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Chapter 11

The Viking Sounding Rocket—The First Design, Building, and Flying of a Space Rocket: Some New Perspectives in Aerospace History[*]

Frank H. Winter[†] and Kerrie Dougherty[‡]

Abstract

The Viking sounding rocket was far more significant in the history of spaceflight and rocketry than first appears. Developed from 1946, the Viking was America's first large-scale liquid-propellant rocket. It also became the first US single-stage rocket to enter space. Retrospectively, considering these achievements, this chapter also shows that the Viking was the world's first rocket *specifically* designed for flight into space. It also took some of the earliest photos in space. Additionally, modified Viking rockets Nos. 13 and 14 served as test vehicles for Project Vanguard—America's first vehicle designed for launching satellites. From 1955 to 1957, a partly reconstructed Viking also became the earliest flown space rocket ever exhibited in a museum and was displayed in the Hayden Planetarium in New York City, part of the American Museum of Natural History. Furthermore, in that capacity, this exhibited vehicle played a significant role in helping to generate early public enthusiasm in the United States for spaceflight and its future possibilities. Indeed, although now largely forgotten and quickly

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overtaken by the worldwide interest in Project Vanguard and followed by the stunning achievement of the Soviet launch of *Sputnik* in the latter year that opened up the Space Age, during that short period, the Viking rocket was an icon of the possibilities of spaceflight.

I. Introduction

The Viking sounding rocket—not to be confused with the Viking spacecraft that famously explored the planet Mars from 1976 to 1978—was conceived shortly after the close of World War II. The late distinguished historian of astronautics, Frederick I. Ordway III, described it as "…the most advanced liquid-propellant rocket [then] under development in America." [1].

Reaction Motors, Inc. (RMI), the first US liquid-propellant rocket company, formed in December 1941, was responsible for the development of the 20,000 lbf (88.96 kN) thrust XLR-10 rocket engine for the Viking. In the course of research for their book, *Pioneering American Rocketry: The Reaction Motors, Inc. (RMI) Story, 1941–1972* (2015) [2], Ordway and Winter discovered and documented many new facts and insights relating to the history of the Viking rocket and its engine, which incorporated several revolutionary technical developments for the time. This paper presents the details of these developments, together with further new research on the significance of the Viking rocket in the history of spaceflight and rocketry.

This paper builds upon earlier histories of the Viking rocket program by the late Milton W. Rosen (1915–2014), Director of the Viking rocket program.[*]

In 1955, Rosen recounted his key role in the history of the Viking rocket in his much-acclaimed book, *The Viking Rocket Story* [3]. He also summarized his work in his IAF paper, "The Viking Rocket: A Memoir," presented in 1972 at the Sixth History of Astronautics Symposium (23rd IAF Congress) held in Vienna, Austria [4].

II. Origins of the Viking Rocket and its XLR-10 Engine

Between March 1946 and June 1951, the United States flew, or attempted to fly, 67 re-built captured German V-2 rockets, mainly at the White Sands Prov-

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[*] In 1955, Rosen also proposed a satellite launch vehicle based upon the Viking. This led to him becoming a leading member, alongside Wernher von Braun et al., of Project Orbiter. This eventually led to the development of the Jupiter-C launch vehicle, based on the Redstone missile, that launched *Explorer 1*, the first US satellite, on 31 January 1958.

ing Grounds, New Mexico. In place of warheads, the V-2s were fitted with scientific payloads to explore the upper atmosphere, thus helping to lay the foundations of space science. These V-2 launches also provided invaluable experience to the US Army Ordnance in the handling of large-scale liquid propellant rockets. The US Navy similarly took a great interest in the development of the rocket, both for continuing the exploration of the upper atmosphere and as a potential missile.

During the war, the American nuclear physicist Dr. Ernst H. Krause participated in early radar research and communications systems at the Naval Research Laboratory (NRL) in Washington, DC. He came to specialize in ionospheric research and the effects of upper atmospheric properties upon communications and later missile guidance systems. By mid-December 1945, Krause had helped to form the NRL's Rocket Sonde Research Subdivision (later re-designated as a Section), with himself as its chief.

At first, the NRL relied upon the captured V-2s for some of their ionospheric research, but soon they realized that the supply of V-2s was dwindling. Although the Aerobee sounding rocket would come into service in 1947, it was far smaller than a V-2 and was limited to much lighter payloads. Consequently, in early 1946 Krause and other Navy officials began to plan for the development of a Navy-sponsored large sounding rocket comparable to the V-2 in payload capacity and "within the context of missile development." [5]. (Although the principal aim of the sounding rocket program was to extend knowledge of "the Earth's atmosphere to as great an altitude as possible," the top US Navy echelon believed that the technology could also be applied towards the potential development of a sea-going long-range missile.) [6].

Consequently, Krause tasked Rosen, who had earned a bachelor's degree in Electrical Engineering from the University of Pennsylvania in 1937 and who had started working at the NRL in 1940 on missile guidance systems, and Carl Harrison Smith Jr., a fellow electrical engineer at the NRL, to plan such a rocket, based upon Krause's general specifications of performance. Since this was originally a Navy project, the vehicle was named Neptune, after the powerful Roman god of the sea.

Rosen and Smith at first considered Aerojet as the company to develop the engine for this new rocket. However, according to Rosen, the location of that firm, across the country in California, was too far away. The other existing rocket company at the time, Reaction Motors, Inc. (RMI), was based in Pompton Plains, New Jersey, which was far closer to the NRL [7]. Therefore, according to the *Daily Log* of Lovell Lawrence Jr., one of the four founders of RMI and its first president, at 10:30 a.m. on 4 March 1946, four officers from the NRL and two civilians "flew in from Washington to discuss possibilities of a new altitude rocket." [8]. These men were Commanders Leslie M. Slack and R. E. Doll, along with Rosen and Smith. Attending the meeting on RMI's side, were, presumably besides Lawrence, John Shesta, and James H. Wyld,[*] two of the other RMI founders, and John A. Pethick, their General Manager.

Figure 11–1: Milton W. Rosen (1915–2014) who served as the Project Manager of the Viking sounding rocket, the US first large-scale liquid-fueled rocket that also appears to have been the world's first single-stage rocket designed and built for achieving spaceflight. Photo courtesy Milton W. Rosen.

The meeting between the NRL representatives and RMI went very well. The project presented an enormous and exciting technical challenge for the young company that was then only five years old. At this juncture, RMI was in the process of developing their 6000C-4 rocket engine, later designated the XLR-11. At 6,000 lbf (26.69 kN) total thrust, this was RMI's most powerful engine to date.[†] In stark comparison, the single-chambered engine for the proposed new Neptune sounding rocket would generate about 20,000 lbf (88.96 kN) thrust, or 3.3 times more power than the four-chambered 6000C-4. This 20,000 lbf (88.96 kN) thrust value was derived from calculating the basic requirement of the rocket to carry a 500 lb (226 kg) scientific payload to an altitude of 100 miles (160.9 km). Krause had likely already set this base-line parameter with his base-line parameter back at the NRL.

From this point, events moved very quickly. In April 1946, just a month after Rosen's visit to RMI, the Chief of Naval Research approved two million dollars for the Neptune development while, by August, the Martin Company won the primary Navy contract to build the airframes for the rocket. The Glenn L.

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[*] Notable as the originator of the Wyld regeneratively cooled rocket motor which he developed from 1935 to 1938 and which led to the formation of RMI in late 1941, two weeks after the bombing of Pearl Harbor. Slack, incidentally, later became a captain and commanded the Navy's first Polaris missile submarine, the USS *Observation Island*. Slack had also served as the Navy's project officer for what became the Viking project.

[†] This engine went on to power the Bell X-1 aircraft that, on 14 October 1947, became the first airplane to fly faster than the speed of sound.

Martin Co. of Baltimore, Maryland, was a well-established aircraft firm that, by this time, had expressed a desire to "get into the game" (i.e., missile and sounding rocket developments). In the same month, RMI received US Navy Bureau of Aeronautics (BuAer) contract NOa(s) 8531 for the engines [9].

The initial contracts with the Martin Company and RMI called for the construction of ten vehicles and their respective engines; later, in June 1952, four additional rockets were added to the contract. The Navy chose Rosen at the outset as NRL's Project Manager for Neptune, with Smith as the Co-Director.

