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A REPORT TO
THE COMMITTEE ON APPROPRIATIONS
U. S. HOUSE OF REPRESENTATIVES

on

PROJECT VANGUARD

A Scientific Earth Satellite Program

for the International Geophysical Year

Surveys and Investigations Staff

March 1959

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February 27, 1959

MEMORANDUM FOR THE CHAIRMAN

By directive dated March 19, 1958, the Committee instructed that a study be made of reliability efforts in ballistic missile programs. The directive was signed by Congressmen George Mahon and Richard B. Wigglesworth, Chairman and Ranking Minority Member, respectively, of the Subcommittee on Department of Defense Appropriations. It was approved by the Honorable Clarence Cannon, Chairman, and by the Honorable John Taber, Ranking Minority Member of the Committee on Appropriations. A report on the reliability study was submitted December 22, 1958.

During the course of the above inquiry, the Staff was instructed to review Project Vanguard. This report sets forth the results of our study. In the preparation of the report it has been necessary to refer to, and in a few instances quote directly from, classified data furnished to the Staff by the Department of Defense. The information does not, however, appear to be particularly sensitive and it is suggested that the Department of Defense may be willing to declassify all of the data set forth herein, if the Committee so desires.

Respectfully submitted,

Robert E. Rightmyer

Robert E. Rightmyer, Director
Surveys and Investigations
House Appropriations Committee

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I. INTRODUCTION

The Committee on Appropriations instructed the Staff, by directive dated March 19, 1958, to inquire into the reliability of our modern weapons. During the course of the study the Staff was directed by letter dated October 16, 1958, to review the Vanguard project. The communication stated:

> "It will be greatly appreciated, if you will request the staff making a study on weapons reliability and related matters, authorized by the Directive dated March 19, 1958, to specifically look into the Vanguard project. It appears that this project has been a relative failure compared to other similar efforts. The Committee should be fully informed regarding the pros and cons of this project from a reliable source outside the Department of Defense as early as possible in the next session."

A report covering all phases of the inquiry into the reliability of weapons was submitted on December 22, 1958. The present report is devoted to Project Vanguard.

The request upon which this inquiry is based carries the clear implication that the Committee is concerned about the validity of the commonly held public belief that Project Vanguard is a failure. The facts developed by the Study Staff in its efforts to probe the pros and cons of the program do

not confirm this common belief. It is, however, easy to see the reasons for such a feeling and to understand why it exists.

The Vanguard program was conceived in pre-Sputnik 1955 in an aura of unwarranted, but none the less real, national complacency concerning the technical supremacy of the United States. It was planned as a comparatively low-level, economical effort and was not to interfere with the ballistic missile developments. The entire program consisted of 15 vehicles. Six of these were test vehicles (TV's), three were reserve or backup test vehicles (TV-BU), and six were planned as vehicles having satellite launching capability (SLV's). Six test vehicles were considered the absolute minimum essential for the development program, and these were to be fired before any attempt was made to launch a satellite. The last six to be fabricated were to be modified to correct any weaknesses disclosed in the testing program, and it was thought there was reasonable assurance that at least one of them would succeed in placing a small scientific satellite in orbit some time during the International Geophysical Year (IGY - July 1957 to December 31, 1958). The planning documents reviewed and discussions with scientists interviewed by the Staff disclose that at the time Vanguard was

initiated the general feeling in the scientific community was that getting one instrumented satellite into orbit during IGY would represent a tremendous accomplishment. Getting more than one out of the six tries would be a desirable but unexpected bonus.

The Vanguard launching vehicle was a new development and, as was to be expected, encountered technical difficulties which caused slippages in the optimistic schedules initially prepared. Test vehicle number 4 (TV-3) was almost ready for delivery when Sputnik I and II were placed into orbit. It was to be the first test of the complete Vanguard rocket and the first flight test of the newly developed second-stage motor. Nevertheless, previous tests had been fairly successful and plans had been made to have TV-3 carry a small sphere which, if all went well, might have orbiting capability. Despite the fact that this was only the fourth test shot in the development program and that only phenomenal luck would produce a satellite, national attention was focused on it. An OSD public information officer led a troupe of reporters to Cape Canaveral to witness and report the event.

The TV-3 test shot failed in the most miserably spectacular manner possible -- it burned on the launch stand. A duplicate of TV-3 was fired six weeks later but did not

succeed in achieving an orbit. TV-4, the sixth shot in a series of tests, was fired on March 17, 1958. The rocket performed perfectly and succeeded in placing a small instrumented satellite into orbit. Since that time four vehicles have been launched. None have been completely successful, although SLV-3, the last one fired, very nearly placed a fully instrumented 20-pound satellite into orbit.

The program was never allowed to complete its development test programs. Instead, it was called upon to produce a satellite on its fourth test shot (the first vehicle to have orbiting capability), and since that time each Vanguard rocket fired has been expected by the public to be successful, i.e., to produce an orbit. Because this has not been done, the program has been condemned by the news media as a failure. It has borne the burden of a hurt national pride -- hurt because Sputnik I was in orbit before any U. S. satellite and because Sputnik II was many times larger than the Vanguard satellite.

It may be possible, in hindsight, to decry the impotence of our 1955 national effort in the field of space research, to question the wisdom of those who elected to pursue our satellite launching efforts independent of ballistic missile developments, and to criticize the failure to recognize the importance of granting the satellite program priorities equal

to those enjoyed by the major missile programs. These criticisms, however, cannot fairly be the basis upon which to judge Project Vanguard; they must be addressed to those who felt that the Vanguard approach was adequate for our national needs and who set the course accordingly.

In its review the Staff has endeavored to evaluate Vanguard within the limits imposed on the project by national policy, as evidenced by the official decisions referred to herein, and without regard for the results accomplished by other countries.

As will appear in the report, our analysis disclosed that mistakes were made in the program, that some degree of mismanagement existed and that, in at least some instances, quality control was not as good as it should have been. The fact remains, however, that Vanguard was brought to "operational" stage in less than half the time required by most missile developments. On its third "try" it placed a small satellite in orbit. The orbit of this satellite is by far the most stable of any earth satellite launched to date (as it never gets closer to the earth than 400 miles, it is not appreciably affected by the earth's atmosphere), and it has already led to an important discovery concerning the shape of the earth. The Vanguard development has contributed a number of advances to the state of the art, some of which are set forth later in this report. Some of the other

satellite launching vehicles have utilized principles proven through the Vanguard program. It is anticipated that further moon probe shots and attempts to launch heavier satellites will employ Vanguard-proven components.

In the overall appraisal and without endorsing the selection of Vanguard as a launching vehicle or the level of effort that was applied, it must be concluded that those responsible for implementing the program within the ground rules established have done a commendable job.

II. SELECTION OF PROJECT VANGUARD

The three military services for several years prior to 1955 had been conducting upper air research programs of varying magnitude. There was, however, no real major effort in any of the military departments and there was little coordination or direction at the OSD level of the limited programs being pursued.

Late in 1954 the international scientific committee that was planning for the International Geophysical Year (IGY) discussed satellite vehicles as a possible means of obtaining scientific information about the upper atmosphere. The committee recommended that the groups preparing individual national programs in support of the International Geophysical Year consider the launching of small satellite vehicles for scientific purposes during the period of the IGY, July 1957

through December 1958. The United States National Committee for IGY, established under the auspices of the National Academy of Sciences, formed a group to study the feasibility of including an earth satellite activity in the United States program for the IGY.

The impetus provided by the suggestion of an IGY satellite aroused increased interest on the part of the military services in developing "space" programs. In March 1955 the Assistant Secretary of the Navy for Air sought approval of a program which included plans for placing a simple, uninstrumented satellite in orbit in two or three years. The program, known as Project Orbiter, was a joint one with Army Ordnance and was based on the use of the Redstone booster and Loki rockets.

Consideration of this request called attention to the fact that the three military departments were taking unilateral actions on space programs, and on March 28, 1955, the Secretary of Defense issued a memorandum directing the Assistant Secretary of Defense (ASD), Research and Development (R&D), to coordinate all research and development plans for earth satellites, and instructing the three military departments not to commit further funds for such projects without prior approval of the ASD (R&D).

