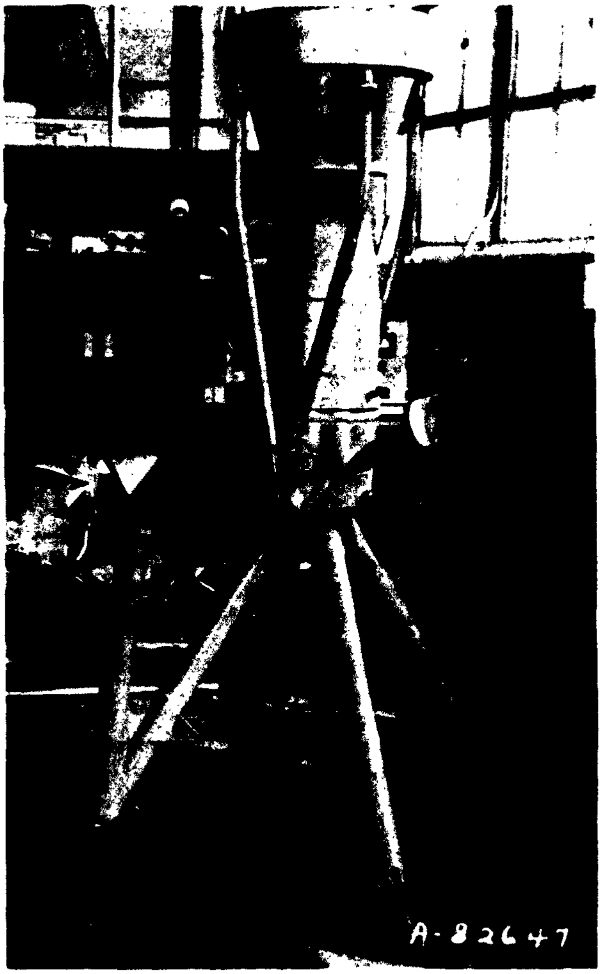

Fig. 3 - First-stage dynamic control mockup (Martin photo)

helium pressurization units and for both stainless steel and aluminum thrust chambers, has been compiled. The stainless steel chamber (a backup unit having approximately 195 percent of the weight of the aluminum chamber) has been lightened by decreasing the tube wall thickness of the divergent section. Further weight savings, due to optimization of the tank assembly design, are not readily apparent owing to an inclusion of weight allowances for increased wall thicknesses to take acid corrosion into consideration and a 2 percent manufacturing tolerance.

A theoretical second-stage propellant performance analysis revealed that the use of fuming nitric acid Type III (RFNA with some free water) produces an over-all decrease in specific impulse of approximately 1-1/2 seconds as compared to pure nitric acid (WFNA is presently contemplated).

Tube burn-through has occurred in attempts to seal pinhole leaks in the aluminum "spaghetti" type thrust chamber. This unit has been sent to the prime contractor for a mockup application. The second aluminum unit was completed through the wire-winding stage but cracking occurred in the throat region while the coolant manifold was being installed; an attempt is being made to salvage this unit. Two additional aluminum chambers are scheduled for fiberglass wrapping instead of wire winding. Thrust-chamber static firing tests have been rescheduled with a two-week delay because of the fabrication complications.

Three aluminum showerhead injectors and one like-on-unlike impinging injector were completed and combustion tested on a heavy uncooled test chamber. In all cases the measured c* was 8 to 10 percent lower than was expected.† Aerojet believes that injector modifications will increase the performance. Some combustion instability has been noted, with a frequency of 700 cycles per second.

Ten experimental fuel and oxidizer valves for the thrust chamber are nearing completion. Design is continuing on a lighter propellant valve with a lower pressure drop.

An experimental tank pressurization system (heavy-walled sphere) has been tested with both the unrestricted (backup) and restricted heat-generator propellant grains. The unrestricted grain produced unstable operation of the gas pressure regulation valve. The restricted grain gave good results, and although a tarry residue was later found in the regulator its operation did not appear to be impaired. Difficulties are being encountered in limiting the maximum regulated tank pressure to 2 psi above that specified for the maximum allowable bleed rate; so far all attempts to achieve this have been unsuccessful.

The draw dies for the 0.109-inch stainless steel (AISI 410) prototype helium tanks have been completed and drawing operations are underway.

The second-stage dynamic control mockup has been delivered. Its weight, center of gravity, and moment of inertia are based on the values calculated for the aluminum thrust chamber assembly. Provisions are being made for providing additional weights to change these parameters to those characteristic of the stainless steel chamber assembly The spatial mockups for the center and upper sections of the propulsion system have been completed.

†The combustion performance index, c*, is directly proportional to the thrust for a given thrust chamber, flow rate, and propellant combination.