III. Defining the Boundary of "Space"

When the Neptune rocket (afterwards known as the Viking) was conceived in 1946, the region of "space" itself had yet to be properly defined. Although the projected minimum 100 mi (160.9 km) altitude for the Neptune vehicle would exceed the 62 mi (100 km) afterwards internationally recognized as the beginning of space, in 1946 that boundary, also known as the "Kármán line" and named after the famed Hungarian-born aerodynamicist Dr. Theodore von Kármán, had yet to be established.[*]

Figure 11–2: Andrew G. Haley (1904–1966), a major pioneer in space law, who with the famous Hungarian-born aerodynamicist Dr. Theodore von Kármán (1881–1963), created the so-called "Kármán line." Photo courtesy Andrew G. Haley Jr.

Von Kármán and his friend, Andrew G. Haley, who had been a fellow founder of Aerojet Company in March 1942 as the second US rocket company, and later also became a highly prominent pioneer in space law, had pondered this profound question for some years. It is beyond the scope of this paper to recount the complex history of this topic, but Haley considered the legal side of this matter in his studies on extensions of the upper limits of international territorial "air space" while von Kármán established its scientific aspects. Their search for a more definitive answer to the question of where space "begins" became height-

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[*] The use of the term "internationally recognized" here is not meant to imply "legal recognition," but merely a general understanding in many countries of this boundary as more or less common knowledge. At the same time, it is very important to note, as explained in Addendum XII. of this paper, the "Kármán line" was never officially codified in any body of law in any country.

ened following the announcement by the White House, on 29 July 1955, that US President Eisenhower had approved the launch of small, unmanned satellites during the coming International Geophysical Year (1957–1958). Haley's first public presentations on the need for a definition of the beginnings of "space" also appeared in 1955, in his speeches and articles under the general heading of "space law." [10].

In mid-1956, von Kármán presented a paper on "Aerodynamic Heating—the Temperature Barrier in Aerodynamic Heating"* in which he used a diagram made by David Masson and Carl Gazley Jr. of the Rand Corporation showing possible ranges of continuous flight in the velocity-altitude coordinate systems. Von Kármán now recognized that this diagram could be modified to also show the approximate altitude that was the most likely limit where aircraft could no longer operate aerodynamically and hence, the beginnings of "space."

Von Kármán therefore suggested to Haley that he make a modification of the diagram, which would include the high-altitude sounding rocket regime, the Earth orbital satellite regime, and the Kepler regime, or the best point for achieving Earth orbital velocity. (According to Strughold, the "Kepler regime," named after the famous astronomer Johannes Kepler, is about 200 km [120 mi], where "the laws of celestial mechanics unhindered by air resistance, are fully effective. It is here where space in its connotation 'outer space' actually begins." That is, as he also stated, air resistance is at zero. Strughold had therefore recognized that there are still air molecules below that level although they get successively thinner and thinner with increased altitude. (In Strughold's viewpoint, stated in 1959, the level of 50 km., or about 30 mi, was "the technical zero line for aerodynamic lift…") [11].

In any case, Haley created a new diagram as suggested by von Kármán and arrived at what he termed the "Kármán [*sic.*] jurisdictional line." This line was placed at an approximate altitude of 55 mi (88.5 km)—although other sources say it was 53 mi (85.2 km)—and marked the level at which (aircraft) aerodynamic flight ceases and centrifugal force (i.e., for spacecraft) takes over. Haley's viewpoint therefore differed considerably from that of Strughold and others who believed that the level of the atmosphere where aerodynamic lift ends is about 30 mi (50 km). But as matters turned out, Haley was far closer to the mark. This was technically proven in design and operational practice when the flights of the X-15 rocket research aircraft reached above 50 mi (80 km)—and actually well above that—from the early 1960s. Of course, the X-15 was a highly complex aircraft designed to fly in what was then referred to as an "extreme environment," other-

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[*] This paper was presented at the "Symposium on High Temperature – a Test for the Future," at the University of California, Berkeley, during 25–27 June 1956.

wise called "the fringes of space." For example, its series of small "reaction control system" hydrogen peroxide thrusters were designed to give the aircraft directional control in what was generally considered "outside the atmosphere"—just as the Viking rocket, as we will see in Section VI of this paper, used small hydrogen peroxide thrusters to similarly achieve directional control beyond the region where aerodynamic flight ceases.

Nevertheless, Haley's creation of the "Kármán jurisdictional line" could not have been better timed since he first presented it to both the astronautical community and the general public at the 8th International Astronautical Congress (held in Barcelona, Spain, 6–12 October 1957) just two days after the launch of the first *Sputnik*, the world's first artificial satellite, had occurred on 4 October 1957 and opened the Space Age. In fact, the "Kármán jurisdictional line" was one of the main topics in his 1957 congress paper, "Space Law—the Development of Jurisdictional Concepts." (Although the IAF version included other elements, the substance of that paper had already appeared some months earlier in the specialized publication, *Journal of* Air *Law and Commerce*, Vol. 24, Issue 3, summer 1957, pp. 286–303, under the title of "Space Law and Metalaw—Jurisdiction Defined." This article was itself derived from a paper presented by Haley at the American Rocket Society Spring Meeting held in Washington, D.C., during 3–6 April 1957.) [12].

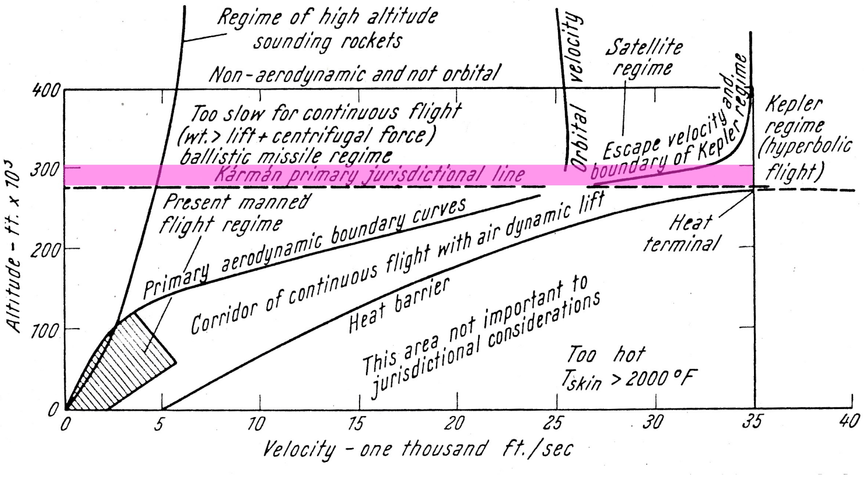

Figure 11–3: The "Karman [*sic*.] Jurisdictional Line," suggested by Haley and von Kármán as the logical demarcation between air and space, presented by Haley at the 8th International Astronautical Federation (IAF) Congress in Barcelona, during 6–12 October 1957, just after the launch of the first Sputnik that opened the Space Age. From Andrew G. Haley, "Law Must Proceed Man Into Space," *Missiles and Rockets*, Vol. 2, November 1957, p. 69, and other sources.

Following this paper, Haley actively promoted the concept and argued for its generalized adoption. But the latter did not happen until 1961, when the V. P. Tchkalov Central Aero Club of the USSR applied to the Fédération Aéronautique Internationale (FAI) for acceptance of the new world records set by the flight of the first man in space, Yuri Gagarin, on 12 April 1961. Soon after, the FAI arrived at a much modified version of the "Kármán jurisdictional line" as the demarcation between the atmosphere and space. In their version, the FAI greatly rounded off Haley's original altitude value up to an even 100 km (62 miles) to be in conformity with *customary altitude values in aviation records* (our emphasis)[*] [13]. This modification was thus, now re-named as the "Kármán line." It should be noted though, that the authors have been unable to find any published public notice of the "adoption" of this term by the FAI during this period [2].

Although the FAI functions as an international standard-setting and record-keeping body for aeronautics and astronautics, Lyall and Larsen state, "it is a non-governmental body and its views do not bind states." [14]. However, up until the time of the presentation of this paper in 2017, the "Kármán line" was the most often cited and "practical" definition as a demarcation between air and space. For this paper, we therefore then chose this more general and widely accepted value of 100 km (62 mi) as the boundary line.

It should, of course, be added that the definition of the "Kármán line" could never be truly precise since this "boundary" is not absolutely constant. The actual separation between the atmosphere and space is dependent upon the density of the air in this region, which is affected by constantly changing temperatures and pressures. However, it should likewise be pointed out that an altitude of 50 miles (80.4 km) is more legally binding between nations as the demarcation between air and space [15].

