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PROJECT VANGUARD REPORT NO. 1

PLANS, PROCEDURES, AND PROGRESS (U)

[UNCLASSIFIED TITLE]

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Project Vanguard Staff

January 13, 1956

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ABSTRACT
[Confidential]

The Naval Research Laboratory has been assigned the prosecution of the project which has as its aim the launching of a scientific satellite during the International Geophysical Year. The Glenn L. Martin Company has taken a contract to provide the launching vehicles. The satellite, to be designed and built by the Naval Research Laboratory, will weigh 21.5 pounds and be 30 inches in diameter. Launching will be from the Air Force Missile Test Center, Florida. The satellite will be tracked by an electronic system from stations along a North-South line in the western hemisphere.

The plans and the progress that have been made are discussed in this report.

PROBLEM STATUS

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

AUTHORIZATION

NRL Problem No. 41A02-18

Manuscript submitted January 10, 1956

PROJECT VANGUARD REPORT NO. 1
PLANS, PROCEDURES, AND PROGRESS
[UNCLASSIFIED TITLE]

INTRODUCTION [Confidential]

Background

On September 9, 1955, the Secretary of Defense announced* the responsibilities of the Department of Defense to launch a scientific satellite during the period of the International Geophysical Year. The Navy Department was assigned management of the technical program with policy guidance from the Assistant Secretary of Defense (R&D).

The Secretary of the Navy on September 27, 1955 directed† the Chief of Naval Research to execute that portion of the program assigned to the Navy.

The Chief of Naval Research on October 6, 1955 requested‡ that the Director of the Naval Research Laboratory proceed with the prosecution of the project, hereafter known as Project Vanguard.

In the memorandum of September 9, the Secretary of Defense said: "The Secretary of the Navy is also requested to advise the ASD(R&D) as soon as practicable of the detailed plan for undertaking the technical program and for coordination of that program with the other military departments." This report, the first in a series, is intended to meet that requirement.

Objectives of Project

The objectives of Project Vanguard are:

(a) To put an object into an orbit around the earth

(b) To prove that the object is in an orbit

(c) To conduct at least one scientific experiment using the object.

Coordination With Other Military Departments

The initial concept of Project Vanguard was a tri-Service effort to achieve a successful orbiting satellite during the International Geophysical Year, each Service providing that phase which it was most capable of providing. The Research and Development Policy Council selected the NRL satellite proposal and directed that that proposal be implemented under the technical direction of the Navy. The Air Force Missile Test Center, Florida, was a logical choice for providing launching facilities. The Army Engineers and the Army Signal Corps were the logical choices to assume responsibility for the tracking stations.

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*See Appendix A
†See Appendix B
‡See Appendix C

Even though the Army and Air Force have not yet officially accepted these assignments, it is felt reasonably certain that these assignments will be approved. The one serious obstacle in obtaining Service approval is the budgetary considerations.

Even though the Services have not shown a lack of interest in Project Vanguard, decisions which may require reprogramming of funds are always very difficult. Unless positive decisions are made soon to cover the cost of the launching facilities and the tracking facilities, serious program delays will result.

Budget

The estimate of fiscal obligations for Project Vanguard as submitted to ASD(R&D) on 8 October 1955, in millions of dollars, is:

	FY' 56	FY' 57	FY' 58	FY' 59	TOTAL
On Station Costs	1.1	1.3	1.5	0.6	4.5
Vehicles	11.0	-	-	-	11.0
Radio Tracking	2.0	0.1	0.1	-	2.2
Telemetering	0.6	0.1	-	-	0.7
Instrumentation (Scientific)	0.3	0.3	-	-	0.6
Data Reduction	0.5	0.7	0.2	-	1.4
Field Services	2.3	0.6	0.2	-	3.1
	17.8	3.1	2.0	0.6	23.5

Not included in this estimate are costs for:

(a) Proving ground services and range instrumentation

(b) Construction, maintenance, and supply of tracking stations

(c) Military personnel assistance

(d) Data communication center

(e) Additional IGY participation

(f) Contingencies

Funds were received on 21 December 1955 from the Department of Defense to cover the fiscal year 1956 obligations; prior to this time, funds were advanced from NRL Naval Industrial Fund.

An agreement between the ASD(R&D) and the National Academy of Sciences provides that the National Science Foundation will seek $4.2 million from Congress on behalf of the International Geophysical Year as their share of the project budget as given above.

SELECTION OF LAUNCHING SITE AND FIRING ANGLE [Confidential]

Both the selection of a suitable launching site and the choice of inclination of the orbit are dependent on the basic requirements to be met by the satellite. Since the National Academy of Science has expressed the desire to have the satellite visible to existing astronomical observatories in the United States and Europe, the USNC Panel on Satellites has requested that the inclination of the orbit be 40 ±5 degrees. Project Vanguard is attempting to meet this request.

At such inclination angles, the launching point can be at any latitude between 45^0 North and 45^0 South. This region covers existing launching points now being used for ballistic missiles, which include rocket handling, launching, and tracking facilities for this use. Such a region would include the Air Force Missile Test Center in Florida, the White Sands Proving Ground in New Mexico, and the Woomera test range in Australia, but because of the necessity for firing in an easterly direction and the requirement for noninhabited areas in the region of first and second stage impact, only the AFMTC is being considered as a launching point.

The AFMTC includes an island string in a general south-east direction away from the launching area which is extensively used for range instrumentation sites. Utilization of these islands for Vanguard would permit radar, telemetering, and doppler instrumentation on Grand Bahama and other islands, for measurement of the first and second stage vehicle operation and Minitrack installation on Barbuda Island for determination of the initial orbital parameters after third stage burn-out. To use this island chain, a launching angle would be used that would bring the trajectory within range of these islands. Of these, the most critical is the island of Barbuda, which must be within an absolute maximum of ±4 degrees of latitude of the point where the orbit intersects its meridian in order to permit coverage by the Minitrack antennas at the initial orbital altitude. A 5-degree range of error in the initial firing angle, as allowed by the vehicle specifications, corresponds very nearly to 4 degrees of latitude at the meridian of Barbuda.

The initial firing angle required to intersect the island of Barbuda is 119 degrees True, based on the earth's rotational velocity and the burning times of the first and second stages now being considered. An initial firing angle error of ±2.5 degrees centered at 119 degrees True would cover the range from 116.5 to 121.5 degrees True, corresponding to a latitude range of ±2 degrees centered on Barbuda Island. This will require a firing angle range from 116.5 to 121.5 degrees True, centered at 119 degrees True. This would result in an orbital inclination varying from about 38 degrees to about 41.3 degrees, centered at 39.6 degrees, as shown in Fig. 1.

LOGISTICS SUPPORT [Confidential]

The test range facilities required by the Vanguard program can be broken down into administrative space, assembly hangar space, range instrumentation, and launching facilities. An examination of these requirements, coupled with the direction of launch required to attain a 30^0 to 40^0 inclined orbit, narrowed the choice of test range facilities to Air Force Missile Test Center, Florida. The White Sands Proving Ground was seriously considered since the existing Viking launching facilities, assembly hangar, and administrative space is entirely adequate for the Vanguard program. Unfortunately, the range safety requirements associated with an easterly launching direction from WSPG imposes intolerable risks. Another alternative considered was the use of Roosevelt Roads where a new launching facility might be constructed. Time, cost, and logistic delay, inherent in this location, resulted in discarding this proposal. Finally, serious consideration was given to

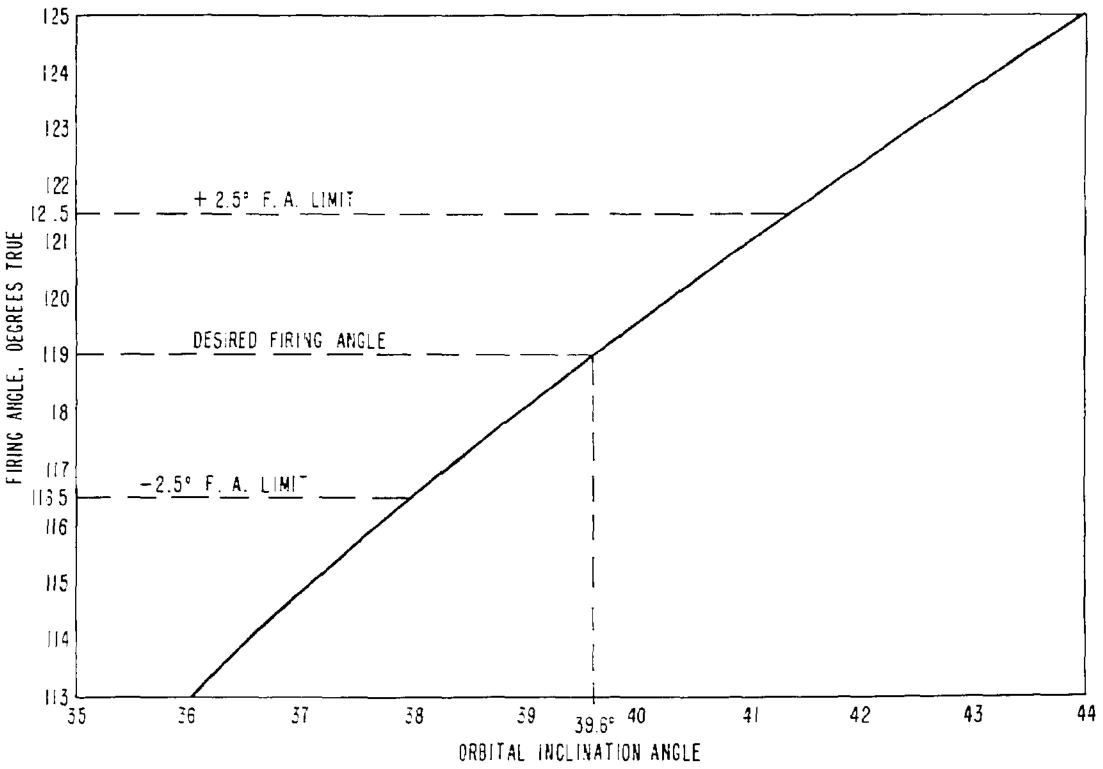


Fig. 1 - Inclination of the orbit as a function of the firing angle

locating the launching facilities on the Grand Bahama Islands which would make possible the use of the AFMTC down-range instrumentation. This, too, was discarded because of time considerations.

The uniqueness of the launching conditions imposed by the NAS specified orbit, which, when added to the desirability of taking advantage of the earth's tangential velocity in attaining orbital velocity for the satellite, limited the test range facility choice for satellite launching to AFMTC. Direct discussions by Vanguard staff and AFMTC authorities to make detailed arrangements for the use of the test range facilities are in process. The "Preliminary Test Plans for Vanguard Launching Operations," dated November 14, 1955, form the basis for the discussions to date. The following breakdown provides the present status of these discussions:

Administrative Space

According to AFMTC authorities, there is no question that Vanguard requirements can be met.

Assembly Hangar

The assembly hangar requirements, in terms of time, can be met initially only by use of an existing facility. The first launch, Viking 13, scheduled for October 1956, precludes the construction of a new permanent hangar. The possibility of constructing a new temporary hangar was discussed. Because of roads and utilities, the cost of a temporary facility approximated the cost of a new permanent facility. Since a temporary facility would have to be removed upon completion of the Vanguard project, AFMTC authorities suggested the advisability of initial joint use of an existing hangar. In terms of Vanguard requirements, this is adequate, provided this assignment is formalized as soon as possible. A subsequent move to a new permanent hangar, which may be made available via other Navy programs, may entail a short delay to the program but should be entirely acceptable.

Range Instrumentation

The adequacy and availability of the necessary range instrumentation is discussed in other portions of this report.

Launching Facilities

Current emphasis on vertical launching in other Defense programs creates a serious competitive situation for the Vanguard program. Vanguard must compete for the use of an adequate blockhouse, a gantry crane, a static firing test stand, and a launching pad. The situation on each of these items is discussed below.

Blockhouse – The blockhouse requirement for Vanguard can be generalized by stating that the equivalent of approximately one-half of the existing Redstone blockhouse will meet the Vanguard requirement. A visit to AFMTC made it quite obvious that there is no available blockhouse which could be assigned to Vanguard without interfering with other existing program plans. An examination was therefore made of all blockhouses, regardless of present occupancy.

The Bomarc blockhouse, now occupied jointly by both Boeing and Lockheed, is adequate to meet the Vanguard requirements if completely assigned to this project. (The blockhouse instrumentation for Vanguard has an equipment volume of approximately 300 cubic feet, using standard equipment racks.) The Northrop blockhouse was not examined from the inside (locked at time of survey). The outside dimensions indicated that it is somewhat larger than the Bomarc blockhouse. However, it does not appear to be large enough to make possible joint use with another full-time program. The North American blockhouse appears to be especially designed to meet their own particular program requirements. There appears to be no space available in the blockhouse for assignment to a joint tenant. The installation of Vanguard blockhouse instrumentation would require removal of a considerable amount of North American instrumentation. The resulting delay to their program must be considered.

Finally, the Redstone blockhouse was examined. Since this facility was designed for a similar type vertical launching problem, it appears to be most easily adaptable to meet Vanguard requirements. The blockhouse is divided into equal instrumentation areas, each of sufficient size to meet the Vanguard requirements. The present Redstone launchings are controlled from the left half of the blockhouse. The Chrysler Corporation is at the present time starting to wire the right half for use to control the launching of their production-type missiles.

An examination was also made of the temporary blockhouse which was used by the Matador program. The high degree of instrumentation reliability which must be available in launching a limited number of vehicles against a fixed time schedule is completely incompatible with the uncertainties introduced by instrumentation exposed to the Fall Florida weather involving hurricanes and heavy rains, even if the instruments are housed in vans.

This survey of existing blockhouse facilities made it apparent that the timely assignment of blockhouse space to meet Vanguard requirements will interfere with one or more existing programs. Disregarding the priorities of present tenants, the adequacy for Vanguard of the existing blockhouses can be arranged in the following order:

(1) Redstone (one-half) – excellent

(2) Boeing/Lockheed (complete blockhouse) – adequate

(3) North American (three-quarters) – acceptable

(4) Northrup (one-half to three-quarters) – acceptable

(5) Temporary blockhouse – unacceptable

Gantry Crane – The check-out and servicing of the Viking and Vanguard prior to launching requires the use of a movable gantry crane or its equivalent. The Redstone gantry at AFMTC and the Viking gantry at WSPG were considered in meeting this requirement. The peculiar design and orientation of the Redstone gantry prohibits its joint use by two agencies on a time-sharing basis without seriously disrupting one, if not both programs. It is estimated that disassembling the Viking gantry at WSPG, transporting it to AFMTC and reassembling it on a new launching pad is feasible in time for the October 1956 launching. However, this does not appear reasonable considering that this same gantry should be available for use in the new launching complex discussed in the summary. The only apparent alternative to meet the gantry crane requirement for the October and December 1956 launchings is to utilize temporary scaffold staging around the vehicle. This temporary scaffold, along with a mobile boom-type crane, is acceptable for Viking 13 and 14, but cannot be accepted for the Vanguard vehicle launchings starting in February 1957.

Static Firing Test Stand – The limited number of vehicles available to this program makes it imperative that each vehicle be given an adequate static test firing prior to the actual launching. Unfortunately, there is no static test firing facility available at AFMTC for use by this program. It is highly desirable that the actual launch be conducted with the same hook-up as was used during the static firing. Any change introduces the possibility of mistakes and delays. Therefore, the most desirable setup is to launch the vehicle from the same stand with the same connections used during static firing. A less desirable situation involves static firing on a special stand at AFMTC, then disconnecting the vehicle, moving it to the launching stand, reconnecting the instrumentation and services, and then finally launching the vehicle. An even less desirable situation can be visualized involving static firing on the Viking stand at WSPG and then transporting the vehicle to AFMTC and launching it under an entirely different instrumentation environment. The unknown risks involved in this last situation can be very serious and should be avoided, if at all possible.

Finally, serious discussions have been held between the contractor and NRL exploring the possibilities of foregoing the static test firings for Viking 13 and 14. The conclusion arrived at emphatically supported the need for static firing of not only all the Vanguard vehicles, but also Viking 13 and 14.

The Vanguard contractor is at the present time making studies which will enable him to recommend a design for the construction of a combined static test and launching stand or a separate static test facility as soon as the blockhouse assignment decision is made.

Launching Pad – The launching pad requirements for Vanguard are relatively simple, provided an adequate instrumentation trench is available. Also, the pad should be no more than 250 to 275 feet away from the blockhouse to avoid excessive voltage drops in the electrical circuits between the vehicle and the blockhouse. The addition of a static firing stand will introduce complications which are under study. One of these complications is the availability of an adequate supply of water to cool the rocket flame to prevent damage to the rocket and the surrounding installations. If a separate static firing stand is provided, all the existing launching pads, with the exception of the specially designed North American pad, are usable for this program.

In conclusion, the launching facility situation can be summarized by the following two plans:

PLAN I

1. Use pad No. 5 (Redstone) for Viking 13 and 14.

2. Use temporary scaffold gantry at pad No. 5.

3. Build a simple static facility near pad No. 5. (The present study may indicate the desirability of constructing a new pad combined with the static facility.)

4. Use right half of Redstone blockhouse.

5. Start construction of a completely new launching facility for Vanguard test vehicles with beneficial occupancy by December 1956. (A minimum of two months are required for instrumentation installation.)