In April 1955 the ASD (R&D) directed his coordinating committee on general sciences to review the plans and programs of the three departments and to submit recommendations for action. The coordinating committee, which was composed of representatives of the military departments, recommended that the satellite program be conducted on a three-service basis with three separate approaches:

1. A joint Army-Navy project utilizing the Redstone booster and Loki rockets -- Project Orbiter.

2. A Navy proposal using Viking as the first stage of a three-stage rocket.

3. An Air Force proposal using the Atlas engine as booster and the Aerobee-Hi as the second and final stage.

While these proposals were under consideration, the President directed the Secretary of Defense to develop the capability of launching a small satellite during the IGY. Thereafter the ASD (R&D) convened a group of civilian consultants to advise regarding the selection of a specific technical program. The group was identified as the "Advisory Group on Special Capabilities" (also referred to as the Advisory Group and the Stewart Committee), and consisted of eight members, two recommended by each of the military departments and two selected by the ASD (R&D). They were instructed to review the various satellite plans and programs and to

recommend an equipment program by August 1, 1955, including suggestions with regard to the governmental and industrial organizations where the different phases of the program might best be carried out and a consideration of the impact of the recommended program on weapon development projects.

The group submitted its report on August 4, 1955. It recommended the development of a scientific satellite vehicle in two phases: (1) An immediate program designed for maximum assurance of placing at least a small (5- to 10-pound) satellite in orbit during 1958, and (2) a program to launch a vehicle capable of carrying a satellite of significantly larger payload (up to 2,000 pounds) or of achieving a significantly higher orbit at some future date. Other findings included:

1. There is a reasonable assurance the U. S. can have the capability to put up a small scientific satellite during 1958.

2. Use of current military programs to accomplish the objective within the IGY period will run some risk of interference with such military programs *** but if properly carried out can result in long-term benefits to the military programs.

3. The group unanimously favored use of the ICBM (Atlas) motor if (a) the ICBM program would be on schedule, (b) the satellite effort would not interfere with the ICBM, and (c) only a single satellite program could be approved.

4. The group declined to resolve the "ifs" (in 3) and presented two alternatives: (a) Use of the Navy proposal based on an improved Viking rocket with two additional stages (this proposal was favored by five of the seven members participating), and (b) use of the Army proposal based on the Redstone missile with three additional stages (this proposal was favored by two members of the group).

The Committee considered proposals of the Army, Navy, and Air Force against the primary question: "What program will be most certain of placing the most useful satellite vehicle on an orbit of at least 150 to 200 statute miles perigee (minimum altitude) within the IGY and with minimum interference to priority military programs"?

The majority reached the conclusion that the Navy's Viking proposal was superior to the Redstone proposal, principally because:

1. The Viking booster offered better performance and more reserve margin.

2. Viking required only two additional stages, whereas Redstone required three or four.

3. The Viking's first-stage engine could be made available without interference from or with weapon projects.

4. One agency, Naval Research Laboratory, had extensive experience with the Viking, with the second stage, and with upper-atmosphere research equipment.

5. Viking appeared to require less logistical support.

6. The associated Aerobee-Hi development would probably be used in more advanced satellite programs.

7. Improved Viking components might eventually be used as a second stage with a ICBM booster to achieve still greater performance.

8. The fact that Viking Project had been declassified was thought to simplify the handling of security problems and to increase the amount of technical data that might be released.

The minority (two members) gave five reasons why they favored the Redstone, but the summary said:

"The greater flexibility of the Redstone as a launcher for a satellite is considered to be the primary reason for its choice in a program having as short a time scale as the IGY period, since it makes it possible to compensate for unforeseen development difficulties."

In a memorandum directed to the Chairman of the Advisory Group under date of August 15, 1955, the Assistant Chief of Army Ordnance said the report of the Group contained some errors of fact, and some errors of reasoning about what can and cannot be done on a given time scale. He also said there were some factors not considered by the Advisory Group and, among other things, pointed out that:

1. "The substitution of the 135 thousand-pound North American rocket engine for the current 75 thousand-pound engine in the Redstone missile is a less complicated operation than the design of a new Viking missile *** There is greater assurance the Redstone with 135,000-pound motor will be available within a 2-year period. Actually the first orbital flight of this improved Redstone motor can take place in August 1957 *** Using 3 scaled Sergeant high speed stages, a payload of 162 pounds can be placed in an orbit with a perigee of 216 miles. Payload can be traded for excess velocity. There is sufficient excess velocity to place a 100-pound payload on the moon.

2. "The development problems confronting the Viking development make it obvious that the probability of success within the IGY is low. This conclusion is reinforced by looking at the development times of major missile programs already completed. Such programs are rarely completed on the originally predicted dates and require five years at the minimum and usually run for approximately 8 years.

3. "The improved Redstone 75 thousand-pound performance permits improved payloads at orbitable altitudes. The following table was computed with 900 ft/sec excess velocity and with existing propellants:

Perigee Altitude (miles)	Payload (pounds)
300	6
216	18

The first orbital flight for this configuration can be scheduled for January 1957 if an immediate approval is granted. Since this is the date by which the USSR may well be ready to launch, U. S. prestige dictates that every effort should be made to launch the first U. S. satellite at that time. Although this time scale is dependent on Sergeant or Loki clusters, the engineering feasibility has been approved by four competent agencies.

4. "The satellite missile does not interfere with the Redstone missile program because the program is in process of being turned over to the Chrysler Corporation and because the designers and planners are completing their work with the Redstone missile. A new program is therefore necessary for adequate utilization of the talent available. If a new and challenging project is not soon placed at Redstone Arsenal, the loss of key personnel will jeopardize the successful completion of the Redstone missile project. Therefore the scientific satellite program will strengthen rather than weaken the Redstone missile project.

5. "In view of the fact that Army Ordnance can provide heavier orbital payloads with shorter time scales and with greater assurance of success, and that the Naval Research Laboratory is already heavily committed to the Aerobee-Hi development for the IGY, it is obvious that the Naval Research Laboratories will be better employed instrumenting properly the large payloads (100 pounds or more) which can be made available."

Based on this memorandum, the Advisory Group held further sessions and both the Redstone sponsors and the Navy Viking group made presentations. The minutes of the Advisory Group state that they found no reason to reverse their previously expressed views favoring the Navy proposal.

Following receipt of the Advisory Group's report, the ASD (R&D) referred the report to his policy council for advice on inter-service cooperation and consideration of the possibility that the scientific satellite program might interfere with the weapons program.

After extensive deliberation, the policy council (Army members did not agree) recommended the selection of the Navy proposal for a three-stage launching vehicle based on the Viking and Aerobee-Hi rockets.

It appears that the Air Force proposals for launching vehicles based on ICBM motors were rejected because of possible interference with the weapon development program. The decision to use the Navy-proposed Viking approach instead of the Army-Redstone was based primarily on the technical recommendations

of the Advisory Group on Special Capabilities, as previously set forth.

On September 9, 1955, the Deputy Secretary of Defense (Reuben Robertson), by directive to the Secretaries of the military departments, promulgated the ground rules for the satellite project. The title of the directive is "Technical Program for National Security Council 5520". The directive states that National Security Council Report 5520 provides for a program to launch a scientific satellite during the period of the IGY. The Staff has been unable to obtain access to NSC 5520 but has been advised by a representative of the Secretary of Defense that important provisions were:

1. The satellite program was not to interfere with weapon developments.

2. The objective was to put one satellite in orbit during the IGY.

The directive referred to above gave the Department of the Navy management responsibility for the technical aspects of the program, and provided for cooperation by the Army and the Air Force in the satellite project which became known as Project Vanguard, or simply Vanguard.

As noted, the Army members of R&D Policy Council did not agree with the decision to pursue the satellite program through development of the Navy proposal. On two separate occasions

during 1956 the Army formally sought approval for a satellite launching attempt based on its missile developments. In April it informed the Advisory Group on Special Capabilities that an Army satellite program would permit the firing of a Jupiter in January 1957 in an effort to orbit a small body. The effort would require six vehicles, $18 million, and delay the IRBM (Jupiter) program approximately six months. This request was rejected and the Army was specifically instructed not to use any part of the Jupiter or Redstone programs for scientific satellites.

Following the successful Jupiter firing in September 1956, the Secretary of the Army recommended to the Secretary of Defense that a six-vehicle program based on Redstone be approved as a backup to the Vanguard program. It was decided not to provide a backup for Vanguard because that program, on review, showed promise of meeting its IGY objective.

Again, in March 1957, the Army proposal was considered and rejected, this time by the Special Assistant for Guided Missiles (Dr. Eger Murphree). In a memorandum for the Secretary of Defense dated March 21, 1957, Dr. Murphree said that if Vanguard was to accomplish its mission a large amount of work would have to be successfully completed in a relatively short time. He pointed out it was not unlikely that real difficulties

might be experienced which would cause a very real delay in the program; in this event it might be desirable to turn to the Army-type satellite, three stages of which had already been successfully launched. He called attention to the fact that the Army Ballistic Missile Agency (ABMA) claimed it could launch a satellite on four months' notice, and recommended that the Vanguard program be reviewed again about the end of 1957 to see if a backup to the program by ABMA was desirable at that time.