Yet, as reported in the authoritative magazine *Aviation* in its June 1947 issue, the Neptune rocket was originally designed to carry payloads "higher than the highest [captured] V-2 flight thus far." [16]. Thus, this one-line definition meant that the American rocket was surely designed for space since a captured V-2 rocket that strictly developed as a long-range (horizontally launched) bombardment missile had already ascended to 104 mi (167 km) on 30 July 1946 [17]. Hence, in retrospect, from this additional evidence, apart from the later "Kármán line" adopted about 1961, we now have to consider this part of aerospace history from an entirely new perspective and conclude that the Viking rocket was indeed, the first true "space rocket" designed for that purpose—especially since the later

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[*] This important point about the FAI rounding off the figure is not explicitly stated by Gangale and McDowell in their recent works discussed in the Addendum, although the latter at least notes the FAI did round it off.

first operational Soviet and US launch vehicles (the Vostok and the Jupiter-C for *Sputnik* and *Explorer 1*, respectively) were modified missiles with upper stages. Moreover, according to the original 1946 Navy Bureau of Ordnance contract awarded to Martin for the Neptune (i.e. Viking), the rocket was to "have a potential [maximum] ceiling of 200 miles [322 km]." This intended *maximum* altitude therefore would have far exceeded the previously cited highest flight of the captured V-2s [18].

IV. Early Phases of the Development of the Viking XLR-10 Engine

By 1948, to avoid confusion with the Lockheed P2V Neptune aircraft developed for the Navy as an anti-submarine patrol aircraft, the rocket was re-christened the Viking after the early Scandinavian seafaring peoples. Rosen credits Thor Bergstralh with the new name, following a poll among his staff [19]. Bergstralh, of Swedish parentage, was one of Rosen's physicists and known especially for adapting aircraft cameras to V-2s. By 1948, he adapted a small analog computer to help determine the location of flown and crashed Viking rockets towards the recovery of their invaluable experimental payload packages.

Figure 11–4: John Shesta (1901–1987), the Russian-born engineer and one of the four founders of Reaction Motors, Inc. (RMI), the first US liquid-propellant rocket company and a key designer of the Viking sounding rocket engine. Courtesy National and Space Museum, Smithsonian Institution photo 78-9336.

Before RMI engineer Edward A. Neu Jr. was assigned to the project, says Shesta, he [Shesta] made "all the necessary calculations and initial drawings" of what became the Viking rocket. His original specifications called for nickel for the nozzle and propellant lines, "but because of some procurement foul-up, the material was not available in time for the first unit. It [the nozzle] was therefore made of stainless steel, which is not as good a heat conductor as nickel. After that, nickel was used." [20]. However, Bernard Pearlman, another RMI pioneer, claimed that he had "suggested to [John] Shesta that perhaps an inner liner made of pure nickel sheet would solve the burnout problem." [21]. Rosen gives credit to Shesta for also designing "the chamber overly large to insure complete combustion and he chose for an injector, an array of conical spray nozzles." [22].

Wyld mainly worked out the needed thermodynamic data while Lawrence, who had had years of experience as an electrical engineer with IBM (International Business Machines), worked out preliminary electrical wiring schematics for the engine and vehicle.

According to a retrospective article on the Viking in RMI's in-house publication, *The Rocket* for July 1956, in September 1946 Harry W. Burdett Jr., RMI's first engineer employee, "was placed in charge of all the thrust chamber development." [23]. Assisting him and Edward Neu in making "thousands of calculations that transformed Shesta's ideas into an engineering design" was Ann Dombras, a fellow engineer at RMI and therefore perhaps the earliest known American woman rocket engineer [24]. Dombras had been educated at Goucher College, Towson, Maryland, as a mathematician, but RMI hired her as an engineer [25]. Pearlman helped design the tools and dies for producing the rocket power plant.

Figure 11–5: Ann Dombras (1922–), known by her maiden name of Ann McCraight during her role in the development of the Viking rocket, was perhaps the earliest known US woman rocket engineer. During 1946, she assisted Harry W. Burdett Jr. at RMI in making calculations towards the design of the Viking rocket engine. From *The RMI Rocket*, Vol. IV, April 1953, p. 2.

Besides Neu, who completed the design of the thrust chamber and injectors, Albert G. Thatcher designed the hydrogen peroxide driven turbo pumps, while Maurice E. Parker managed the valves and controls. Even the valves were to see their share of innovations. For example, Arthur Sherman of RMI's Valves and Controls Group, devised an alternate solution for the regulators for the vehicle's pressurization system that "would drastically [reduce] the weight and improve the stability of the pressure control throughout the flight." [26].

Senior Project Engineer Peter H. Palen also played major roles, most notably in working out the gimbaling system that was one of the great early advances in modern US rocketry, as described below. This and other notable innovations set the Viking apart from the V-2 and made it the most sophisticated rocket of the period. The Viking was also unique in that it literally evolved over time, with no two vehicles alike. Similarly, the engine of each vehicle was an improvement over the previous one, related to the configuration changes.

V. Aerodynamic Evolution of the Viking

The airframe of the Viking was aluminum instead of steel, thus making it the first large rocket built almost entirely of aluminum. This made the vehicle far lighter and the resulting “weight economies” enabled the rocket motor, despite having less than half the thrust of the V-2, to reach much higher altitudes than the latter. As explained by Gatland in his book *Development of the Guided Missile* published in 1954, “The Viking has the astonishing mass ratio of 0.80, the propellant comprising 80 per cent of the all-up weight; this compares with 67 per cent for the A-4 [the V-2] and 55 per cent for the [far smaller] Aerobee [sounding rocket].” The rocket’s configuration also underwent a marked change from the earlier to later models. This was driven by data derived from the rocket’s actual performances and enabled it to carry increasingly heavier payloads and reach greater altitudes, thereby enabling it to go deeper into space [27].

For the first configuration of the rocket, from Viking No. 1 to Viking No. 7, the vehicle was long and skinny; from Viking No. 8 onwards, its diameter greatly increased while the vehicle’s length decreased. The body diameter was enlarged to 3 ft 9 in (1.14 m). (Prior to this, the Viking was slightly lengthened from round to round for the first four rockets). The primary purpose of the later major dimensional changes that commenced with Viking No. 8 was to afford an additional 50 percent propellant capacity for increased thrust duration, and therefore the ability to reach greater altitudes than earlier models of the vehicle. In addition, the trapezoidal fins used on the first seven rockets were replaced by far smaller triangular fins, because far less air resistance would be encountered at higher altitudes, thus providing an additional weight saving [28].

Internally, the engine’s propellants and electronics systems, and control systems also underwent marked changes commencing with Viking No. 8. However, the thrust remained about the same throughout the series and varied only slightly from round to round, averaging about 20,450 lbf (90.966 kN). This increased to nearly 21,430 lbf (95.325 kN) for the later flights, but the rocket’s propellants remained the same: liquid oxygen and alcohol, just as had been used in the German V-2. In fact, it appears that the propellants choice was the only, or most prominent, feature directly taken from the V-2 [29].

