N77-33069

THE VIKING ROCKET: A MEMOIR[+]

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Quite often, history is a matter of recollection, based upon unorganized documents, memoranda, and recalled conversations—some more or less relevant. In the present case, that of the Viking rocket, we are fortunate in having two sources written at the time the events were occurring. The first is the complete set of Naval Research Laboratory (NRL) Rocket Research reports[+++] that describe in technical and chronological detail the histories of each of the ten Viking rockets—their design, instrumentation, the course of field operations, and the subsequent analysis of results. The second source is my book The Viking Rocket Story, that covers the same ground, but in less technical and more readable prose. Although it speaks about rockets, the book deals primarily with people—the men who built, tested, and launched the rockets, whose worries, fears and frustrations are portrayed along with their joys and triumphs.

In most cases I will let the sources speak for themselves, quoting directly where possible, but interpolating some present thoughts when desirable in the interest of clarity. The story of Viking is best told through its launchings, and I have chosen four of the twelve total. These four include the first one, the beginning, so to speak; the fourth, a launching at sea in the mid-Pacific; the eighth, sometimes referred to as the high-altitude static; and the tenth or last of the original series. Summary performance data on all twelve Vikings appears in Tables I and II at the end of this paper.

The launchings took place (except for the Pacific Ocean) at the White Sands Proving Ground, an Army testing installation in a remote, desert location in Southern New Mexico. The Proving Ground occupies a natural basin (the Tularosa Basin) ringed by mountains; the basin is about 50 miles across and 100 miles long, roughly the size of the state of Vermont.

[+] Presented at the Sixth History of Astronautics Symposium, International Academy of Astronautics, Vienna, Austria, October 1972.

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But now to the story, quoting first from the Naval Research Laboratory report on the first Viking flight test.

> On May 3, 1949, the first Viking rocket launching and flight was achieved at White Sands Proving Ground, New Mexico, where the rocket reached a peak altitude of 50 miles. The Viking, formerly known under the name Neptune, was originally conceived by NRL scientists as a vehicle for carrying research instruments into the upper atmosphere. For several years, the V-2 rocket has been used for this purpose with considerable success. But the supply of V-2's is limited and as a vehicle for research the V-2 has certain disadvantages with regard to payload flexibility and stability in flight. In sponsoring Viking's development the Laboratory's purpose is two-fold: to obtain an improved vehicle for the continuance of upper-air research and to advance the rocket art in the United States. The development program encompasses the design, fabrication and launching of ten Vikings of which each rocket is an improvement over its predecessor. The field operations include one or more static firings of each assembled rocket, after which the flight firing is conducted. The program is so devised that the experience gained from each rocket contributes to the design of the next and all other succeeding rockets of the series.
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> Description of the rocket. The Viking is a high altitude sounding rocket designed to carry a 500 pound instrument payload to altitudes of about 100 miles in nearly vertical flight. The vehicle is a conical tipped cylinder, 45 feet in length and 32 inches in diameter. Four swept-back fins (total span, 9 feet and 2 1/2 inches) are spaced equidistantly around the aft end of the cylinder. The weight at takeoff is about 10,000 pounds including 7,000 pounds of propellants.
>
> Propulsive force is obtained from a 20,000 pound (sea level) thrust rocket engine. The rocket propellants, liquid oxygen and ethyl alcohol, are fed to the engine by means of a turbopump. The turbine is driven by steam obtained from the decomposition of hydrogen peroxide. Nitrogen gas is used for pressurizing the pump and rocket propellant tanks, for actuating pneumatic controls, and for coasting-flight stabilization. During powered flight the vehicle is stabilized in pitch, yaw and roll by means of internal controls. Error signals from gyro pick-offs are differentiated, amplified, and fed to solenoid-controlled hydraulic valves. For pitch and yaw corrections, these valves control hydraulic servos which rotate the gimbal-mounted thrust unit about either or both of two axes. Roll correction is obtained by diverting turbine exhaust steam through ports on two opposite fins and by means of trim tabs. The roll hydraulic valves control the position of steam deflectors which are mechanically linked to trim tabs on the same two fins.
>
> After burnings' end the error sensing system is switched to control an array of gas jets. These jets provide correcting moments in pitch, yaw, and roll to remove error moments introduced at or after burning's end. This post-cutoff stabilization system operates for about the first 20 seconds of coasting flight. (Later versions of Viking incorporated an active coasting flight control system, using steam jets that operated during all of coasting flight to stabilize the vehicle in pitch, yaw and roll. The steam was obtained from decomposition of hydrogen peroxide.)
>
> The rocket is serviced with ethyl alcohol, hydrogen peroxide, and liquid oxygen, in the order mentioned. Then the gas storage sphere is charged with nitrogen to a pressure of 3400 psig. The final operations are conducted from two remote panels installed in the blockhouse at White Sands Proving Ground. The gyros are nulled and the thrust unit is centered from the controls panel. The propellant tanks are pressurized and the rocket is fired from the firing desk.