A review in accordance with the above recommendation was never made. Sputnik I was placed in orbit on October 4, 1957. Sputnik II was placed in orbit on November 3, 1957. On November 8, 1957, the Secretary of Defense directed the Department of the Army to proceed with preparations for launching a scientific satellite by use of a modified Jupiter-C which had been developed in connection with the nose cone re-entry problem. The vehicle was launched on January 31, 1958, and succeeded in placing in orbit a satellite weighing almost 31 pounds. This consisted of a burned-out final stage weighing about 13 pounds and a satellite proper weighing about 18 pounds.

The first stage of the Jupiter-C rocket was powered by the Redstone ballistic missile engine, which had been under develop-

ment for many years. The particular unit employed had undergone successful static-test firing and had been in storage at Redstone Arsenal since November 1956. The upper stages were solid propellant units designed specifically for the re-entry test vehicle. As of February 15, 1958, this satellite was in orbit and was producing data of scientific value.

III. HISTORY OF PROJECT VANGUARD

Vanguard, a part of the U. S. Scientific Satellite Program of the IGY effort, comes under the policy jurisdiction for scientific matters of the National Academy of Sciences (NAS - a quasi-governmental organization) and its sub-organizations - committees - for the IGY. The National Science Foundation (NSF - a Government agency) has acted as agent for NAS in formal relationships with other Governmental agencies. Overall management of the project was, however, centered in the Department of Defense (DOD) until October 1, 1958, when it was transferred to the National Aeronautics and Space Agency (NASA).

As previously noted, the Secretary of Defense, on September 9, 1955, gave the Department of the Navy management responsibility for the Vanguard. Within the Navy Department this responsibility was delegated through the Chief of Naval

Research to the Director of the Naval Research Laboratory (NRL), who gave technical responsibility and project authority to the Director, Project Vanguard (Dr. John Hagen). Actual contracting authority was retained by the Office of Naval Research, parent organization of NRL.

The Glenn L. Martin Company, Baltimore, had been the prime contractor for the Viking rocket and on September 23, 1955, a contract was entered into with that company for the Vanguard launching vehicle. The contract carried with it responsibility for development of the vehicle including design, construction, testing and preparation for flight. It provided for a 6-vehicle flight test program for which nine test vehicles (TV's) were to be fabricated, and for six vehicles having satellite launching capability (SLV's), or a total of 15 vehicles. There was, however, no contractual provision requiring that a satellite actually be placed into orbit. The principal subcontracts entered into by the Martin Company were:

General Electric Company - Development of the first-stage engine - October 1, 1955

Aerojet General Corporation - Development of the second-stage engine - November 14, 1955

Grand Central Rocket Company - Development of the third-stage motor - February, 1956

(A parallel program for development of a third-stage engine was entered into with the Allegany Ballistics Laboratory of the Department by the Navy directly in April 1956. This development has been continued independent of Vanguard. However, it is planned to use this motor on the final Vanguard in an effort to orbit a greater payload than would otherwise be possible.)

The Vanguard was plagued with a number of difficulties from the very outset. Delivery and launch schedules developed in November 1955 (two months after the prime contract had been awarded) were overly optimistic. They had to be revised in March 1956 (see table I, page 26, after General Electric and Aerojet General Corporation had advised that more time than was reflected in the November 1955 schedule would be required to meet the specifications on weight and performance. There was also minor interference with the program caused by delay in determining the final specifications and in coordinating the work of the several sub-contractors. In the late fall and winter of 1956 the project ran into serious development problems. The General Electric Company's first-stage engine performance was below specifications. The Aerojet General Corporation's second-stage engine and tank fabrication difficulties required new approaches, and the third stage was over-weight and required additional development to meet performance specifications. It was suspected that the structural design of the vehicle was inadequate to withstand

the vibration loads. As a consequence, design and production were stopped completely for about one month until this problem was resolved.

It was obvious at this time that delivery of vehicles would be about six months behind the initially planned dates and the launching schedule was again revised in February 1957. (See table I, page 26)

By early spring of 1957 most of the serious problems which had developed appeared to have been solved or somewhat alleviated, but this had not yet been proven through actual flight testing. The second-stage engine appeared to be the most difficult problem. There was gradual erosion (not burn-through) of the aluminum combustion chamber which decreased the velocity increment available from the second stage. This problem was not solved until October 1957 and there was another revision of the launch schedule. At this time planned launching dates were running eight to nine months behind the original schedule. (See table I, page 26)

By October 4, 1957 (the date Sputnik I was launched into orbit), the Vanguard Program was two years old -- that is two years had passed from the day the Navy was instructed to proceed with the development of a satellite launching vehicle. Development work was considered to be about 90 per cent

complete. Two preliminary test shots (TV-0 and TV-1) had been fired; however, the booster for both of these shots was the Viking rocket and neither of them had carried a second-stage engine. TV-2 was on the launch pad at Cape Canaveral preparatory to being launched as the first flight test of the newly developed GE engine. It was also to be the first flight test of the actual Vanguard configuration, but with dummy second and third stages. Test vehicles 3 and 4 had not been delivered. They were still at the Martin plant at Baltimore and had not been accepted by the Navy. Manufacturing of the final test vehicle (TV-5) had been completed. The satellite launching vehicles were in various stages of the manufacturing cycle, but none of them had been completed.

A White House Press Release issued October 9, 1957, is quoted in part as follows:

> "4. In May of 1957, those charged with the United States satellite program determined that small satellite spheres would be launched as test vehicles during 1957 to check the rocketry, instrumentation, and ground stations and that the first fully instrumented satellite vehicle would be launched in March of 1958. The first of these test vehicles is planned to be launched in December of this year.
>
> * * * * * *
>
> "I consider our country's satellite program well designed and properly scheduled to achieve the scientific purposes for which it was initiated. We are, therefore, carrying the program forward in keeping with our arrangements with the international scientific community."

These statements were taken as "commands" by those responsible for the program that the October 1957 launch schedule was to be adhered to and that there was to be no further slippage in the program. The Nation's news media appear to have ignored the fact that the statement speaks only of "launching satellite spheres" -- it does not say the rockets will be successful in placing the "satellite spheres" into orbit.

Planned launching dates set forth on the October 1957 schedule were allowed to slip just one month as is shown in table I, page 26. TV-2 was launched October 23, 1957; TV-3 December 6, 1957; and TV-4 on February 5, 1958. Thereafter there was one launching each month through June 1958, when SLV-2 was launched. From December 6, 1957, to June 26, 1958, six vehicles having satellite capability were launched. Only one, TV-4, launched March 17, 1958, was successful in placing a satellite into orbit. Table II, page 27, gives some data concerning each of the shots fired, including a brief statement of the cause or causes of failure.

Following the failure of SLV-2 on June 26, 1958, the Director of the Advanced Research Projects Agency (ARPA), a unit of DOD which in May 1958 had been given responsibility for all satellite and other outer-space programs, ordered

further launching attempts suspended. He instructed a technical group to look into "all aspects of the Vanguard for the specific purpose of recommending the best future course for the project from the standpoint of the national prestige and of scientific accomplishment."

The principal conclusions of the group as set forth in its report dated July 18, 1958 are:

1. Overall design and operations are believed to be sound. All three engine systems have performed well, both separately and together.

2. There appear to be no major problem areas in operations or in overall management.

3. The costs involved in either completing or cancelling the program are comparable.

4. Study of the failure history indicates that there is now about an even chance of getting one or two successful flights out of the remaining five Vanguards. (Staff comment - It is believed that the inability to determine the reliability with any degree of accuracy accounts for this indefinite conclusion. If the reliability is about 15 per cent, the chances are about 50-50 of getting one orbit out of five tries; if the reliability is 30 to 35 per cent the chances are about 50-50 of getting two out of five tries.)

5. There is no longer any requirement for completion of Vanguard launchings prior to the end of 1958, and the launching schedule can be relaxed several months if reliability might thereby be improved.

During the course of its review the technical group interviewed Dr. R. W. Porter, Chairman of the Earth Satellite Panel of the U. S. National Committee for the IGY, on

July 2, 1958. Dr. Porter informed them that the feeling in the scientific community with regard to accomplishment and prestige was that two successful flights from the then remaining five Vanguard vehicles would provide very significant data and would regain a considerable portion of the Nation's prestige; that one successful flight would be worth while; and that it was extremely desirable to accomplish one or two successful Vanguard flights before April 1, 1959.

Dr. Porter also advised at that time that the remaining scientific satellite packages intended for Vanguard could be repackaged for use on other launching vehicles but that such a procedure would involve delay and extra cost.

Following submission of this report and in accordance with a recommendation made by the group, a captive flight test was made of the complete second stage. It performed well and on September 26, 1958, SLV-3 was launched. It missed placing a 20-pound satellite into orbit by the narrowest of margins.