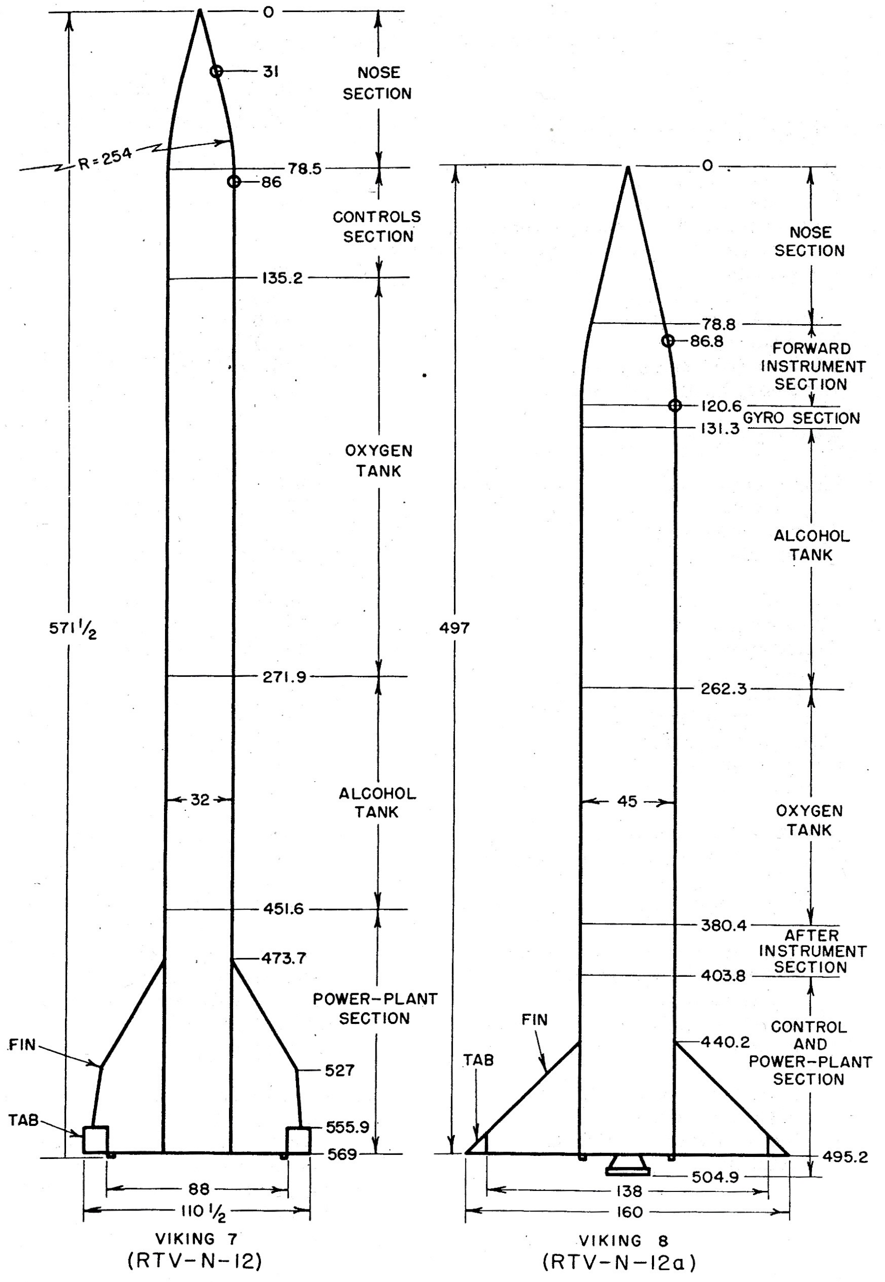

Figure 11–6: Viking No. 7 and 8 rockets compared (i.e., Model 1 and 2). No two Viking sounding rockets were ever alike and each, including their engines, were slightly modified based upon actual operational results of each vehicle but a major configuration change was made with Viking No. 8. Courtesy Naval Research Laboratory. Note the different designations between the two different Viking models.

VI. The Viking Control and Gimbaling Systems

The decision to use a gimbaling system for the Viking engines was by no means "arbitrary," according to Norris E. Felt Jr., the Operations Manager of the Martin Company during that period. The anticipated "unconventional flight path of the Viking, *viz*., a high altitude nearly vertical trajectory," resulted in "some unusual problems in the design of an automatic stabilization system." These problems were solved by arriving at three separate subsystems, he wrote. "[T]here is the motor control system which obtains corrective moments by altering the line of thrust of the liquid rocket engine [i.e., the gimbaling]. The second system, the aerodynamic roll system, employs moveable tabs attached to two of the [four] fins. Finally, there is a [small] thrust reaction control system, which obtains control moments by the use of small [hydrogen peroxide] jet motors [i.e., thrusters]. Results of the flights to date [i.e., up to 1955] indicate that the basic approach was sound." (Therefore, the basic principle of the Viking's hydrogen peroxide thrusters presaged the reaction control system in the later X-15 rocket-propelled research aircraft designed to fly in an "extreme environment," which NASA referred to as the "fringes of space" in its descriptions of the flights of the X-15.) [30].

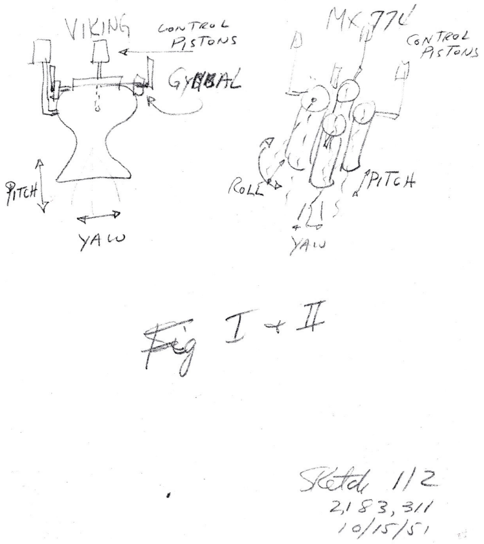

Figure 11–7: The gimbaling of the Viking's Reaction Motors, Inc. single XLR-10 engine was a particularly major advance in rocket technology and was based upon the gimbaling of RMI's XLR-35 four-chambered engine for the MX-774 experimental test missile, also a predecessor of the Atlas missile. Drawing by Lovell Lawrence Jr., 15 October 1951, from the Lovell Lawrence Jr. Papers, National Air and Space Museum.

Early in the Viking program, it was further proposed that the vehicle's control moments for pitch and yaw be acquired by the deflection of vanes placed within the exhaust path. Robert H. Goddard, the American rocket pioneer, had conceived a similar approach as early as 1928 and operationally used it by 1932. In his arrangement, the vanes were linked to an onboard gyro so that the "gyro-stabilized vanes" corrected the rocket if it veered too much during its flight. (That is, Goddard used this system for the control, or stabilization of his rockets in flight, and it was *not* a guidance system.) [31]. However, due to Goddard's penchant for secrecy, it is doubtful that the Viking team were fully aware of this feature in his rockets. In any case, Rosen once indicated to the principal author of this paper (Winter) that he (Rosen) was "unaware" of technical details of Goddard's rockets during the developmental period of the Viking [32]. But it is more likely, that the Rosen team knew of the control approach in the German V-2 that was actually mainly used for guidance purposes in this rocket.

The chief difference in the systems of these rockets was that the exhaust gases *passed by* the deflector vanes in Goddard's rockets; in the V-2, the vanes were placed directly *in the path* of the gases and the link to the rocket's gyro/computer systems was part of a *combination* stabilization/guidance system for steering the rocket towards the target. Again, the V-2 was a missile built for long distance horizontal flights, while Goddard's rockets were designed solely for high altitude experimental flights although in both cases stabilization en route still had to be controlled.

Robertson Youngquist, the Martin Company's Project Propulsion Engineer for Viking, had strongly advocated a gimbaling system to Martin early in the program when it was still called the "Neptune." He made a study of this system and stressed the great weight saving of gimbaling, as well as its simplicity, and the elimination of issues of vane durability, among other advantages over the use of vanes. He may have been aware that by 1946, RMI was already developing a type of gimbaling for its XLR-35 rocket engine for their experimental MX-774 rocket in which each of the four chambers of the engine swiveled backwards and forwards in one axis. Youngquist's proposal was accepted and the RMI's Neptune engine team subsequently borrowed the gimbaling system *in principle* from the MX-774 project, although re-engineered for a single chamber engine [33].

In his resume written in ca. 1959, Youngquist claimed credit for introducing and gaining "acceptance of the then-advanced concepts of gimballing a large rocket motor, [as well] as roll-control by turbine-exhaust, and *attitude-control in space* [our emphasis] by use of gas jets." In his more complete resume, dating earlier to 1958, Youngquist provided greater detail, claiming that he had had "full responsibility…for all propulsion aspects of this [rocket] development" for the Martin Company. This work included Martin's own "…conception, functional design, and development of the Viking propulsion system and all Martin components." This involved propellant tanks and the "helical (anti-slosh) peroxide tank" down to "flexible piping and bellows to gimballed motor…propellant fill and drain valves, and other items." [34].

However, RMI's Peter Palen, in partnership with Shesta and Wyld, had been responsible for working out the details at the original gimbal system of the

MX-774. On 1 January 1947, Palen, calling himself the "lead" inventor, sent a memo to Mason W. Nesbitt, then RMI's Chief Engineer, to seek approval for a patent on the concept, with Shesta, and Wyld as co-inventors. The finished concept was called a "swivel mount." Nevertheless, Nesbitt, denied the request for the patent claim because in his opinion, "It is known that several patents have been granted on controllable thrust angle rocket engines," though only Goddard's 1939 patent [US patent No. 2,183,311 of 12 December 1939] is cited. In fact, swiveling rocket engines go back far earlier than is generally believed. For instance, Onofrio Abruzzo of St. Margherita, Sicily, Italy, was granted US patent No. 80,107 on 15 July 1868 for such a concept as adapted to steer his proposed manned flying machine, which he called an "Aerial Car." However, these pre-Goddard rocket motor swiveling concepts were all for solid-propellant (gunpowder) rocket systems, whereas Goddard's designs were meant for liquid-propellant systems. Yet, whatever the patent situation, the MX-774 is credited as the first known liquid-propellant rocket to *fly* with a gimbaled engine. The vehicle's first flight occurred on 13 July 1948; two other flights were made on 27 September and 2 December of that year. The first Viking (No. 1) rocket flight was on 3 May 1949 [35].