> In anticipation of the extensive field operations required for launchings of ten Vikings, a rocket servicing crew was formed at the Martin Company (the rocket's builder) in May 1948. The crew was composed of engineers and technicians, eight from the Martin Company, three from the Naval Research Laboratory and one from Reaction Motors (the engine builder). [Note that the launching crew consisted of only twelve people, assisted later by some Naval personnel at White Sands.]
>
> The rocket arrived in New Mexico on January 15, 1949, and was transported to the Navy technical area. A receiving inspection was made, components were bench tested, installations were made and functional tests of the control system and power plant were conducted for the remainder of the month. After completion of a hangar pre-flight test, the rocket was ready for transportation to the launching area.
>
> On February 28, the rocket was erected in the launching area in preparation for a static firing. The static firing of a Viking is an operational test in which the completely assembled rocket is fired and the performance of the various systems and components are measured using the flight telemetering system. The rocket is secured to the launching stand by bolts which engage the support pads on the fins. Temporary piping attached to the launch stand is used to spray carbon dioxide and water into the tail section in case of fire. The normal duration of a static firing is 30 seconds, about which time the rocket should cut itself off through operation of an alcohol low-level sensor. However, an emergency shut-down can be made from the firing panel in the blockhouse.

I will not continue the harrowing story of the long series of attempts to static fire and flight test the first Viking. Suffice it to say that this operation continued over a span of two months during which various parts of the rocket either failed or refused to operate properly. The most notorious of these bad performers were the valves used to vent oxygen from the rocket propellant tank. These valves had the annoying property of freezing in the open position so that they could not be closed in preparation for a firing. This malfunction occurred repeatedly, despite replacement of the valves and redesign in the field. We pick up the story on May 3 after the static firing and in preparation for the flight, with the vent valves behaving in characteristic fashion.

> The first attempt on this date was halted at 8:30 in the morning when the vent valves failed to close properly. Because the weather was becoming progressively worse and because there was a possibility that the rocket would have to be returned to the hangar if the launching were not conducted on this date, the ensuing operations had to be conducted with rapidity. There was no opportunity to top off oxygen although it was known that the oxygen level would be reduced by boil-off.
>
> A series of test operations were quickly conducted in an effort to find a procedure for ensuring closing of the oxygen vent valves. The procedure finally used consisted of repeatedly closing and opening the vents prior to pressurization. It was, of course, not possible to keep the vents permanently closed because of the pressure rise due to oxygen boil-off. The previously described expedient finally resulted in a successful closing of the oxygen vents. The rocket was pressurized and launched successfully at 0914 Mountain Standard Time on May 3, 1948.

The launching is more graphically related in <u>The Viking Rocket Story</u>. The count-down passed from X-minus-20-seconds to minus 3 when the command was given to fire.

> The plug dropped, steam shot out of the turbine exhaust, the whole rocket shuddered, and then slowly, majestically, rose up from the launching stand as its long, fiery jet played upon the ground.
>
> Takeoff!
>
> We could no longer see it from the blockhouse, but we could hear it roaring overhead—and each of us prayed for it to keep burning. Sixty-five seconds, the most we could hope for with our oxygen low, might get us close to a hundred miles. The seconds ticked away slowly and then suddenly, much too early—burning's end. What was it—fifty-three, fifty-four, perhaps fifty-five seconds? The time was very uncertain. The vital numbers started coming over the phone from C Station. Altitude at burning's end - 17 miles, velocity - 3,300 feet per second, time to peak - 160 seconds, peak altitude - 51 miles. I was disappointed, and so were the others, at first. We felt better when we heard the remarks from C Station. Good flight! . . . Straight up the middle of the range! Fifty-one miles - damn good for a first rocket!
>
> We filed out of the blockhouse, all of us except Pres Layton, who was slumped over the firing desk, exhausted. We walked out to the launching stand and stood around it. It was still warm. One of the crew looked up and said, "I can't believe it's gone. I can still see it standing there."

We continue this Viking history with an account of the shipboard launching as related in the NRL Rocket Research report.