Third Stage

Parallel development of the third-stage solid-propellant propulsion units (Figs. 4 and 5) has continued with scaled-down unit and component testing. Both contractors, the Allegany Ballistics Laboratory (ABL) and the Grand Central Rocket Company (GCR) are spending considerable effort in establishing test methods for determining thrust-axis alignment and dynamic balance of the units. The required thrust-axis alignment tolerance is approximately 25 percent of that now being achieved on large rockets with close-tolerance manufacturing techniques.

ABL has conducted firings of the scaled-down (10-inch-diameter) Model 42-DS-4350 propulsion system with the BDI double-base propellant, and experienced some resonance disturbances; in subsequent testing, however, a reduction in this effect was achieved. A specific impulse of approximately 200 seconds was achieved with a sea-level nozzle; the thrust-time curve was essentially constant. The propellant grain design has been completed, and both the fiberglass-reinforced plastic and the steel (backup) cases have been designed. Both sea-level and altitude nozzle designs for these cases have been completed, with the exception of the exit cone for the altitude nozzle. Prototype black-powder igniters are being fabricated.

GCR has extended the burning time of its scaled-down (15-inch-diameter) Model 42-XS-4350 test motor to 27 seconds with satisfactory results, using an over-expanded nozzle. Heavy (nonflyable) test nozzles are being tested at various chamber pressures. Erosion and heat transfer appear to be within the design limits. Some evidence of instability has been noted in tests of the polysulphide-perchlorate propellant at various chamber pressures. The required c* (see footnote on page 8) has been reached. Several scaled-down "heat-source" igniters have been tested, and acceptable operating characteristics were achieved.

Flight Control

Guidance

A breadboarding of the Vickers magnetic amplifier autopilot has been completed ahead of schedule and studies have been made of its gain and frequency response. A subminiaturized electronic autopilot amplifier has also been breadboarded and will be available if required. The standard electronic autopilot amplifier is complete for use as a secondary backup.

Minneapolis-Honeywell has completed basic analysis and REAC studies of open-loop transfer characteristics of the gyro reference system and of cross-coupling effects between the axes; they are also well along with the breadboarding of associated electronics. Two problem areas exist: environmental vibrations, and cooling. A study of shockmount characteristics is in process, and consideration is being given to the use of Freon in a "one-shot" application for in-flight cooling of the gyro unit. Preflight cooling will be accomplished by an external system.

Air Associates, Inc. have received a contract for supplying the integrating accelerometers which will be used in conjunction with a timing mechanism to determine the vehicle velocity at second-stage burnout and provide a computed time for third-stage launch.