6. Move Viking gantry crane from WSPG to new facility.

7. Combine static test facility with launching stand in new facility.

PLAN II

Same as Plan I except perform Viking 13 and 14 static firing tests at WSPG.

Any decision to adopt Plan II in lieu of Plan I must carefully weigh the risks involved. The technical opinions of both NRL and the Glenn L. Martin Company strongly recommend against its adoption since only two vehicles - Viking 13 and 14 - are available to test-fly some of the basic Vanguard components. Flight failure of either of these Vikings will require substitution of a new Vanguard vehicle to make the programmed tests.

Tracking Stations

In addition to launching a satellite into a successful orbit, it is also necessary to prove that the satellite is in fact orbiting. This requires tracking the satellite, computing its orbit, and then publishing a predicted path over the various inhabited portions of the earth's surface. Since the plane of the orbit will be inclined approximately 40 degrees to the equatorial plane, a tracking system has been devised (Minitrack, discussed earlier in this report) which, when properly located, should provide the necessary information.

It is proposed to locate nine Minitrack stations, with the exception of one on Barbuda Island, along the 75° West meridian every twelve degrees of latitude, plus or minus one degree, starting at about 40° North down to 40° South latitude. Barbuda Island is located down range from AFMTC and is to be used in addition to determine the initial orbit of the satellite after launching from AFMTC. These stations are tentatively planned in the following general areas:

1. Chesapeake Bay Annex of NRL (test station)
2. Northern Florida
3. Cuba
4. Island of Barbuda, Leeward Islands
5. Panama Canal Zone
6. Quito, Ecuador
7. Lima, Peru
8. Tocapilla, Chile
9. Santiago, Chile

The Department of the Army has been requested to assist in establishing and operating these stations. Since the time of this initial request (SecNav Conf letter to SecArmy Serial 01886 dated 23 December 1955), the detailed plans have become more definite. Station 1, CBA, will be established, manned, maintained, and operated as a prototype and training station by NRL. Equipment for the other tracking stations will be checked out at this station prior to sending it on to its ultimate station. Likewise, this station will be set up to train complete tracking station teams under the immediate supervision of the Vanguard staff.

Station 4, Barbuda Island, also represents a special situation since it actually is part of the satellite launching complex. This station must make the initial measurements after the satellite enters into its orbit in order to determine the approximate orbit actually achieved. This approximate orbit determination will make subsequent measurements by the remaining stations more readily feasible. It is planned that the Army establish this station, provide routine maintenance and housekeeping, and assist NRL personnel in the operation of the tracking and telemetering equipment. NRL personnel will retain the final maintenance responsibility for the tracking and telemetering equipment.

The remaining stations should be considered Army stations – established, manned, maintained, and operated by Army personnel. The NRL will provide two technical advisors to the Officer-in-Charge of each station. These technical advisors are expected to be withdrawn from these stations after approximately six months operation. This removal recommendation shall be initiated by the NRL after the operation of the tracking equipment has been proved satisfactory. This recommendation must be approved by the individual Officer-in-Charge of each station before it will receive action.

Correspondence has been initiated to request the Army to conduct a map and an intelligence study to provide a selection of possible overseas tracking station locations. The following criteria have been provided to guide this study:

1. Station locations are desired at 0°, 12°, 24°, 36° South latitude $\pm 1^\circ$, plus the Panama Canal Zone, Havana, and Island of Barbuda.

2. Stations should be within fifteen miles of a major population center to provide living facilities.

3. Stations should be at least five miles from airways or airports.

4. Stations should be at least two miles from high-tension power lines or large power plants or power users.

5. Maximum use should be made of existing roads to minimize the need for road construction.

6. Terrain height in the adjacent area should not exceed 10 degrees elevation for at least one-half mile, increasing to 20 degrees at five miles.

7. Gradient at center of site, to include a north-south-east ell with 500-foot legs, should be less than 1 degree.

8. The station should be approximately 750 to 1000 feet square.

9. Good optical sighting conditions are desirable.

10. There should be tie-in with the existing triangulation net, with first-order triangulation being desirable.

11. A small site should be available ten miles west of the station to locate the telemetering turn-on equipment trailer.

The results of this study should be available by the end of January 1956. These will then serve as a guide for an on-site survey party which should get underway during the first week in February 1956. This survey party must be capable of making, whenever possible, final site selection decisions, taking into consideration the technical requirements, the estimated cost of construction and operation, and the particular site aquisition problems. Present scheduling indicates that this site selection and construction planning must be completed by about May 1956 in order to provide adequate time for construction.

Each station will occupy between 20 to 25 acres and will require a complement of approximately 20 technicians, observers, and operators. Constructional features are minimal consisting essentially of seven surveyed concrete pads (about 5 by 50 feet), communication antennas, hard stands for three trailers, a power unit, and an operations building similar to a 20 by 80 foot Quonset, plus a remote site about ten miles west consisting of one trailer and associated antenna. It is anticipated that personnel will obtain quarters and subsistence locally.

Communication Facilities

It is planned to provide each tracking station with communication circuits linking each to the other and each to a central collecting and computing agency.

a. Orbital Data Net – This net will be used for transmission of the primary tracking data back to a central computation facility in the United States within twenty minutes of a tracking event. This information should have priority on its assigned channels over all but distress messages. Between five and ten clear channel assignments will be required, spaced between three and thirty megacycles. Data transmission will be via teletype equipment.

b. Scientific and Administrative Net – This net will be used for the exchange of technical data and for administrative communications between the field stations and NRL. Between five and ten channels spaced between three and thirty megacycles will be required. Existing networks, wherever available shall be utilized to meet this requirement.

THE LAUNCHING VEHICLE [Confidential]

Requirements

The requirements which have been established for the launching vehicle are as follows:

Orbit – The limits of an acceptable orbit were defined as a minimum perigee of 200 miles altitude, and an inclination to the equator sufficient to assure passage over observatories in the United States. A launching azimuth of 119 degrees True meets the latter requirement for a launching from the Air Force Missile Test Center in Florida.

Payload – A 21½ pound payload has been specified. It must be observable by both radio and optical means.

Propulsion – The vehicle must be capable of attaining orbits with inclinations up to 45 degrees.

Flight Path Control – The vehicle must have a control system capable of governing its flight path and velocity as necessary to attain an orbit within the limits specified and to hold azimuthal errors within ±2½ degrees.

Design

The launching vehicle will be a finless, three-staged, rocket-propelled craft. Stages have been identified in the order of firing as first stage, second stage, and third stage. A preliminary configuration is shown in Fig. 2. While this configuration shows a payload sphere of 20 inches in diameter the design is being based on a 30-inch diameter sphere.

The first stage is of cylindrical monocoque construction, consisting of skin, frames, and longitudinal members with integral propellant tanks. The first-stage power plant is the General Electric Company X-405 rocket engine. The guidance system for the first and second stages will be common and will be housed in the second stage. Control of the vehicle in pitch and yaw during the first-stage powered flight will be accomplished by tilting the thrust chamber in a gimbal support by means of electrically-controlled hydraulic actuators. Roll control will be accomplished by means of reaction-producing steam jets, tangentially mounted to produce couples about the rocket's longitudinal axis.

The second stage is also a finless cylindrical section of monocoque construction which has two principal sections – a forward section to house the instrumentation and an after section to house the power plant package including the tanks. The second-stage power plant is the Aerojet-General Corporation AJ10-37 rocket engine. The guidance system, located in the second stage, will provide flight-path information to the control systems in both the first and second stages and information for the spatial alignment of the second-third stage combination prior to ignition of the third-stage power plant. The second-stage powered-flight control system is similar to that employed in the first stage. In addition, a reaction system to control the second stage in pitch, yaw, and roll during coasting flight will be installed. It is planned to operate this system on a periodic (off-on) basis in order to conserve energy. A common controller for the coasting-flight and second-stage powered-flight systems will be used insofar as practicable.

The third stage of the launching vehicle will consist of a solid propellant rocket, a structure for its attachment to the second stage and for giving it spin, the satellite, and a satellite mounting structure. The third stage will be stabilized by rotation about its longitudinal axis prior to third-stage rocket ignition. The second-stage controls will orient the rocket properly before spin is imparted. A mechanism will be provided in the third stage for the separation of the spherical payload from the remainder of the stage after an orbit has been established.

A contract has been negotiated with the Glenn L. Martin Company for the design, testing, and preparation for launching of the Vanguard launching vehicle.

The Naval Research Laboratory is responsible for services and equipment associated with telemetering, tracking, data reduction, and range safety.

The Trajectory

A preliminary trajectory for the launching vehicle is shown in Fig. 3. The velocity, altitude, and time data shown in this figure are based on a rocket having a gross weight of 22,500 pounds and a configuration designed to house a 20-pound payload. Studies are being conducted also for a vehicle having an over-all weight of 20,000 pounds. A design gross weight has not been decided, but it will not be less than 20,000 pounds or more than 22,500 pounds. The vehicle is launched vertically and after a period of 20 seconds is programmed into a controlled zero-lift trajectory which is maintained throughout the first and second stages of powered flight. The first stage is jettisoned at the initiation of second-stage thrust;

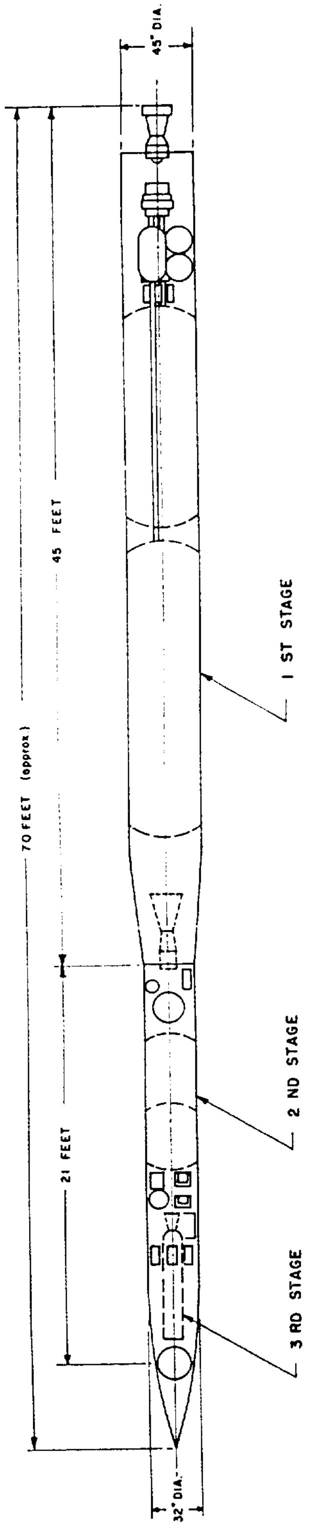


Fig. 2 - Preliminary Vanguard configuration

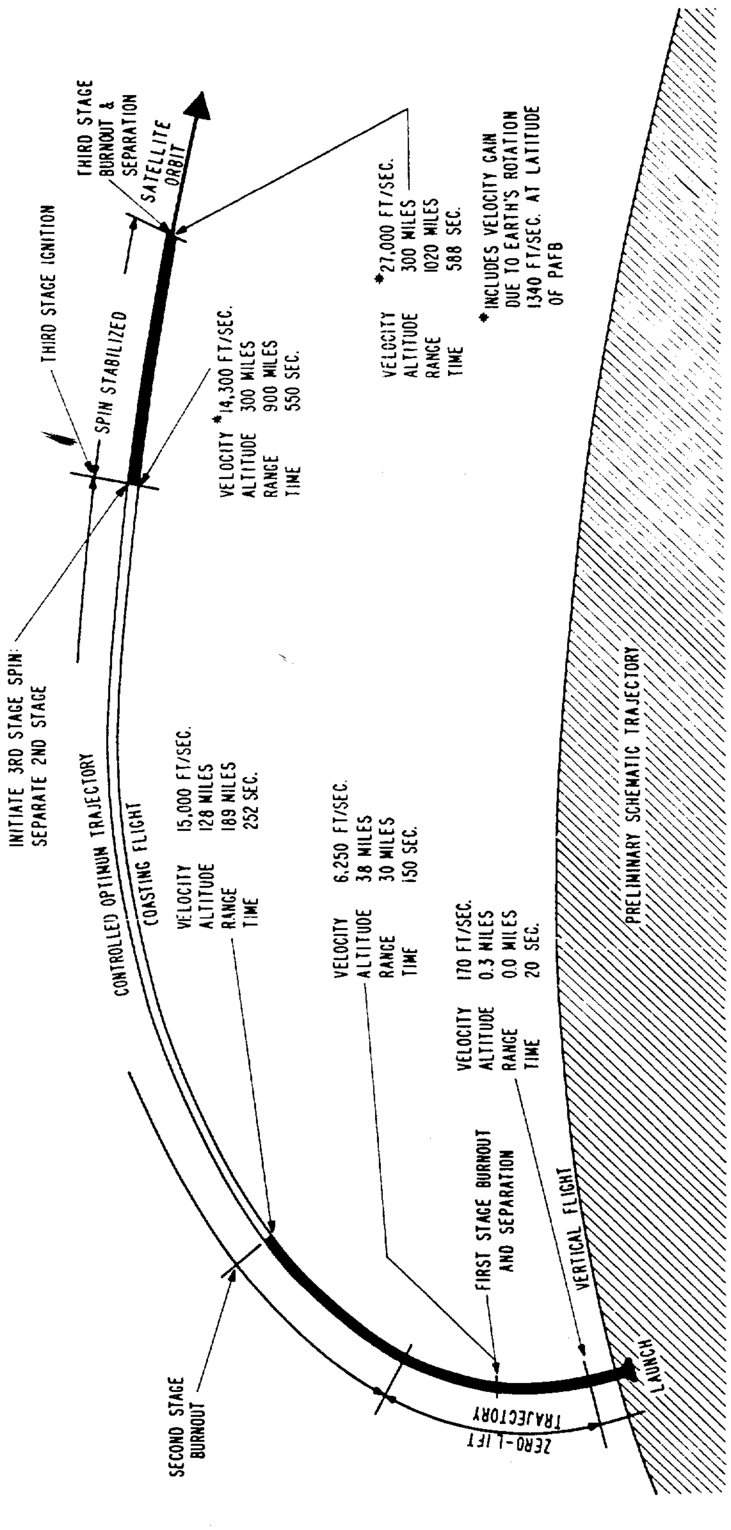


Fig. 3 - Preliminary trajectory for the launching vehicle

the second stage remains with the third stage throughout the coasting period. It is dropped at the time of third-stage ignition, after the correct spatial alignment of the third stage has been attained.

Approach to Development

It was decided to proceed as rapidly as possible with the preparation of a definitive launching-vehicle-system specification. It was realized from the beginning that the weight distribution between the three stages of the launching vehicle would have to be optimized. It was decided to determine by analysis if the specified perigee and apogee altitudes imposed unnecessarily difficult control requirements. Because the specified apogee does impose such a restrictive requirement, it has been removed.

In order to expedite development by separate agencies, a component package concept has been established, particularly with regard to power plants.

A test program including component and subsystem tests has been planned to establish component and subsystem adequacy as early in the program as possible. The flight test program, described later in this report, was formulated to determine if the actual performance meets the requirements of the Vanguard mission.

The prime contractor and NRL are working cooperatively on the preparation of the launching-vehicle system specification which should be complete before January 31, 1956.

System Optimization

A program to determine the optimum distribution of weights among the three stages of the Vanguard vehicle system was initiated at the beginning of the Vanguard program. The initial objective of this optimization program has been to determine a set of values for the three stage weights which will yield a maximum projection velocity for a given set of values of certain weight parameters and propulsion and aerodynamic variables.

The method and the assumptions used are described briefly below. The method has been applied using preliminary estimates for the values of the relevant weight, propulsion, and aerodynamic parameters. The optimum stage weights are functions of these parameters, and hence can be expected to vary as these parameters are varied. It is planned to conduct a parameter study to investigate these effects. It is also planned to continue to conduct optimization studies for more accurate values of the appropriate weight, propulsion, and aerodynamic parameters as these are obtained. The results of these optimization studies will be used to evaluate and dictate design.

It is convenient to discuss the optimization analysis by considering first the assumptions and procedures used to calculate individual vehicle system trajectories, and second, the method of analyzing selected sets of these trajectories in order to determine the optimum weight distribution. In conducting any individual optimization study it is assumed that the projection altitude and the weight of the entire vehicle are fixed. Typical values for these quantities are 300 miles for the projection height and 20,000 pounds for the total vehicle weight. However these parameters, themselves, are susceptible to optimization. Studies of these parameters are also planned.

Each individual trajectory is presently calculated assuming a round, nonrotating earth. After the calculation of ten seconds of vertical flight an initial tilt angle is assigned. The corresponding zero-lift trajectory to second-stage apogee is then calculated by means of the NAREC computer. The second-stage apogee height, which is taken to be the projection height, varies with the tilt angle. By calculating a sequence of trajectories for various initial tilt angles, the computer determines the trajectory having the desired projection height.

The corresponding projection velocity, i.e., the velocity at third-stage burnout, is a function of the values selected for the three stage weights. Since the total weight of the vehicle is assumed to be fixed for any optimization study, only two of the stage weights are independent variables. The projection velocity is thus a function of two variables, the second-stage and third-stage weights, i.e., $v = f(w_2,w_3)$. The value of v corresponding to any pair of values of w_2 and w_3 is determined by calculating a set of trajectories in the manner described above.