Like those of the Goddard, V-2, and MX-774 rockets, Viking's stabilization system—in this case its gimbaling system—was linked to an on-board gyro arrangement to correct the rocket's flight path in relation to the center of gravity. However, according to the Martin Company's Norris E. Felt Jr. cited above, "[i]t was discovered that the [Viking] rocket body was a fairly efficient transmitter of vibration of the motor's gimbal structure at the latter's resonant frequency…The result was a rather violent vibration of the entire rocket." [36]. A great deal of effort was thus spent "in the design of filters to minimize the chatter problem," including the use of computers to analyze and arrive at the final solution to the problem [37]. Fortunately, these only required minor changes in the hardware.[*]

VII. Testing Phase of the XLR-10 Viking Engine

XLR-10 engine testing was carried out from 1947 at RMI's testing facilities at Lake Denmark, New Jersey. This was part of the Picatinny Arsenal at Rockaway Township, Morris County, New Jersey. Since the XLR-10 was, at the time, RMI's largest engine, it presented its own technological and other chal-

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[*] For more treatment on the engineering development of the Viking, consult References 3 and 30. See also, W. G. Purdy, "Designing the Viking Rocket," in *Machine Design* (Cleveland), Vol. 24, March 1952, pp. 164, 210, 213–214. A different article by the same author, titled "The Viking Rocket," appears in *Aeronautical Review*, Vol. 11, January 1952, pp. 16–20.

lenges. At this early point, the engine for the "Neptune" vehicle still did not have a proper designation and was known only by the Company's designation, 2000C1—meaning, 20,000 lbf (88.96 kN) of thrust from one chamber.

As with all RMI engines, the 2000C1 was regeneratively cooled. However, cooling the engine during static-firing required a lot of water. In a letter to the BuAer dated 29 July 1947, Lawrence outlined the water requirements: "Cooling water for use [for the 2000C1]," he wrote, "…is estimated at 1,000 gallons [3,785 liters] per minute at a pressure of approximately 100 psi [689.476 kN/m^2]. This water will be taken from the reservoir [at Lake Denmark] adjacent to the test stand…" In fact, at one time a serious water shortage crisis at Lake Denmark threatened to curtail all Viking test firings [38].

The Viking test stand was unique for the time, with a rotatable platform that could be fired at any angle. The stand also measured the thrust [39]. The test program consisted of three phases: (1), the motor tested alone but using a pressure-fed system and mounted on an A-frame; (2), the motor pump-fed and on an A-frame; and (3), the final tests, using the rotating platform. Tests were later made in a simulated Viking airframe configuration mounted on the rotary beam test stand. At the same time, RMI's William P. Munger, assisted by Albert G. Thatcher and Henry A. Jatczak, developed the rocket's turbo-pump that was separately tested. This key component is credited with being the first turbine-driven LOX pump to be developed in the United States [40].

The initial static test of the engine took place at 6:20 p.m. on 17 October 1947 [41]. James Preston Layton, the Chief of Propulsion for the Martin Company, served as the crew chief in charge of testing the Viking series, both in the static tests and launches. In this capacity, he is cited for his "meticulous planning for static firing and flight tests and attention to safety." [42]. He is likewise credited with possibly formulating the modern "X-time" schedules ("X minus 15 minutes," for example) in which every rocket test procedure sequence is called out in seconds and minutes and verified, or put on hold if there is a problem, before the next operation in sequence, up to the X moment for the actual time of firing [43].

There were some 400 test firings at Lake Denmark, with other static tests later made at the White Sands Proving Grounds prior to the launches. Although there were "numerous burnouts" during the testing, no major problems along these lines were encountered. By the spring of 1948, dynamic tests on the "steering system" (officially termed the "Gimbal Control System") were carried out at RMI, while Martin conducted its own dynamic analysis of this system. On 21 September 1948, the first official acceptance test firing was conducted, in which the XLR-10 delivered 21,000 lbf (93.413 kN) thrust for 66 seconds in apparently a flawless performance. As Rosen put it, “There was much rejoicing in the test area.” [44].

VIII. The Viking Flights

Since the Viking rocket flights are well covered in the literature, only the salient points are presented in this section of this chapter. With the exception of Viking No. 4, all the rocket flights took place at White Sands.

Viking No. 1: Launched 3 May 1949. Although unrecognized at the time, this vehicle was of the design that later became known as the Model 1 Viking, or the long and skinny model. The rocket stood 45.25 ft (13.7 m) tall with a diameter of 32 in (81.2 cm). However, due to premature engine shutdown from “leakage on the turbine housing” the vehicle only ascended up to 51.5 mi (82 km), or half the planned distance. [If one accepts the suggested proposal by McDowell discussed in the Addendum and Ref. 59—of 80 km or approximately 50 mi as a more accurate indicator of where “space” begins—it would now appear that the Viking 1 flight did obtain, and slightly exceed this altitude, and was thus probably the *first* single-stage liquid-propellant, non-military US rocket to do so, and also most likely the first in the world to achieve this accomplishment. By “non-military,” we mean that that the rocket was neither originally planned nor built as a weapons system, i.e., to carry a warhead, although the Viking project was certainly sponsored by the US Navy, which later considered it as a potential long-range weapon.]

Later, RMI decided to weld, instead of bolt, the turbine case together; thereafter, this method was applied to all Viking engine turbo-pumps without further difficulties [45].

Viking No. 2: The slightly longer Viking No. 2 experienced a similar flight, reaching 32.3 mi (51.9 km).

Viking No. 3: Now 47.4 ft (14.4 m) high, this vehicle had a control malfunction and reached just 50 mi (80.4 km). [This would have been the *second* Viking flight into “space” under McDowell’s definition].

Viking No. 4: This was the only one in the series fired from aboard ship. It was launched from the USS *Norton Sound* near Christmas Island in the Pacific Ocean on 11 May 1950. This time, the 48.6 ft (14.8 m) long rocket worked flawlessly, carrying its 959 lb (435 kg) scientific payload up to 106.4 mi (168 km). It was, therefore, *the first rocket to cross the currently-accepted Kármán line of 100 km (62 mi) into space* (our emphasis), although this would have been the Viking’s *third* flight into space under the McDowell definition of space.

It is less well known that the Viking No. 4 mission had a military objective under the code name of Project Reach, "to advance the art of rocketry in the United States in the interest of National Defense." This meant the flight was used by the Navy to gain experience launching a large-scale liquid-propellant rocket from aboard a ship at sea, in the event they would later pursue the development of a ship-launched guided missile. In fact, an NRL report at the time (marked SECRET) proposed that the Viking, with a converted guidance system and warhead, could be turned into a 150 mi (241.4 km) range guided missile. Later, there was a planned *Super Viking* vehicle with a range of 500 mi (805 km), though neither plan was carried out [46].

Viking No. 5: Launched 21 November 1950. It carried a 675 lb (306 kg) scientific payload to 107.5 mi (172.9 km), making it *the second Viking into space* according to the Kármán line. [This would have been the *fourth* Viking to reach space under the McDowell definition].

Viking No. 6: Launched 11 December 1950. It was of lighter weight, with aluminum fins instead of steel ones, although this created greater aerodynamic heating and structural stress. At 25 mi (40 km), the fins buckled, causing the rocket to momentarily fly out of control; the maximum altitude reached was only 40 miles (64 km).

Viking No. 7: Launched 7 August 1951, it was the last of the Model 1 series and was fitted with strengthened fins. The rocket reached 135.6 mi (218.2 km), a new world record, surpassing the previous vertical record of the V-2. It thus became *the third Viking into space* [or the *fifth* using McDowell's interpretation]. Viking No. 7 obtained the highest measurements of atmospheric density and atmospheric winds of any of the Viking rockets although the X-ray and cosmic ray plates it carried were found damaged upon recovery.

Viking No. 8: The shorter, fatter Viking No. 8 was the first Model 2 type, being 45 ft (13.7 m) in length and 41.6 in (105.6 cm) in diameter, with four smaller triangular fins. However, on 6 June 1952 an unexpected thrust surge occurred during its customary pre-launch static firing. Although held down, the vehicle broke loose and flew upwards, breaking apart at about 4 mi (6.4 km).

Viking No. 9: Launched 15 December 1952, this flight almost exactly matched that of Viking No. 7. Reaching 135.6 mi (218.2 km), it was the *fourth Viking flight into space*. [This would have been the *sixth* flight of the Viking to reach space under McDowell's definition]. On this flight, the rocket obtained excellent cosmic ray emulsion records, as well as more photos from space.

