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Vanguard 1: The Little Satellite That Could

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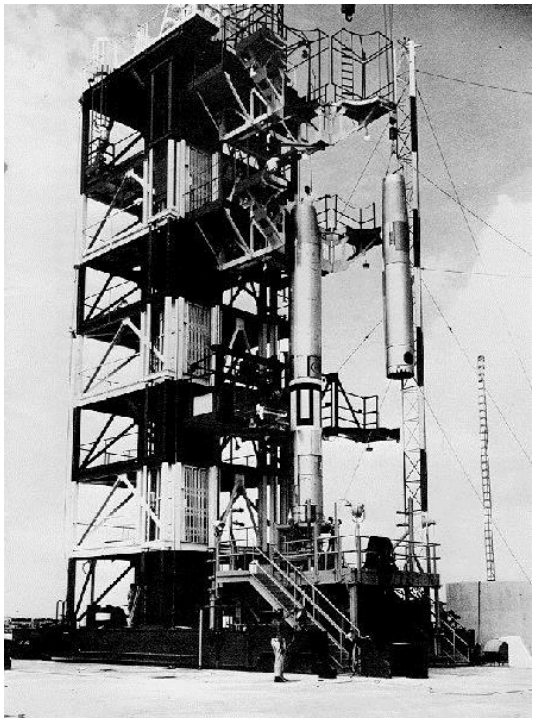


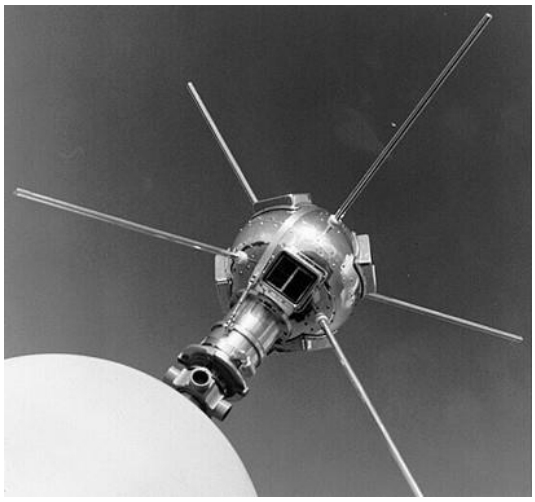
A Vanguard rocket being prepared for launch. (NASA)

Recovering from Disaster

After the disastrous failure of the Vanguard TV-3 launch attempt on December 6, 1957, Vanguard's NRL (Naval Research Laboratory) team had to pick up the pieces and get ready for the launch of TV-3BU (Test Vehicle-3 Back Up). The contractor for the first stage, the Martin Company (now part of the aerospace giant Lockheed-Martin), and the builder of the engine, General Electric, were able to track down the cause of the TV-3 failure to a loose fuel line connection. This loose connection caused a pressure drop in the GE X-405 engine's fuel injector assembly which allowed combustion products to travel up the fuel lines resulting in a catastrophic failure. Modifications were immediately made to TV-3BU and its processing procedures to avoid a repeat of this incident.

Work to repair the damage caused by the TV-3 explosion at launch complex 18A proceeded quickly and was completed ahead of schedule. This allowed TV-3BU to be erected on the launch pad before the end of December of 1957 for the start of its long prelaunch checkout. Like TV-3 before it, this launch vehicle would not carry an operational Vanguard satellite. Instead it would loft a simple test satellite. This satellite was a 16 centimeter (6.4 inch) in diameter polished aluminum alloy sphere weighing only 1.47 kilograms (3.25 pounds). It was equipped with a pair of transmitters operating at a frequency of about 108 MHz that used six short aerials sticking out of the tiny sphere. One of these transmitters was powered by batteries and would last just a few months. The other transmitter made use of solar cells mounted on the exterior for power as part of a test to determine their usefulness on future spacecraft. These solar cells were divided among six banks set equidistant around the satellite's spherical exterior so that they could provide power regardless of the satellite's orientation.

The only actual instrument carried by the satellite was a pair of thermistors to measure the tiny satellite's temperature. These measurements would help assess the sphere's thermal protection measures. The primary purpose of this payload, in addition to verifying that it went into orbit, was to provide an opportunity to exercise the Vanguard tracking network. As a by product, data on the evolution of the satellite's orbit would provide some scientifically useful information.