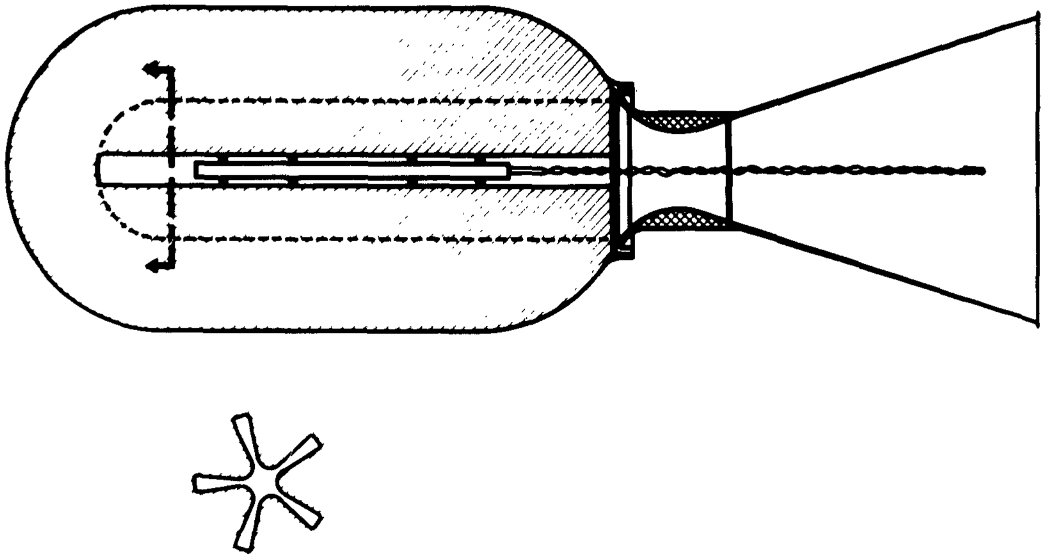

Fig. 4 - Grand Central Rocket Company's third-stage rocket configuration

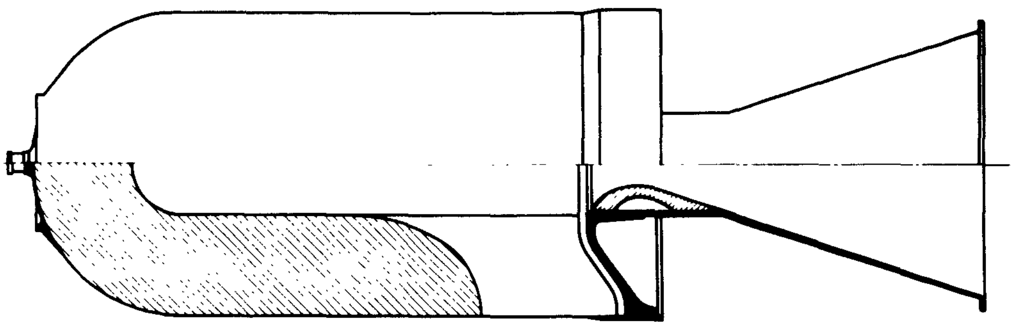

Fig. 5 - Allegany Ballistics Laboratory's third-stage rocket configuration

Proposals for the flight-control programmers have been received from several suppliers. One approach under consideration utilizes a 135-inch perforated tape (equivalent to a 42-inch-diameter drum) for a timing interval of 720 seconds. It includes a 400-cps 2-phase source, stabilized to one part in 10,000, driving a 1.5-watt hysteresis type synchronous motor.

The pitch-yaw control system was reanalyzed utilizing new information on missile dynamics. Nyquist plots revealed no change from the previous analyses. The first-stage dynamic mockup has been run with Viking components altered to simulate Vanguard parameters. The correspondence between measured and computed response (magnitude and phase versus frequency) is good. The system (unstiffened structure) peaks in amplitude at approximately 15 cycles per second. Analysis has started on the structural feedback problem for the Vanguard configuration. In addition, testing of the pitch-yaw amplifier for TV-3 was started.

REAC desk computer studies have been made on the second-stage pitch-yaw jet system. The results correlate closely with those obtained by graphical (phase plane) analysis. Design information has been completed for the electrical systems required by the propulsion equipment of the first- and second-stage roll and second-stage pitch-yaw dynamic mockups. In addition, the propulsion system for the pitch-yaw dynamic mockup has been designed and most of the hardward chosen. This propulsion system will be a duplicate of the Vanguard pitch-yaw system and will utilize the same valves and jets. The helium supply will consist of a helium bottle cascade adjacent to the mockup with a flexible feed line leading to the mockup.

Design has been completed for a two-chamber spring-return pneumatic actuator utilizing 600-psi helium for directing the first-stage roll nozzles.

Various methods of supplying the necessary heat of vaporization to the propane supply for the second-stage roll control system have been investigated. The two most attractive methods were (1) the use of a battery-operated heater, and (2) the addition of extra propane to store the energy as sensible heat. A compromise solution was reached in which the propane is maintained at 110°F by a ground-powered electric heater until launch. From launch until the roll system is utilized during second-stage powered flight, the heat is carried in the propane. Loss of heat during first-stage operation is minimized by the use of insulation on the propane tank.

Maximum anticipated roll moments for the launching vehicle have been computed. These include effects of aerodynamic forces, acceleration of the turbopump, and misalignment of the first-stage thrust vector. Excepting conditions at burnout, the torque is at a maximum of 130 pound-feet at an altitude of 36,000 feet. At first-stage burnout, a maximum torque of 85 pound-feet occurs because of turbine deceleration. These results establish the requirements for the first-stage roll control system.

The analysis of third-stage spin stabilization was extended to obtain data on flight-path angles and transverse motion. Effects of thrust vector misalignment, principal axis misalignment, and initial angular velocity were determined at several spin rates. The results indicate that a minimum spin rate of 150 rpm is desirable; detrimental effects occur at smaller spin rates.

Staging

Preliminary specimen tests have been conducted on sections simulating the first- and second-stage separation area. The results of the first tests indicate that a fairly regular skin cut can be accomplished by using primacord. A minimum number of small fragments are evident when 0.020-inch aluminum alloy retainer is used to house the primacord. Specimen blast doors were separated as shown in Figs. 6 and 7. This skin cut is to occur in the immediate type separation only,* at second-stage launch.

A number of sets of trajectories have been calculated on the NAREC in order to determine in detail the effects of delayed second-stage ignition* on the over-all vehicle performance and trajectory characteristics.

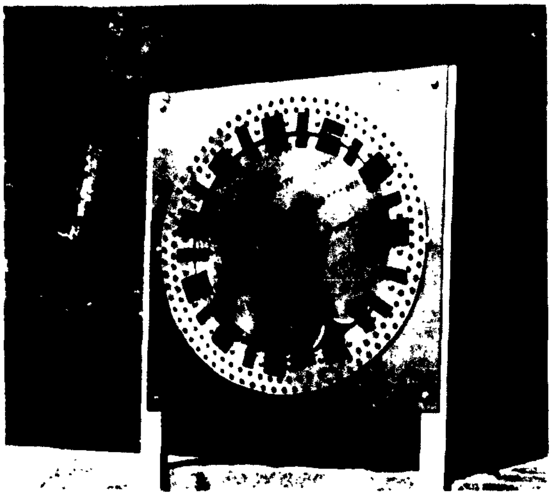

Fig. 6 - Primacord and detonator in place on blast door specimen (Martin photo)