> On May 11, 1950, Viking Rocket No. 4 was launched from the USS NORTON SOUND at the equator in the Pacific Ocean. This rocket reached an altitude of 105 miles with a 900-pound payload of instruments designed to study cosmic radiation and atmospheric pressure. Early in the program, NRL was requested to design the Viking to test methods of launching large, stabilized rockets from shipboard. In August 1949, the laboratory requested use of the NORTON SOUND to fire a Viking at sea on or about May 10, 1950. The Chief of Naval Operations approved this request and initiated "Project Reach" for the launching of an upper-atmosphere research vehicle for the study of cosmic radiation at the equator, and gaining practical experience in the shipboard handling, launching and tracking of large bombardment-type missiles. The ensuing preparations, which occupied a period of seven months, culminated in the first successful firing and flight at sea of a large stabilized rocket.
>
> The first three Vikings were fired at the White Sands Proving Ground in New Mexico. Although the highest altitude was 50 miles, the performance of each of these models was sufficiently good to demonstrate the soundness to the rocket's basic design. Static firings of each fully-assembled rocket were conducted at White Sands prior to the flights. Full use of the vehicle for carrying upper-atmosphere instruments was initiated in Viking 3 which was devoted to cosmic-ray research, solar spectroscopy, and atmospheric pressure measurements.
>
> Early in the Viking program, both scientific and military interest were evinced in the firing of a large rocket from shipboard. The feasibility of such a shipboard launching was demonstrated when a V-2 was fired from the USS MIDWAY in September 1947. The principal scientific value of shipboard launchings is to extend widely the areas over which atmospheric studies can be made. From 1946 until 1949 the rocket upper-air research program in the United States was confined to the White Sands, New Mexico area. Although a great deal more remains to be done at White Sands, it is essential that studies be made at numerous geographical locations. For example, in the case of cosmic radiation,

> geomagnetic latitude is important, since the ability of the earth's magnetic field to deflect an incoming particle depends in part upon the magnetic field direction, which varies with geomagnetic latitude. In essence, the earth's magnetic field performs a geographical sorting, in accordance with cosmic ray energies.
>
> The military value of firing a large rocket at sea is immediately apparent. Because of the ship's mobility, the launching area is extended to include all accessible waters, and thus to the range of the missile there is added the range of the ship. [Bear in mind that this was written about ten years before the first launching of a Polaris missile from a naval vessel.]
>
> The Navy Department in 1947, designated the USS NORTON SOUND as a facility for the evaluation of guided missiles and as a mobile launching site for scientific investigations requiring specific geographic locations. Previously, a seaplane tender, the NORTON SOUND was converted to an experimental guided-missile ship in the summer of 1948. Also in 1948, NRL issued a report that laid the plans for a shipboard launching. The report dealt with handling and launching problems, telemetry, tracking and recovery of rocket-borne equipment, and also pointed out the necessity of several land-based firings before attempting a Viking launching at sea. The performance of Viking No. 1, however, was sufficiently good to enable the laboratory to propose the 4th Viking as the vehicle for the shipboard launching.

The significant difference in a shipboard firing arose from the motions of the ship, its pitch and roll, that could be a problem in the separation of the rocket vehicle at launching. The design of the launcher was critical, hence, we chose a simple, fixed mechanism: a pair of rails aligned vertically at one side of the rocket. Two sets of rollers, one set at the vehicle's aft end, the other set 10 feet forward of the aft end, engaged the rails and constrained the rocket to move with the ship until its ascent had freed it from the railway.

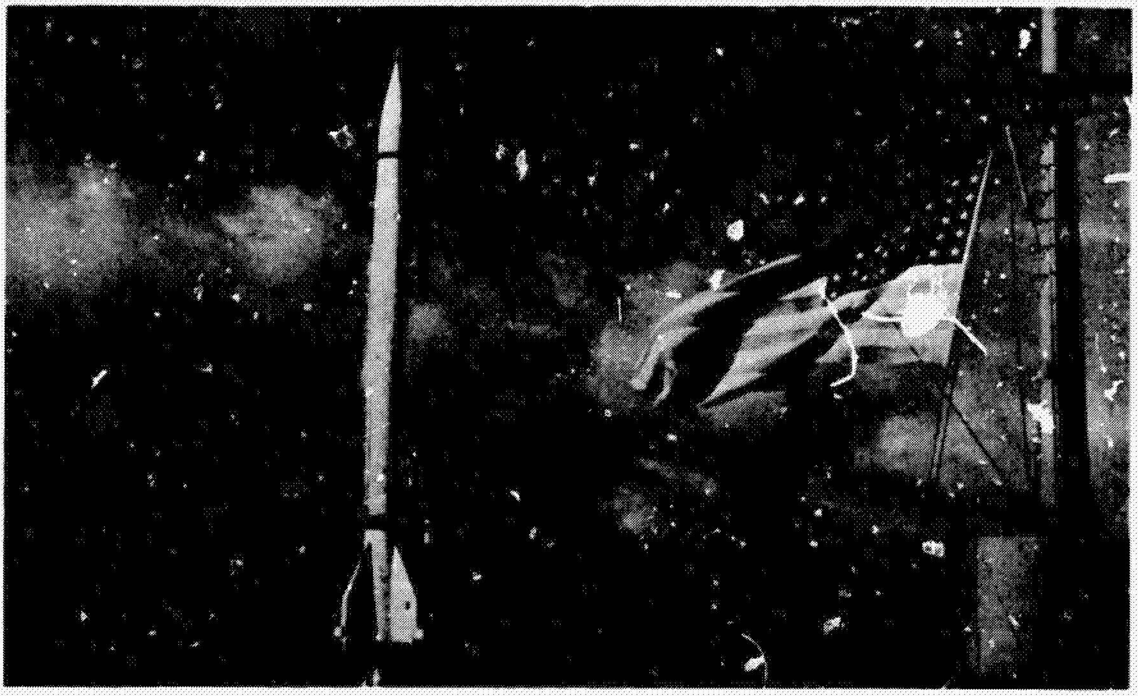
Two dummy Viking missiles were built in order to test the launching technique prior to the firing of Viking 4. Each dummy duplicated the live rocket in the essential features required for the launch test. Externally, it was nearly identical, using the regular tail and tank section skins. Internally, duplication of the actual rocket ceased. The dummy missile was powered by a solid propellant JATO which produced an average thrust of 5700 pounds for 3.5 seconds. The JATO bottle was cocked at an angle from the missile's axis in order to carry it away from the ship—about 400 feet at impact. The gross weight of the dummy was made proportional to the thrust, so as to produce the same acceleration and velocity in the tower as those of the actual Viking.