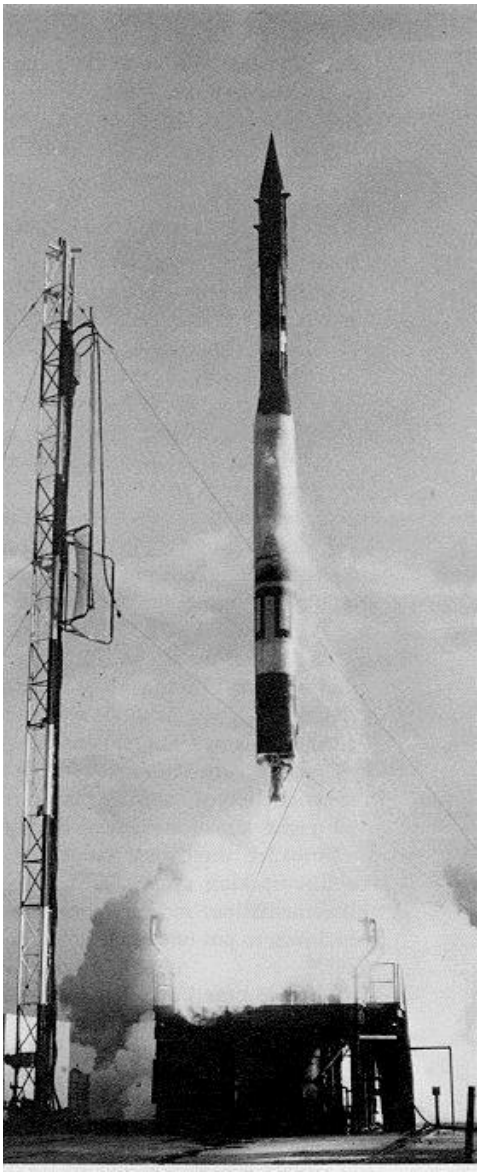


The Vangaurd 1 satellite. (NASA)

The first attempt to launch the rocket on January 23, 1958 was called off when heavy rains shorted out some of the cables used by ground instrumentation. The next three days saw three more scrubs caused by a variety of problems. When it was discovered on January 26 that the second stage AJ-10 engine was damaged, the launch of TV-3BU was pushed back to February 3 so that a replacement engine could be ordered and installed. Since the Cape Canaveral test range could only support one launch at a time, this delay gave the ABMA team led by Wernher von Braun a brief three-day window to squeeze in a launch attempt with their Juno 1 launch vehicle. The ABMA attempt succeeded in placing the United States' first satellite into orbit on the night of January 31, 1958 as envious Vanguard personnel watched on (see **Explorer: America's First Satellite** in the February 1998 issue of *SpaceViews* for more information on this mission). The team that was suppose to orbit America's IGY (International Geophysical Year) satellite would have to be content to take second place to their Army colleagues.

As it turned out, the new February 3, 1958 launch date was overly optimistic and it was not until February 5 before TV-3BU was finally ready to fly. When TV-3BU lifted off, all seemed to be going well at first. But at an altitude of 460 meters (1,500 feet) the rapidly accelerating rocket's control system malfunctioned. Spurious electrical signals from the balky system caused the ascending rocket to rapidly pitch down. The structural loads this maneuver caused were more than the pencil-thin TV-3BU could take and it broke in two at the aft end of the second stage after 57 seconds of flight. Vanguard's second attempt to launch a satellite had ended in failure. This set back, along with the launch failure of ABMA's Explorer 2 one month later, was quite disheartening to the Vanguard team. They felt that if the tried and true Jupiter C/Juno 1 could succumb to failure, how could the far more complex Vanguard succeed?

Success at Last



Launch of Vanguard 1. (NASA)

After the TV-3BU failure, TV-4 was subsequently modified and prepared for another attempt to launch a grapefruit-sized test satellite. All during early March of 1958 the launch team had to wrestle with repeated electrical and mechanical problems as well as intermittent bad weather. After three scrubbed launch attempts, the Vanguard team started yet another two-day long countdown on March 16, 1958 in the hope of getting their bird off the ground. As

before, there were a series of minor delays in the countdown. At the last second there was yet another delay this time to allow the passage of Explorer 1 overhead. Engineers wanted to avoid the Space Age's first "traffic jam" because the ABMA satellite's transmissions might interfere with the reception of Vanguard's signal. Finally at 7:15:41 am EST on March 17, 1958, TV-4 lifted off and climbed into the sunny Florida sky. Telemetry streaming back to the Vanguard tracking stations showed that the first stage operated as intended. A near perfect performance by the second then the third stage followed. There was now every reason to believe that the test satellite had succeeded in reaching orbit.

Confirmation that Vanguard had achieved orbit finally came around 9:30 am EST when the minitrack station in San Diego, California picked up signals from both transmitters. Vanguard 1 had made it into a 650 by 3,968 kilometer (404 by 2,466 mile) orbit with a period of 107.9 minutes inclined 34.25 degrees to the equator. Initial calculations estimated that the satellite would remain in orbit until around the year 4000 AD. Vanguard had finally succeeded in meeting its commitment of launching one satellite during the IGY two years, six months and eight days after receiving authorization. Any successes after this would be a welcomed bonus. Even though they were not the first in orbit, the Vanguard team's success was nonetheless an impressive engineering achievement. While the Soviet Sputnik and ABMA Explorer satellites had made use of military rockets adapted to the task of launching a satellite, the launch of Vanguard 1 marked the first time where a satellite was launched into orbit with a high performance rocket specifically designed for the task.