A word about the stage weight as a variable is in order. It is convenient to consider such a variable stage in terms of a fixed weight, which include such items as the power plant, and a variable weight. The variable weight consists of two parts, one corresponding to the usable propellant, and the other to the additional items, such as certain tank structures, whose weights are directly proportional to the weight of usable propellant. The constant of proportionality is expressed in terms of the propellant-tank mass ratio which is defined as the ratio of the weight of the usable propellant to the total variable weight. For convenience, the two parts of the variable weight can be referred to simply as the propellant weight and the tank weight, although the latter also includes certain outages. For the purpose of calculating a single trajectory, an ordinary fixed rocket can be described in terms of the standard variables such as the propellant mass ratio, the specific impulse, and the thrust and drag functions. However, in calculating in certain sets of trajectories involving rocket stages having variable weights, it is important to introduce the propellant-tank mass ratio as an additional parameter.

The optimization problem can be translated into the problem of determining a point, i.e., a pair of values for w_2 and w_3, for which the function $v = f(w_2,w_3)$ has its maximum value. This point is determined in the following way. For a fixed value of w_3, say, values of v are calculated for several values of w_2 in order to determine the point at which v has its maximum value when regarded as a function of w_2. At this point the following relation holds:

$$\frac{\partial v}{\partial w_2} = 0. \tag{1}$$

This process is repeated for several values of w_3 to obtain several points, and hence also a corresponding curve, for which the relation in Eq. (1) holds. The corresponding curve along which relation

$$\frac{\partial v}{\partial w_3} = 0 \tag{2}$$

holds is determined in an analogous fashion. Conditions (1) and (2) are true simultaneously at the intersection of these two curves. At this intersection point, and hence for the corresponding values of w_2 and w_3, the projection velocity is a maximum. The corresponding value of w_1 is determined by the condition that the total weight of the vehicle is fixed.

The results of a recent optimization study are presented in Table 1. The values used for the relevant weight and propulsion parameters and the corresponding optimum set of values for the three stage weights are shown. The parameter values are illustrative; however, they do not represent the final design of the Vanguard vehicle system.

TABLE 1

Optimization Study Results

ASSUMPTIONS (total vehicle weight = 20,000 lb)

First Stage	
Sea level thrust (lb)	27,000
Sea level specific impulse (sec)	254
Exit area (in.^{2})	176.72
Diameter (in.)	45
Fixed weight (not including cyl. tanks)(lb)	1,637
Tank factor (including outages)	16.574/17.574

Second Stage	
Sea level thrust (lb)	3,500
Sea level specific impulse (sec)	121.625
Exit area (in.^{2})	306.122
Diameter (in.)	32
Fixed weight (not including cyl. tanks)(lb)	625
Tank factor (including outages)	10.069/11.069

Third Stage	
Fixed weight (not including cyl. tanks)(lb)	65
Altitude specific impulse (sec)	247
Tank factor	16.4/17.4

RESULTS

First Stage	
Usable lox (lb)	9,254
Usable fuel (lb)	4,207
Turbine peroxide (lb)	292
Lox tank (lb)	158
Fuel tank (lb)	128
Peroxide tank (lb)	40
Outages (lb)	284
Total stage weight (lb)	15,910

Second Stage	
Usable RFNA (lb)	1,878
Usable UDMH (lb)	637
RFNA tank (lb)	119
UDMH tank (lb)	80
Outage (lb)	51
Total stage weight (lb)	3,390

Third Stage	
Usable propellant (lb)	599
Bottle weight (lb)	36
Total stage weight (lb)	700

Trajectory	
Projection altitude (mi)	300
Projection velocity (ft/sec)	25,925
Excess over orbital velocity (ft/sec)	2,182

Status of the Work

Design of the first stage has proceeded to the point of completion of layout drawings which show first-stage power-plant attachment points. A first-stage tail-section mockup has been designed and released for manufacturing. Equipment installations for this mock-up are in design. First-stage tankage design is in progress. A dynamic test section of the first stage is in design.

Several preliminary configurations have been studied; weight and structural analyses have been made in support of weight optimization and payload penalty studies. On the basis of preliminary structural analysis, a first-stage diameter of 45 inches and a second-stage diameter of 32 inches were established. Taking into consideration the temperatures, pressures, and airloads, including the effects of maneuvers and gusts, environmental studies were made to determine the effects of handling, transportation, launching, and flight.

The problems of vibration on the test stand and in flight have been studied and the vibrational environment has been defined, based on vibration studies made in the Viking rocket. First-stage engine-mounting vibration analyses are being made to determine the lower frequency limit of vibration. Structural tests which will establish the integrity of the vehicle and its subassemblies are being formulated. A test program and facility requirements are being drawn up to define and solve structural feedback, vibration, flutter, and other dynamical problems. A structural configuration for Viking 14 has been established. Bending moments are being determined for four conditions: (1) Free-free with tanks empty, (2) free-free with tanks loaded, (3) cantilevered beam with tanks empty, and (4) cantilevered beam with tanks loaded. Power-plant weight and structural requirements were established and mounting provisions evaluated. A gimbal mounting was compared with a ball-and-socket engine mounting; the latter was found to be much stiffer.

Aerodynamics

An experimental investigation of the expected pressures, forces, and moments on the Vanguard vehicle configuration was performed in the APG/BRL Supersonic Flexible-Throat Wind Tunnel on 28 October 1955. The forces on a 3.1% scale model were measured for a Mach Number range of 1.57 to 2.0. Pressure distribution on a 2% scale model was measured for Mach numbers between 2.0 and 4.5. The models were made to a preliminary configuration. The results are being employed to estimate aerodynamic forces and moments on the Vanguard vehicle in flight.

On October 21, 1955 the requirements for the satellite were established as follows:

1. A spherical body of 30 inch diameter will be separated from the third stage after attainment of orbiting velocity.

2. The satellite will weigh 21.5 pounds and have a moment of inertia about its roll axis of approximately 40 pounds per square inch. A preliminary weight breakdown of the satellite is:

Structure (including separating mechanism)	11.5 lb
Minitrack (including power supply)	4.0
Telemetry (including power supply)	4.0
Scientific instrumentation	2.0
Total	21.5 lb

3. NRL will provide the satellite, including the separating mechanism (the weight of this mechanism will be included in the total weight of 21.5 pounds).

4. The thrust load will be applied to the sphere along its diameter which coincides with the longitudinal axis of the third stage, through a thrust bearing, in order to minimize the spin imparted.

Upon establishment of these requirements, a preliminary study of their influence on the design and performance of the launching vehicle was initiated. This investigation considered three effects: (1) the effect of aerodynamic drag on performance, (2) the temperature rise at the stagnation point of the sphere, and (3) the structural weight required to accommodate the sphere. The airload problem is considered not severe since the maximum anticipated dynamic pressure is about 650 to 700 pounds per square foot at 40,000 feet. A temperature rise of over 900°F was predicted.

This study established that it is not feasible to use a spherical shape for the nose of the vehicle without some means of insulating it from aerodynamic heating. It is obvious now that a detachable nose cone which is jettisoned as early in flight as feasible must be used. The structural weights indicated by this investigation are being considered in the optimization studies.

Several trajectory studies have been pursued. Preliminary test vehicle trajectories were computed to establish instrumentation and range safety requirements. The advantages of employing a controlled, constant-thrust attitude instead of zero lift during second-stage powered flight have been investigated. Preliminary results indicate no significant performance gain, but studies are being continued. Aerodynamic transfer functions for several flight times during ascent have been obtained for a nominal Vanguard configuration. These functions are being analyzed for variations of various parameters – pitch moments for instance. The stability of the third stage during powered flight has been studied. Mathematical expressions have been derived for determining motion with thrust misalignment and spin. Computations have indicated that a spin rate of 100 rpm is sufficient to restrain within tolerable limits the dispersion due to thrust misalignments. These computations will be repeated after third-stage weight, moment of inertia, center of gravity location, burning time, thrust characteristics, etc., have been refined.

Aerodynamic load distribution has been derived for angles of attack up to 5 degrees to be used in predicting structural bending moments.

Propulsion

The launching vehicle initially proposed by NRL was a three-stage rocket with the first stage employing a modified Hermes liquid rocket engine as developed by the General Electric Company, the second stage using an Aerojet General Corporation Aerobee-Hi liquid rocket engine, and the third stage being propelled by a solid rocket based on scaling the Thiokol Corporation T-65 booster. On the basis of preliminary calculations it appeared possible to obtain the necessary impulse from these engines and their advanced state of development offered a definite advantage. It was found that the General Electric engine meets the requirements for the first stage, but trajectory and weight studies showed that a second-stage engine of higher thrust than the Aerobee-Hi unit is needed. Proposals were invited, received, and evaluated from two possible suppliers of a second-stage power plant, namely Aerojet General Corporation and Bell Aircraft Corporation. Aerojet was given a contract for this power plant. It was decided not to limit third-stage design to the use of the scaled T-65 booster. Initial proposals for the third-stage solid rocket were received from several solid-propellant producers, namely Aerojet General Corporation, Alleghany Ballistic Laboratory, Atlantic Research Corporation, Grand Central Rocket Company, and Thiokol Chemical Corporation. The specification has been revised on the basis of optimization studies and all of the initial bidders were invited on December 30, 1955 to submit new proposals.

During the period since the negotiation of the prime vehicle contract, several studies in the propulsive area, in addition to the power plants themselves, have been pursued. These studies are in progress:

1. Facilities required for power-plant design, development, and functional testing.

2. Propellant characteristics - red fuming nitric acid, unsymmetrical dimethylhydrazine, and hydrogen peroxide.

3. Optimum tank configurations.

4. Intensive investigation of a minimal-weight pressurization system for the first stage, including heat exchanger systems with ambient or cold gases.

5. Optimum relative position of propellant tanks.

6. Propellant utilization - six different systems have been reviewed. Tests of NRL liquid level sensors were continued by North American Aviation Corporation for an Air Force application with close liaison with NRL.

7. Optimum ground equipment and servicing equipment design and optimum servicing procedures.

8. Liquid-oxygen topping provisions.

The First-Stage Power Plant - The General Electric Company Model X-405 rocket engine will be used for the first-stage power plant. The performance requirements for this power plant are summarized in Table 2. This engine consists of a regeneratively-cooled thrust chamber, gimbal mounting, propellant valves, turbo pump, and high-pressure lines. This unit is being purchased as a package and will be tested and delivered as a complete system. The gimbal mounting permits angular deflection of the motor thrust vector by ±5 degrees from the centerline of the vehicle and incorporates an adjustment for aligning the line-of-thrust with the centerline of the vehicle when the gimbal is in the neutral position. The propellants are liquid oxygen, as the oxidizer, and a homogeneous mixture of gasoline, silicone oil, and ethyl alcohol as the fuel. The propellants are delivered to the thrust chamber by turbine-driven pumps; the turbine is powered by the decomposition product of hydrogen peroxide.

The design, fabrication, and testing of the first-stage engine and engine components are ahead of schedule. A model specification has been prepared, an engine mockup has been completed, inspected, and found to be substantially acceptable. The Malta Test Facility has been reactivated and test pits 3, 5, and 25 have been prepared for Vanguard first-stage power-plant testing. One 60-second duration run on a Vanguard-type injector in a development-type thrust chamber has been made to test pit 3 instrumentation. Vanguard injector and thrust-chamber calibration runs have been started. Turbo-pump modifications have been designed and incorporated and turbo-pump tests under simulated loads began in December 1955 in Pit 5. Propellant valves are designed and are being manufactured. A 150-second duration run has been made successfully on the gas generator. The gimbal, thrust structure, and engine bellows designs have been completed. The first-stage power-plant design test program is shown in Fig. 4.

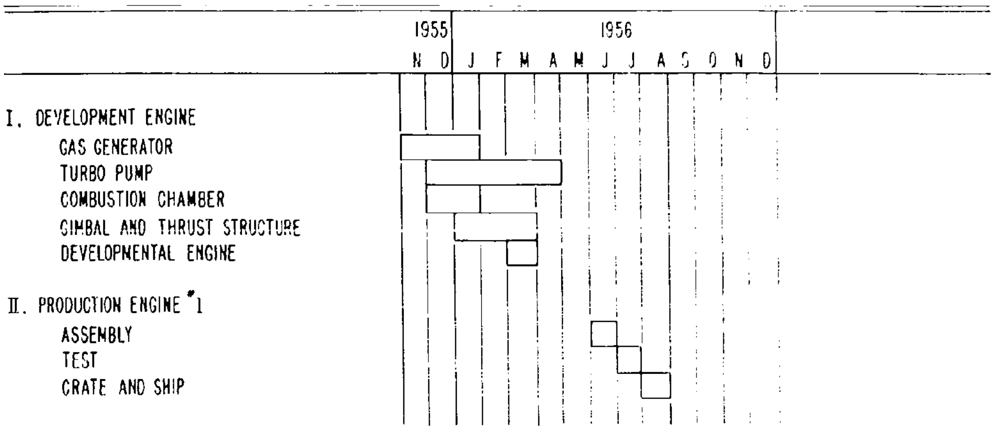


Fig. 4 - First stage power-plant development test schedule (GE/S-405 liquid rocket engine)

TABLE 2
First-Stage Power-Plant Performance Requirements

Thrust	27,000 lb (nominal sea level)
Specific impulse	254 sec (nominal sea level)
Chamber pressure	585 psig
Oxidizer flow rate	71.7 lb/sec (nominal)
Fuel flow rate	32.6 lb/sec (nominal)
Optimum mixture ratio (Oxidizer to Fuel)	2.2 (by weight) (nominal)
Hydrogen peroxide flow rate	2.0 lb/sec (90%)
Expansion ratio	5.5 to 1
Burning time	135 sec (nominal)
Engine dry weight	425 lb (nominal)
Engine wet weight	450 lb (nominal)

The Second-Stage Power Plant - The Aerojet-General Corporation Model AJ10-37 liquid-propellant rocket engine will be used for the second-stage power plant. Performance requirements for this power plant are shown in Table 3. This is a packaged engine, which consists of a thrust chamber regeneratively cooled with the oxident, a gimbal structure, valves, lines, tanks, pressurization system, and electrical system. The gimbal structure will allow the angular deflection of the motor thrust line by ±5 degrees from the centerline of the vehicle and will include an adjustment to provide a means of aligning the motor's line-of-thrust.

TABLE 3
Second-Stage Power-Plant Performance Requirements

Thrust	7500-8000 lb (at altitude)
Specific impulse	278 sec (at altitude)
Impulse-to-gross-weight ratio	245
Nozzle-expansion ratio	15 to 1 (minimum)
Total impulse	900,000 lb-sec

The propellants are hypergolic; red fuming nitric acid (type 3a) has been specified as the oxidant, unsymmetrical dimethylhydrazine is the fuel. Flow of the propellant to the thrust chamber is effected by helium gas pressurization of the propellant tanks.

The Aerojet General Corporation has completed a preliminary design of a pressurized system and has indicated that they can deliver a second-stage power plant which will deliver 900,000 lb-sec impulse at an impulse-to-gross-weight ratio of 241 if the use of a hot helium system is acceptable. The capabilities of a conventional helium system and of a hot helium system are compared graphically with specification requirements in Fig. 5.

Testing of an injector for the Model AJ10-37 has been initiated. A preliminary developmental test schedule is shown in Fig. 6.

The Third-Stage Power Plant - A solid-propellant rocket motor will be used for the third-stage power plant. Performance specifications are shown in Table 4. It is anticipated that a contract for the development of a third-stage solid-propellant rocket will be initiated by January 30, 1956. It is planned to support two parallel solid-propellant development efforts, at least through the development qualification test phase.

TABLE 4
Third-Stage Power-Plant Performance Requirements

Thrust	2400 lb (at altitude)
Total impulse	107,000 lb-sec
Specific impulse	247 sec (at altitude)
Burning time	44.4 sec
Gross weight	524 lb
Total usable propellant	431 lb
Weight empty	59 lb
Payload weight	21.5 lb
Special structure (spin) weight	12.5 lb

Flight-Path Control

The requirements for control of the vehicle's flight can be defined simply as those necessary (1) to impose the directional control at the point of projection required to meet orbit eccentricity and azimuthal requirements and (2) to effectively utilize the propulsive energy necessary to achieve orbital velocity. An analysis has been made, which shows the allowable elevation errors for an orbit whose perigee is no less than 200 miles altitude and whose apogee is no more than 800 miles. On the basis of this study an elevation accuracy requirement of ±1 degree was imposed on the flight-path control system. Azimuth control accuracy is not as severe; an accuracy of 2.5 degrees has been established as adequate. The apogee requirement imposes the more severe limitations; this requirement has been lifted but elevation accuracy requirements will not be relaxed. More detailed control-system requirements will depend on the system utilized.