Viking No. 10: Viking No. 10 was not so lucky. On 30 June 1953, the rocket's engine exploded at launch although enough parts were salvaged to later rebuild it at Martin's plant in Baltimore. The new rocket was designated Viking

10R (presumably meaning “Viking No. 10, Rebuilt,” or perhaps, “Refurbished”). It was later launched on 7 May 1954 as Viking No. 10 and reached 136 mi (218 km), becoming *the fifth Viking into space*. [This would have been the *seventh* flight of the Viking sounding rocket into space under McDowell’s 80 km definition]. The rocket’s experiments performed flawlessly and provided the first measurements of the atmospheric positive ion composition at high altitude.

Viking No. 11: Launched 24 May 1954, this flight performed spectacularly, establishing a new world altitude record of 158.4 mi (254.9 km) for a single stage rocket; it became *the sixth Viking into space*, achieving the highest altitude of all the Viking rockets. [This would have been the *eighth* Viking flight into space using McDowell’s definition]. The maximum speed obtained was 4,300 mph (6,919 km/hr). It also carried out the first reentry from space; upon reaching its apogee, the nosecone was pointed down and separated, using small hydrogen peroxide thrusters. This maneuver was photographed throughout. Photographs taken during this flight revealed, for the first time, the planet Earth as a sphere. At the time, the photos were somewhat incorrectly hailed as the first photos from space; but they certainly were the highest photos of the Earth up to that time. The highest exposures of cosmic-ray emulsions were also made from Vikings 9, 10, and 11.

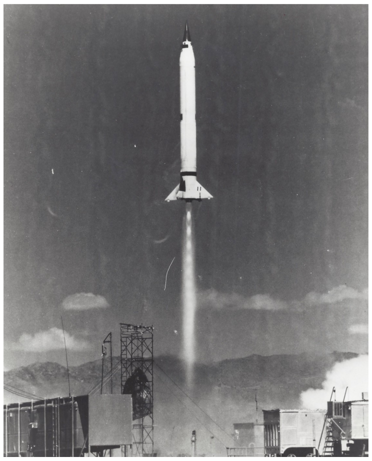


Figure 11–8 (left): Viking No. 11 in its record launch to the rocket’s highest altitude of 158.4 mi (254.9 km) on 24 May 1954. Courtesy US Navy.

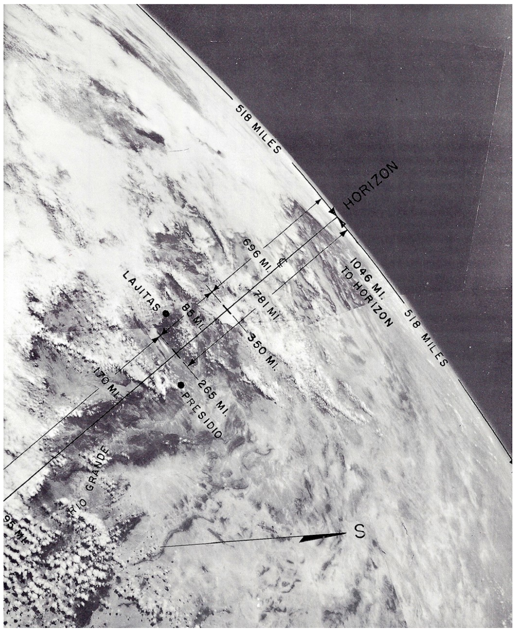
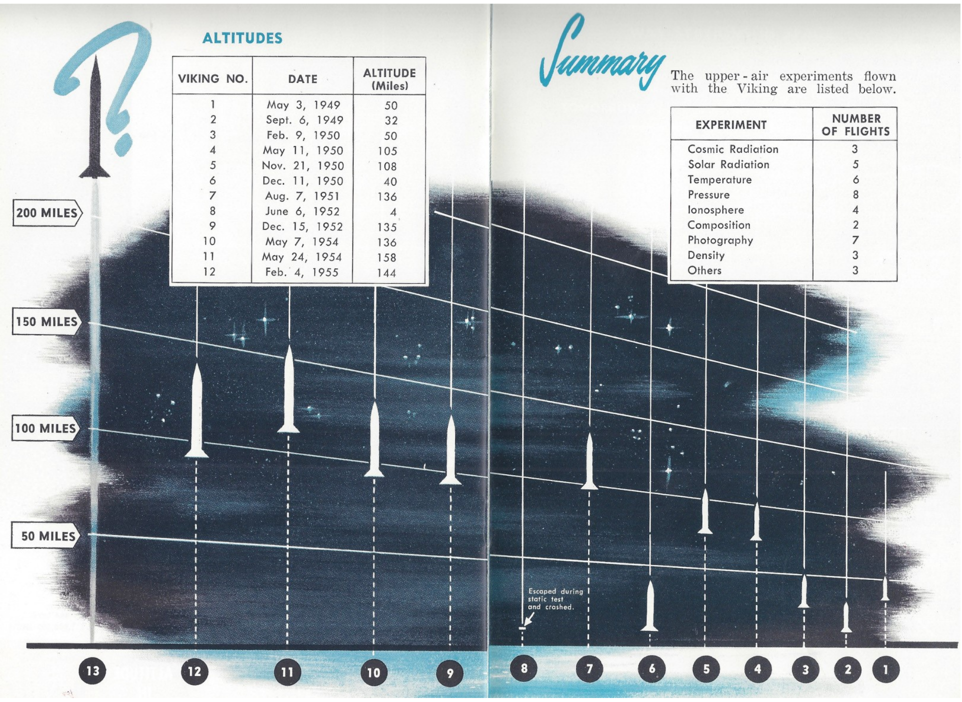


Figure 11–9 (right): Composite photos of Earth from space by Viking No. 11. Except for the ship-launched Viking No. 4 launched aboard the USS *Norton Sound* in the Pacific Ocean, all the Viking sounding rockets were launched from the White Sands Proving Grounds, N.M. Courtesy US Navy.

Viking No. 12: Launched 4 February 1955, Viking No. 12 flew to 144 mi (231.7 km), becoming *the seventh Viking into space*, or the *ninth* according to McDowell's interpretation of where space begins. The nosecone reentry experiment was repeated although the gas jet control system malfunctioned, causing the nosecone to reenter facing point-up, not point-down.

Overall, the greatest scientific achievements of the Viking flights were among the first measurements of winds, temperatures and pressures in the upper atmosphere and electron densities in the ionosphere; and the first record of the ultraviolet spectra of the Sun. These greatly contributed to the beginning of the then, new field of *space science*, which had already been opened by the flights of captured V-2 rockets carried out by both the United States and the Soviet Union; US flights commenced in 1946 at White Sands while Soviet launches of captured and modified V-2s began in 1949 from Kapustin Yar, located near Stalingrad (now Volgograd).[*]



VIKING NO.	DATE	ALTITUDE (Miles)
1	May 3, 1949	50
2	Sept. 6, 1949	32
3	Feb. 9, 1950	50
4	May 11, 1950	105
5	Nov. 21, 1950	108
6	Dec. 11, 1950	40
7	Aug. 7, 1951	136
8	June 6, 1952	4
9	Dec. 15, 1952	135
10	May 7, 1954	136
11	May 24, 1954	158
12	Feb. 4, 1955	144

The upper-air experiments flown with the Viking are listed below.

EXPERIMENT	NUMBER OF FLIGHTS
Cosmic Radiation	3
Solar Radiation	5
Temperature	6
Pressure	8
Ionosphere	4
Composition	2
Photography	7
Density	3
Others	3

Figure 11–10: Summary of Viking sounding rocket flights, No. 1-12. From private collection of Frank H. Winter.

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[*] For details of the scientific results of the Viking flights, consult DeVorkin, *Science with a Vengeance*, cited in Reference 2. There are also several NRL Viking "Rocket Research" reports in the "Viking Sounding Rocket (RTV-N-12)" files in the National Air and Space Museum as well as other materials in the Museum's archives.

The Soviet Union's high-altitude scientific experiments were conducted first by the R-1A rocket, based on the R-1, which was a Soviet version, with some modifications, of the V-2. It was followed by a series of specialized scientific rockets as follows: the R-1B, the R-1V, the R-1D and the R-1E. The R-1 was first launched on 10 October 1948, although a series of these experimental missiles were fired in horizontal flight paths to determine their greatest ranges. The first scientific, high altitude vehicle, the R 1-A, or "experimental geophysical" rocket as they called it, was launched on 24 May 1949. [It reached 62 mi (100 km) and technically probably became the first Russian rocket to reach space under the FAI definition of the Kármán line]. Other Soviet geophysical rockets carried dogs to gauge the effects of high-speed acceleration upon living organisms, besides experiments to analyze the upper atmosphere, measure cosmic rays and take far-UV spectra of the Sun. However, it is beyond the scope of this paper to cover this area of early space science further.