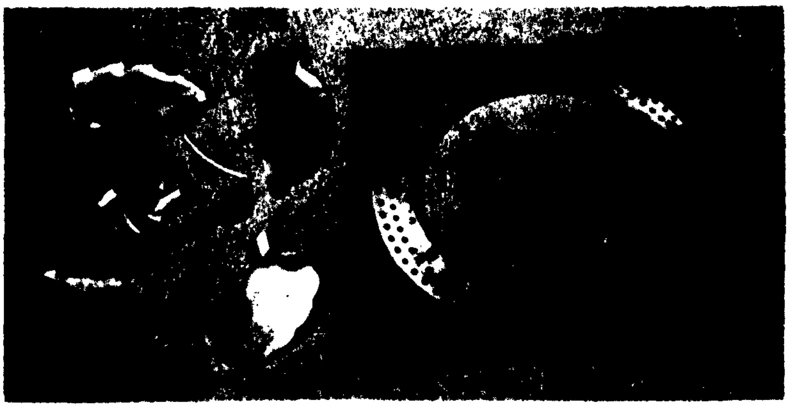

Fig. 7 - Blast door opening and fragments resulting from primacord detonation (Martin photo)

*Project Vanguard Report No. 4, p. 10.

Electrical Systems

Studies of various battery combinations and a load analysis of vehicle requirements are in process. The results of a laboratory test of a Silvercel battery (14HR-30) under a simulated Vanguard load indicate that it will be necessary to start the second-stage hydraulic pump from the second-stage battery prior to placing this battery on the rocket bus.

The present indication is that a rotary inverter will be used to power the ac systems. A static inverter has been ordered for evaluation.

Hydraulic Systems

The hydraulic accumulators for both stages are to be provided by the Bendix Aviation Corporation. The hydraulic reservoirs are to be manufactured by the prime contractor; design is completed, but not yet released to manufacturing.

Ground Test Equipment

Design of the factory, hangar, and static firing test equipments was subcontracted to Polarad Electronics Corporation. Minneapolis-Honeywell will supply the gyro calibration and checkout panels. This equipment includes (a) power supply, (b) controls monitoring, (c) signal generator and scope, (d) remote junction, (e) controls test and (f) gyro monitoring. In addition a unit tester will be used to simulate vehicle circuits and will serve to check out the test equipment. The unit tester will simulate (a) vehicle power sources (electrical and hydraulic), (b) follower pots and cathode followers of servos, (c) servo demodulators and actuating relays to simulate the discontinuous jet controllers, and (d) check out meters for determining operation of test equipment used to align and calibrate the vehicle system.

Minneapolis-Honeywell has received a German-manufactured dividing head (for accurate calibration of the gyro) and are modifying the servo drives. They have established panel layout and are breadboarding test circuits; they expect to have a prototype available by end of July 1956. Design for first-stage static and flight firing circuits has been completed and second-stage circuit design is in process.

Manufacture

During this period, the following items were released for manufacture:

1. Mockups and operating models:
    a. First-stage powerplant dynamic model
    b. Second-stage powerplant dynamic model
    c. Spin mechanism for third-stage spin and separation test
    d. Pitch-yaw dynamic model for second-stage cutoff stabilization

2. TV-1 components:

   a. Adapter section for mounting third stage

   b. Spin and separation mechanism for third-stage separation

   c. Third-stage nose cone (for use on TV's 1-3)

   d. Range safety wiring installations

3. TV-2 components:

   a. First-stage tail structure

Vehicle Instrumentation and Tracking

Telemetering

ppm/am Systems

Production of the prototype ppm/am first- and second-stage telemetering transmitters has been initiated and a unit is expected to be available in August 1956. Four ppm/am calibrators are due to be delivered by 11 June.

The construction of a ppm/am ground station at NRL (intended for GLM plant check out on TV-0) is well on schedule. Meanwhile, delivery of one ppm/am ground station by the contractor (an IGY station which is being loaned to Vanguard for early trailer installation) appears likely, with the possible exception of camera magazines, by 23 May. Production of the remaining stations has been initiated. Major items of test equipment for the ppm/am systems have been delivered.

fm/fm Systems

The Bureau of Aeronautics has unofficially indicated that Vanguard's request for the loan of an AN/UKR-5 fm/fm and pwm/fm ground station will be granted.

pwm/fm Systems

The delivery of components for the pwm/fm second-stage and third-stage telemetering transmitters from ASCOP has begun on schedule. Tests of the packaged unit for TV-0 are now in progress.

The recording pwm/fm ground station is now in operation but is not yet fully checked out. BuAer has authorized the transfer of pwm/fm ground station components at the GLM plant from Project BULLPUP to Project Vanguard; this will enable GLM to check out the pwm/fm system installations.

Blockhouse Installation

Preliminary planning and purchasing of blockhouse equipment has begun, and the delivery of power supply units for remote turn-on of rocket equipment is nearly complete. The planning of the blockhouse layout and wiring requirements will begin shortly.