The underlying philosophy upon which the Vanguard flight-path-control-system development is being based involves consideration of the following factors in the order named:

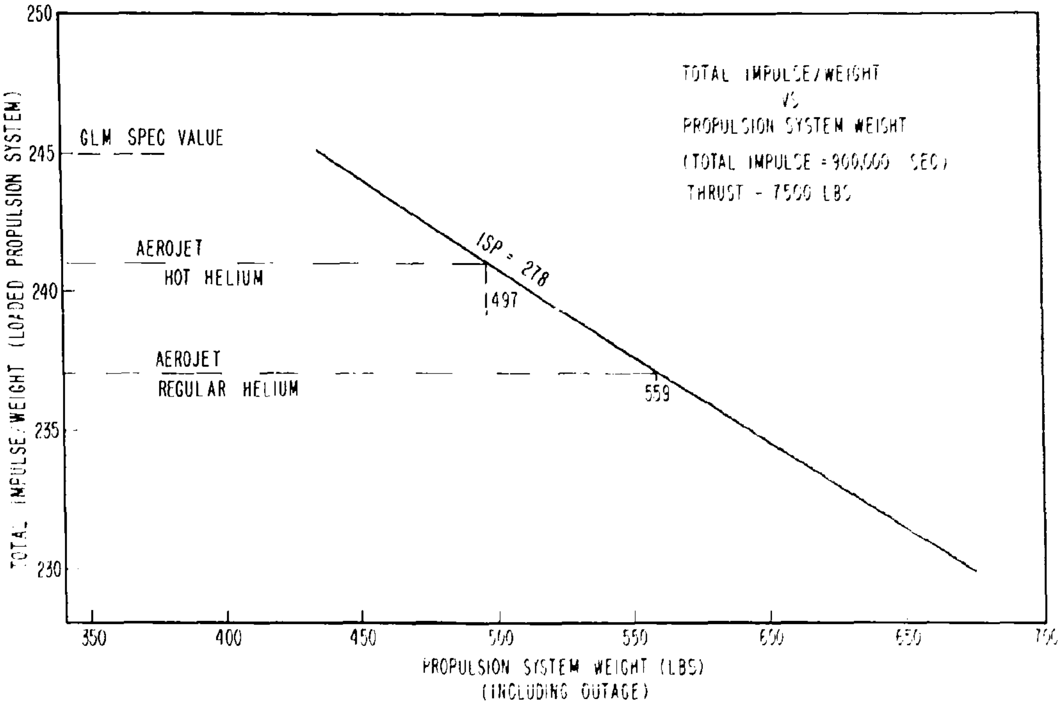


Fig. 5 - Comparison of a conventional helium system and a hot helium system

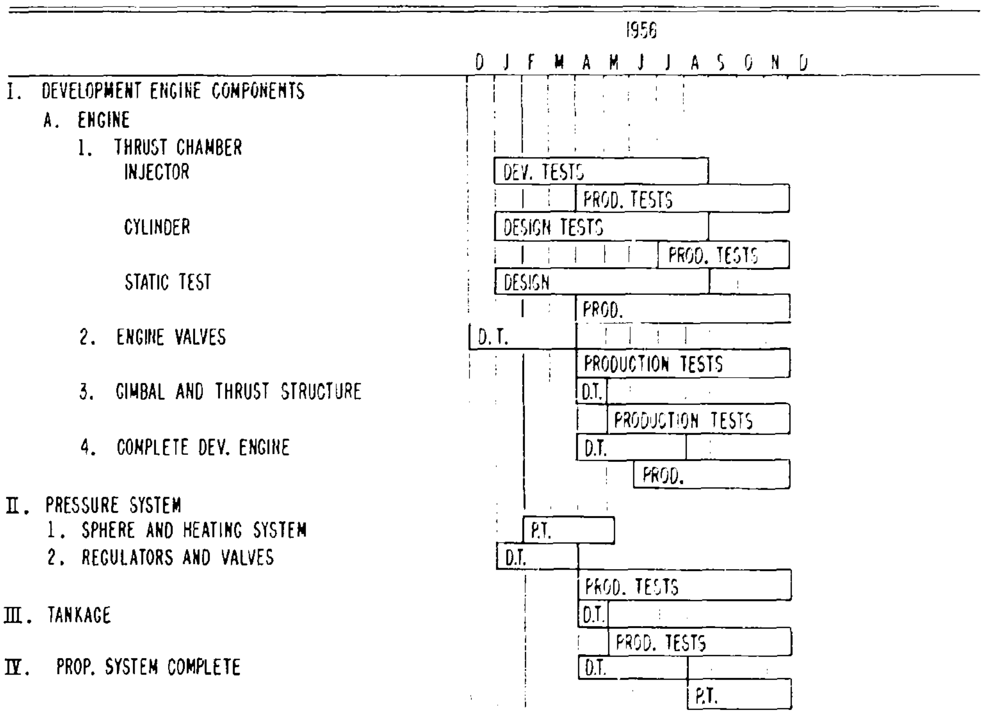


Fig. 6 - Second-stage power-plant development test schedule, preliminary (Aerojet-General AJ10-37)

(1) adequacy, (2) simplicity, and (3) availability. During the study phase, however, attention will not be limited to a single type of system. A simple system, comprised of a reference system and a time-governed elevation-angle programmer, all contained in the vehicle, is being studied. It is realized that such a system may not be able to meet the requirements specified. It is believed that a similar system with flight path and possibly second-stage impulse trimmed in accordance with in-flight trajectory measurements will do the job. Supporting studies have been initiated.

The use of a single guidance (reference) located in the second stage is being considered. The first-stage controls will receive correction demands from this reference system and the third stage will be given the correct orientation and angular momentum prior to its detachment. The use of common controller components, insofar as is practicable, will be made.

Since a gyro (reference) system is common to all types of flight-path control being studied, reference system accuracies were defined which were deemed adequate for all types of control. These accuracy requirements were 0.5 degree in pitch and 2.0 degrees in roll and yaw, after ten minutes of flight. The pitch allowable error was further broken down to 0.1-degree alignment error, 0.1-degree torquing error, and 0.3-degree drift. Environmental conditions were specified as 5 g, vibration between 0 and 1000 cps, and 0-to 8-g linear acceleration.

Reference system requirements were outlined and proposals were requested. The Aerodynamics Division of Minneapolis Honeywell proposed the use of three strapped-down HIG6 gyros; all other proposals were for three-axis platforms. The various proposals were evaluated on the basis of adequacy, status of development, contractor ability to deliver within the desired delivery time (10 months), and cost. The Minneapolis Honeywell proposal was rated superior, and negotiations are proceeding with that company.

In order to backup this work it is proposed to continue to study and maintain an accurate status record of the progress of various guided-missile gyro developments being conducted by Kearfott, Minneapolis Honeywell, and Sperry. A check point has been set for April 1956, at which time the progress of the strapped-down HIG6 development will be surveyed and parallel effort initiated, if considered necessary. It is now planned to use the existing Viking reference system in the Viking 13 and 14 test vehicles.

Various studies are under way to support the definition of control requirements:

(1) The flight trajectory computer (701) program has been modified to include the third-stage trajectory (excluding misalignment effects). First- and second-stage thrust variations have been shown to have considerable effects on perigee and apogee altitudes obtained.

(2) A problem has been initiated to evaluate the effects of third-stage misalignments.

(3) An analysis is underway to determine the feasibility of controlling second-stage cutoff with an integrating accelerometer.

(4) A simulated trajectory study is in progress to establish the feasibility of a simple program to generate the required trajectory (including tolerances of power-plant performance parameters).

(5) Stability analyses have been initiated for: (a) first-stage pitch/yaw controls, (b) first-stage roll system, (c) second-stage coasting-flight reaction system, (d) third-stage

separation and spinning system, and (e) Viking 14 pitch/yaw reaction system. The first-stage missile dynamics expression contains two positive real roots in its denominator for both maximum dynamic pressure and burnout conditions. Preliminary analysis indicates a stable missile can be obtained with a control system that employs lead circuit compensation. Using takeoff moments of inertia and center-of-gravity values, a preliminary pitch/yaw controller was designed for the first stage which meets a Nyquist criterion on $M = 1.5$ for a system sensitivity of 2-degrees motor deflection per degree of error, with a natural frequency of approximately 4 rad/sec. Realistic time constants were employed.

(6) The use of magnetic amplifier autopilots is being studied.

(7) Control system modifications for Viking 13 and Viking 14 have been designed; and Test Vehicle 2 control requirements (flight components, spares, ground and test equipment) have been defined.

(8) Telemetering requirements for controls performance evaluation have been defined.

A preliminary block diagram of the flight-path control system is shown in Fig. 7.

Auxiliary Systems

Hydraulic – A first-stage hydraulic system diagram for Test Vehicle 2 is in preparation. Acceleration and velocity requirements of the engine in the gimbal and actuator loads have been calculated. From these values flow requirements will be determined. Second-stage hydraulic requirements are being defined to facilitate determination of the optimum power source and servo parameters. A first-stage hydraulic pump of 10 horsepower capacity was established as adequate.

Electrical -- A preliminary estimate of electrical power requirements has been made from which an optimum source can be established. Monopropellants and various types of batteries have been studied. Silvercel batteries appear to be most suitable. Conversion means under consideration include static converters and static high-voltage dc supplies.

Flight Test Program

The flight test program has been formulated on the premise that the performance of each flight will be evaluated quickly and that the design of the systems which are tested in a particular flight will be modified if necessary, as rapidly as is possible. Various systems of the launching vehicle will be fed into the test program as rapidly as they are ready. In general, the instrumentation of the test vehicles will be heavy, whereas that of the ultimate launching vehicle will be very light, that is, limited to those instruments necessary to the evaluation of the launching vehicle performance.

All launching vehicles will be statically tested in the field prior to flight. This practice, established in the Viking program, is considered essential. From these static firings it will be possible (1) to establish the integrity of systems, (2) to obtain performance data from which optimum adjustments for flight will be made, (3) to determine the proper functioning of instrumentation and observe interaction between systems. This applies to both the first and second stages. Second stages will be statically tested, prior to their incorporation in the launching vehicles.

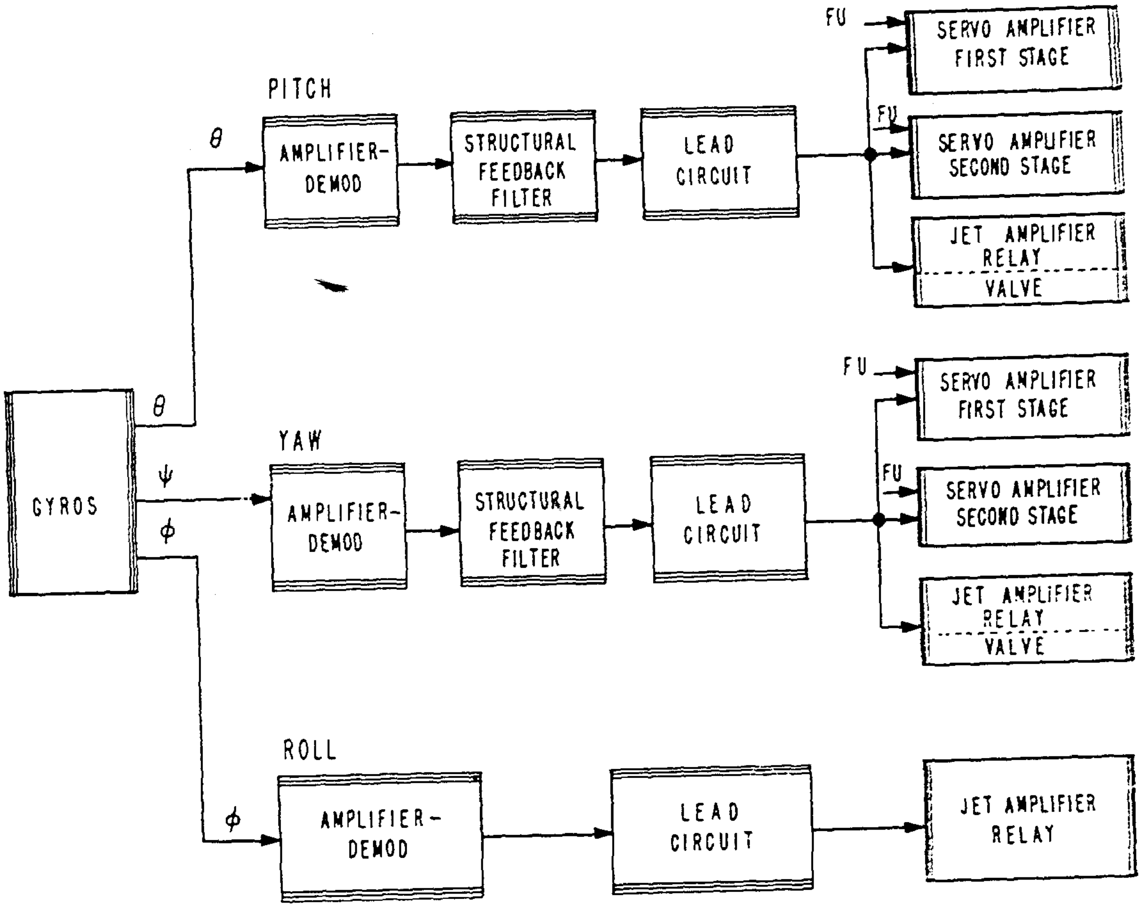


Fig. 7 - Preliminary block diagram of Vanguard launching vehicle flight-path control system

Permanent field crews will be established sufficiently in advance of the first test firing and will be maintained throughout the test program. This will include a contractor crew, which will prepare and service the rockets for flight, and a government crew, which will provide the services which are to be government supplied and such technical observers as are necessary to the performance of the government's evaluative functions.

Test Plans and Objectives

The proposed flight test program is shown in Fig. 8. The first test firing, scheduled for October 1956, will use the Viking 13. Viking 14 is being modified to carry a live third stage. Test Vehicle No. 1 is the first rocket to carry the launching vehicle first stage. This is the first vehicle for which a back-up vehicle is to be provided.

THE SATELLITE [Confidential]

Requirements

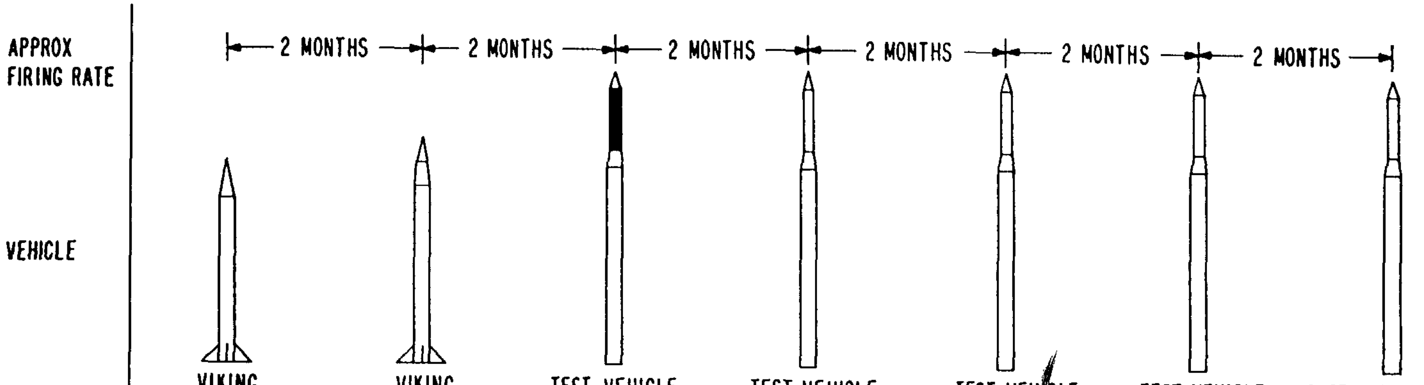
The weight of the satellite has been set at 21.5 pounds. This weight is the total weight including shell, internal structure, instrumentation, antennas, and separating mechanisms. It is obvious, therefore, that the shell, internal structure, and separating mechanism must be as light as possible so that the maximum scientific instrumentation can be included. The surface of the satellite, however, must be such that the orbital equilibrium temperature inside the package falls within the limits necessary to assure good operation of the experimental equipment, yet it must also have a good optical reflectivity for tracking purposes. The optimum configuration is spherical and the most desirable diameter when all factors are considered is 30 inches.

Status of Work

Detail design of the satellite cannot proceed until the results of optimization studies are known. The greatest problem in establishing the shape of the satellite is weight. If the satellite is spherical, the second-stage shell must be large enough to house it, and this results in a weight penalty, mostly in the second stage, compared to the original conical configuration which was considered. Performance studies of the over-all vehicle indicate that the performance margin may be so small that such an increase in weight may well prevent placing the satellite in its orbit. Accurate weight estimates are now being prepared, the results of which will affect the design of the satellite. Results of this study are expected in the latter part of January 1956.

The problem of heating during ascent has been investigated. A spherical nose would attain a skin temperature in excess of 1000° F. It is possible to use a lightweight spherical satellite if it can be protected during the heating period of flight by providing a heat-resisting disposable conical nose. After the heating period, the maximum of which is estimated to be from the last half of first-stage flight until half way through second-stage flight, the cone would be jettisoned. This cone is carried as a weight penalty for the second stage.