On October 1, 1958, the President transferred responsibility for Project Vanguard to the newly created National Aeronautics and Space Administration (NASA). The launching program was again suspended and the Administrator of NASA appointed another group to study the Vanguard and other satellite and lunar-probe launching vehicles. This group, as of February 15, 1959, had

not submitted its report. However, staff representatives have interviewed the Assistant Administrator of NASA and the Chairman of the study group. It appears that the group will recommend no major changes in the Vanguard program, and it is anticipated the remaining vehicles will be launched on the dates shown below:

SLV-4	February 17, 1959
SLV-5	March 13, 1959
SLV-6	April 10, 1959
TV-4BU	June 2, 1959

Some information on the estimated probabilities of placing one or more satellites into orbit with the four remaining Vanguard launching vehicles is set forth in the section of this report devoted to reliability.

TABLE I

COMPARISON OF SIGNIFICANT VANGUARD SCHEDULES

VEHICLE DELIVERY AND LAUNCH

Vehicle No.	November 1955		February 1957		October 1957		January 1959		Actual	
	Deliver	Launch	Deliver	Launch	Deliver	Launch	Deliver	Launch	Deliver	Launch
TV-0*	8/1/56	9/27/56	-	-	-	-	-	-	9/20/56	12/8/56
TV-1	10/1/56	11/29/56	-	4/25/57	-	-	-	-	1/9/57	5/1/57
TV-2	12/1/56	1/31/57	5/3/57	7/26/57	-	-	-	-	6/14/57	10/23/57
TV-2BU	1/15/57	Backup	7/5/57	9/6/57	-	Backup	-	-	8/2/57	NS **
TV-3	2/1/57	3/29/57	8/30/57	10/15/57	-	12/4/57	-	-	10/9/57	12/6/57
TV-3BU	3/15/57	Backup	9/27/57	Backup	10/18/57	1/9/58	-	-	11/11/57	2/5/58
TV-4	4/1/57	5/30/57	10/25/57	12/6/57	11/22/57	2/12/58	-	-	11/20/57	3/17/58
TV-5	6/1/57	8/1/57	12/20/57	2/14/58	1/17/58	3/19/58	-	-	1/11/58	4/28/58
SLV-1	8/15/57	Oct 57	1/17/57	3/21/58	2/14/58	4/23/58	-	-	2/5/58	5/27/58
SLV-2	10/15/57	Dec 57	2/14/58	4/25/58	3/14/58	5/28/58	-	-	5/12/58	6/26/58
SLV-3	12/15/57	Feb 58	3/14/58	5/30/58	4/11/58	7/2/58	-	-	6/13/58	9/26/58
SLV-4	2/15/58	Apr 58	4/11/58	7/3/58	5/9/58	8/6/58	-	2/17/59	8/18/58	-
SLV-5	4/15/58	Jun 58	5/9/58	8/8/58	6/6/58	9/10/58	-	3/13/59	1/21/59	-
SLV-6	6/15/58	Aug 58	6/6/58	9/12/58	7/3/58	10/15/58	1/7/59	4/10/59	2/13/59	-
TV-4BU***	5/15/57	Backup	11/22/57	Backup	12/20/57	-	3/8/59	6/2/59	-	-

* TV - Test Vehicle SLV - Satellite Launching Vehicle

** NS - Not scheduled - Cannibalized; parts salvaged and shell on display at Smithsonian Institution

*** TV-4BU - Not fired because of success with TV-4. Will be used as SLV with different third-stage engine in effort to orbit 50-pound instrumented satellite.

TABLE II

ACTUAL LAUNCHINGS OF VANGUARD
TEST VEHICLES AND SATELLITE ATTEMPTS

(TV - Test Vehicle Series)

TV-0 - 12/8/56	Test of range facilities, telemetering, and range instrumentation by use of Viking Rocket No. 13. No Vanguard components involved. Successful.
TV-1 - 5/1/57	Test of Vanguard third stage for separation, spin-up, ignition, propulsion. Test of Vanguard control system. Viking No. 14 used as first stage. Extensive telemetering carried. Complete success. No orbit capability. (Sputnik - 10/4/57)
TV-2 - 10/23/57	Test of new Vanguard, first stage, Vanguard control system, vehicle structure. Second and third stages inactive. Complete success. No orbit capability.
TV-2 - BU	Backup. Not needed because of TV-2 success. Has been cannibalized - shell on display at Smithsonian Institute.
TV-3 - 12/6/57	First test of complete vehicle, complete control system. (First flight test of second stage.) First stage failed, at lift off. Remainder had no opportunity to function. First vehicle to have orbit capability. Failure.
TV-3 Backup 2/5/58	Repeat of Test TV-3. This again represents first test of second stage and complete control system. First stage propulsion worked. Control system malfunction broke up rocket at 60 seconds. No test of second or third stage. (Had orbit capability.) Failure.

TV-4 - 3/17/58	Same objective as TV-3. First test of second stage. Defects discovered in previous tests corrected. Successfully put 3.25-pound test satellite into orbit. First stage above normal, second stage a little below normal. Third stage normal. Complete Success. (Note: This is within IGY.)
TV-4 Backup	Not used. Converted to launch vehicle for use later in program.
TV-5 - 4/28/58	Last of series of test vehicles. Complete system with regular IGY scientific satellite. (Had orbiting capability.) First and second stages worked. Control system sequence failed. Third stage not activated. No orbit. (SLV - Satellite Launching Vehicle Series)
SLV-1 - 5/27/58	Start of "Launching" Series. Faulty second stage burn-out threw rocket off course beyond capability of control system to correct. First and third stages and satellite functioned properly. Twenty-minute flight to 1850 miles in space. No orbit.
SLV-2 - 6/28/58	Second stage cut off prematurely to terminate sequence. Low thrust due to clogged filters in oxidizer feed system. No orbit.
SLV-3 - 9/26/58	Second stage thrust too small because of clogged filter in fuel feed system. All remainder worked. Final velocity slightly too small (1 percent) to maintain orbit. No orbit.

SUMMARY - February 1, 1959

Planned test vehicles (TV's) in program	9
Planned satellite vehicles (SLV's) in program	6
Total vehicles in program	15
Test vehicles launched	7
Satellite vehicles launched	3
Total launched	10

Vehicle Launching Schedule - February 1, 1959

SLV-4	February 17	
SLV-5	March 13	
SLV-6	April 10	
TV-4BU	June 2	
To be launched		4
TV-2 Backup not scheduled for launching		1
	Total	15

IV. PROS AND CONS OF PROJECT VANGUARD

In response to the request in the directive for information about the pros and cons of Project Vanguard, the Staff has attempted to digest in brief form the important accomplishments of the project (Pros) and the important factors adversely affecting it (Cons). In any project of considerable magnitude, it is not difficult on an ex-post-facto review to single out mistakes. This is particularly true of a development program like the Vanguard where, because it is pushing the state of the art, there are no established sign posts pointing the way. In an effort to be as objective as possible, the Staff has attempted to avoid reporting obvious but unavoidable or insignificant human errors, and has tried to report as "cons" only those actions and decisions which appeared to have had a major impact on the program.

A. "Pros"

As has been pointed out, the Staff study group is firmly convinced that the Vanguard project is not a failure if the rulebook used in creating it is also used in passing judgment on it.

Two objectives were established for it:

1. To place an instrumented satellite in an orbit around the earth.

2. To prove that the satellite is in orbit and to furnish orbit information for scientific purposes.

The rulebook used in establishing Vanguard said it could have 15 vehicles with which to accomplish objective No. 1 and that, if necessary, it could have until December 31, 1958, to prove it had done so.

On March 17, 1958, Vanguard launched an instrumented satellite weighing 3.25 pounds into an orbit whose minimum perigee of 400 miles gives an estimated orbital life of 200 years. This satellite is much smaller than the one it was hoped would be launched into orbit by Vanguard. There are, however, four vehicles remaining in the program and there is estimated to be a 50-50 chance that at least one of them will launch the 20-pound satellite into orbit.

The National Science Foundation furnished the Staff a series of reports setting forth detailed information on the scientific data which have been obtained from the Vanguard and other satellites. The Foundation also called attention to the fact that the over-all scientific program developed for use with the Vanguard launching system has made possible the total program of space vehicle scientific instrumentation, observation, and data reduction carried out under IGY auspices. Many other sources outside the DOD have given assurance that the information obtained through observation of the Vanguard has

been and will continue to be useful to the scientific community. The Staff has made no attempt to analyze these data. However, it appears that the orbital data yielded by the Vanguard have permitted the most accurate and significant determination of the earth's shape which has thus far been made. This determination has resulted in considerable revision of previously held views.