Range Instrumentation

A proposal has been received from RCA for modifying the AN/FPS/16(XN-1) radar. The complete modification would be as follows:

1. A rack-mounted digital data system similar to that of the XN-2 would be provided.

2. The range would be extended to 250 nautical miles.

3. The frequency would be changed to make the radar compatible with the C-band (mod 3) radar chain of AFMTC.

4. Training, installation, and checkout assistance, and field maintenance would be provided.

Two alternate proposals were included which would cost less but would omit, in one case, ambiguity resolution, and in the other case both ambiguity resolution and the digital data system. The best delivery date (at Moorestown, N. J.) for these alternate modifications would be 31 January 1957 as compared to 30 April 1957 for the complete modification.

Firm delivery dates are being requested for the eight DOVAP transponders (for range safety installations) being manufactured by BRL prior to commercial production. The tightness of the schedule may necessitate alternate procurement.

Both XN-1 radar data and real-time DOVAP information are under consideration as backups for the vehicle-borne integrating accelerometer means of predicting the time of firing of the third stage. At present the XN-1 appears to be the better system for this purpose.

Range Safety

Procurement of eleven S- and C-band radar beacons has been initiated. These beacons are now under development by Melpar (model 1245) for SCEL; they will be manufactured to the basic specifications of the AN/DPN( ) with modifications.

Procurement of AN/ARW-59 receivers for use as range safety command receivers in early test vehicles has been initiated by requisition to BuAer. Environmental tests have disclosed that the AN/ARW-59 is the best qualified receiver for third-stage use if required by AFMTC in TV's 1 and 2 and the TV-2 backup vehicle. A two-channel decoder developed by NRL for use with this receiver will undergo environmental tests before the design is finalized.

THE SATELLITE

Configuration and Design

In the last progress report* it was stated that the minimum satellite would be an unpressurized sphere, 6 inches in diameter, with four spring-actuated rod-type antennas mounted on the equator. As a backup for this unit, a 20-inch unpressurized sphere with telescoping powder-actuated antennas is being designed; its weight will be of the order of 8 pounds. The 20-inch diameter is necessary if the telescoping antennas are to be fully enclosed, and it will also accommodate the spring-actuated rod antennas if this should be desired. Moreover, the physical structure of this satellite is the same as that of the 20-inch 21.5-pound satellite,* so that only two basic configurations (i.e., the 20-inch and 6-inch spheres) need be designed.

The tubular internal structure of the 20-inch sphere is being designed to flex under thermal loads; this structure will support the antennas, the skin, and any skin-mounted equipment. Although the 20-inch design is versatile enough to permit many types of experiments, it is anticipated that skin-mounted equipment will be held at a minimum; however, in the 21.5-pound satellite, temperature gages, erosion gages, antennas, and the ion chamber and aspect indicator for the experiment on solar Lyman-alpha radiation would be skin-mounted. The cylindrical column which houses the separation mechanism will support the total satellite weight under all anticipated conditions.

A mockup of the internal structure for the 20-inch sphere is now being fabricated in aluminum for the purpose of checking structural analysis and fabrication techniques to be employed in the final article. An aluminum model of the 6-inch sphere (riveted and screwed construction) has been fabricated for the purpose of making antenna-pattern measurements on a mockup of the launching vehicle third stage, and vibration tests on the antennas. Determination of the internal structure of the 6-inch sphere will await the results of temperature studies now in progress.

A meeting with contractor is scheduled for 14 May 1956 to discuss the fabrication of several satellite configurations with either HK31XA-H24 (magnesium-thorium) alloy or FS1-H24 alloy as a basic material.

Specifications for a satellite separation mechanism have been drawn up, and a meeting with contractors to discuss these requirements is scheduled for 15 May 1956. Information proposals from the contractors are to be received by 1 June and a contract will be let after evaluation of these proposals.

Environmental Studies

Studies have continued on the feasibility of regulating the temperatures of the satellite instrument compartments within a narrow range despite large variations in skin temperature. A thermal diode has been designed which utilizes the movements of a metal bellows filled with a condensable vapor to alter the thermal conductivity of support paths in accordance with the need of the instrument compartment to gain or lose heat.† The

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*P.V.R. No. 4, p. 14

†P.V.R. No. 4, p. 15

calculated front-to-back thermal conductivity ratio is 200 to 1; this value will be checked experimentally. The unit would weigh approximately 0.1 pound and be small enough to fit into the minimum satellite. At least two units would be used, one reverse-mounted with respect to the other.

Experimental studies have begun on heat flow in complicated geometries which are crude analogs of the proposed satellite systems. The minimum satellite configuration has been investigated in order to evaluate radiation transfer from shell to package, and attempts are being made to estimate the insulator heat transfer. It appears that the proposed configuration will allow sufficient thermal isolation of the internal package to permit more than 15 orbits under adverse circumstances, e.g., failure of the thermal diodes.