The first dummy missile was fired in the Santa Barbara Channel off the coast of California two weeks before the NORTON SOUND sailed on the expedition to the mid-Pacific. The firing had been delayed several days in the search for sea conditions producing ship's motions of sufficient amplitude. The idea was to fire the dummy missile at the worst possible moment in the ship's roll cycle so as to produce the most severe "tip-off." Then the live Viking would be fired at the most favorable time in the ship's motion and would be assured a safe separation. The dummy was fired successfully and confirmed the calculations of "tip-off" due to ship's motions.

The NORTON SOUND sailed from Port Hueneme on April 26, 1950, and was joined by the destroyer OSBOURN 250 miles west of San Diego on the following morning. This fleet of two vessels then proceeded, over a period of 10 days, to the launching area at the geomagnetic equator in the vicinity of Christmas Island, some 2000 miles due south of Hawaii.

The NRL report describes a long series of difficulties and mishaps associated with operations at sea. The high humidity of the tropical night air was a source of great concern, depositing moisture on lines and connectors and shorting electrical circuits. We had to learn how to operate the rocket's vibration-sensitive control system on a continually moving ship. Nevertheless, after several trials Viking 4 was launched successfully from the deck of the NORTON SOUND as it proceeded along the equator near Christmas Island (Figure 1). The dispatch from the ship's Captain to the Navy Department read:

> SEA-GOING VIKING SERIAL NUMBER 4 WITH HEAVY INSTRUMENT LOAD LAUNCHED ON GEOMAGNETIC EQUATOR 1600 LOCAL TIME ELEVENTH MAY X ALL SCIENTIFIC OBJECTIVES



Official U.S. Navy Photograph

Fig. 1

> ACHIEVED MUCH VALUABLE EXPERIENCE GAINED NO CASUALTIES X MAXIMUM ALTITUDE 106.4 STATUTE MILES MORE THAN DOUBLE PREVIOUS VIKING RECORDS AND NEW RECORD FOR SHIP-LAUNCHED MISSILE X MANEUVERED BENEATH 3/10 CLOUD COVER TO EXCELLENT OPENING FOR FLIGHT X OSBOURN AND HELICOPTER SUPPORT OPERATIONS HIGHLY SUCCESSFUL X PROCEEDING PEARL X

On the return trip to Hawaii some 250 members of the Viking project complement and the ship's crew, who had never before crossed the equator, were initiated into the mysteries of the Society of Shell-backs.

We resume the Viking history with the NRL report on Viking 8.

> In the Fall of 1950 NRL and the Martin Company began considering major revisions to the Viking rocket in order to extend its altitude ceiling. The original design requirements (500 pounds of payload to 100 miles) had already been exceeded by Viking 4, and minor changes in Vikings 5 and 6 promised to raise the altitude ceiling to 125 miles. Two avenues lay open for further increase: (1) improvement in specific impulse, and (2) improvement in mass ratio. Attempts to increase the engine specific impulse witnout major redisign (principally, by injector redesign) had not been successful, although such improvement is certainly possible. Mass ratio had been improved continually through the first seven Vikings. A large gain could be made only by a significant increase in propellant capacity without a corresponding increase in structural weight. This was the primary purpose of the redesign. A secondary aim was the rearrangement of power plant and control equipment to improve accessibility of the various components.
>
> The design changes, originally scheduled for Viking 7, were achieved too late for incorporation in that rocket, which was built to the original configuration. It achieved a record altitude of 136 miles. Viking 8, then was the first model of the new design. The rocket was never brought to the flight firing stage. During the static firing at White Sands Proving Ground, coupled vibrations between the motor and structure exceeded static load limits and caused the rocket to tear loose from the launching stand after 15 seconds of burning. Flying in a static firing condition, the rocket continued under power until it was cut off by radio at 61 seconds. It reached an altitude of 20,000 feet and landed four miles from the launching site.