It is believed that accomplishments other than orbiting a satellite should be considered among the pros of the project. The most important segment of the entire complex is the launching vehicle. As will appear later in this report, some $73.5 million out of a total program cost of $111 million has been or will be spent on the vehicles.

The Vanguard vehicle is a three-stage rocket. The first stage is a fully developed, highly reliable system. The only time it has failed to work properly when called upon to do so was during its most publicized launching of December 6, 1957. It is the belief of those consulted, both inside and outside the DOD, that the Vanguard's first stage, because of its high efficiency and relatively low weight, may prove to be very useful as a second stage for the large boosters that will be available in the future. The third stage is also an efficient and highly reliable rocket. In the flights so far conducted it

has performed successfully four times out of four opportunities to do so.

The possibility of future applications for this rocket are not known. However, it has been learned, that an alternate third stage, which will be used on TV-4 backup vehicle scheduled to be fired on June 2, 1959, is expected to give Vanguard the capability of launching a 100-pound satellite, and this makes it appear that the present third stage may be obsolete. The second stage is a high-performance but less reliable engine. Whether all of its problems have been or ever will be solved remains to be proven. Significantly, however, the Vice-President of the Martin Company in charge of Vanguard Cape Canaveral operations advised the Staff that he thinks many of the difficulties experienced with this engine have resulted from too much testing and too many adjustments after delivery by the manufacturer.

The Vanguard development has been of value to ballistic missile programs and to the Air Force lunar probe shots. The Vanguard second-stage engine was used as the second stage for the two Thor-Abel re-entry test shots which are reported to have travelled some 6,000 miles.

Aside from the vehicle itself, the Vanguard complex includes ground launching facilities and a tracking system.

It is claimed by those connected with the project that the telemetering equipment developed as part of the ground launching facilities and the world-wide Minitrack system for tracking the satellite are contributions of major merit.

The Staff discussed the Vanguard program with a number of informed people not connected with the DOD. All of them expressed the view that the Vanguard development represented a considerable accomplishment when viewed in the light of the time available to it and the magnitude of the effort.

B. "Cons"

Many important people, including prominent scientists, feel that the greatest single factor adversely affecting the U. S. efforts to launch a suitable earth satellite during the IGY was the decision to develop the launching vehicle entirely independent of any military missile program. This decision, which was apparently made by the National Security Council, has been termed a "national tragedy" by some of those interviewed during the inquiry.

It appears to be quite clear in retrospect, and indeed seemed clear to some at the time, that a program coupled to a military missile development would provide earlier and more certain capability. Some scientists indicated that such an effort would contribute to missile capability rather than hinder it.

Another factor which may have adversely affected the chances of success, and which certainly adversely affected the public understanding of the project, was the vagueness of the goals. Although the stated objective was to place a satellite in orbit, there was no clear statement as to the probability of success to be expected from the small number of attempts scheduled. However, the present recollection of the program managers is that the informally accepted goal was to develop a capability that would yield about a 50-50 chance of getting one satellite into orbit in six attempts. The information released to the public by national leaders did not make this point clear. The program as established was not compatible with a goal of near certainty of success, but was more nearly compatible with a 50-50 chance.

The fact that these probabilities were never brought home to the public has certainly influenced public evaluation of the project strongly and unfavorably. This accounts in a measure for the fact that a project which is almost a success in terms of standards set for it has been adjudged a failure before it has run its allotted course.

Following the selection of Vanguard, other factors emerged which probably affected the program and its chances of success adversely to some extent.

Both the complexity of the task and its cost were underestimated, resulting in overly optimistic time schedules. The underestimated cost, coupled with the fact the decision to proceed with the satellite was made in July 1955, a date not compatible with DOD appropriation submissions, resulted in a decision to finance the project from funds otherwise available. The funds were apportioned on a "hand-to-mouth" basis, which arrangement interfered with long-range plans and programs as there was always doubt whether sufficient funds would be made available. Appendix A, page 61, gives some details regarding the funding arrangements.

The requirement of noninterference with military programs, the austere initial budget, the rigid time limit imposed by IGY, the absence of a suitable priority (until Sputnik), resulted in management attitudes and decisions which curtailed reliability efforts and programs to a level below that characteristic of the complex missile programs. In particular, they prevented the establishment of multiple launching facilities and a greater testing program which could have provided more assurance of success.

One of the factors influencing the selection of the Navy proposal was that the Martin Co., proposed as prime contractor, had available a design group that had nine years' previous

experience with the Viking rocket. One week after the Vanguard contract was signed, the Martin Co. was awarded the contract for the development of the Titan, an intercontinental ballistic missile having the highest national priority. Martin divided the Viking team, with several of the more experienced engineers going to Titan. Although denied by the Martin Co., it seems almost certain that this maneuver deprived the Vanguard project of talents which might have expedited its development and possibly made it a more reliable vehicle.

Some informed persons have advised that in general there was an absence of an attitude of interest, enthusiasm, or urgent concern regarding Vanguard in the highest echelons of DOD. It was reported that some top-level people, including the then Secretary of Defense, expressed the view they did not care what is on the other side of the moon or why the grass is green. It was pointed out that while the attitude reflected by these expressions did not find its way into official directives, the scientists and other people associated with Vanguard felt that they represented an official view that Vanguard had little value or interest except to the scientific world.

Organization difficulties interfered with the smooth operation of some facets of the program. There was divided

responsibility in the Navy Department and failure, especially in the early stages of the program, to define properly the duties and authority of organization units and personnel. The Martin Co. found it difficult to get timely decisions at Cape Canaveral since there was, at least in the early part of the program, no single source of final authority. The Martin Co. also had internal organizational problems. It did not establish an appropriate quality control group at Cape Canaveral until 1958 and did not recognize the necessity for coordinating the work of the principal subcontractors into a team effort. The program management concept, at least until the latter stages of the program, seems to have been: "Martin is the prime; Aerojet General, General Electric, and others are just subcontractors, responsible only for delivering a product which meets the specifications; and there is no reason to treat them as associate contractors in the production and launching of the complete vehicle". It is the opinion of some people, particularly those consulted at Cape Canaveral, that good "team" effort early in the program might have reduced some of the launching delays and made it possible to expedite the test program.

During the course of its review the Staff observed that a general air of looseness and informality seemed to have

prevailed in this program. Difficulty was experienced in locating documentation for views that were fairly generally held by those associated with the project. The lack of formalization of the goal of the program insofar as it relates to the chances of success has already been commented on. There was no documentation to support the assertion now generally made that it was "understood" that the project would not be acceptable if planned as anything other than a low-budget effort. The Staff found it impossible to obtain documentation on instructions given the program managers and the prime contractor following Sputnik I. It was generally stated that they were told to "Get a satellite into orbit without further delay".

It appears that the looseness, lack of formalization, and early management problems may have resulted from the fact that Vanguard grew out of the Viking program. Viking management concept and procedures were geared to a program involving the production of two vehicles a year and little more than $1 million in annual costs. The rockets were hand made and in essence were produced, modified, and launched by the men who designed them. The Naval Research personnel connected with this program had close personal contact with these people and there was little need for formalization of plans, objectives, and procedures.

The short time scale allocated for Vanguard, the complex design, and the necessity for producing a relatively large number of vehicles in a short time made it necessary to carry on many facets of the program simultaneously and to adopt production-line techniques requiring a concept of management quite different from that of the Viking effort.

Publicity officially released, following Sputnik I, caused a crash program to be undertaken. Work at Cape Canaveral was put on a three-shift basis. This action, according to those closely associated with the program, was poor procedure. The groups working on different shifts tended to work independently and strict control over the operations being performed became impossible.

In the general hysteria which prevailed, work which should have been done in the hangar was left undone; and because of poor communication and lack of continuity of working forces, people working on the launch pad assumed the required operations had been performed in the hangar. This situation contributed to the adjustments which had to be made during "check out" procedures just prior to the launch attempt.

It should be noted that none of the people interviewed claimed that any vehicle was launched before it was thought to be ready. Some of them, however, felt that their judgment as

to "readiness" was no doubt influenced by the pressure on the program to "get a satellite into orbit" so as to meet the expectations of the public.

Although prime responsibility for the Department of Defense Vanguard effort has always been centered in the Naval Research Laboratory, review and coordinating responsibility was shifted a number of times. Initially the Assistant Secretary of Defense for Research and Development had review responsibility; in May 1957 the project was placed under the Special Assistant for Guided Missiles (SAGM); in May 1958 it was transferred to ARPA; and in October 1958 all responsibility, including that previously assigned to the Navy, was transferred to NASA. It is not possible to demonstrate that the shift from the ASD (R&D) to SAGM delayed the program. In the case of the other two transfers of authority, specific launching delays occurred, as has already been discussed in this report.