The problem of heating during orbital flight has been investigated to determine a suitable shell material. Every practical material is being investigated with the object of obtaining the most efficient and most reliable structure and shell possible. To date the field of practical materials for the shell has been narrowed down to three. These



	VIKING NO. 13	VIKING NO. 14	TEST VEHICLE NO. 1	TEST VEHICLE NO. 2	TEST VEHICLE NO. 3	TEST VEHICLE NO. 4	SATELLITE LAUNCH VEHICLE NO. 1
SYSTEM STATUS		Prototype 3rd stage spinning & separation systems	Interim Guidance & Control System Dummy 2nd Stage	Prototype Guidance. Prototype powered flight & coasting control systems. Third stage changes derived from test Vehicle No.1	Prototype systems with changes derived from test vehicle No.2	Final systems with changes derived from Test Vehicle No. 3	Prototype satellite launch vehicle. Changes derived from Test Vehicle No.4
OBJECTIVES	1. AFMTC familiarization 2. Facilities checkout 3. Flight test telemetry tracking & range safety systems	Test 3rd stage for 1. Separation 2. Start 3. Stabilization	1. Test 1st stage aerodynamic & propulsion performance 2. Continue 3rd stage testing	1. Test 2nd stage aerodynamic & propulsion performance 2. Test performance of complete vehicle systems	Test performance of complete vehicle systems	Verify flight trajectory of complete vehicle with reduced instrumentation, final tracking, range safety, and telemetering systems	Launch scientific payload into orbit
OPERATION BACKUP			Spare Vehicle No. 1 available for repeat firing	Spare Vehicle No. 2 Available for repeat firing	Spare Vehicle either No. 1 or No. 2 available for repeat firing	Spare Vehicle either No. 1 or No. 2 available for repeat firing	Spare satellite launch vehicle available

Fig. 8 - Proposed Vanguard flight test program

materials are HK31-T6 magnesium thorium, aluminum alloy 5052-0, and pure beryllium. Fabrication difficulties, rigidity, and many other factors rule out, at this time, such materials as commercially pure titanium, Inconel "X," and others. There is assurance that aluminum can be fabricated to the required thickness. There are indications that the HK31-T6 could also be fabricated. It is not known for certain if pure beryllium can be obtained or fabricated. Pure beryllium is the most desirable material of the three from the strength-to-weight standpoint. It is felt at this time that an aluminum shell and structure can be fabricated within the allowed weight. The aluminum, with an Alzak (aluminum oxide) finish, has the desirable properties of high solar reflectivity and high emissivity. Calculations indicate the temperature within the satellite, with such a coating, would remain low enough for all equipment to operate properly. While this is one solution to the orbital heating problem, the other materials, which may be more advantageous, are being investigated.

In addition to the investigation of suitable materials, fabrication techniques are being explored, such as drawing, welding, and spinning.

The problem of accomplishing separation of the satellite from the remainder of the third stage has also received consideration. The two basic methods which appear to have most promise now are: (1) A "caterpillar" type device ignited after third-stage burnout, and (2) A piston-type device which utilizes the expanding gas of a smokeless powder or similar charge.

TELEMETERING AND RANGE INSTRUMENTATION EQUIPMENT [Confidential]

Requirements

The instrumentation requirements for Project Vanguard are as follows:

1. Telemetering for the test-vehicle program.
2. Telemetering for satellite launching vehicles.
3. Obtaining trajectory data for test vehicles.
4. Obtaining minimum usable trajectory information for satellite launching vehicles.
5. Compliance with range safety regulations including flight-path control.

The main criteria are adequate performance and reliability with minimum payload penalty. Following these criteria, equipment has been chosen on the basis of experience in other programs. Where adequate performance cannot be obtained with existing equipment, developmental equipment will be utilized. In general the plan follows a concept of instrumenting heavily for the test program but using the minimum number essential during the actual satellite launchings.

Telemetering Equipment

The use of two basic systems has been planned for the test and final programs, i.e., the PPM/AM system and the PWM/FM system. Minor use will be made of the FM/FM system during the test program for vibration and strain-gage data handling. The allocation for the test program is as follows:

First Stage - PPM/AM

Second Stage - PPM/AM, PWM/FM

Third Stage - PWM/FM

Channel switching will be employed wherever a transmitter may be located in a higher stage and also telemeter a lower stage. For satellite firings the telemetering allocation is as follows:

First Stage - PPM/AM

Second Stage - PWM/FM

Consideration is being given to the possibility of transmitting PWM data on a 70-kc subcarrier to permit unmodified use of present AFMTC magnetic-tape recording equipment.

The PPM/AM transmitter consists of a 15-channel high-accuracy medium-frequency-response transmitter having a sampling rate of 312.5 cps. The rf oscillator is crystal controlled with a peak power output of 30 watts. The transmitter weight is 24 pounds with in-flight calibration. This transmitter has been used in its present pressurized-unit-package form in 28 rocket flights up to an altitude of 158 miles with good reliability and minimum maintenance. The ground stations are synchronized by a positive pulse code which locks an oscillator, resulting in minor signal drop-out during erratic rocket motion. Operation during the rocket's passage through ionizing regions and during flame pluming at ranges up to 40 miles has been good. Both airborne and ground station equipment is in current production for IGY use. It is proposed to operate two ground stations at Cape Canaveral and one at Grand Bahama Island.

The PWM/FM system has been chosen for its lightweight, good accuracy, reliability, and recordability on magnetic tape. It does not have sufficiently high-frequency response to be used exclusively. Operation of one ground station by NRL at Cape Canaveral has been planned. In addition, AFMTC has been requested to supply and operate one ground station at Cape Canaveral, one at Grand Bahama Island, and to provide magnetic-tape recording at all chain island stations. No specific units of PWM/FM equipment are available off the shelf, packaged in single pressurized-containers suitable for high-altitude rocket use. However both airborne and ground equipment can be obtained on a four- to six-month delivery basis. The power output being planned is 15 watts and all transmitters will be crystal controlled.

Specific vibration and strain-gage measurement requirements are in the process of being established, and when completed will establish the detailed needs for FM/FM telemetering transmitters. AFMTC will provide such ground decoding and recording as required.

An improved ground telemetering antenna development is being carried out by contract with the New Mexico College of Agriculture and Mechanical Arts. The primary purpose is to increase the gain of the ground antennas to permit reduction in transmitter power and weight and also better coverage of extended portions of the trajectory. The design consists of a three-element helix array (made up of standard 8-turn helices) and has a calculated gain of 19 db above an isotropic source for circularly polarized incoming waves as opposed to gains of 10 to 12 db for the 8-turn helices in present standard use. Antennas will be made available to AFMTC for interim use prior to their obtaining the higher gain antennas under current production.

The use of the new NEMS-Clarke crystal-controlled FM receivers with dual band intermediate frequency is being planned by NRL and AFMTC. In this connection prototype evaluation data have been obtained from BRL and current field tests at WSPG are being followed. Developmental work is being initiated at NRL on a pulse receiver to permit minor improvements in automatic-gain-control range and to substitute use of the GL 6299 tube for the 416B in a low noise-figure front-end application.

It appears that adequate telemetering of the test program through burnout of all stages and beyond can be obtained with safety factors of 25 to 30 db on a firing azimuth trajectory of 114 degrees or greater. Expected severe flame attenuation at Cape Canaveral should be offset by installations planned at Grand Bahama Island.

The status of the telemetering equipment may be summarized as follows:

PPM/AM ground stations - under contract, delivery expected by May 1, 1956.

PPM/AM transmitters - Specifications being prepared for rebidding (six usable on hand).

PPM/AM calibrators - under contract, delivery expected to start in May 1956 (two usable on hand).

PWM/FM ground stations - under contract, delivery expected May 1956.

PWM/FM transmitters - order being readied for one set of components for packaging.

FM/FM transmitters - requirements not firmed up.

NEMS-Clarke Receivers - MIPR for three units ready to go to OCO.

Ground antennas - under contract, delivery to start in February 1956.

Range Instrumentation Equipment

The range instrumentation equipment is needed for three functions:

1. To obtain trajectory information.

2. To comply with AFMTC range safety regulations.

3. To afford a secondary possible release determination time of the third stage by ground measurement and computation in real time.

The available range instrumentation equipment is somewhat limited at AFMTC due to the primary requirements having been generated by level-flight missile workloads. More suitable ballistic missile equipment is being procured but will not have been installed or debugged in time for use on this program. Hence, the desire for accurate trajectory gathering equipment must be balanced against undue penalties in cost or time.

Under these conditions AFMTC has been asked to do the following:

1. Provide optical coverage by Askania theodolites, ballistic cameras, and fixed cameras to the extent possible.

2. Install units of the AN/FPS-16(XN-2) radar equipment.

3. Take over the supply Dovap coverage from Cape Canaveral and the Grand Bahama Island areas.

The AN/FPS-16(XN-2) radar equipment was selected since it is a C-band instrumentation radar capable of high angular accuracy (0.1 mil) and high tracking rates. It is now under development by RCA. The XN-1 model will undergo final evaluation tests in January 1956. Use of one of these radars at Grand Bahama Island will permit tracking beyond burnout of the second stage. Some modifications, considered feasible by RCA, will have to be made to extend the range and tracking rate of the XN-1 model.

Primary consideration is being given to use of the AN/DPN-31 beacon transponder in connection with the AN/FPS-16 radar. A superheterodyne modification kit will be required for the beacon to safely meet the range requirements. Alternative possibilities for procurement of a suitable beacon will be investigated.

Supplementing this radar will be the use of Dovap. AFMTC has agreed to supply ground station services. A MIPR is being prepared for the procurement of Dovap transponders of the type being procured by BRL for IGY use. BRL has indicated that it will run off a small number of these units in its own model shop to meet early Vanguard requirements.

To comply with the AFMTC rocket cutoff and destruction regulation, units of the AN/ARW-59 receivers and KY-55 decoders will be used. One unit is on hand and is being studied for rocket packaging.

Major responsibility for rocket antenna design will be delegated to the Glenn L. Martin Company. However, independent studies are being made by contract with NMCAMA for a cutoff receiver antenna. In addition BRL has indicated an interest in assuming responsibility for the rocket Dovap antennas. All three avenues will be explored.

The status of the range instrumentation equipment may be summarized as follows:

1. Use of AN/FPS-16 radar is being planned, (XN-1) and (XN-2) models will be made available as soon as possible.

2. AN/DPN-31 beacon is being studied as a suitable beacon if a superheterodyne modification kit is available.

3. AFMTC will assume responsibility for Dovap ground stations.

4. MIPR is being prepared for IGY-type Dovap transponders.

5. AN/ARW-59 receivers are being studied for repackaging.

6. Available AFMTC optical coverage will be used.

Data Reduction

AFMTC will assume responsibility for the reduction of optical, radar, and Dovap data. PPM/AM telemetering data will be reduced by NRL. Compatible automatic equipment being manufactured by Radiation Inc., is under investigation. FM/FM data will be reduced by AFMTC. PWM/FM data will probably be reduced by NRL and, should the Radiation equipment be procured, will be done automatically by that equipment.

MINITRACK SYSTEM [Confidential]

General Description

The Minitrack system is a radio system for tracking the satellite regardless of the time of day or weather conditions, and for telemetering from the satellite to a ground recording station. Operating as a phase comparison angle tracking system, it is an outgrowth of radio tracking and guidance developments that have been carried on at NRL since 1952. The Minitrack components within the satellite (including antennas, batteries, transmitter, turn-on receiver, and telemetering modulator) will require less than 6 pounds of weight for an operating period of two weeks. The Minitrack ground stations will include a number of antenna arrays and electronics trailers, communication facilities, and alternate optical tracking equipment (supplied by NAS-IGY). Each of these stations will measure north-south and east-west angular position, and time of transit of the satellite whenever it passes over within about 4 degrees of latitude of a station. System accuracies are heavily dependent on the condition of the ionosphere and the angle of passage of the radio path from the satellite through the ionosphere. Predicted tracking and time resolution errors vary from less than 10 seconds of arc and 4 milliseconds of time resolution, for passes within about 1 degree of latitude of the station between midnight and sunrise, to as much as 1.6 minutes of arc and nearly 100 milliseconds of time for passes that miss the station by 4 degrees of latitude during daylight.

Because of the inclined orbit being considered for Vanguard, a number of Minitrack ground stations will be required. At a maximum orbital inclination of 40 degrees, as preferred by NAS-IGY, a total range of 80 degrees of latitude will be covered by the suborbital satellite point. Each Minitrack ground station can cover a north-south zenith angle of ±45 degrees. At an average satellite height of 300 miles, this corresponds to a total latitude coverage per station of about 8 degrees. For complete coverage 100 percent of the time, 10 stations distributed along a meridian of longitude would be required.

Telemetering will be performed by modulating the Minitrack transmitter by the coded telemetering data on demand from the ground stations, utilizing a turn-on transmitter at the ground. The signal from this transmitter will be received in the satellite on a subminiature receiver. The output stage of this receiver will actuate a relay which will energize the scientific instrumentation circuits, the telemetering coder circuits, and the high-power modulated Minitrack transmitter for a fixed length of time, possibley 60 seconds.

System operation for both the tracking function and the telemetering function of the Minitrack system have been based on a safe usable signal at an 800-mile satellite height.

Minitrack Satellite Components

The Minitrack components within the satellite include a low-power oscillator, a high-power modulated oscillator, a turn-on receiver with relay output, and an antenna system including filters for duplexing, phasing lines for feeding a circularly polarized quadripole antenna, and a switch to select either low- or high-power output. A block-diagram of the Minitrack satellite package is shown in Fig. 9.

Low-Power Oscillator - The low-power oscillator is the primary signal source for the Minitrack system, operating at all times, and radiating at all times except when the telemetering function is called for by the ground turn-on transmitter. It will operate at 108.00 Mc, the Minitrack operating frequency, with a power output of between 10 and 50 milliwatts, unmodulated. Although initially it was considered to be a simple LC oscillator made of

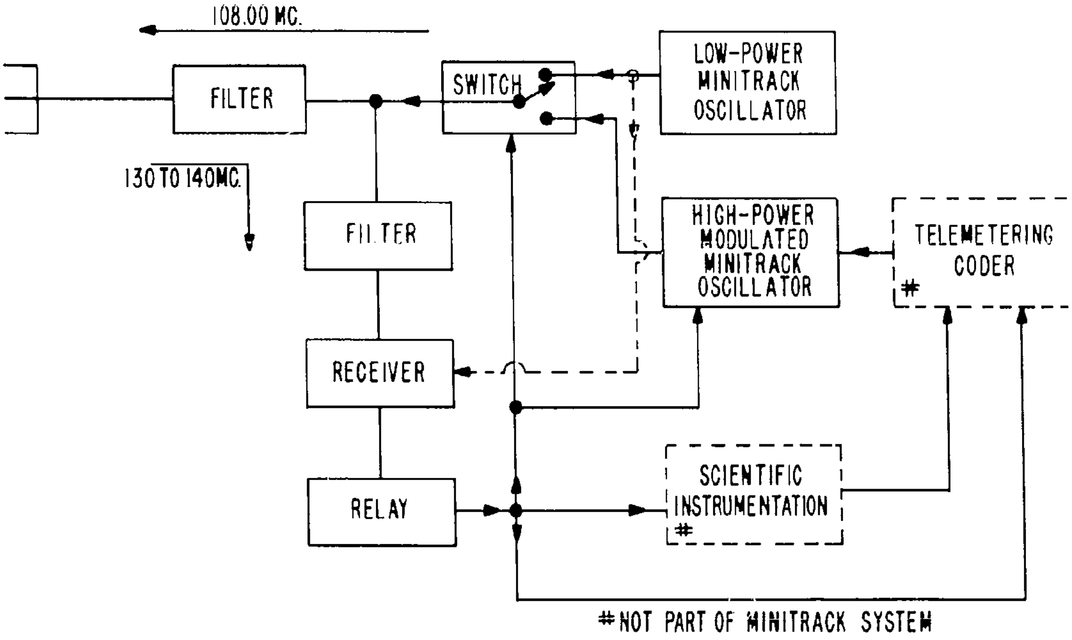


Fig. 9 - Block diagram of Minitract satellite components

stable components, utilization of a crystal control has since been deemed necessary. A variety of units have been made for this application, utilizing subminiature tubes. Because of weight limitations, low filament-drain tubes must be used, such as the type CK 6611. Alternate transistor units have been suggested for this application by Bell Telephone Laboratories as exemplified by the type M2039 and related developments. A development with BTL for this and other satellite package transistors is being initiated through the Bureau of Ships as a participant in the tri-service transistor development at BTL. This development should produce complete transistor oscillator circuits which will be compared with paralled subminiature tube developments now underway. The type that proves most suitable at that time in terms of the satellite environment will be selected for use in the actual flight units. One possible defect with transistors may be the temperature within the satellite package. It now appears that temperatures as low as 0° C can be reached under the best conditions of outside surface finish of the satellite, such as the Alzak treatment. However, any degradation of this surface will either decrease the visible reflectivity, thereby increasing the satellite heat intake, or decrease the heat emissivity, thereby decreasing the heat loss from the satellite. Either of these conditions can only increase the satellite temperature. A definite answer to this problem would have to be obtained before transistors could be utilized. For transistor operation, the operating temperature should not exceed 60° C.

High-Power Modulated Oscillator – The high-power modulated oscillator operates both as a Minitrack source and as a telemetering transmitter during the period when telemetering operation has been commanded by the ground station. It was originally conceived as a modulated amplifier to amplify the low-power oscillator signal, but investigation as to weight efficiency to be expected indicated a saving if a separate crystal oscillator at higher power plus a second modulated amplifier were used. Subminiature tubes utilizing filamentary cathodes of several hundred milliamperes will be used for this unit. The operating frequency will be 108.00 Mc, the power output will be at least 1/2 watt, with 50% amplitude modulation using a 10,000-cycle modulation bandwidth.