A more graphic description of the events surrounding this firing is taken from The Viking Rocket Story:

> As the second hand on the large clock swept through the last minute before X-minus-15, we became quiet. Jim Hartman was at the firing desk, substituting for Hardin who took over the fire-watcher station and was peering at the rocket through binoculars. Mason was at the controls panel; Munnell and I were between the two operators a step behind them. At X-minus-15-minutes Hartman turned on master power and Mason switched the gyros to erect. When after [illegible] minutes the gyro meters did not come to zero, Mason requested permission to erect the gyros from the panel controls. Munnell assented. This procedure left some uncertainty about the true position of the gyros, a condition that would never be tolerated for a flight, but could be accepted on static. The count proceeded without a hold. At X-minus-1-minute the rocket was pressurized. Munnell, Hardin, and I hung over Jim Hartman at the firing desk as the meter needles swung up, wavered and then stood still.
>
> Forty-five seconds . . . Hardin nodded to Munnell, indicating that he was satisfied with the pressure levels. Ed flicked on his green light. The rocket was cleared for firing.

Thirty-five seconds . . . I turned to the telemeter men and called for recorders. The work was relayed to the telemeter house seven miles uprange. We waited.

Twenty-five seconds . . . The answer came back. Recorders were on. Lieutenant Cooper, the Navy project officer, started the count down in a hushed voice.

Twenty, nineteen, eighteen, seventeen . . .

Twelve, eleven, ten, nine . . . the ready lights were all green.

Five, four, three, two . . . Fire!

Igniter on . . . plug drop . . . fire light . . . the motor had started. At plus four seconds, the firing panel meters wavered and dropped to lower levels. I looked at Ed to see if he had noticed it. He had and was glancing alternately at the panel meters and the rocket. At nine seconds we heard a dull throbbing sound in the jet blast. The thought flashed through my mind: Should we cut it or let it run longer to get enough time on the record? How long was enough? At thirteen seconds the rocket started heaving almost imperceptibly. Then without warning, before our horrified eyes, it tore loose from the stand and started slowly to rise. We saw the tubes and cables that were connected to the rocket for static test snap one by one as the tail moved upward out of our sight. A great cloud of dust billowed toward us as the mighty roar of a flying rocket bore down upon the blockhouse roof.

Takeoff! The rocket has broken loose! The rocket is flying! The alarming words flashed out from the blockhouse. At the telemeter station the men dashed up to the roof to start training their antennas which had been lashed down for the static.

Plus twenty-five seconds . . . Nat Wagner yelled at me across the blockhouse, "Shall we cut it?"

As the seconds slipped away I pondered this deadly question. The rocket was lost, with only half a tank of alcohol it could not go far, not possibly leave the range. If we cut it too early, it might fall on one of the installations close to the launching area.

"No!" I shouted back. "Don't cut it. You don't know where the rocket is!"

Thirty-five seconds . . . Nat and I were staring at each other across the blockhouse. I knew he wanted to stop the rocket and I felt it would be a mistake. There was no time to explain the conditions - a tank half full to start, fifteen seconds of fuel burned on the ground.

Fifty-five seconds . . . "We're going to cut it," Nat announced. He pressed the button. We waited in silence, not knowing whether he had stopped the rocket or whether it had cut itself off previously. We had ceased to hear its sound many seconds before.

Finally, at 120 seconds, we heard a muffled explosion. We looked at each other; that must be impact. We rushed out of the blockhouse and scanned the horizon. To the southeast we saw a gray mushroom of smoke rising slowly against the pale, blue sky. We estimated its distance as four or five miles. I walked toward the launching stand. The two tie-down blocks from the rocket were still in place, bolted to the crossbeams of the stand. Attached to the blocks were a few scraps of structure that had been torn from the rocket when it broke loose. The two shiny stubs of aluminum pointed upward, silent evidence of the rocket's awful power.