Although the objectives of the Viking program were for the benefit of the US Navy, it became the most ambitious US rocket project up to that time. Initiated with a desire to explore and advance rocket technology, the rocket amply fulfilled its primary goal of reaching "…higher than the highest [captured] V-2 flight thus far." Other technological achievements attained by the Viking program included gaining extensive experience and advances in radio telemetry for both engineering and scientific data.

There were no further Viking sounding rockets after the Viking 12 flight: at a cost of several hundred thousand dollars each, in 1940s–50s dollars, the vehicle was simply too expensive. Each XLR-10 engine cost about $70,000 ($988,362 in 2020 values). Consequently, the far smaller, simpler solid-propellant-boosted liquid-propellant Aerobee sounding rocket, together with newly developing (and far cheaper) solid-propellant rockets, would serve the bulk of future US sounding rocket needs.

IX. Viking Rockets in the Vanguard Satellite Program

The rocket engines for Viking No. 13 and 14 were static fired in RMI's test area by late 1953. RMI then sent them to Martin for eventual mating with their respective Martin-built rockets, but they were never used due to delays plus the cancellation of the program. However, after Martin won the contract to build the Vanguard satellite launch vehicle—greatly helped by the company's experience and expertise acquired from the Viking program—it was also decided to adapt the remaining two Viking vehicles as test vehicles for the new Vanguard satellite program. Since the Vanguard program is well covered in the literature, we will only briefly sum up the final two Viking missions [47].

Viking No. 13: On 8 December 1956, Viking No. 13, now refurbished and re-designated TV-0, was launched as the first sub-orbital test vehicle for Project Vanguard. It was the rocket's first night ascent from the US Air Force Missile Test Center at Patrick Air Force Base, Florida (also called the Cape Canaveral Missile Annex). The principal objective of the flight was to test the transmitter that was part of the new Minitrack satellite tracking system. The single-stage rocket successively completed its mission and achieved an altitude of 126.5 mi (203.6 km) and a down range of 97.6 mi (157 km), landing in the Atlantic Ocean. It was *the eighth Viking rocket to reach space*. [This would have been the *tenth* Viking flight to reach space using McDowell's definition.] [48].

Viking No. 14: On 1 May 1957, at 1:30 a.m., the final Viking rocket, now re-designated TV-1 (Test Vehicle 1) achieved the second sub-orbital test flight in another night launch from Cape Canaveral. It carried as its second stage a prototype Project Vanguard solid-propellant rocket built by Grand Central Rocket Company. This solid-propellant second stage later became the third stage of the final three-stage Vanguard vehicle. Three stages were needed to put a satellite into orbit. In this flight, the main goals were to test the solid-propellant rocket that was designed to provide a proper propulsion trajectory; and, to test techniques and equipment used to launch and track the rocket. Vanguard TV-1 was also wholly successful, with the two-stage rocket achieving an altitude of 121 mi (195 km) and a down range of 451 mi (726 km), before landing in the Atlantic Ocean. TV-1 thus became *the ninth Viking rocket sent into space*, or, the *eleventh under McDowell's definition.* Hence, the last two Viking rockets played significant roles in initiating both the US space and launch vehicle programs. Indeed, the Viking rocket program was inextricably linked to the creation of the Vanguard satellite launch vehicle in several other respects although it is beyond the scope of this chapter to cover these. However, the reader may consult John P. Hagen, "The Viking and the Vanguard," in Eugene M. Emme, ed., *The History of Rocket Technology* (Wayne State University Press: Detroit, 1964), pp. 122–141.

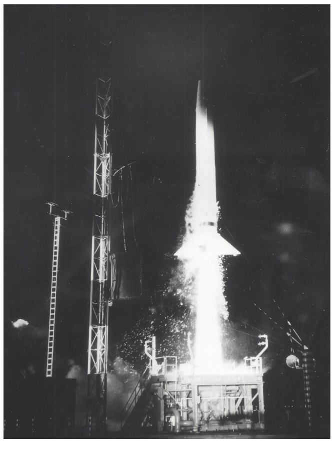

Figure 11–11: Final Viking No. 14 launch, at Cape Canaveral, Florida, as Project Vanguard Test Vehicle (TV-1) on 1 May 1957 for America's first satellite program. Although started off as a "sounding rocket," the Viking therefore played a direct role into America's early space program. Photo courtesy NASA.

X. The Viking Rocket as a Technological Celebrity in Popular Culture and its Role in Generating Early US Support for Spaceflight

The Viking rocket also played major roles in two different ways in generating early popular support for the importance and possibilities of spaceflight. The first was its appearance in a museum, while the second was this rocket's unique role during the early to mid-1950s as an early icon of "real" and proven "space hardware," so-to-speak, representing the further possibilities of spaceflight during that period. The Viking thus helped generate greatly increased public enthusiasm in the United States for spaceflight and this aspect was particularly promoted by Rosen. Indeed, Rosen himself, through his much-publicized connection as the former director of the Viking project, was then a "celebrity" in the development of this technology and its greater technological promise.

In 1954, wreckage from the recovered Viking No. 11 was salvaged and later incorporated by the Martin Company into a full-scale cut-away Viking model that was donated to the Hayden Planetarium in New York City. Complete with an XLR-10 engine, the rocket, however, was painted white with a Martin Company logo on its tail rather than with its official colors and markings. Nevertheless, at the Hayden, it was exhibited horizontally as the centerpiece of their "Viking Hall," as they called it. This highly publicized exhibit officially opened on 30 June 1955 for a two-year stay. In addition to the full-length rocket, the exhibit featured, according to a detailed account in the July 1955 issue of the RMI's house organ, *The Rocket*, a "spectacular photograph taken by a Viking camera at an altitude of 155 miles [249 km]…from space" besides a presentation of the scientific "findings of Viking No. 11." Also featured was a push-button activated launch of a model of a Viking in "an animated diorama of the Viking launch site at the White Sands Proving Ground," along with a recorded commentary that included a "countdown." A section of the exhibition, titled "Reports From Out Of the World," employed a "vivid color transparency panel to interpret the Viking's findings." Depicted on one panel were "the mysterious cosmic rays that constantly bombard our atmosphere from an unknown source." Also on display was "an actual photographic emulsion exposed to cosmic rays on a Viking flight." [49].

Thus, the Hayden's Viking exhibit was likely the world's first presentation of a flown space rocket in a museum, featuring used parts from the space rocket. This same issue of RMI's magazine, *The Rocket*, rightly added that the Viking Hall "constitutes the first public exhibit of its kind" and interpreted "the impressive story of upper atmosphere research…and how it relates to man's future in space." Moreover, for many visitors, this may have also been the first museum exhibit treating the promise of artificial satellites: a panel showed various possible satellite orbits along with an explanation that satellites might one day serve "radio and television signal relaying…and meteorological and astronomical observation." [50].

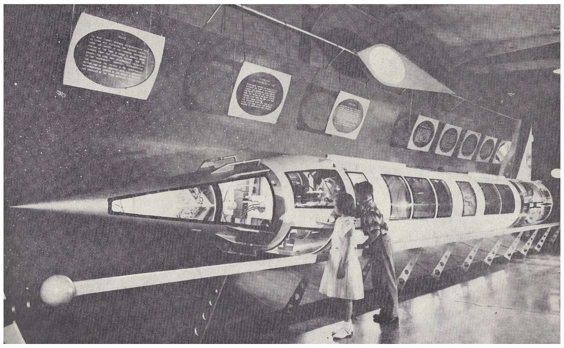

Figure 11–12: Viking rocket, made from actual flown pieces, from Viking No. 11, reconstructed and with see-through plexiglas panels on exhibit at the Hayden Planetarium, New York City, in 1955, perhaps the first flown space rocket in a museum, the Hayden a part of the American Museum of Natural History. From private collection of Frank H. Winter.

Rosen delivered an address at the official opening ceremonies of the exhibit. Among other remarks, he explained, "there are no [final] specifications for [the] Viking. There never have been" and "our desires [for a design] changed from year to year, from month to month, sometimes from day to day." In short, it was always a dynamic and evolving experimental "high altitude" program [51].

Rosen's book, *The Viking Rocket Story*, was also promoted at the exhibit and signed copies were placed on the tables of the dignitaries at the official opening. Today, signed first edition copies are collector's items.