Turn-On Receiver – The turn-on receiver receives a signal from the ground turn-on transmitter and actuates a relay in its output stage. This relay in turn switches the antenna from the low-power oscillator to the high-power modulated oscillator and energizes the filaments of the high-power oscillator, the telemetering coder circuits,and the scientific instrumentation. The type of this receiver will depend on the outcome of two developments now under way, one for a superheterodyne receiver utilizing the low-power Minitrack oscillator as its local oscillator, the other for a stabilized super-regenerative receiver. Because of reliability considerations, the outcome now leans toward the superheterodyne unit, although significant weight saving might be possible with the super-regenerative unit. This receiver must be closely tailored to the ground turn-on transmitter and antennas to preclude the possibility of false turn-on signals depleting the satellite battery life. In addition, a very simple coding will be used, consisting of a single audio tone modulating the turn-on signal, to which the audio circuit will be tuned. The operating frequency and the actual tone assigned to the turn-on transmitter will remain at a confidential classification; all other details of the Minitrack system will be unclassified. The operating frequency tentatively assigned is between 130 and 140 Mc with a single audio tone modulation. The output relay of this receiver will have a time characteristic such that the correct tone must be received for at least three seconds before it will actuate, and it will then hold for a predetermined time interval based on telemetering user requirements, probably 60 seconds. For a ground transmitter power of the order of one kilowatt an i-f amplifier voltage gain of about 10,000 will be required.

Antenna System – The antenna system in the satellite will be a circularly polarized quadripole arranged in a plane normal to what was the launching axis of the satellite.

Phase corrections to produce circular polarization will be obtained from a harness of subminiature coaxial cable. Filters to allow duplex operation of this antenna for transmission at 108.00 Mc and reception at the designated turn-on frequency will utilize quarter-wave sections of this same cable. The antenna radiators may consist of lengths of 1/8-inch-diameter double-wrap flexible speedometer cable to allow storage behind the third-stage fairing during the launching phase, with sufficient strength and resilience to prevent snagging or breaking at the third-stage spin and power phase. An rf switch actuated by the turn-on receiver relay is included to transfer the antenna from the low-power to the modulated high-power oscillator during telemetering operations.

Minitrack Ground Stations

The Minitrack ground stations being considered at the present time include six fixed antenna arrays for angle tracking, one fixed antenna array for transmission of the turn-on signal, one directable antenna array for telemetering reception, a rhombic communication antenna, one Minitrack ground station electronics trailer, one telemetering ground station trailer, one communication trailer, an administrative office and bunking building, an optical tracking setup by IGY-NAS, and power generators, vehicle maintenance units, etc. A typical ground station layout is shown in Fig. 10.

Basic requirements are:

1. The area is to be about 23 acres, roughly square.

2. The gradient of the land is to be less than 1 degree in the region of the Minitrack antenna layout.

3. The adjacent terrain must not exceed an elevation angle of 10 degrees for at least 1/2 mile, nor 20 degrees for 5 miles, referred to the center of the Minitrack antenna layout.

4. The site must be as near as possible to alternate roads but at least 2 miles from heavy electrical power installations and at least 5 miles from airports or airways.

5. The area should have better than average visibility for optical tracking.

The Minitrack ground station antennas will be located along the two arms of a cross, which is oriented in an east-west/north-south direction, as was shown in Fig. 10. Antennas A1, A2, and A3 are used to measure the angular position of the satellite in the east-west direction, and antennas A4, A5, A6, and A7 are used to measure the angular position of the north-south direction. Antennas A1 and A3, and A4 and A7 are separated by roughly 500 feet, or 50 wavelengths at 108.00 Mc, to permit "fine" angular measurements good to about 10 seconds. Ambiguity resolution across the ±6-degree east-west beam pattern is provided by antenna pair A2 and A3, separated by 50 feet, or 6 wavelengths. Ambiguity resolution across ±6 degree in the north-south angle is provided by antenna pair A5 and A7, separated by 50 feet, and across ±45 degree in this direction by antenna pair A5 and A6, separated by $7\frac{1}{2}$ feet (3/4 wavelength).

The Minitrack ground station antennas will be 12-element arrays above a fixed ground plane, with dimensions of about $7\frac{1}{2}$ feet by 55 feet. At the operating frequency of 108.00 Mc, these arrays will have a gain of 16 db above isotropic, with beamwidths at the 6-db points of 90 degrees in the north-south direction and 12 degrees in the east-west direction. A corporate feed structure will be used in the phasing harness, and will be designed to give minimum side lobes at an angle of 70 to 90 degrees from the pattern axis. A primary

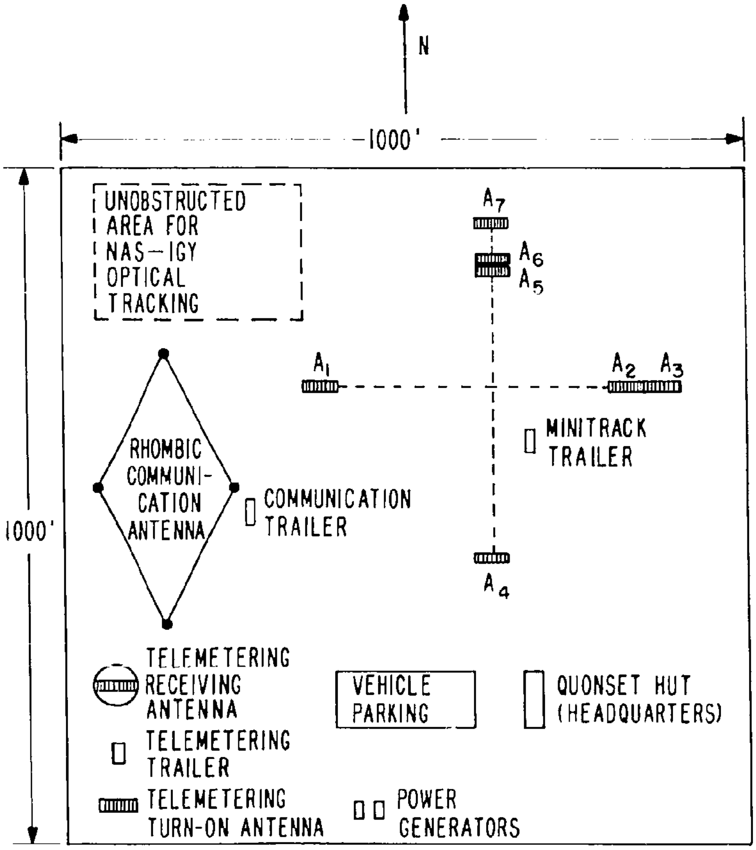


Fig. 10 - Minitrack ground station layout plan

design aim in these antennas is the requirement for constancy in the far-field phase contour of the array, within ±1 degree. This is required because pairs of these antennas are used in a phase-comparison system where differences in the phase-patterns of the two antennas in the pair would appear as a change in the angular position of the source. Specifications for these antenna arrays have been completed. Invitations to bid were mailed early in December 1955. It is expected that the first six antenna arrays will be available for test by 1 July 1956.

The telemetering turn-on antenna will be a similar array designed for use between 130 and 140 Mc. Since no requirements have been set up for a constant phase contour, no problems are anticipated in its design. The telemetering receiving antenna will be similar to the Minitrack ground station arrays, but without the precision of phase contour. This antenna, however, will be mounted so that its axis can be changed from east-west to north-south after the orbit has been determined, to change the major axis of the fan beam from north-south to east-west. This is required to permit a longer period of telemetering than would be possible with a 12-degree beamwidth. This mount will require tilting after rotation to align its axis with the north-south zenith angle predicted for the next passage of the satellite.

The Minitrack ground station electronics will be mounted within the Minitrack trailer. The equipment will be operated continuously to eliminate thermal shocks due to filament turn-ons, and to maintain a constant operating temperature. The trailer will be air conditioned to further aid in establishing a constant temperature. Present plans call for an operating console combined with two racks to house all of the ground station electronics.

Six receivers, five phase-measurement circuits, five recording phase-measurement circuits, and five recording phase-meters will be required to provide the north-south and east-west angular position of the satellite without ambiguity. A block diagram of the receiver unit of the Minitrack ground station is shown in Fig. 11, and of the phase measurement and recording units in Fig. 12.

In the receiver unit, each antenna has a 108-Mc preamplifier mounted at the antenna array to amplify the signal sufficiently to allow it to be fed over a maximum of 500 feet of coaxial line to the Minitrack trailer. These units will have low gain, not over 20 db, to minimize differential phase shifts between operating pairs. They will utilize two GL 6299 low-noise amplifier triode tubes. Within the receiver units proper, double conversion is utilized to allow a narrow predetection bandwidth and good image rejection. This is necessary because of the extremely low signal levels to be expected from the satellite compared to other existing signals on both sides of the 108.00-Mc operating frequency. The first conversion, from 108.00 Mc to 10 Mc, is obtained by using a special local oscillator unit that provides two frequencies phase-locked at a 500-cycle difference frequency. Immediately after this conversion, antenna channel pairs are added and further amplification is accomplished in a single amplifier channel to eliminate differential phase distortion. After amplification at 10 Mc, each channel is converted to 0.5 Mc using a conventional single 9.5-Mc local oscillator, which is a component in the special local oscillator. After final high-gain amplification in a 0.5-Mc amplifier each channel feeds a square-law detector, thus generating a 500-cycle signal whose phase, compared to the phase difference between the two special local oscillators, is exactly the same as the original phase difference that existed between the signals received at each antenna of the antenna pair constituting the channel. These signals from each antenna pair channel, plus the 500-cycle special local oscillator difference or reference frequency is fed to the phase-measurement and recording unit. The 500-cycle frequency to which the special oscillator unit is referred is obtained from the phase-measurement and recording units. The bandwidth of the 0.5-Mc i-f amplifier will be about 10 kc.

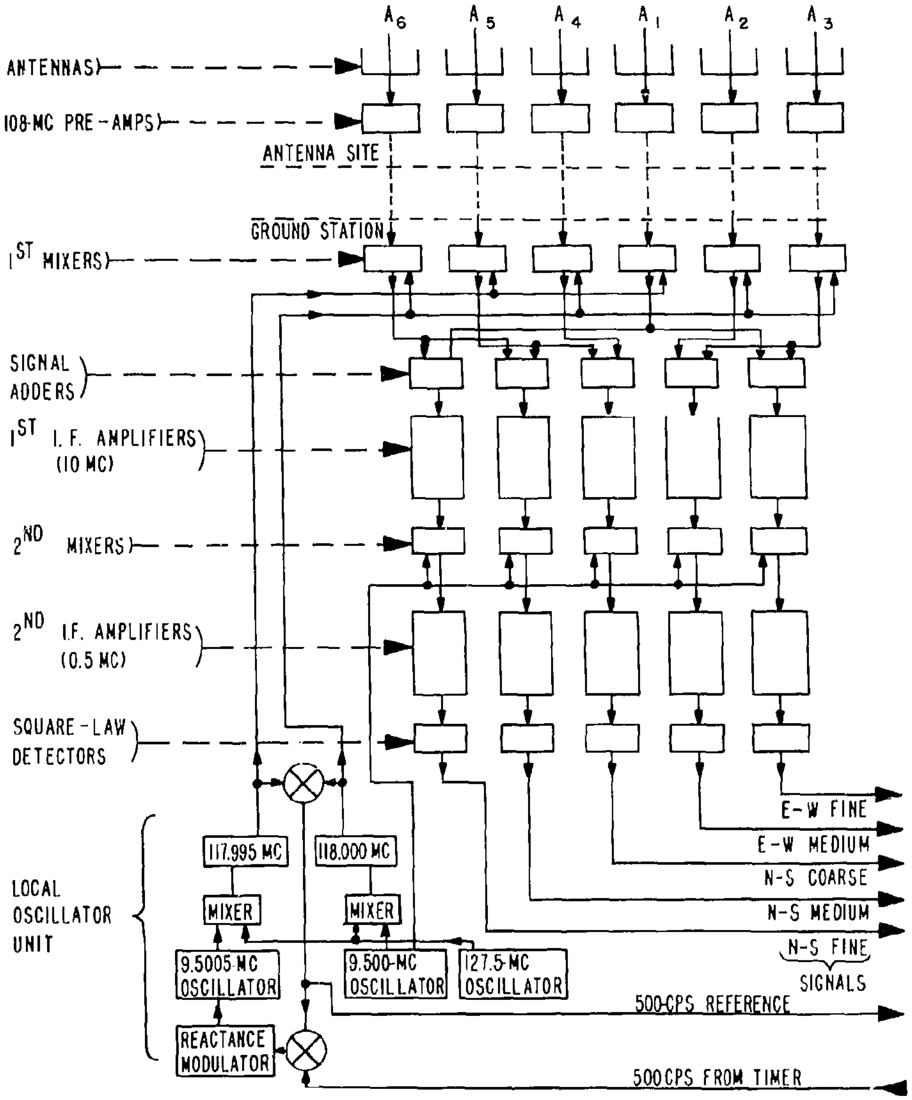


Fig. 11 - Block diagram of Minitract receiver unit

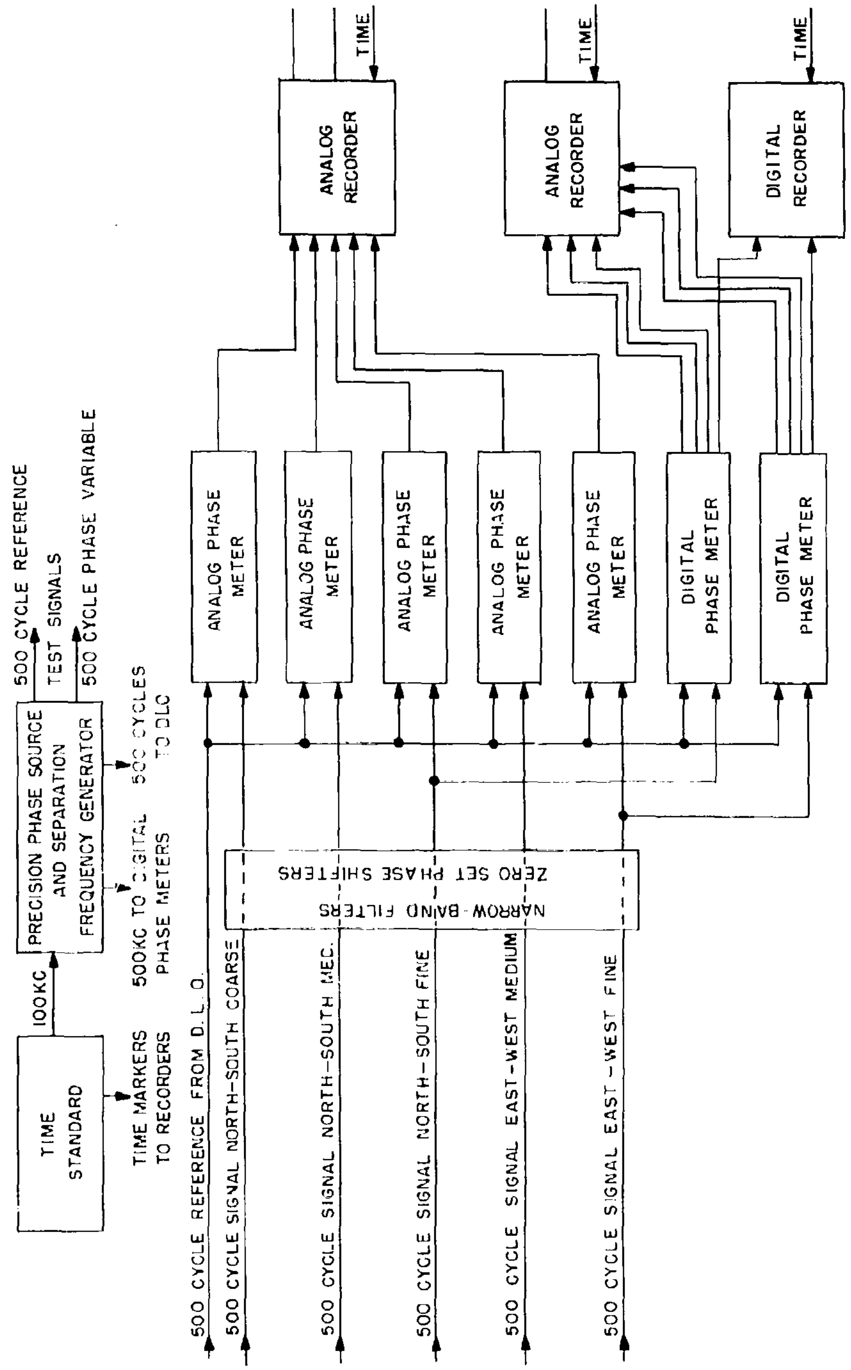


Fig. 12 - Block diagram of phase measurement and recording units

The phase-measurement and recording units (Fig. 12) include a time standard, a precision phase source, five phase meters, and five recorders. The time standard serves both as an absolute time standard at the station and as a source of synchronous 500-cycle frequency for locking the special oscillator unit. This unit will be maintained against station WWV at least once per day, and should have a drift rate over 24 hours of less than 1 millisecond. The precision phase source furnishes the necessary 500-cycle phase-variable calibration signals for system alignment, as well as an alternate source of 500 cycles for use as the locking frequency for the special oscillator unit.