The low-temperature emissivity studies of tough, visibly transparent coatings on polished metal have been completed.

Vibration data will be obtained during developmental firings of the vehicle propulsion systems, including both third-stage units, and used in determining the vibration environment to which both the satellite and the vehicle instruments will be subject during powered flight. Bids are due on 18 May for the provision of a random vibration shaker to simulate this environment for satellite test purposes.

An investigation has been undertaken to determine the degree of damage to thin targets produced by small high-velocity fragments. Fragments with velocities of 15,000 - 20,000 feet per second will be produced in a spray from the impact of a projectile on a thick target in a vacuum; these fragments will strike thin targets that simulate the satellite skin, and the resulting data on penetration and crater damage should provide a more accurate basis for estimating the damage to the satellite that may be anticipated from the impact of meteoric dust.

Instrumentation

The Minitrack system is discussed in a separate section of this report.

A comparative study has been completed on the three proposed telemetry coding systems and one system was selected as being a best compromise between weight, power requirements, flexibility and reliability. The system selected utilizes only two magnetic cores, one for all high-frequency channels and the second for all low-frequency channels. Switching transistors are used to select inputs for the two cores. Work continues on circuit details, and a study is underway for optimizing the weight and power requirements of this system.

Considerable progress has been made in the study of nondestructive readout of flux levels in memory cores used for storage of peak and integrated orbital signals. Present techniques seem to offer great promise of continuous readout with simultaneous acceptance of input information. Progress in this phase, coupled with encouraging results from the study of weight and power requirements for the coding system have indicated a possibility of continuous transmission of data without interrogation from the ground. Peak memory devices would of course require periodic reset, but it seems practical to do this by using two memory units, one transmitting information from the preceding orbit and the second storing information on the current orbit. By alternating functions of these two cores on successive orbits, data would be available to arbitrarily located recording stations on the flight path. Switching between cores could be accomplished by such means as monitoring skin temperature or use of solar cell arrays to detect transit from daylight to darkness or vice versa. Additional equipment and circuitry might well require any weight saved in airborne interrogation equipment but might add reliability and eliminate interference with Minitrack data.

Experimental ion chambers for the proposed satellite measurements of solar Lyman-alpha radiation have been fabricated, and 9 of the original 22 were found acceptable, calibrated, and placed on life test. The remainder required reworking to eliminate defects attributed to leaks in the lithium fluoride windows and to cloudy windows. Of these, nine have been redelivered in satisfactory condition and the remaining 4 will be delivered shortly. Electrometer circuitry has been developed for the Lyman-alpha measurements, with particular emphasis on the prevention of drift. Performance tests over a two-week period indicate that this equipment can meet all of the satellite requirements.

General design plans are now complete for using a differential pressure gage to measure meteor penetration of two pressurized chambers in the satellite, and a contract for four differential and four absolute pressure gages was placed with the Giannini Company. A nonminiaturized version of the meteoritic collision detection equipment has been flown in an Aerobee-Hi rocket, but no information on the success of the experiment has reached NRL.

THE MINITRACK SYSTEM

System Calibration

Calibration techniques for the Minitrack system have been investigated during the last reporting period. Visits were made to the Ballistic Research Laboratory of Aberdeen Proving Ground, the Flight Development Laboratory of the White Sands Proving Ground, the Physical Science Laboratory of the New Mexico College of Agriculture and Mechanic Arts, and the Naval Ordnance Test Station, Inyokern. As a result of these investigations the use of fixed ground ballistic cameras against a star-background reference at night with a high-flying aeroplane carrying a pulsed light source commanded from the ground station timing system, and a Minitrack test transmitter is indicated. The New Mexico College appears to be set up to read the quantities of ballistic camera plates that will be required to meet the schedule of calibration runs anticipated. They can also compute the angular position of each fix in terms of the Minitrack angle system.

Aerobee-Hi Tests

To check the Minitrack satellite tracking system at high altitudes, a crystal-controlled transmitter operating at 108 Mc was carried in NRL Aerobee-Hi number 42 fired on 8 May. A similar attempt in Aerobee-Hi 39, fired on 2 May, was incomplete because of failure of the rocket to ignite after the boost phase.

The airborne antenna system consisted of four equally-spaced radiators projecting radially from the rocket at the base of the nose section in a circularly polarized turnstile arrangement. These radiators were made up of telescoping rods furnished by the Diamond Ordnance Fuze Laboratory. They were projected from inside the rocket by powder squibs at the time the transmitter was energized (about 60 seconds). Ground reception of the signal was good. The rocket was tracked to blowoff except for a one-minute loss on one ground recorder due to the blowing out of the fuse in the drive motor circuit.

