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Vanguard and Its Legacy

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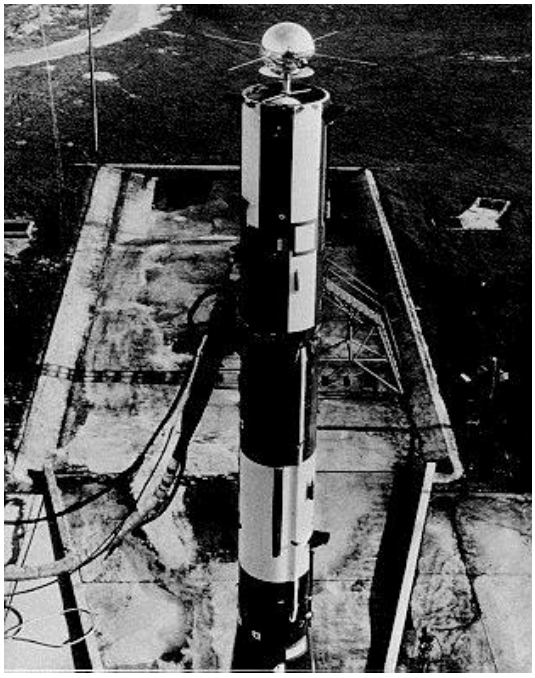
Introduction

A key component of NASA's infant space science program was Project Vanguard. Originally developed by the Naval Research Laboratory (NRL) as America's first official satellite program (see **Vanguard: America's Answer to Sputnik** in the December 1997 issue of *SpaceViews*), Project Vanguard and much of its NRL team were transferred to NASA once it was established in October 1958.

Despite a dismal orbital launch record of only one success in seven tries by the time NASA assumed control, it was recognized that Project Vanguard was at the cutting edge of space science and technology. As a result, Project Vanguard had much to offer future NASA programs in the way of experience and technology. But in addition to this, Project Vanguard also arrived with a ready supply of hardware consisting of four flight-ready launch vehicles and an assortment of scientific satellite payloads just waiting to be launched.

Vanguard 2

After the string of four failures that followed the launch of Vanguard 1 in March of 1958, the project team and its industrial partners had much work ahead of them to improve the reliability of the Vanguard launch vehicle (see **Vanguard 1: The Little Satellite That Could** in the March 1998 issue of *SpaceViews*). After a five month stand down, the former-NRL team was ready to launch their first satellite under NASA management. By early 1959, the components of SLV-4 (Satellite Launch Vehicle 4) had been exhaustively tested and assembled at Launch Complex 18A at the Eastern Test Range in Florida.



The Vanguard 2 satellite mounted atop the SLV-4 before final preparations for launch. (NASA)

The payload for this launch vehicle would be one of the project's "standard" satellites consisting of a polished, 51-centimeter (20-inch) magnesium alloy sphere holding a pair of transmitters, recorders, scientific instruments, and mercury batteries to power it all. For this particular mission, the primary instrument was a pair of small photocell-equipped telescopes designed to produce the first images of Earth from orbit for a period of two weeks. Supplied by the Army Signal Corps which was developing a weather satellite under the aegis of ARPA (Advanced Research Projects Agency), these units would use the spin of the satellite to scan a line across the face of the Earth. The forward motion of the satellite would then allow a picture of the scene below to be produced one line at a time. This payload was virtually identical to that carried by the ill fated SLV-

3 launched just before NASA assumed control of the project. As before, it was hoped that these first crude images of the Earth from orbit would provide data on the planet's radiation budget as well as guidance in designing more capable imaging systems in the future.

On February 17, 1959 SLV-4 smoothly lifted off and headed towards space. Once the third and final stage had burned out, the 10.8-kilogram (23.7-pound) Vanguard 2 was in a 557 by 3,319 kilometer (346 by 2,063 mile) orbit inclined 32.9 degrees to the equator. After a string of three unsuccessful Moon probes, NASA finally had its first successful launch into space.

But everything was not totally well with the Earth's newest artificial companion. According to the original plan, a clamp holding Vanguard 2 to its solid propellant third stage was to release once in orbit allowing a spring to cleanly separate the two. While this took place more or less as planned, a residual discharge or "burp" from the free flying third stage rocket motor just after separation resulted in the stage bumping the released satellite. Instead of spinning predictably about a predetermined axis, the minor collision introduced a precession that set Vanguard 2 wobbling as it traveled around the Earth.

Without a means of determining exactly where it was pointing, the stream of brightness values returned by Vanguard 2 could not be reassembled into a coherent picture by scientist back on the ground. While certainly a disappointment to the experiment's designers, the data Vanguard 2 returned during its 27 day active life was still quite useful. Detailed analysis of the data yielded statistics on scene structure and illumination as observed from orbit. All this information would aid the development of future weather satellites.

More Advances

With the successful launch of Vanguard 2, attention turned to the next satellite. Unlike the simple satellites carried earlier, the payload for SLV-5 had an entirely different configuration. Provisionally dubbed "Vanguard 3", this 10.6 kilogram (23.3 pound) payload actually consisted of a pair of satellites. The first, Vanguard 3A, was a 33 centimeter (13 inch) in diameter fiberglass and phenolic resin sphere carrying a precision magnetometer designed to map the Earth's magnetic field.

Connected to Vanguard 3A by a 6.4 centimeter (2.5 inch) wide, 44.5 centimeter (17.5 inch) long cylinder was a second satellite designated Vanguard 3B. This passive satellite was a laminated sheet plastic and aluminum foil balloon that would inflate to 0.76 meters (30 inches) across after it separated from Vanguard 3A in orbit. Lacking a transmitter or other active instrumentation, Vanguard 3B would be tracked optically to yield information on the density of the uppermost reaches of Earth's atmosphere.