Returning to the NRL rocket research report we quote as follows:

> The destruction of Viking 8 can be attributed to a combination of factors. Of primary importance was the failure to shut off the power plant before the rocket had broken loose. Although cutoff could have been effected at any time prior to 14 seconds of burning, no action was taken to initiate it. If, in the light of foregoing paragraphs, it appears incredible that no action was taken, it should be remembered that 4 to 6 months are required to assemble and analyze the data presented in this report, whereas the firing crew had 5 to 8 seconds in which to recognize the situation, to evaluate it, and to take appropriate action. The mistake in this case arose from the fact that judgment was required in order to initiate action. Under the emergency procedures used in early Viking firings, cutoff would have been given at about 5 seconds when gages on the firing panel indicated operation at reduced thrust. But during the course of 10 static firings without mishap, there was a tendency to relax the rigid emergency procedures and to rely more on the operator's judgment, since the characteristics of the rocket had become better known and the crew more experienced. On Viking 5, a low thrust static firing was allowed to run for 30 seconds. It should have been realized that, because of the redesign, Viking 8 required the same degree of caution as Viking 1.
>
> The decision to restrain the airframe during static firing at two points instead of four was reached early in the design period many months before the firing. Subsequent structural analyses and static load tests showed this scheme to be adequate for normal conditions, plus specified factors of safety. That the design was inadequate for the abnormal conditions of Viking 8 is now obvious. The question of how far to go in protecting a rocket against abnormal conditions has never been answered satisfactorily. Once a specific condition has occurred, corrective action is always taken. But, should an attempt be made to foresee and design for as many abnormal conditions as possible? Increased factors of safety are obtained only at the expense of lower performance. One lesson can be learned from the Viking 8 experience— for a vehicle that is still in an experimental stage of development, adequacy alone is not a sufficient criterion.

This history closes with an account of the launching of Viking 10 introduced as follows in the NRL report:

> The 10th Viking, launched from the Naval site at the White Sands Proving Grounds, at 10:00 a.m. on May 7, 1954, carried 675 pounds of instruments to a peak altitude of 136 miles. The first attempt to fire this rocket on June 6, 1953, resulted in an explosion and fire which destroyed the combustion cylinder and severely damaged several other power plants and control components. The rocket was returned to the contractor's plant for repair and an extensive investigation of the nature and causes of the explosion was made.

A graphic description of this first firing attempt is taken from The Viking Rocket Story:

> We were in the blockhouse again, shortly after noon and went through a second count down, punctuated by brief holds, the last of which occurred at X-minus-2-minutes.
>
> "On-the-mark time will be running at X-minus-2-minutes.
>
> . . . Mark! . . . X-minus-2-minutes."

Hardin put the safety key in the firing desk; until this key was engaged the rocket could not be pressurized or fired.

"Coming up on X-minus-1-minute . . . Mark! . . . X-minus-1-minute . . . fifty seconds . . . forty-five seconds . . . forty seconds . . . thirty-five seconds . . . Recorder on! . . . twenty-five seconds . . . Recorders are on! . . . Twenty, nineteen, eighteen, seventeen . . .

At ten, Pitts' voice was joined by the others who were relaying the time in unison so that the rhythmic count took on the air of a religious chant.

"Seven, six, five, four, three, two, one, zero!"

Hardin pushed the firing switch, the plug dropped from the rocket's nose, and the turbine exhaust belched forth a stream of ominous black smoke. Suddenly, without warning, in less than a second, a terrific blast smote the blockhouse as the rocket's tail seemed to disintegrate. White steam, orange flames and gleaming metal shot out from the tail in an explosion of unbelievable violence. Then a great ball of flame rose from the tail and enveloped the rocket.

"Misfire! The rocket's on fire! No shoot, the rocket is burning."

When we saw the explosion, Hardin, without hesitation, threw the firing switch to cutoff. Schlecter ordered the carbon dioxide and all water sprays turned on. Then he turned to Pitts and said, "The rocket is out of our control. It belongs to the firemen now."

The four giant fog nozzles at the edge of the launching mat, each one pointed at the base of the rocket, were turned on. The water came out with agonizing slowness, trickling toward the flaming rocket. When, finally, the full force of the spray hit the tail, a great cloud of steam obliterated the area.

Joe Pitts in the center of the blockhouse was being bombarded with questions and suggestions. His primary concern, and rightly so, was the safety of all personnel in the immediate area. Those in the blockhouse could be considered safe, as long as they stayed inside, but there were dozens of people outside, several hundred yards from the rocket, some of whom, out of curiosity, might approach it.

"All personnel stand clear, stand clear, take cover! The rocket is burning." Pitts' words blared forth from the loudspeakers outside the blockhouse. "All personnel stand clear and take cover!"