The ground installation consisted of eight antennas providing both fine and coarse antenna systems in a Mark II Minitrack arrangement. For the fine system, north-south and east-west baselines were composed of six-element dipole arrays connected to hybrid junctions by RG-8/U transmission lines. Hybrid junction outputs were amplified by special low-noise preamplifiers and by i-f amplifiers with common local oscillators and automatic gain controls so that product detectors could be utilized. The fine system outputs were recorded on an eight-channel Sanborn recorder.

Antennas for the coarse baselines consisted of single dipoles connected to hybrid junctions by RG-8/U transmission lines. For this system, only one output from each baseline hybrid junction was amplified, with low-noise preamplifiers feeding Clark receivers. The outputs from both coarse baselines were recorded on a two-channel Sanborn.

While the peak altitude of the rocket was low (approximately 117 miles), it is known that the noise introduced on the record by atmospherics and the ionosphere is very small. With the low antenna gain, the system bandwidth, and the transmission line losses taken into account, the transmitted power was approximately equivalent to that calculated for a satellite transmitter of 30 milliwatts output operating at 200 miles altitude against a standard Minitrack antenna system. On this basis the 10-20 milliwatt power for the Minitrack transmitter appears adequate. The signal level on the coarse antenna system was likewise usable, even though only a single dipole antenna was used.

Although insufficient data on ionospheric effects were obtained on this flight, the system operation experience and the verification of the system parameters were extremely valuable.

Tracking Stations

Locations

Site selections have now been completed at all locations contemplated for Minitrack installations. The Prime Minitrack stations will be located at:

Blossom Point, Maryland (approximately 38.4° N. Lat.)
Fort Stewart, Georgia (approximately 32° N. Lat.)
Batista Field, Havana, Cuba (approximately 22.9° N. Lat.)
Coolidge Field, Antigua Island (approximately 17.1° N. Lat.)
Rio Hata, Panama (approximately 8.5° N. Lat.)
Mt. Cotopaxi, Quito, Ecuador (approximately 0.6° S. Lat.)
Ancon, Lima, Peru (approximately 11.8° S. Lat.)
Antofagasta, Chile (approximately 23.5° S. Lat.)
Peldehue Military Reservation, Santiago, Chile
(approximately 33.5° S. Lat.)

Optical tracking stations may be established by the Smithsonian Institution at the Quito and Antofagasta Minitrack sites.

Blossom Point Test Station

Land clearing at the Blossom Point Test Station is progressing rapidly. Bids for the erection of the administration building at this site have been released, and the awarding of a contract is scheduled for the week of 21 May. Arrangements for the concrete work associated with antenna fields, power lines, telephone lines and road preparation are proceeding. The estimated operational readiness date for this site is about 15 June. All contracts for this site are being made by the Diamond Ordnance Fuze Laboratory of the Army Ordnance Department.

Ground Antenna Arrays

Two contractors are developing ground antenna arrays for use with the Minitrack system, which will be evaluated at the Blossom Point Test Station during June and July 1956. Selection of the antenna to be procured in quantity will be made at this time. However, the two designs do not utilize the same number and spacing of support piers, so that a final determination of the pier requirements at the overseas sites, particularly in the AFMTC range, could not be available in time for inclusion in the final site criteria for submission to the contracting agencies on this time schedule. For this reason a universal antenna mounting has been designed that will permit mounting of either antenna on a set of 14 piers, using jack-posts for vertical adjustment of the antennas. Drawings of this mount have been provided the contracting agencies for the Blossom Point, Mayaguana, Grand Turk and Antigua sites.

The two antenna contractors, the D. S. Kennedy Company of Cohasset, Massachusetts and the Technical Appliance Corporation of Sherburne, New York, appeared to be on schedule as of the first of May. Deliveries from both of these companies are expected on 1 June 1956.

Antenna Layout

The original antenna layout proposed for the Prime Minitrack stations* utilized seven antennas on a cross pattern, with the ambiguity-resolving antennas near the fine-measurement antenna pairs at the extremities of the cross. The east-west ambiguity-resolving antenna was immediately adjacent to one antenna of the east-west fine antenna pair, and there was some concern as to the effect on the pattern of the fine antenna pair. This potential difficulty, plus the necessity for longer transmission lines, led to consideration of locating the ambiguity-resolving antenna near the center of the baseline cross. Although this would place the antenna near the operating location of the ballistic camera, it would reduce the requirement for knowing the range of the target source during calibration runs to eliminate parallax effects. As a result, a new antenna configuration has been selected, utilizing eight antennas in a near-balanced cross arrangement (Fig. 8). In this arrangement, the fine-measurement antenna pairs are separate from all other antenna pairs; an increase in system accuracy should result. In addition, they could be operated as pairs of antennas in a Mark II configuration as a possible backup system.