The achievements of the Viking also reached television audiences and may well have constituted the first dedicated TV coverage of a specific rocket. The spectacular flight of Viking No. 11, in particular, was well covered. The Sunday, 9 January 1955 television broadcast of the series "Adventure" included films recorded by the high-speed camera installed on the rocket taken during its highest flights [52]. The following day, Douglas Edwards showed the films on his nationally broadcast news program. Besides these appearances, there was a special Viking documentary screened as part of the "Armstrong Circle Theatre" on Channel 4 in New York City during the spring of 1956. The Viking rocket therefore clearly entered popular culture, becoming a "technological celebrity" of the time. Yet, there were other instances of the vehicle and/or its engine placed upon public exhibition. In 1957, for example, more than 200,000 visitors at the Berlin International Trade Fair in Germany, hosted by the United States Information Agency, viewed a Viking engine [53].

To add to Rosen's own celebrity, in 1954, following the world record-breaking Viking No. 11 flight, he was the first recipient of the American Rocket Society's James H. Wyld Memorial Award. Rosen's celebrity in the aerospace community, at least, continued, and he afterwards became a top official of the

National Aeronautics and Space Administration (NASA) after its formation in 1958. (Prior to this, and following his position with the Viking project, Rosen served as the Technical Director of Project Vanguard that was America's first space program.) However, it is also true that the early and brief iconic phase of the Viking rocket's history itself became largely forgotten by the general public when this aspect was quickly overtaken by the world-wide interest in Project Vanguard—first announced in 1955—then followed two years later by the stunning achievement of the Soviet launch of the first Sputnik satellite on 4 October 1957 that opened up the Space Age. (By coincidence, the Viking rocket at the Hayden had been removed from exhibit just a few months earlier that year.) [54].

Nevertheless, the Viking rocket, with its silver-gray painted RMI rocket engine and other components visible through a length-long Plexiglas covering, finally wound up in one of the world's most visited museums, the Smithsonian Institution's National Air and Space Museum (NASM) in Washington, D.C. In 1974, after years of storage at the Hayden following the closure of the Viking Hall in 1957, the cut-away Viking was offered to the Smithsonian. Following refurbishment by the Martin Company, the rocket was placed on exhibit—in time for the NASM's Bicentennial opening in July 1976. Still on exhibit today, millions have enjoyed the rocket, now painted in official colors as Viking 12, although the number change on the vehicle is not explained in the NASM records on this artifact. However, except for aerospace historians and enthusiasts, the vehicle's larger history has been overlooked, particularly its role and markings as probably the first liquid-propellant rocket ever designed, built, and flown for achieving spaceflight.

For the record, this Viking in the NASM collections is registered as Cat. # 1976-0843.

Figure 11–13: The same rocket as in Figure 11–12, now on exhibit in the "Missile Pit" of the National Air and Space Museum in Washington, D.C. Photo by Frank H. Winter.

Lastly, it should be noted that the Viking vehicle was also one of the roots of the famous hypersonic X-15 rocket research aircraft. During the early 1950s, RMI developed its more advanced experimental "Super Viking" rocket engine, with 50,000 lbf (222.411 kN) thrust, later designated the XLR-30. This engine was planned for possible utilization in a greatly uprated sounding rocket, or a 500–600 mi (804–965 km) range missile. This engine was actually built and tested although this story is also beyond the scope of this paper. In any case, while neither of the above mentioned RMI projects came about, the tested and proven XLR-30 did enable RMI to win the engine award competition for their development of the X-15 power plant. The XLR-30 subsequently became the basis for the development of RMI's XLR-99 engine of 57,000 lbf (253.549 kN) thrust [55].

XI. Dedication

This paper—now, a chapter in this book—is humbly dedicated to the memory of Frederick I. Ordway III, who originally proposed it as he had been involved in the Viking project when he worked at RMI as a young engineer during 1951 to 1953.

Sadly, however, Ordway did not live to see this project come about since he passed away on 1 July 2014. Fred's proposed joint paper proposal was not forgotten, however, and is now presented in his memory.

Additionally, the authors wish to extend our sincerest gratitude to Stephen E. Doyle for helping us try to "set the record straight" on the Kármán line issue that was crucially important in this paper by referring us to the Gangale book discussed below.

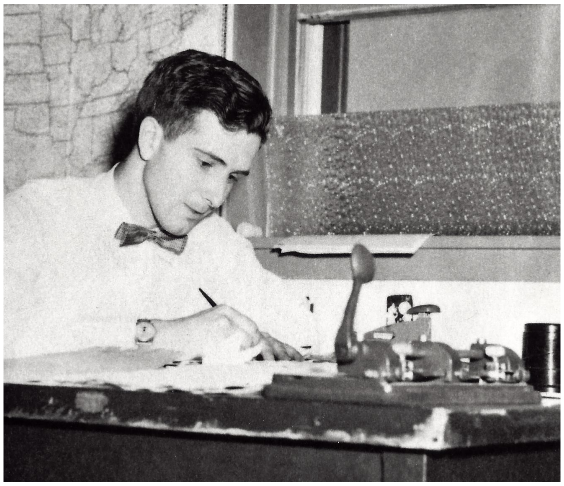

Figure 11–14: Frederick I. Ordway III, working at his desk as a young engineer at Reaction Motors, Inc., in 1951, on the Viking project. Photo courtesy Frederick I. Ordway III.

XII. Addendum: New Light on the Kármán Line

Following the original presentation of this paper in September 2017, two new works were published in 2018 discussing the controversial history of the Kármán line. The first was the book *How High the Sky? The Definition and Delimitation of Outer Space and Territorial Airspace in International Law* by

Thomas Gangale, the publication of his doctoral thesis in Juridical Sciences in Space, Cyber and Telecommunications Law from the University of Nebraska-Lincoln. According to a review of this book, Gangale "explores the oldest and most intractable controversy in space law: how far up does national airspace go, and where does the international environment of outer space begin?" [56]. This work is therefore germane to one of the leading premises of our paper, namely that the "Kármán line" has been an attempt to define the boundary between the upper atmosphere of Earth and the beginning of "space," which was set at an altitude of 100 km (62 mi) by the FAI.

Gangale criticizes the validity of the Kármán line on several technical and historical grounds [57]. The main one that concerns us here is that it was never codified into international law. Furthermore, Gangale emphasizes that the Kármán line has been disregarded by other organizations, notably by the US Air Force and NASA, and that it was customary for the Air Force to bestow the honor of "astronaut wings" upon all those pilots of the NASA/US Air Force operated X-15 rocket research aircraft who had flown above 50 mi (80 km). A central question thus emerged in regard to the original paper, namely: "How best to treat the 'Kármán line'?" By extension, another question was: "Did these criticisms of the Kármán line invalidate the main premise of the paper, that the Viking sounding rocket was the first single-stage liquid-propellant rocket specifically designed and built to fly into space and succeeded in these goals?"

Very fortunately, the other publication appearing in 2018 easily resolved the first question. This was the article "The Edge of Space: Revisiting the Karman [*sic.*] Line," by Dr. Jonathan C. McDowell, an astrophysicist with the Harvard-Smithsonian Center for Astrophysics [58].

In essence, McDowell recognizes the various flaws with the Kármán line and proposes the solution of a much more reasonable barrier or altitude of 80 km (approximately 50 mi), that exactly matches the beginnings of space as recognized by the US Air Force and approved by NASA. Moreover, McDowell's article contains mathematical proofs besides additional historical references in arriving at his proposal. In the conclusion of this work, he thus states: "On the basis of these physical, technological and historical arguments, I…suggest that a value of 80 km is a more suitable choice to use as the canonical lower 'edge of space' in circumstances where such a dividing line between atmosphere and space is desired." [59].

In fact, if one accepts McDowell's suggestion for a more realistic value of 80 km for the Kármán line, the Viking sounding rocket now appears to have entered the "space" regime more times than first appeared. We have noted in the body of the paper these putative additional altitude milestones for the Viking rocket in all those instances where the rocket reached or exceeded altitudes of 80 km.

As for answering the second question as to whether a changing definition of the Kármán line invalidates the main premise of the original paper that the Viking sounding rocket was "the first single-stage liquid-propellant rocket specifically designed and built to fly into space and succeeded in these goals," we firmly conclude that this claim remains valid. Our sections (IV. to VI.) on the design, and especially on the development of the Viking's control and gimbaling systems—and particularly the rocket's reaction control system of hydrogen thrusters that presaged a very comparable system in the later X-15 hypersonic rocket-propelled research aircraft designed, according to NASA, to fly into the "fringes of space"—show that these efforts clearly focused upon a vehicle that was carefully planned to *far exceed* the vertical performances achieved by the captured V-2 long-range missiles that were converted to vertically-fired sounding rockets.

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