During the course of the inquiry a number of allegations concerning mismanagement, incompetence, failure to meet specifications, and friction came to the attention of the Staff. Some of these statements had been made publicly, some in hearings before Congressional groups, and some were made directly to the Staff. Effort has been made to determine the facts in each case where the allegations were such as to permit

specific inquiry. It is worth noting that many of the allegations were made by people having no facts but who were, nevertheless, quite willing to condemn the program solely on the basis of results of the launching efforts to date. The Staff believes, on the basis of its study of Vanguard and recent study of other missile programs, that the "cons" in the Vanguard project are not significantly greater than those in other comparable efforts.

V. ASPECTS OF RELIABILITY IN VANGUARD PROGRAM

There are two important uncertainties associated with any new undertaking, such as this satellite attempt, which goes beyond the existing proven equipment into new areas of development. The first, which may be called the design uncertainty, is concerned with the question, "Does the system as proposed actually have the capability of achieving the objective?" The success of TV-4 and near success of SLV-3 remove this uncertainty.

The second, or reliability uncertainty, is concerned with the question, "Can all of the parts and components that are needed be manufactured, assembled, tested, and operated by the people involved in a sufficiently reliable manner to insure the required chance of attaining the objective?"

It is self-evident that the reliability that must be achieved and the effort that must be expended to attain it will

depend upon the goals established. Thus it becomes important to ascertain, if possible, what "chance" of attaining the objectives was established as the goal at the outset of the Vanguard program.

The brief table which follows shows the reliability required to insure the indicated chance for achieving the objective. "Reliability" is the probability of success (orbit) in any one attempt (equivalent to the fraction of success to be expected in a large number of attempts with identical items).

TABLE III

If the objective is at least one satellite in orbit out of six launching attempts:

Chance of Success	Chance of Failure	Reliability Required
95%	5%	40%
90%	10%	33%
50%	50%	15%

If the objective is at least two satellites in orbit out of six launching attempts:

95%	5%	57%
90%	10%	50%
50%	50%	25%

Experience available at the beginning of the Vanguard program indicated that reliabilities of 40-50% for a three-stage system would require long expensive programs with extensive attention to reliability. However, officials in the program believed that a reliability of 15% could be achieved within the time and funds available.

A. Reliability Goals

In attempting to find information regarding the original goals set for the reliability of the Vanguard vehicles, who set them, and on what basis, the Staff has reviewed the documentary record and has talked to officials in the IGY, OSD, Navy, and the prime contractor, The Martin Company. The pertinent clauses in the Navy-Martin contract are as follows:

"DESIGN SPECIFICATION FOR
VANGUARD LAUNCHING VEHICLE

"1.0 INTRODUCTION

"1.1 Scope. - This specification with its appendices and references defines the requirements of the Naval Research Laboratory for the design, manufacture, testing, and preparation for launching of VANGUARD launching vehicles and test vehicles.

"1.2 Objective. - The objective of Project VANGUARD is to establish a satellite in a predetermined orbit around the earth. The satellite will be built by the Government and placed in its orbit by the VANGUARD launching vehicle.

". . . . . .

"1.5 General Procedures. - The Government will exercise such direction and controls as are necessary to assure itself that launching and test vehicles meet

their objectives both in performance and reliability. The Government will determine the performance and degree of reliability that can be reasonably expected within the time-scale framework." (Underscoring supplied.)

As is evident from the very general tone of these clauses, no numerical estimates or requirements of reliability were specified. The Staff has not been able to establish that the Government (NRL) ever formally determined the "degree of reliability that could be reasonably expected within the time-scale framework" (1.5 above) or set any definite reliability goals for the contractor.

The Director of Project Vanguard (Dr. Hagen) stated that the original proposal envisaged a reliability that would give a "reasonable" chance of putting one satellite in orbit in six tries, but that the project was conducted with the aim of doing everything possible under the circumstances to improve this probability. Dr. Hagen defined the term "reasonable chance" as having meant to him approximately a 50-50 chance, i.e., 50% probability. (The corresponding goal for reliability would have been approximately 15% as shown in table III.)

Officials of the Martin Company, Baltimore Division (Vice President Varrier and Project Engineer Markarian), did not commit themselves to any numerical statement as to the reliability goal which they set for themselves. They merely

emphasized that they were "confident" that they could get at least one satellite of planned size in orbit.

The minutes of the first meeting (October 20, 1955) of the Satellite Panel of the U. S. National Committee (USNC) contain this statement: "It appears that at the present time the objectives of the Project VANGUARD are to put one satellite into orbit, with six vehicles scheduled to try this". Officials of USNC state that they have no knowledge that any more definite estimate of the probability of launching success was ever made by DOD.

The Stewart Committee used the terms "reasonable assurance" and "reasonable chance" in describing their expectations.

Since none of the officials in this program clearly and formally stated or defined their goal (and may have had different ideas among themselves as to what it was), the confusion and unwarranted expectation of success on the part of the public is understandable, particularly since the project name -- Vanguard -- itself implied a goal, or a promise, of a successful "first" satellite.

B. Limiting Factors Affecting Reliability

In any development program, reliability is affected by coordinations or compromises involving time, money, weight, parallel approaches, and competition with other projects. Managerial judgment must strike the balance.

At the outset, the final deadline for attaining the Vanguard program mission (a satellite in orbit during IGY) was fixed as December 31, 1958. To design, procure, test, improve components for, and assemble and prepare a series of vehicles for launching requires a certain amount of time. The larger the number of vehicles to be procured and launched, the greater the time required, unless a dual test program is arranged; and even then both lines may have to be stopped for fixing defects uncovered by either line. Thus the single rigid limitation of available time put a limit upon the number of TV's and SLV's which could be usefully scheduled. A completely independent backup program would have been an alternative. This suggestion for backup came up repeatedly throughout the program but was undertaken only after Sputnik. The record is clear that although the Stewart Committee recommended establishment of a backup program, the DOD decided against it; relying on the Army capability to be used on a crash basis if needed. It is of interest to note that ONR requested an additional launching pad and six additional SLV vehicles. The request was not approved. The USNC for the IGY, through NSF, suggested to DOD that six more SLV's be scheduled (January - February 1956). The request was not approved. Obviously with more TV's or more SLV's or an additional backup

program, the chance of achieving more orbiting satellites would have been increased.

Limitation of funds is a factor which obviously can affect reliability greatly but it does not appear to have been a critical element, excepting as it established the general size and scope of the program. All funds requested for Vanguard were eventually made available. There were times, however, when the precarious funding situation approached the brink of cessation of activity.

The uncertainty and difficulty of the financing and the relatively low priority established for the program could have tended to inhibit requests for additional funds in support of greater reliability efforts. The technical leaders interviewed indicated they saw no tangible evidence that this was so or that the precarious funding actually retarded the effort.

In the technical design of a rocket to carry a given pay-load, a judgment must be made as to the size, to achieve the best balance between (a) cost, which in general increases with size, (b) reliability of components, which in general will be better if the rocket is large enough to permit extra weight for more reliable components, and (c) reliability of the propulsion system, which is likely to be uncertain if the size is scaled-up too radically beyond the state-of-the-art.

After the basic Vanguard size and design were accepted, the decision was made to design for light weight. The contract with The Martin Co. provides:

> "3.1.2.4 (Requirements, General, Structural Design, Design criteria)
>
> "(a) Weight Considerations - Because of the penalty that weight imposes on performance, every effort shall be made to reduce the weight of the vehicle."

If the available thrust of all motors met the specifications, any saving in weight below the design limit would result in a more-than-minimum orbit. Conversely, if the thrust were below the specifications, an orbit might still be achieved if the total weight were below the design limit. It is understandable that the contractor responsible for the detailed design would consider it better to have a rocket of ample thrust/weight ratio at the sacrifice of some reliability than to attempt to achieve high component reliability at the cost of increased weight, which might result in loss of orbiting capability. On the other hand, those who felt responsible for the reliability and had confidence in the performance of the motors could argue strongly for using some of the weight margin to attain greater component reliability. Typically this is the type of decision that must be a managerial one. In Vanguard, the question of high reliability versus thrust/weight was generally resolved in favor of keeping the margin of safety in the thrust/weight ratio.

C. Reliability Efforts

Clauses in the Navy-Martin contract read as follows:

> "3.1.3.6 (Requirements, General, Construction) Simplicity. - Simplicity of satellite-launching vehicle construction shall be emphasized in the interest of providing reliability and decreased weight. Every effort shall be made to keep the number and complexity of components in the launching vehicle to a minimum. Application of this principle must not jeopardize attaining the mission of the vehicle.
>
> ". . . . .
>
> "3.1.10 (Requirements, General) Reliability. - The vehicle shall be designed and components selected on the basis of available reliability data to insure reliability consistent with the state of the art. Reliability studies and statistical testing to establish such data shall not be required. (Underscoring supplied.)