Communication

In Project Vanguard Report No. 1, dated January 13, 1956, the orbital data net and scientific and administrative net requirements were described for communication between

*P.V.R. No. 1, p. 37

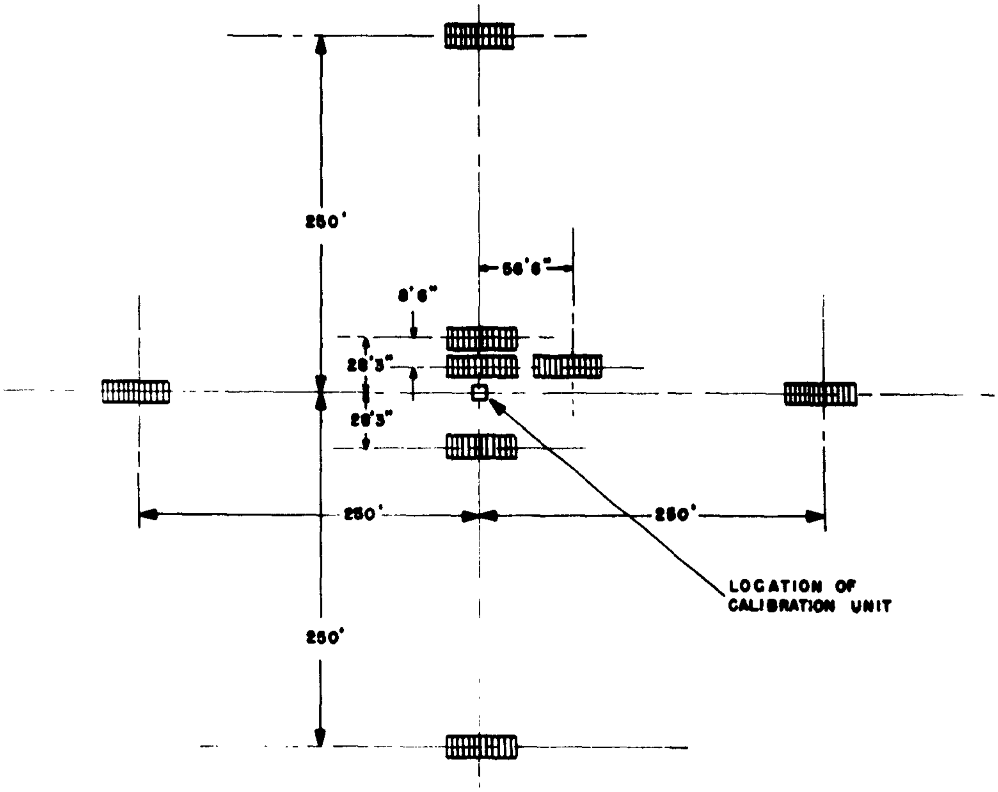

Fig. 8 - New 8-antenna-array antenna layout for Minitrack; each array is approximately 7-1/2 feet wide by 55 feet long, consisting typically of 12 folded dipoles against a ground screen

the Prime Minitrack sites and a central collecting and computing agency. The requirements have been clarified and revised as follows:

There shall be no requirement for direct communication between the Prime Minitrack stations, but only from these stations to a central communication station, which shall be linked by teletype with the designated technical control point for the Minitrack system at the Naval Research Laboratory and with the Central Computing Facility. Messages between the Prime Minitrack stations shall be relayed via the technical control point.

The orbital data net, also known as the primary data net, shall be used for the transmission of the primary tracking data from the Prime Minitrack stations to the Central Computing Facility. Transmission shall be by teletype, and a single data message shall contain six data groups, three of nine digits and three of six digits, plus address and symbol groups. Transmission and confirmation is required within 20 minutes of a tracking event. An average of about two data messages per day from each Prime Minitrack station can be expected. This net shall also be used for alerting the individual Prime Minitrack stations by the central computing facility to the expected time, altitude and north-south angular position of the next satellite passage over that station. An alerting message shall consist of three data groups, one of nine digits, one of six digits, and one of four digits, plus address and symbol groups. Alerting messages require transmission and confirmation within 30 minutes of origination. The equipment used for this net shall aim at a 95 percent probability of fulfilling these requirements.

The scientific and administrative net shall be used for routine exchange of technical and administrative data between the Prime Minitrack stations and the technical control point at the Naval Research Laboratory. Voice, cw, and teletype transmission shall be permissible on this net. No restrictive transmission times exist for this net.

DATA PROCESSING

Orbital Data

In reply to bid requests on the orbital computer facilities and services issued by the Office of Naval Research on 9 March 1956, proposals have been received by NRL from three possible contractors. It was determined that the International Business Machine proposal was the only one that met all of the requirements set forward in the bid request; it also presented the lowest cost to the government. A letter from NRL recommending that negotiations be undertaken with the International Business Machine Company for the equipment and services was sent to the Office of Naval Research Contract Branch on 8 May 1956. A formal negotiating conference with representatives of NRL, the ONR Contract Branch, and IBM in attendance has been set for 17 May at NRL.

Second-Stage Apogee Prediction

An error study has been conducted on the characteristics of the data to be used in predicting the second-stage apogee and the formulation of the equations involved is being developed. Methods of instrumenting the task are also being investigated.

* * *

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