I surveyed the situation and was sick at heart. Schlecter and Pitts had done all that could be done; there was nothing left now but waiting. The rocket was still standing, as if by a miracle, but it would be suicide to approach it. Captain Quirk, the Navy commanding officer, was in the blockhouse and had set a guard on the door - no one could leave. I saw the firing pit fill up with white vapor. Oxygen, I surmised - we must have dumped the whole tankful into the pit. But there were still three tons of inflammable alcohol in the upper tank and, worse yet, four hundred pounds of highly explosive peroxide in the tail with a fire, now confined to the east quadrant, only a few inches away. Surely the peroxide would go up any minute and then all would be over. I looked at my watch - it was twelve-thirty.

> Twelve-thirty-two. The blockhouse was a beehive of excitement; knots of men packed at each of the three windows, watching the rocket, a scant two hundred feet away, with a horrified fascination. The other men were scattered about the blockhouse interior, some in small groups, others milling around and glancing furtively from time to time at the small open patches of window space. Joe Pitts was at his rostrum in the center of the room, and was busy receiving reports and relaying information to people all over the range. Now and then, individual voices could be heard above the incessant buzz of conversation.
>
> "Stand by, no shoot, no shoot. The missile is burning."

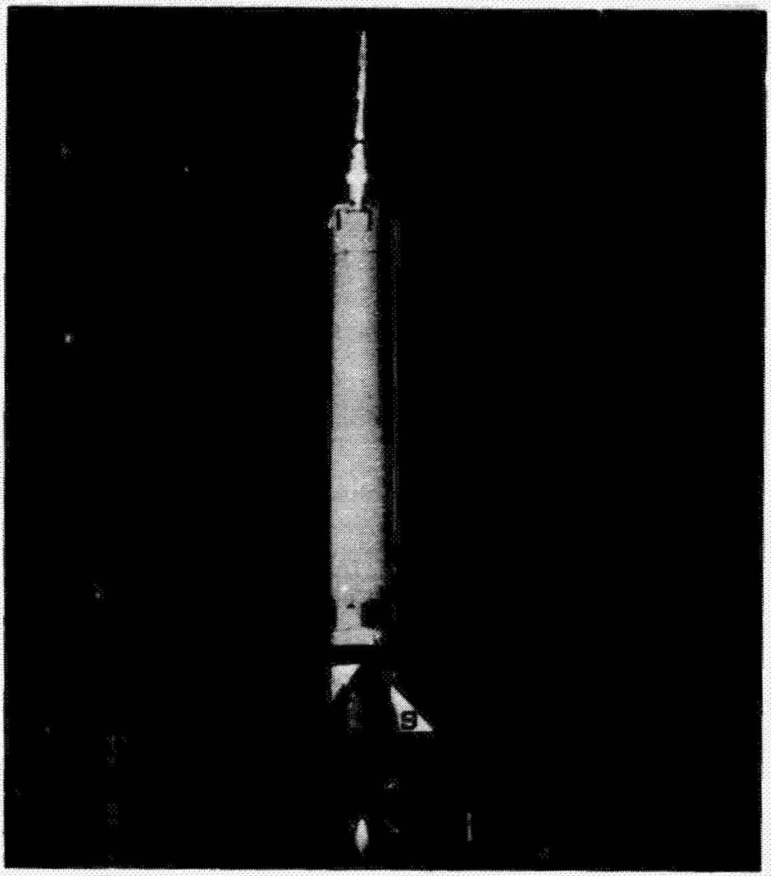
Five hours later the scene is described as follows:

> Five-thirty. Although the fog nozzles and fire hoses had been turned off two hours before, the tail was still dripping water into the pit. The metal was cold, but everywhere there were signs of the searing heat that had followed the explosion. All the tail access doors, both large and small, had been ripped off and hurled from the rocket, some as far as a hundred feet. Large peices of skin material were missing, and from the fused edges of the jagged holes we could tell that some of the metal had been vaporized. Inside the blackened shell there was only devastation. The east quadrant was gutted, the controls can had exploded, and inside there was a fused mass of metal, wire and glass. The fire wall above the motor was dished upward, with a large gaping hole at its center. The motor itself was a most horrible sight. It had been blown apart into two pieces; its massive head was jammed against the gimbal ring, and its nozzle hung awkwardly by two alcohol hoses like a broken jaw.
>
> Five-fifty-eight. The sun had dropped behind the Organs and the Western sky was red as we climbed into our vehicles and slowly drove away from the launching area. We had been there fourteen hours, a long, unforgettable day that had seen us push a button that brought instant disaster and, finally, had watched a valiant fight to save a crippled machine that meant so much to all of us. As I looked back at the white rocket, now sheltered by its gantry framework, I could hear the oft-repeated words, "You'll never see this rocket fly."
>
> I resolved that somehow, someday, Viking 10 would fly.