As Soviet authorities and even some in the West scoffed at the diminutive size of Vanguard 1 and its lack of sophisticated instrumentation, it was proving to be a very useful tool. The battery-powered transmitter continued to operate until the mercury cells were exhausted in June of 1958. But the tiny satellite's solar cell-powered transmitter continued to operate until 1965. After this optical tracking allowed scientist to track the changes in its orbit. These changes and their causes provided much valuable data.

First it was noticed how the minute force caused by sunlight reflecting off the little satellite perturbed its orbit. This combined with atmospheric drag whose magnitude waxed and waned noticeably with the level solar activity decreased estimates of Vanguard's orbital life from 2,000 to only 240 years. Other perturbations in the orbit lead to a more refined estimate of the Earth's oblateness. It was also discovered that the Earth's geoid was distorted by a few meters into a pear shape with the pointed end at the north pole and the flattened end in the south. These measurements indicated that there was large scale convection taking place inside the Earth which supported the then-new theories of continental drift and seafloor spreading. Although they had earlier avoided involvement in orbiting satellites, the Department of Defense, whose military branches were quickly becoming interested in accurately lobbing nuclear warheads over intercontinental distances, took note of these discoveries.

Moving Towards Operational Launches

With the successful launch of Vanguard 1, its backup launch vehicle, TV-4BU was returned to the Martin Company's Maryland facility for removal of test instrumentation and upgrades to critical systems so that the rocket could be used later in the program. The final test flight, TV-5, would attempt to launch the first "operational" Vanguard satellite. This payload was a 51 centimeter (20 inch) in diameter lightweight magnesium alloy sphere weighing 9.8 kilograms (21.5 pounds). Unlike the simple Vanguard 1, this new satellite would carry scientific instruments to measure the intensity of solar X-ray emissions in the 1 to 8 Angstrom band as well as make space environment measurements.

The first stage of TV-5 was erected on the launch pad during the first week of April 1958. The attachment of the upper stages had to wait for some time as problems with hydraulic disconnects identified in the film footage of the Vanguard 1 were solved. These problems were quickly resolved and the last Vanguard test vehicle smoothly lifted off at 9:53 am EST on April 28, 1958. While the first stage operated perfectly, the second stage firing sequence failed to complete itself electrically. As a result, the third stage was never armed and subsequently did not fire to place the payload in orbit.

With the completion of Vanguard's test flight, flights with production rockets could commenced. First up was SLV-1 (Satellite Launch Vehicle-1). The satellite carried on this mission was identical to that on TV-5 except that the solar X-ray instrument was replaced with one to measure solar Lyman-alpha emissions in the 1,100 to 1,300 Angstrom band of the ultraviolet. Launched on May 27, 1958, SLV-1 operated perfectly until the second stage shutdown. At that time some sort of disturbance caused a loss of the attitude data from the control system's pitch gyro. As a result of the malfunction, the third stage was

pointing 63 degrees off course when it fired and the payload failed to reach orbit.

On June 26, 1958 SLV-2 lifted off with a satellite payload identical to that carried by the ill-fated TV-5 launch vehicle. But this flight would fare no better than the last two. A restriction in the second stage's oxidizer feed system caused its engine to cease firing after a burn of only 8 seconds. This premature shut down in turn caused the stage's propellant tanks to overpressurize. While the payload never made it into orbit, the fact that the second stage withstood the excess pressure verified the structural integrity of the tank design under adverse flight conditions.

The flight of SLV-3, launched on September 26, 1958, was to carry a 10.6 kilogram (23.3 pound) satellite into orbit. This orbital payload was equipped with a set of simple infrared photocells that would use the spinning motion of the spherical satellite to produce crude images of the Earth's cloud cover. A tape recorder was also carried so that data could be stored for later transmission to the ground. Unfortunately this flight also proved to be unsuccessful. This time the problem was traced to contamination in the second stage fuel system which reduced its performance. By the time the third stage had burned out, the payload was traveling only 76 meters per second (170 miles per hour) too slow to achieve orbit. The would-be satellite reached a peak altitude of 426 kilometers (265 miles) before it arced back towards the Earth and burned up on reentry about 15,000 kilometers (9,200 miles) downrange.

With these latest failures, Martin Company's Corrective Action Team had their work cut out for them. While these flights failed to place their payloads into orbit, they were successful from the engineering point of view. Without exception, every flight returned plenty of good telemetry which in addition to other data, such as tracking photography, allowed the engineers to pin down the source of the problem and correct it on subsequent flights. But while Vanguard launches were suspended for a few months to allow modifications to be made to the last of the Vanguard launch vehicles, changes in the political climate were overtaking the Vanguard program and the rest of the United States' space programs. With the formation of NASA on October 1, 1958 as the sole civilian space agency, most space science programs run by the military as well as the Vanguard project were passed to the new agency. While the NRL was still responsible for the management of the Vanguard program, NASA was now running the show.

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