It is confirmed by both Navy and Martin officials that Martin felt that it would not be feasible, because of the limitations on cost and time, to mount a strong program of life testing to determine reliability of components. It is not clear why The Martin Co. officials seemed to feel that these limitations also precluded a coordinated "reliability program" of design review, test analysis, and reporting of unsatisfactory procedures, workmanship, or equipment.

As previously noted, Martin Co. reliability efforts may have been compatible with achieving a reliability of around 15% but certain aspects of the reliability effort, such as the reporting function, appear to have been deficient in the

early stages of the program and were not compatible with achieving a high level of reliability.

On procurement of most items, Martin required qualification or performance tests to appraise the performance specified by the designer, but their design philosophy was characterized by some Naval officers as being one of "adequacy is good enough".

Because of the large number of items requiring correction, as reported by the Vanguard Operations Group (VOG) at the launching site, NRL requested Martin, in July 1957, to establish a Quality Assurance Program in the field, and this was eventually done about the end of that year. The VOG then discontinued its reporting, depending on the Martin Quality Assurance reporting system. Although the number of items to be corrected decreased considerably after the Martin Quality Group was established, the VOG resumed its own series of reports on deficiencies after a few months.

The Martin Cocoa Division has begun returning defective equipment to the home plant for correction. This appears to represent a desirable change in procedure, since it will tend to force Martin, Baltimore, to maintain higher standards of workmanship. However, activities of the Quality Assurance Group at the launching site are limited primarily to detection

of errors in workmanship and performance, and design deficiencies are not likely to be detected in advance of testing by a quality assurance group in the field.

The first-stage motor had been given a thorough series of qualification tests, being required to operate successively for six successive runs having a total running time of 1,000 seconds. The second-stage motor was apparently procured under much less stringent qualification testing, and the controls may not have had completely adequate system tests.

The above examples of reliability efforts, or lack thereof, are some of those that the Staff has noted, but in the context of the uncertain (but low) reliability goal for the project, it cannot fairly be concluded that they indicate unreasonable executive judgment or that the program has not been reasonably well managed.

D. Analysis of Flight Results

Table II, page 27, gives the historical sequence of launch attempts and indicates in each case the most probable cause of failure as provided to the Staff by DOD from official Flight Analysis Records. From the reliability standpoint, it is instructive to examine these defects in somewhat more detail to determine if possible whether they are due to (a) design deficiencies, (b) unreliability of parts, (c) faulty

procedures (in manufacturing, assembly, or testing, or preparing for launch).

The destruction of TV-3 was attributed to an inlet pressure too low for the fuel pump. This pressure was, however, stated to be within specifications set for the pump. Thus, without more information the malfunction might be charged either to a defective pump (part) or to faulty procedure (procedure) if the difficulty might have been detected in pre-launch checking.

The breakup of TV-3-BU was due to a part failure in the control system (part) or to faulty inspection or installation of wiring (procedure).

The non-ignition in TV-5 was attributed either to a relay failure (part) or to mismatch of design tolerances on the relay specifications (design).

The sudden change in attitude at second stage shut-down in SLV-1, was attributed either to faulty thrust pressure switch (part) or to inadequate design of shut-down equipment (design). The design was improved in later SLV's.

The faulty performance of the second stage in SLV-2 was attributed to inadequate removal of scale from the oxidizer tank (procedure).

The low thrust of the second stage in SLV-3 was attributed to contaminants introduced into fuel at fuel-up (procedure).

In the seven test flights (four in test vehicles, three in launching vehicles), one placed a satellite in orbit. Of six malfunctions, two were chargeable to procedures, two chargeable either to design deficiency or to part failure, and two either to procedures or part failure.

Although there is too little information for firm conclusions, it appears that the failures are due neither to chronic failure of any particular part nor generally to poor quality or reliability of parts. Those failures due to design deficiencies might possibly have been prevented by tighter design review. Redesign already completed should prevent their recurrence. Recurrence of procedural difficulties can be removed by improved procedures. However, it does appear that more attention to the preventive aspects of reliability, in addition to that given to the corrective aspects of reliability, would have improved the chances of success. It may, of course, be argued that the tight time scale, low budget, and limited test facilities would not have permitted any extensive increase in the preventive aspects of the reliability efforts.

Three other important items of information emerge from a review of the flight results:

a. The success of TV-4 and near success of SLV-3 show that the system has the expected capability. No fundamental road blocks to success exist.

b. The initial estimates of 1 chance in 6 to get a satellite into orbit were not greatly in error and were probably conservative. (Actual score: 1 in 7 and almost 2 in 7 using four test vehicles and three SLV's.)

c. The sequence of launching attempts on 2/5/58, 3/17/58, 4/28/58, 5/27/58, and 6/28/58 shows that the team launching had achieved a capability of launching about one per month. They could presumably have launched three more after the September 26, 1958, attempt and within the IGY if they had not been stopped for program review. Thus the over-all schedule did not turn out to be markedly unrealistic, in spite of slippages early in the program.

E. Prospects of Success from Remaining Four Vehicles

Although the predictions of the development and operating teams, based on their own experience and judgment, may furnish the best basis for estimating the probability of success in future launchings, it is possible to derive some rough estimates from an analysis of the success-failure records. It must be stressed in connection with any such estimates, however, that the quality of the system tends to improve after each shot. A shot is not a complete failure because orbit is not achieved. Each shot gives information about difficulties which can be corrected to improve the chances on later attempts.

Based upon the information given in table II, the following score chart (table IV) can be constructed. In this table a + sign indicates that the indicated component had a chance to operate and did so successfully, a - sign indicates opportunity followed by failure, and o indicates no opportunity. The score is the fraction obtained by dividing the successes achieved (numerator) by the opportunities (denominator).

TABLE IV

	1st Stage	2nd Stage	3rd Stage	Guidance and Control
TV-1	o	o	+	+
TV-2	+	o	o	+
TV-3	-	o	o	o
TV-3-BU	+	o	o	-
TV-4	+	+	+	+
TV-5	+	+	o	-
SLV-1*	+	+	+	-
SLV-2	+	-	o	+
SLV-3	+	-	+	+
Score	7/8	3/5	4/4	5/8

*Difficult to say whether faults are chargeable to second stage or control system.

A rough estimate of the "average" reliability of the launching vehicle is the product of the success-ratios of the four major components:

$$R = 7/8 \times 3/5 \times 4/4 \times 5/8 = \frac{0.21}{64} = 0.33$$

From appropriate statistical tables, this is found to indicate that there is an 80% chance of putting at least one of the next four shots into orbit and a 40% chance of putting at least two into orbit. But because of the small numbers involved, the rules of statistics say one cannot place much confidence in the statement. Assuming a 50% confidence, one can conclude only that the reliability is greater than 0.05 and that there is better than an 18% chance of putting at least one satellite in orbit. This is a very conservative estimate because it does not properly allow for improvements made, and is based on such small numbers. Also, the reliability might be increased by improvements yet to be made, perhaps even as a result of another failure.

Perhaps a better estimate of the reliability of the remaining vehicles can be obtained by getting engineering estimates from the various technical people involved. This has been done, and the estimates range from 20% to 40% reliability from those who will give numbers; and from "a good chance to

get one" to "quite likely to get two or three" from those who are unwilling to make numerical estimates.

Putting all this information together, it seems safe to conclude that there is probably a 50-50 chance of getting at least one more satellite in orbit. In other words, the chance of placing an additional scientific satellite in orbit is as good now as the estimates of success made at the outset of the program.

APPENDIX A

BUDGET DATA

The review of the existing records and interviews with the program managers and the prime contractors produced convincing evidence that Vanguard was conceived as a limited project involving expenditures of some $20 million to $30 million. According to data furnished by DOD, a total of $111,085,000 had been expended or programmed for expenditure as of January 1959. A number of factors account for the increase, but the largest single factor is that realistic estimates of the total program cost were not made initially. What has been loosely referred to as "costs" appear to have been limited to an estimate of the cost associated with the launching vehicles. The Martin Company's contract, which covers the development, fabrication, and the launching of the rockets, initially provided for costs of some $29 million. Martin Company officials advised on January 8, 1959, that they had already expended some $53 million and they estimate their contract will involve about $59 million. This difference of $30 million is roughly divided into $15 million for change orders and an overrun of $15 million on originally estimated costs, or about 50% overrun.

The Martin Company's contract, which accounts for about 50% of the cost of the project, does not include all the costs associated with the launching vehicle and does not include any of the costs incident to optical and radio tracking, the satellite and its instrumentation, or data processing. A summary of the cost by program items and spending agency is presented below.