The 500-cycle reference signal from the special oscillator goes directly to the seven phase meters. The five 500-cycle signals from the respective antenna pairs pass through narrow-band filters and zero-setting phase shifters. Both analog and digital phase meters and recorders are used. The analog recorders, upon which the analog data will be presented directly, will also be used to record digital data in decimal form. The analog recordings are sufficiently accurate for course resolution and for immediate indication of the character of the fine data. The digital data will be presented on the direct writing recorders 10 times per second for immediate readout of the fine data and 100 times per second on an additional digital recorder. The digital recorder, used as a backup recorder, will record the digital outputs in binary decimal form on 35- or 70-mm film in a form suitable for automatic readout.

A system analysis of the Minitrack angle tracking system is based on the following parameters.

1. A phase-detector signal-to-noise ratio of 30 db, corresponding to a phase resolution of 1.8 degrees, or 10 seconds of space angle.

2. Ground antenna gain $G_r = 40$; based on a $7\frac{1}{2}$-by 55-foot array of 12 dipoles, having a beamwidth of 90 by 12 degrees at the 6-db points.

3. Satellite antenna gain $G_t = 0.5$; based on a planar turnstile array of 4 elements approximately 1/4 wavelength long.

4. Satellite transmitter power $P_t = 10$ milliwatts.

5. Wavelength $\lambda = 2.8$ meters at 108.00 Mc.

6. Maximum range $R = 800$ miles or 1280 kilometers.

7. Predetection bandwidth $B = 10$ kc; based on a transmitter stability obtained from a crystal controlled oscillator.

8. Post detection bandwidth $B_d = 10$ cps; based on the required velocity resolution for angular rates up to 1.5 degrees per second.

The received signal power is

$$P_r = \frac{P_t \, G_t \, G_R \, \lambda^2}{(4\,\pi R)^2} = 6 \times 10^{-15} \quad \text{watts.}$$

A noise analysis of a phase comparison detector system as a function of predetection and postdetection bandwidths has been made by J. J. Freeman (NRL Report 4598). Based on this report, the received power required for the conditions stated is 3×10^{-16} watts, giving a safety factor of $6 \times 10^{-15}/3 \times 10^{-16}$ or 20 times (13 db) at 800 miles. The safety factor becomes 250 (24 db) at 200 miles.

The telemetering components at the Minitrack ground station will include a telemetering trailer, the telemetering turn-on antenna (already described), and the telemetering receiving antenna (already described). The telemetering trailer will house the telemetering receiver, the decoding and recording units, and the turn-on transmitter. The decoders and recorders will depend on what type coding is used in the satellite by the scientific research groups and will follow well known techniques. The telemetering turn-on transmitter will be a single-tone amplitude-modulated unit of about 1-kw output power. It is planned to aim the telemetering turn-on antennas slightly westward so that the satellite intercepts the turn-on beam at least five seconds before it intercepts the Minitrack antenna beam. Because of the proximity of the turn-on antenna and transmitter to the ultrasensitive Minitrack receiver-antenna units, a time-sharing method of operation must be resorted to, whereby the Minitrack input circuits are disabled while the turn-on transmitter functions. It is planned to have a telemetering station at all Minitrack ground stations.

A telemetering system analysis is based on the following parameters:

1. A detector signal-to-noise ratio of 20 db for usable system operation.
2. A receiver noise figure of 4 db.
3. Ground antenna gain $G_r = 40$.
4. Satellite antenna gain $G_t = 0.5$.
5. Satellite transmitter power $P_t = 0.5$ watt.
6. Maximum range $R = 800$ miles $= 1280$ kilometers.
7. Bandwidth $B = 10$ kc.
8. Wavelength $\lambda = 2.8$ meters.

The received signal power is

$$P_r = P_t \frac{G_r G_t \lambda^2}{(4\pi R)^2} = 3 \times 10^{-13} \text{ watts.}$$

The signal power in a 10-kc bandwidth to be equal to the noise is 4×10^{-17} watts, or 164 db below 1 watt. For a 20-db signal-to-noise ratio, using a 4-db receiver, the signal level required is 140 db, or 10^{-14} watts. Thus a safety factor of $3 \times 10^{-13}/10^{-14}$ or 30 times or about 15 db exists above the minimum system requirements.

The communication facilities at the ground stations include a large rhombic antenna and a communication trailer. An arrangement of communication nets has been set up as follows:

Orbital Data Net: This net will be used for transmission of the primary tracking data back to a central computation facility within 20 minutes of a tracking event. This information should have priority on its assigned channels over all but distress messages. Between five and ten clear channel assignments will be required, spaced between 3 and 30 Mc. All data will be transmitted by teletype equipment.

Scientific and Administrative Net: This net will be joint with other routine operations on existing nets. Between five and ten channels spaced between 3 and 30 Mc will be required. This net will be used for the exchange of technical data and for administrative communication between the field stations and between the field stations and NRL.

Backup Amateur Net: This net would be for emergency use, and would utilize amateur radio operators at the field stations to transmit to amateurs in the vicinity of Washington, D.C., via the amateur bands.

Station Layout

A total of eight Minitrack stations including an operating test station at the Chesapeake Bay Annex of NRL are now contemplated, spaced at approximately 10-degree intervals of latitude from Washington, D. C. to below Valparaiso, Chile. With this spacing, a probable data recovery of 60 percent should be realized for an orbital altitude of 200 miles at an inclination angle of 40 degrees. For orbital altitudes of 350 miles at this same inclination, the probable data recovery is 100 percent. An additional station in the vicinity of the island of Barbuda in the Leeward Islands will provide the initial tracking data after the orbit is attained. Figure 13 shows the geographic locations of the contemplated stations.

Time Schedule

The Minitrack development program is based on an intensive equipment test and modification program, and personnel training program at the Chesapeake Bay Annex of NRL. At this location, a complete Minitrack system will be in operation by mid-spring of 1956. All components of the system to be used at the field stations will be tested and evaluated at this test site, and modified on the basis of these tests. The complete prototype system will be tested here prior to the construction of the final field station components by a contractor. All final field station components, exclusive of antennas, will be tested at CBA against balloon-borne and airborne transmitters to give a final check to this equipment. It is planned to have representatives of the equipment contractor present during the latter stages of testing to familiarize them with the operating characteristics of the equipment. It is also planned to have the senior members of the field crews in attendance during the final test period, as well as when the field equipment for their station is being tested.

In addition to the Minitrack system, a so-called "Poor Man's Minitrack" has been proposed to provide a system suitable for use by organizations of limited means to track the satellite electronically. By use of this system, accurate transit times should be possible at any sub-orbital location where accurate timing and means of determining the vertical system pattern are available. The system utilizes a minimum of specialized components, and is peculiarly suited to the measurement of transit times of a moving body of relatively constant angular rate. The system, shown in Fig. 14, is comprised of only two "fine" antennas with no ambiguity resolution, feeding a hybrid junction and a simple AM receiver-detector-recorder system. This same system can be used to give ambiguity resolution and north-south angular information by the use of additional antennas and receivers. As the satellite passes across the pattern of these antennas, it produces a null at one output of the hybrid whenever the signals at the hybrid inputs are 180° out of phase, and a null at the other output when the signals are in phase. Thus, a null is produced at each output for every wavelength change in the angle of arrival of the signal to the two antennas, corresponding to about 1 degree of space angle for a 500-foot separation of the antennas. Tests indicate that this null can be measured to an accuracy of a few degrees of phase, corresponding to about 0.5 minute of space angle. The system has the advantage

Fig. 13 - Geographic station locations of the Minitract system

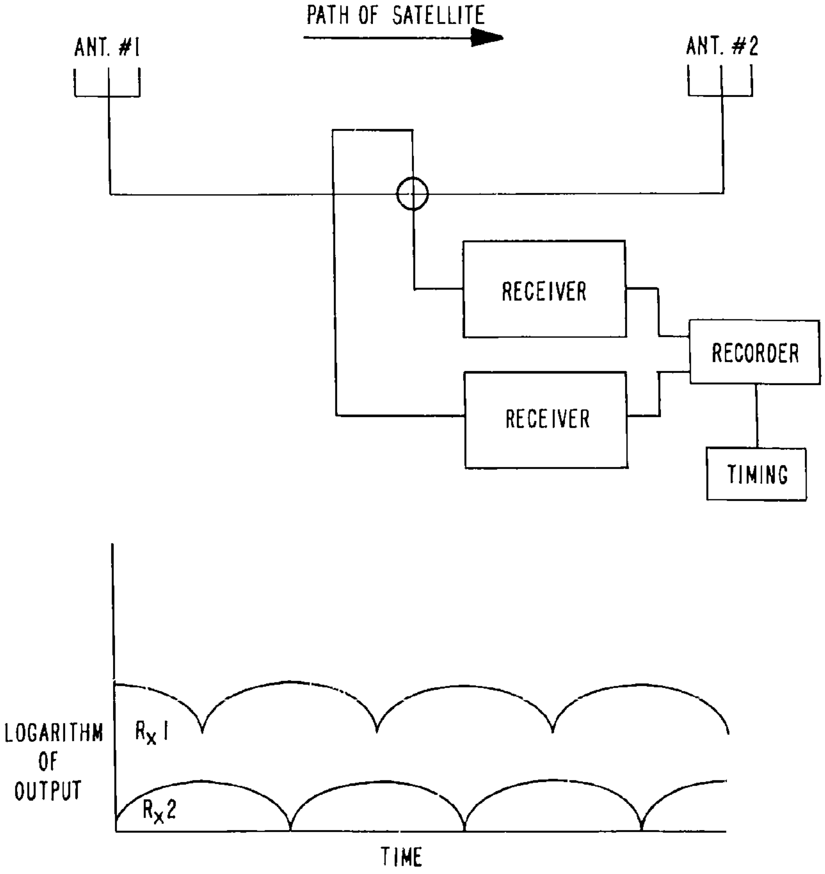


Fig. 14 - Poor man's Minitrack

of having no active components which can change the differential phase at the recorder. Tests of this system are being continued in the hope that such a system design can be published to permit trained electronics groups, such as are found in universities and scientific societies around the world, to produce such systems for a cost of about $10,000.

The Minitrack system as described will be capable of angular accuracies of between 10 seconds and 1.6 minutes of space angle, depending on the ionosphere and the zenith angle to the satellite. This prediction is based on a simulated ionosphere according to Seddon. Electron densities were based on those existing during similar sun-spot periods in 1947. The errors stated are due entirely to the frequency used, and could be reduced by approximately the square of the frequency ratio if a higher frequency were used. Thus, with a 324-Mc frequency, accuracies nine times better than those predicted, or about 11 seconds, would result under the worst conditions of measurement, and a possible improvement to about 3 seconds under the best conditions. Inasmuch as these accuracies approach those expected from optical tracking methods, and would be available any time a passage over a ground station occurred, a method of meeting them is being considered. This method would make use of the turn-on transmitter already included in the system to turn-on a 324-Mc transmitter as the high-power modulated transmitter. At the ground stations, three more antenna arrays of 1/9 of the area of the 108.00-Mc units, spaced at 660 feet (200 wavelengths) would be used to pick up these signals. The present form of the Minitrack antennas would serve as ambiguity resolution for these higher frequency units. The Minitrack ground station racks are presently being designed to include provision for the two additional phase comparisons that would be required for the adoption of this system.

OPTICAL TRACKING [Confidential]

Optical tracking of Vanguard satellites will be primarily for scientific objectives. The optical tracking program has been budgeted for and is being organized by the Technical Panel of the Earth Satellite Program of the U.S. National Committee for IGY. No funds have been allocated to the program as of January 1956 but it is expected that funds will be available by early spring.

The TPESP has established a special committee, now under the chairmanship of Lyman Spitzer, to oversee the optical program. The TPESP is asking the Smithsonian Astrophysical Observatory to start the actual organization of the optical tracking and data reduction program. It is currently intended, subject to further deliberation, to ask the SAO to continue management of the optical program throughout IGY. It has been stipulated by TPESP that those responsible for the optical program will work closely with Vanguard personnel.

In addition to the scientific research objectives, there are Vanguard requirements for optical tracking. For example, it will be necessary to boresight the Minitrack antennas. Current plans are that where possible optical tracking and minitracking will be done at the same sites. A request will be made to TPESP to furnish services for the small amount of optical tracking required by Project Vanguard.

The optical tracking program can also serve Project Vanguard as a backup in case the radio tracking fails. For this reason the radio and optical tracking and data reduction programs should be carefully coordinated and integrated. Vanguard personnel will work closely with the TPESP to effect the required coordination and integration.

Since the TPESP optical program is still only in the formative stages, it is not yet possible to present any firm plans. The TPESP Optical Tracking Committee has been reviewing various techniques, and tentatively concludes that photographic methods may be possible, and if so, would be desirable. This is being studied further. As stated above, plans are to set up optical stations at Minitrack locations insofar as seeing conditions and other pertinent factors will permit. There will also be a number of optical tracking stations at other locations as yet undetermined. In addition it is planned to enlist professional and amateur astronomers throughout the world in the observing program. The organizational details are still being worked out, but presumably the Astronomical Centers at Harvard and Copenhagen would be used in some way.

THE SCIENTIFIC PROGRAM [Confidential]

Introduction

The scientific program of studies planned for the initial Project Vanguard satellites comprises two categories: physical researches and studies of the environment encountered by the satellite vehicle and its payload.

A considerable number of physical researches suggest themselves for inclusion in the limited payload of the first earth satellites. At the present time, two experiments recommend themselves as being well suited for the initial Project Vanguard satellites. One experiment will study the variation in solar Lyman alpha radiation intensity from one revolution to the next. The second experiment will study the cosmic-ray rigidity spectrum and observe time variations in the cosmic-ray intensity.

In order to conduct experiments such as these successfully, it will be essential to possess an adequate knowledge of the environment to be expected in the satellite vehicle itself. For example, it is important to know the temperatures and pressure which will be encountered by experimental apparatus mounted in the satellite. Such a need arises in connection with the use of transistors. Transistorized circuitry is extremely light and hence ideally suited for satellite installations. On the other hand, transistors are temperature sensitive, hence they are practical only if satellite temperatures fall within certain limits. Pressure levels inside the satellite will be functions of gross properties of the surface, such as its ability to resist puncture by meteoric particles. The temperatures experienced in the orbiting vehicle will be functions of the radiation and absorption characteristics of the surface. Surface conditions will also affect the ability to see and track the satellite. Accordingly, actions of meteoric and micrometeoritic particles and atmospheric ions upon the satellite surface should be known. These environmental effects can be estimated. Ultimately, however, knowledge of environment should be based upon appropriate observations made in the satellite itself. Accordingly, several environmental studies will be made in the early Vanguard satellites. These will include measurements of surface erosion, surface and internal temperatures, and internal pressures.

Data obtained in the satellite will be sent to stations on the earth by means of a radio telemetering system. This system will be operated in conjunction with the Minitrack radio tracking system.

Detailed planning of the program which has been outlined is under way.

Each of the individual aspects of the program is considered in the following discussion of the experiments and the instruments as they are presently conceived. It is expected that a number of the details will continue to be modified as the work progresses. In its main features, however, the program of investigations planned for the early Project Vanguard satellites is considered to be feasible, and gives promise of yielding much worthwhile information.

The Satellite

The satellite vehicle system would include two concentric spheres, the outer or surface sphere, and a smaller central sphere, about a foot in diameter, which would house much of the research instrumentation. Each sphere would be pressurized independently with helium and welded seals would be used throughout. However, the various equipments would be designed so as to operate even though the outer sphere loses its pressure.

The orbiting satellite vehicle will weigh in the neighborhood of 10 kilograms. Approximately one-tenth of this weight will be devoted to the instruments for conducting the physical researches and the environmental studies. According to present thinking, one satellite would include the Lyman alpha experiment, while a second would include the cosmic-ray experiment. The environmental studies would probably be conducted in both vehicles.

The environmental instrumentation, per se, would weigh about 100 grams. It is estimated that the Lyman alpha instrumentation would weigh about 600 grams, and that the cosmic-ray instrumentation would weigh about 300 grams. A battery pack weighing about 200 grams should serve the needs of both the physical experiment and the environmental studies. Thus, the complete scientific installation in the satellite carrying the Lyman alpha experiment would weigh approximately 900 grams, or about two pounds. The corresponding total for the cosmic-ray satellite would be expected to be somewhat less.

Temperatures between 5° and 50°C would be acceptable to all of the items operating in the satellite but the primary limitation is imposed by the transistor characteristics. More advanced transistors probably will be able to operate successfully in the range from -20° to +80°C. It is expected that this temperature range can be maintained within the central sphere provided the surface sphere is coated with an appropriate material such as ALZAC. This material is highly reflective to solar radiation, yet highly emissive with respect to infrared radiation.

Spin rates between 250 and 400 rpm will probably occur in the Vanguard satellites. It is expected that the various equipments proposed can be designed to withstand the accelerations to which they would be subjected in these vehicles.

The telemetering system will be tied in with the Minitrack system, although a number of components will be provided specifically for the telemeter. The telemetering transmitter will be turned on with the aid of the Minitrack system. Following a warm-up period of a few seconds, it will enter the beam of the ground receiving antenna. It is estimated that the telemetering reception interval during each revolution will be at least eight seconds long at 200 miles (perigee). It may be possible to increase this to as much as a minute at 200 miles.

A commutator using ferrite or transistor components would be used to sample the environmental study instruments at the beginning of each interval of telemetering transmission. The remainder of the time would be devoted to providing a continuous channel for use with either the Lyman alpha or the cosmic-ray experiments.