The rocket was rebuilt, returned to the White Sands Proving Ground and successfully launched almost a year later to peak altitude of 136 miles (Figure 2). It made valuable measurements of upper atmospheric pressure, density, and winds, and determined the ion content of the atmosphere above an altitude of 100 kilometers.

From the foregoing stories of Viking firings, there emerge some of its basic contributions to the progress of rocket design and development. Viking was the first large rocket to successfully employ the gimballed motor that became a standard feature of Thor, Atlas, Titan, and Saturn, and almost every rocket of the last twenty years. We suffered with and mastered the problems of instability and vibration in gimballed motor systems and adopted the transfer function method of analysis.

Through Viking innovations, the mass ratio (MR) of rocket vehicles was advanced to much higher levels. Viking spanned the gap between the V-2's MR of 0.67 and the Thor-Atlas values of 0.94. Integral tanks, extensive use of aluminum and magnesium, low thrust-to-weight ratio—these were some of the measures that ploughed the ground leading to high mass ratio.



Official U.S. Navy Photograph

Fig. 2

Because of its extensive use for upper air research, Viking had to develop a coasting-flight stabilization system consisting of a gyro-controlled array of gas jets. Such a system has been a standard feature of succeeding launch vehicles and spacecraft, particularly those intended for manned flight.

An unusual feature of the Viking experience is the small amount of funds and manpower that were required. The entire Viking development and launching program, extending over a period of eight years, cost no more than five million dollars, and absorbed the energies of no more than 100 engineers, technicians, and factory workers. Economy was a necessity--and we made of necessity a virtue. Will such times ever return to our field?

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4. NRL Report 4513, "Rocket Research Report No. XIX - The Viking 10 Firings," M. W. Rosen and J. M. Bridger, May 5, 1955.

5. Milton W. Rosen, *The Viking Rocket Story*, New York: Harper and Brothers, 1955.

TABLE I. PERFORMANCE DATA (VIKINGS 1 THROUGH 12)

Viking No.	Launched	Peak Altitudes (miles)	Maximum Speed (feet per second)	No. of Static Firings	No. of Flight Attempts	
1	May 3, 1949	50	3,450	2	3	Premature cutoff due to steam leaks in turbine.
2	September 6, 1949	32	2,675	1	2	Same as Viking 1.
3	February 9, 1950	50	3,440	2	1	Rocket cut off by radio when westward drift became excessive.
4	May 11, 1950	105	5,160	1	2	Shipboard firing. Peak altitude almost the maximum possible.
5	November 21, 1950	108	5,150	2	1	Long burning time due to reduced thrust.
6	December 11, 1950	40	4,030	1	1	Night firing. Fins failed. Rocket executed violent maneuvers.
7	August 7, 1951	136	5,865	1	1	Highest flight of original airframe design.
8	June 6, 1952	4	——	1	0	Rocket broke loose on static firing and destroyed itself.
9	December 15, 1952	135	5,795	3	2	First successful flight of larger airframe.
10	May 7, 1954	136	5,720	2	2	Motor exploded on first flight attempt. Rocket was rebuilt and flown.
11	May 24, 1954	158	6,300	1	1	Highest Viking flight to date.
12	February 4, 1955	144	5,900	2	1	Successful flight. Last minute holds almost caused cancellation.

TABLE II. FLIGHT TIMES, MOTOR THRUSTS, WEIGHTS (VIKINGS 1 THROUGH 12)

Viking No.	Launched	Burning Time (seconds)	Time to Peak (seconds)	Time to Impact (seconds)	Motor Thrust (pounds)	Gross Weight (pounds)	Payload (pounds)	Oxygen (pounds)	Alcohol (pounds)	Peroxide (pounds)
1	May 3, 1949	54.5	164	291	20,450	9,650	464	3,250	3,445	160
2	September 6, 1949	49.5	133	394	20,465	9,985	412	3,580	3,420	265
3	February 9, 1950	59.6	169	420	20,450	11,050	528	4,160	3,870	280
4	May 11, 1950	74	242	435	20,450	11,450	959	4,170	3,830	280
5	November 21, 1950	79	248	450	18,800	11,390	675	4,380	3,780	270
6	December 11, 1950	70	145	292	20,800	10,890	373	4,250	3,850	260
7	August 7, 1951	72	266	530*	21,080	10,730	394	4,210	3,740	255
8	June 6, 1952	61	50*	100*	21,400	12,810	—	5,800	3,240	330
9	December 15, 1952	99	287	540*	21,170	14,615	765	6,075	5,280	390
10	May 7, 1954	100	290	595	20,990	14,750	830	5,900	5,530	385
11	May 24, 1954	103	309	557	21,400	15,005	825	5,810	5,790	385
12	February 4, 1955	102	299	540	20,500	14,815	887	5,600	5,815	390

*Estimated