A. Non-Navy Administered Costs	Amount
1. Natl. Sci. Found. (NAS) - Optical tracking, program administration, scientific experiment support	$5,236,000
2. U. S. Air Force - Range construction and support	3,661,000
- Range use charge for launchings	4,227,000
3. U. S. Army - Prime construction tracking station	750,000
Subtotal	$13,874,000
B. Navy Administered Costs	
1. Radio Tracking - Construction, equipment, maintenance, operations, communications, satellite transmitters; data recording and transmission on all U. S. satellites	$14,551,000
- Tracking and recording data from Soviet satellite	1,085,000
2. Vehicles - Development, procurement, testing, telemetering, flight operations	73,470,000

3. Theory, Data Processing-Analysis - Reduction, publication of orbital and other information	$5,037,000
4. Satellites and their Instrumentation - Testing, flight, telemetering of data, data recording, reduction and publication	3,068,000
Subtotal	$97,211,000
Total	$111,085,000

The funding pattern for Vanguard has been unique. At the time the Navy was given instructions to proceed with the contract (September 1955), it was told to finance the program from any funds available, with the understanding that reimbursement would be made as soon as funds could be made available from other sources. Specific appropriations for the project have not been made to the Department of Defense. Consequently, each request for funds made by the program managers has caused some concern, and in some instances there has been considerable delay between the time the funds were initially requested and the date they were finally available for obligation.

The sources of the funds expended or planned for expenditure in connection with the Vanguard are shown below:

DOD emergency funds (FY's 1956, 1957, 1958)	$47,385,000
DOD authority to transfer from any available appropriated funds - FY 1958	34,200,000
National Science Foundation and National Academy of Sciences	18,362,000
Funds from classified source	2,500,000
Costs absorbed by Air Force and Army from regular appropriations	8,638,000
Total	$111,085,000

The tabulation below shows the dates on which funds were requested by NRL and the dates on which they were received.

Date Funds Requested by NRL	Funds Received	
	Date	Amount
30 Sep 55	21 Dec 55	$15,500,000
	29 Dec 55	2,500,000
15 Mar 56	20 Jun 56	5,800,000
	3 Oct 56	15,000,000
	5 Oct 56	5,500,000
14 Nov 56	15 Feb 57	10,000,000
	25 Mar 57	1,826,000
15 Mar 57	Jun 57	5,800,000

Date Funds Requested by NRL	Funds Received Date	Amount
23 Apr 57	10 Oct 57	$7,000,000
30 Oct 57	11 Dec 57	4,400,000
	28 Jan 58	22,800,000
	28 Jan 58	1,085,000
Total NRL administered costs		$97,211,000

From the information obtained by the Staff it has not been possible to determine the extent to which the unavailability of funds may have interfered with the expeditious prosecution of the program. Representatives of the prime contractor advised that the low-level concept of the program would have prevented the establishment of backup programs and of any elaborate reliability effort. However, they said that they could not point to the unavailability of funds as having influenced the prosecution of the program as it was conceived. The program managers, on the other hand, said that failure to recognize the magnitude of funds which would be required, and to make appropriate provisions for them, interfered with long-range planning, increased the amount of administrative work, and caused uncertainties on their part and on the part of the contractors. Several persons mentioned that the piece-meal manner in which funds were made available kept the project on a hand-to-mouth existence most of the time.

APPENDIX B

U. S. SATELLITE EFFORTS - 1958

Launched

EXPLORER I	Jan. 31	In orbit as of 2/15/59
EXPLORER II	March 5	Orbit not achieved
VANGUARD I	March 17	200-yr. orbit
EXPLORER III	March 26	In orbit until 6/27/58
VANGUARD	April 28	Orbit not achieved
VANGUARD	May 28	Orbit not achieved
EXPLORER IV	July 26	6-yr. orbit
EXPLORER V	August 24	Launch attempt failed
VANGUARD	Sept. 26	Orbit not achieved
PIONEER I	Oct. 11	Effort to orbit moon failed
EXPLORER VI	Oct. 23	Failed to launch
PIONEER II	Nov. 8	Orbit not achieved
PIONEER III	Dec. 6	Moon shot failed
SCORE (ARPA Project using ATLAS Booster)	Dec. 18	In orbit until 1/21/59

Summary

Orbits Achieved 5

In Orbit 1/31/59. 3

APPENDIX C

ADVISORY GROUP ON SPECIAL CAPABILITIES

Buchheim, Robert W., Electrical Engineer, BE; MS; Ph.D., Yale '53). Experience includes servomechanisms, auto-navigator computers, missile guidance and control systems, analysis and design of satellites and space vehicles. Research Engineer, the RAND Corp. (Joined Group Jan. '57.)

*Clement, George H., Mechanical Engineer (Univ. of Cal., '41). Asst. to Pres. RAND Corp., Santa Monica, Calif. Experience includes analysis and design of large missiles, satellites, and space vehicles; tool, stress, and structure design and analysis, Douglas Aircraft Co.

*Furnas, C. C., Chemical Engineer (Ph.D., Mich., '26), Experience includes Dir. Res., Curtiss-Wright, '42-'46; Dir., Cornell Aero. Lab., '46-'54; Chancellor, Buffalo Univ., '54-; ASD (R&D), '55-; Chairman, Committee on Guided Missiles, RDB, '51-'53; Tech. Advis. Panel on Aeronautics, ASD (R&D), '53-'55; Memb. Adv. Group on Special Capabilities, '55 (resigned Dec. '55 to become ASD (R&D).)

*Kaplan, Joseph, Physicist (Ph.D., Johns Hopkins, '27). Member, Nat. Acad. Science. Presently Chairman, U. S. Nat'l Com., International Geophysical Year '57-'58; Prof. Phys., UCLA. Experience includes Chairman, Dept. Meteorology, UCLA, '40-'44; Dir. Inst. of Geophysics, UCLA, '46-'47. Noted for contributions to spectroscopy and composition of upper atmosphere.

*Lauritsen, C. C., Physicist (Ph.D., Cal. Tech., '29). Prof. Phys. since '35. Experience includes membership on numerous science advisory committees, NDRC, DOD, USAF. Member, National Academy of Sciences. Noted for contribution to theories of electron emission, high-energy physics, nuclear physics. Member, Von Neumann Bal. Missiles Sci. Advis. Com.

McMath, Robert R., Astronomer, Engineer (BCE., Mich., '13). Presently Dir., McMath-Hulbert Observatory, Pontiac, Michigan. Chairman, Board of Directors, Motors Metal Mfg. Co., Detroit. Experience includes OSRD, and Advisor to DOD in aeronautics and guided missiles. (Resigned Jan '58)

*Porter, R. W., Electrical Engineer (Ph.D., Yale, '37). Presently Engineer for Gen. Elec. Co. Experience includes RDB, USA, and G.E. Co. in fields of servomechanisms, aircraft armament, missile-guidance systems, rocketry and propulsion, radar. Past Pres., Amer. Rocket Soc., Chair., Natl. Acad. Sci. Tech. Panel on Earth Satellites.

*Rosser, J. Barkley, Mathematician (Ph.D., Princeton, '34). Professor of Mathematics, Cornell. Experience includes rocket ballistics, numerical analysis, symbolic logic, digital computers. Consultant on rocket ballistics and computing machines to various Government agencies since 1943. Member, Von Neumann Ballistic Missiles Sci. Advis. Com.; Past Pres., Assoc. for Symbolic Logic; Fulbright and Guggenheim Fellow, Univ. of Paris, '53-'54; Director Res., Inst. for Numerical Analysis, NBS, '49-'50.

*Smith, Paul A., Secretary. Geodetic Engineer (B.S.E., Mich., '24). Experience includes precise geodetic surveys and computations; navigation and cartography; technical, economic and legal aspects of international civil aviation. Consultant to ASD (R&E).

Springs, James O., Executive Secretary since 1957. Physicist, lawyer. (Syracuse Univ., AS, '36; LB, '40; AB, Physics, '42). Member, N. Y. State Bar. Experience includes research and design of direction finding and high-speed communications systems. Professional staff asst. to Director of Guided Missiles; Exec. Secy, Scientific Advis. Com. to Sec. Def.; Secy, Anti-Ballistic Missile Com.

Stewart, Homer J., Chairman. Aeronautical Engr. (Ph.D., Cal. Tech., '40). Chief, Liquid Propulsion Systems Division, Jet Propulsion Lab., Cal. Tech., and Prof. of Aeronautics. Experience includes dynamic meteorology, fluid and supersonic flows, design and tests of rockets and guided missiles. Member, Sci. Advis. Board, USAF, '49-; Guided Missiles Committee, RDS, '48-'52; OSRD, U. S. Weather Bur., '44; Consultant to Aerojet Corp.

*Member of the original group participating in selection of Vanguard.