Physical Researches

The Lyman Alpha Experiment - This experiment has been proposed by Dr. H. Friedman and his colleagues of the Electron Optics Branch of the NRL Optics Division. The object of experiment is to determine the maximum variation in the intensity of solar Lyman alpha radiation during each revolution of the satellite. The experiment would thus reveal short time variations in the average Lyman alpha emission. It would record flare peak intensity throughout the daylight portions of the flight with a dynamic range of at least 100.

An ion chamber has been developed which is sensitive to only the narrow region of the spectrum centered on the Lyman alpha line of hydrogen. Sensitivity and speed of response are adequate for monitoring the normal level of Lyman alpha radiation and the increase expected with flare activity. The instrumentation would include circuitry for storing the peak signal developed by the detector during each revolution of the satellite around the earth. This signal would be read out at the start of a 5-second telemetering interval and would be followed by instantaneous observation of solar Lyman alpha radiation for the remainder of the telemetering interval. Included for the purpose of determining aspect relative to the sum would be a photocell whose information would also be telemetered. The minimum time required for the reading out of all information would be 5 seconds.

The instrumentation would weigh approximately 600 grams and occupy a volume of about 500 cubic centimeters. It would be capable of operating continuously for 500 hours:

The Cosmic-Ray Experiment - The cosmic-ray experiment planned by L. H. Meredith of the Rocket Sonde Branch of the NRL Atmosphere and Astrophysics Division would seek to investigate the rigidity spectrum of primary cosmic rays. The magnetic field of the earth sorts out cosmic rays according to their magnetic rigidity. By measuring the primary cosmic-ray intensity of various geomagnetic latitudes from a satellite, it is possible to study the rigidity spectrum. A Geiger counter would be used to make these measurements.

Data storage, obtained by the use of ferrite cores, probably would be used to measure total flux during an entire orbit interval. The core would then be "read out" at the beginning of the telemetering interval and the instantaneous rate telemetered during the remainder of the interval.

Environmental Studies

Temperature Measurements - Thermally, the early Vanguard satellites are expected to consist of two regions, the external surface region, and a central insular region housing the main concentration of instruments. The temperature of the surface is expected to vary rather widely as the satellite passes successively through daytime and nighttime conditions.

The instrumentation island would be thermally insulated from the skin and would have a relatively large heat capacity so that its temperature excursions around the orbit would be relatively small.

It is planned to mount a pair of thermistors on the surface, and one thermistor on the instrument island to measure temperatures.

Pressure Measurements - Three snap switches for measuring pressures would be installed inside the surface sphere, which would be launched in a pressurized condition. These would give signals at the times at which the pressure dropped below three preselected values; for example, these could be set to operate at 600, 300, and 50 mm Hg. The final signal would also start the operation of a Pirani gage which would read pressures in the range from 1 mm Hg to 10^{-2} mm Hg. This instrumentation would permit determination of leakage rates.

It should be possible to distinguish leakage due to imperfections in welding and sealing from leakage due to meteoric punctures.

Surface Erosion - It is planned to coat a portion of the outer surface of the satellite with a material having suitable electrical resistance characteristics. This surface would form a circuit element. As it is eroded and decreased in thickness, its resistance would increase. Thus, it would be possible to obtain measures of the erosion rates.

* * *

APPENDIX A
Memorandum from the Secretary of Defense

COPY

THE SECRETARY OF DEFENSE
WASHINGTON

SECRET

Sep 9 1955

MEMORANDUM FOR THE SECRETARY OF THE ARMY
THE SECRETARY OF THE NAVY
THE SECRETARY OF THE AIR FORCE

SUBJECT: Technical Program for NSC 5520 (Capability to Launch a Small Scientific Satellite During IGY)

REFERENCES: (a) Deleted

(b) Deleted

1. The National Security Council Report 5520 provides for a program to launch a scientific satellite during the period of the International Geophysical Year (July 1957-December 1958). The implementing directive charges the Secretary of Defense with the over-all responsibility of the scientific satellite program as delineated in NSC 5520, and the Assistant Secretary of Defense (R&D) has been assigned the responsibility for coordinating the implementation of the scientific satellite program within the Defense Department by reference b.

2. In carrying out the technical program preliminary to launching the satellite, the following course of action is approved:

a. A joint three-service program be established to produce and launch a small scientific satellite based on the Navy proposal involving the improved Viking (booster), Aerobee-Hi (second stage), solid-propellant modified Sergeant (third stage).

b. The Navy Department will manage the technical program with policy guidance from the Assistant Secretary of Defense (R&D) and will provide the funds required to implement the action in a above with the understanding that reimbursement will be made as soon as funds can be made available from other sources.

c. The Departments of the Army and Air Force will participate in the prosecution of the technical program and will assign appropriate priorities to permit attainment of the schedule to be established by the Navy for such work. Any major interference resulting from such priorities will be brought to the attention of the Assistant Secretary of Defense (R&D).

d. The Assistant Secretary of Defense (R&D) will continue the Technical Advisory Group already established to advise the ASD (R&D) and the military departments on the technical program.

SECRET 1 SecNav Cont. No. S-2303
S-229

3. Any departmental interest or requirement in connection with the scientific program of observation after satellite launching will be programmed by the military departments in accordance with existing policies and procedures.

4. It is requested that the addressees, as appropriate, provide for the immediate implementation of the action above. The Secretary of the Navy is also requested to advise the ASD(R&D) as soon as practicable of the detailed plan for undertaking the technical program and for coordination of that program with the other military departments.

5. In order to provide for the coordination of inter-agency matters and the exchange of information on this program with other government agencies, separate action is being taken to establish a coordinating group under the chairmanship of the Assistant Secretary of Defense (R&D) with membership to be invited from State, Central Intelligence Agency, National Science Foundation and National Academy of Sciences.

6. The international scientific purposes, the classified military-related rocketry, and the political and propaganda aspects of this program pose special problems with regard to security classification and information release. The following principles apply:

a. The classification of equipment and techniques pertaining to the launching and rocketry which are common to military weapons systems will be governed by the security classification of the military weapons.

b. Information regarding the satellite itself, any inclosed instrumentation, the orbit and other items relating to the scientific program will be unclassified, at least by time of launching.

c. All information material intended for public release relating to this project will be submitted to the Office of Security Review. In this regard the Department of Defense is operating under the specific guidance of the Operations Coordination Board. Information on military participation in the program and possible relationship to military programs will be kept to a minimum.

REUBEN B. ROBERTSON, JR.,
DEPUTY

APPENDIX B
Letter from the Secretary of the Navy

SECRET

COPY

SECRET

27 Sept 1955

From: Secretary of the Navy
To: Chief of Naval Research

Subj: Technical Program for NSC 5520 (Capability to Launch a Small Scientific Satellite During IGY)

Encl: (1) Sec Def Memo of 9 Sep 1955, same subject

1. Enclosure (1) allocates responsibility for the subject program.

2. The Chief of Naval Research is hereby directed to execute that portion of the program assigned to the Navy.

3. The Chief of Naval Research should prepare for secretarial signature the reply required by paragraph 4 of enclosure (1).

J. H. SMITH, Jr.

Assistant Secretary of the Navy (Air)

SECRET

00900

APPENDIX C
Letter from the Child of Naval Research

SECRET

COPY

DEPARTMENT OF THE NAVY
OFFICE OF NAVAL RESEARCH
WASHINGTON 25, D. C.

ONR:101:aaj
Ser 001270
6 October 1955

SECRET

From: Chief of Naval Research
To: Director, Naval Research Laboratory

Subj: Technical Program for NSC 5520 (Capability to Launch a Small Scientific Satellite During IGY)

Encl: (1) Copy #2 of SecNav Secret ltr of 27 Sep 1955 - SecNav Control No. S-2437

1. Enclosure (1) is forwarded for retention. A copy of the SecDef memo of 9 September 1955 on the same subject has been forwarded previously.

2. The Director, Naval Research Laboratory is requested to proceed with the prosecution of this project and to furnish to the Chief of Naval Research information on which to base the report required by paragraph (4) of the SecDef memo of 9 September 1955.

F. R. FURTH

SECRET

00900

APPENDIX D

Project Vanguard Master Plan

[Confidential]

The broad outline of a master plan has been prepared and is presented here; the dates shown are the present estimates of the completion of the various items. The plan will be one to which the contractors and the other participating agencies contribute, but it is the responsibility of the Naval Research Laboratory to prepare the final plan as a guide in the management of the program.

	1955	1956	1957
A. DEFINITION OF MISSION			
I. Time Scale	Sept 9		
II. Satellite Specifications	Oct 21		
III. Selection of Orbit		Feb 1	
IV. General Configuration of Launching Vehicle	Sept 23		
V. Methods of Orbit Determination	Nov 9		
VI. Scientific Experiments (first satellite)		May 1	
B. ORGANIZATION			
I. Project Organization	Sept 1		
II. Acquisition of Personnel		July 1	
III. Budget and Funding		Jan 1	
IV. Necessary Priorities		Jan 1	
V. Selection of Major Contractors			
a. Vehicles		Feb 15	
b. Minitrack		Oct 1	
c. Telemeter		Feb 15	
C. LAUNCHING VEHICLES			
I. Contracts and Specifications			
a. Prime contractor			
1. Initiating contract	Sept 23		
2. System specifications	Nov 18		
3. Final contract		Jan 16	
b. First-stage power plant			
1. Preliminary design specification	Oct 1		
2. Initiating contract	Oct 1		
3. Model and test specifications		Jan 15	
4. Final contract		Jan 16	

	1955	1956	1957
c. Second-stage power plant			
1. Preliminary design specification	Nov 14		
2. Initiating contract	Nov 14		
3. Model and test specification		Jan 15	
4. Final contract		Jan 16	
d. Third-stage power plant			
1. Preliminary design specification	Oct 15		
2. Initiating contract	Nov 1		
3. Model and test specifications		Jan 15	
4. Final contract		Jan 16	
II. Vehicle Design			
a. General		Feb 15	
b. Propulsion			
1. First stage			
(a) System design		Mar 1	
(b) Component design		Mar 15	
(c) Component design tests		Apr 1	
(d) System design tests		May 1	
(e) Qualification tests		Aug 1	
(f) Acceptance tests		Aug 1	
(g) Deliveries (first unit)		Aug 31	
2. Second stage			
(a) System design		Feb 1	
(b) Component design		Feb 15	
(c) Component design tests		Aug 1	
(d) System design tests		Aug 15	
(e) Qualification tests		Oct 31	
(f) Acceptance tests		Oct 31	
(g) Deliveries		Nov 30	
3. Third stage			
(a) System design			
(b) Case and nozzle design			
(c) Design tests			
(d) Qualification tests			
(e) Acceptance tests		Oct 15	
(f) Deliveries		Nov 1	
c. Flight-path control			
1. System design		June 1	
2. Component procurement		Oct 1	
3. Breadboard tests			Jan 1

	1955	1956	1957
4. Prototype tests			Apr 1
5. System tests			May 1
d. Instrumentation (end organs)			
1. Data requirements		Jan 15	
2. Instrument selection		Mar 15	
3. Instrument procurement (Viking 14)		Aug 1	
III. Design Test Facilities and Equipment			
a. Facilities			
1. Prime contractor		Aug 1	
2. First-stage power-plant contractor		Dec 1	
3. Second-stage power-plant contractor		Dec 15	
4. Third-stage power-plant contractor		Mar 15	
b. Test equipment			
1. Prime contractor		Aug 1	
2. First-stage power-plant contractor		Dec 15	
3. Second-stage power-plant contractor		Dec 15	
4. Third-stage power-plant contractor		Mar 15	
IV. Manufacture and Acceptance			
a. Viking 13		Aug 1	
b. Viking 14		Oct 1	
c. Vanguard test vehicle 1		Dec 1	
d. Vanguard test vehicle 2			Feb 1
e. Vanguard test vehicle 3			Apr 1
f. Vanguard test vehicle 4			June 1
g. Spare test vehicle 1			Jan 15
h. Spare test vehicle 2			Mar 15
i. Spare test vehicle 3			May 15
j. Satellite launching vehicle 1			Aug 15
V. Field Test Preparation			
a. Test plans	Nov 14		
b. Facilities			
1. Hangar		June 15	
2. Blockhouse		July 1	
3. Launching mat		July 1	
4. Gantry		July 1	
5. Static test structure		July 1	
6. Launching area instrumentation		Sept 1	

	1955	1956	1957
c. Propellant supply			
1. Alcohol		Sept 10	
2. Oxygen		Sept 17	
3. Gasoline			Jan 15
4. Hydrogen peroxide		Aug 10	
5. Nitric acid			Feb 15
6. UDMH			Feb 15
7. Solid propellants		Nov 1	
d. Organization of field crew		June 15	
VI. Instrumentation			
a. Facilities and common equipment			
1. Field laboratory		July 1	
2. Trailers		July 1	
3. Flight batteries		July 1	
4. Test equipment		July 1	
b. Telemetry			
1. PPM/AM			
(a) Transmitters (first units)		July 1	
(b) Flight antennas for Viking 13		July 1	
(c) Ground stations (first units)		June 1	
2. PDM/FM			
(a) Transmitters (first units)		July 1	
(b) Flight antennas for Viking 13		July 1	
(c) Ground stations (first units)		June 1	
3. FM/FM			
(a) Transmitters (first units)		Aug 1	
(b) Flight antennas for Viking 14		Oct 1	
(c) Ground stations		Oct 1	
c. Tracking (launching vehicle)			
1. Optical (for Viking 13)			
(a) Ballistic cameras		Oct 1	
(b) Theodolites		Oct 1	
(c) High-speed cameras		Oct 1	
2. Radar			
(a) Beacons (first units)		July 1	
(b) Flight antennas		July 1	
(c) Radars (XN1)		July 1	
3. Doppler			
(a) Transponders (first units)		July 1	
(b) Flight antennas		July 1	
(c) Ground stations		Oct 1	

	1955	1956	1957
d. Range safety equipment			
1. Receivers (first units)		July 1	
2. Flight antennas		July 1	
e. Data reduction			
1. Telemetered data			
(a) PPM/AM		Sept 1	
(b) PDM/FM		Sept 1	
(c) FM/FM		Nov 1	
2. Tracking data			
(a) Optical		Oct 1	
(b) Radar		Oct 1	
(c) Doppler		Oct 1	
VII. Field Operations			
a. Viking 13			
1. Test plan		July 15	
2. Delivery		Aug 6	
3. Static firing		Sept 18	
4. Flight		Sept 27	
b. Viking 14			
1. Test plan		Sept 15	
2. Delivery		Oct 5	
3. Static firing		Nov 20	
4. Flight		Nov 29	
c. Vanguard test vehicle 1			
1. Test plan		Nov 15	
2. Delivery		Dec 5	
3. Static firing			Jan 22
4. Flight			Jan 31
d. Vanguard test vehicle 2			
1. Test plan			Jan 15
2. Delivery			Feb 5
3. Static firing			Mar 19
4. Flight			Mar 29
e. Vanguard test vehicle 3			
1. Test plan			Mar 15
2. Delivery			Apr 5
3. Static firing			May 21
4. Flight			May 30

		1955	1956	1957
f. Vanguard test vehicle 4				
1. Test plan				May 15
2. Delivery				June 5
3. Static firing				July 23
4. Flight				Aug 1
g. Satellite launching vehicle 1				Oct
h. Satellite launching vehicle 2	2 months schedule			
i. Satellite launching vehicle 3				
j. Satellite launching vehicle 4				
k. Satellite launching vehicle 5				
l. Satellite launching vehicle 6				
D. SATELLITE				
I. Configuration		Oct 21		
II. Specifications			May 1	
III. Structural Design			Sept 1	
IV. Manufacture			Nov 1	
V. Testing				
a. Design tests				Feb 1
b. Environmental tests				July 1
VI. Instrumentation Assembly				May 1
VII. Acceptance Tests				Aug 1
E. ORBIT COMPUTATION				
I. Analytical Formulation				Jan 1
II. Computer Contract			Apr 1	
III. Programming				Sept 1
IV. Computer Operations				
V. Preparation of Ephemeris				
F. MINITRACK (including satellite telemetry)				
I. Satellite Equipment (first units)				Jan 1
II. Ground Stations				
a. Sites				
1. Selection			Apr 1	
2. Acquisition			Aug 1	
3. Construction				Aug 1

	1955	1956	1957
b. Communication			Aug 1
c. Antennas (first units)			
1. Minitrack			Jan 1
2. Telemetry			Jan 1
d. Minitrack electronics			Jan 1
e. Telemetry electronics			Jan 1
f. Poor man's Minitrack		July 1	
g. Miscellaneous field equipment			July 1
h. CBA test facility		Apr 1	
i. Field crew training			July 1

* * *

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Naval Research Laboratory. Report 4700 [SECRET]. PROJECT VANGUARD REPORT NO. 1, PLANS, PROCEDURES, AND PROGRESS [Unclassified Title] by Project VANGUARD Staff. 62 pp. & figs., January 13, 1956.

The Naval Research Laboratory has been assigned the prosecution of the project which has as its aim the launching of a scientific satellite during the International Geophysical Year. The Glenn L. Martin Company has taken a contract to provide the launching vehicles. The satellite, to be designed and built by the Naval Research Laboratory, will weigh 21.5 pounds and be 30 inches in diameter. Launching will be from the Air Force Missile Test Center, Florida. The satellite will be tracked by an electronic system from stations along a North-South line in the western hemisphere.

The plans and the progress that have been made are discussed in this report. [Confidential Abstract]

SECRET

1. Satellite vehicles
I. Project Vanguard

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