While this multiple satellite technique was an innovative means of making the best use of a rocket's payload capability (one that NRL engineers would put to extensive use in future Navy satellite programs), Vanguard 3 would never have a chance to prove itself. SLV-5 failed on April 13, 1959 when pitch control was lost in the second stage of the launch vehicle after its first stage had separated. After this disappointing failure, NASA canceled the lost payload's "Vanguard 3" designation in an attempt to establish the agency's early practice of saving official satellite designations (like "Vanguard", "Pioneer", and "Explorer") for payloads that survived launch and actually made it into space. The "Vanguard 3" moniker would be reserved for the next Vanguard satellite to reach orbit.

The next Vanguard rocket, SLV-6, was earmarked to launch the next "Vanguard 3" contender. Unlike the innovative design of the previous payload, a standard Vanguard satellite would be launched this time. This 10.8 kilogram (23.8 pound) satellite was to be placed into a high inclination, 48 degree orbit in order to measure the Earth's radiation budget over a large fraction of its surface. Instruments on the satellite would measure the amount of incoming light from the Sun, the reflected light from the Earth, as well as the amount of infrared radiation emitted by the Earth's surface and atmosphere. Such information would be vital in developing more advanced and accurate models of Earth's weather and climate.

Because of the high inclination of the intended orbit, SLV-6 would have to perform an untried roll maneuver shortly after launch to set it on the more northerly course required for this mission. On June 22, 1959 SLV-6 lifted off and successfully rolled from its initial azimuth of 48 degrees to 100 degrees before pitching over as planned. But as had happened too often before, things went awry after the second stage took over. Immediately after ignition of the AJ-10 engine, pressure plummeted in the second stage's tanks resulting in a reduced propellant flow. After the AJ-10 sputtered for 40 seconds, the helium pressurant tank exploded because of the heat build up

destroying the ascending rocket. Vanguard had failed again.

The Last Launch

With only one flight-ready launch vehicle left from the original batch of Vanguard rockets ordered by NRL and no commitment from NASA to procure more, Project Vanguard now had only one last chance to orbit a satellite. For this flight, SLV-7 was used. Using TV-4BU (Test Vehicle 4 Back Up) hardware left over from Vanguard test program, the rocket had been returned to the Glenn L. Martin Company facility in Baltimore to be stripped of test instrumentation and refurbished to become SLV-7 after the successful launch of Vanguard 1 on TV-4. Unlike all the other Vanguard rockets which used a conventional, steel-cased solid propellant third stage built by the Grand Central Rocket Company, SLV-7 would use the more advanced, fiberglass-cased unit developed by the Allegheny Ballistic Laboratory.

This new rocket motor, called X-248, had been developed in parallel with Vanguard's original third stage motor as a high-performance backup to the latter. Because of its unparalleled performance, the X-248 had already been incorporated in a number of other rockets by the time Project Vanguard was ready to use it. By the summer of 1959, the X-248 had already been flown three times as the third stage of the Thor-Able space carrier rocket. The substitution of the X-248 as Vanguard third stage promised to more than double the rocket's original payload capability.

For this last launch, a highly modified version of the standard Vanguard satellite was employed. With a significantly increased payload capability, much more equipment could be crammed into the 23.8 kilogram (52.3 pound) satellite giving it the instrument payload equivalent to two standard Vanguard satellites. Like the ill fated satellite carried by TV-5 in April of 1958, this satellite would carry a suite of instruments to monitor solar X-ray emissions as well as study the radiation and micrometeoroid environment in orbit. A proton magnetometer similar to the one carried by the original "Vanguard 3" would be housed in a special 66 centimeter (26 inch) tall conical fiberglass housing on top of the satellite's spherical 50.8 centimeter (20 inch) main body. The magnetometer, in addition to being able to map the Earth's magnetic field, would also be capable of measuring kilohertz-frequency radio emissions that could probe the Earth's ionosphere from above. All of these data could be recorded for later playback when within range of a ground station. To simplify the design and save further weight, the X-248 third stage would stay attached to the satellite once in orbit yielding a total mass of 43.0 kilograms (94.6 pounds) - almost 30 times larger than the original, grapefruit-sized Vanguard 1.

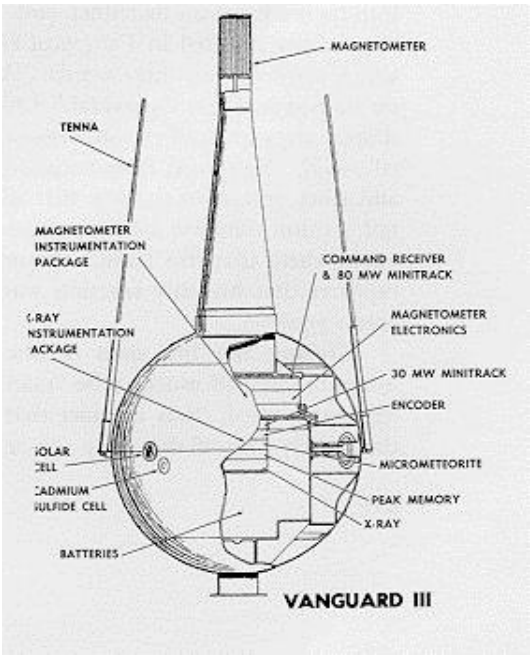


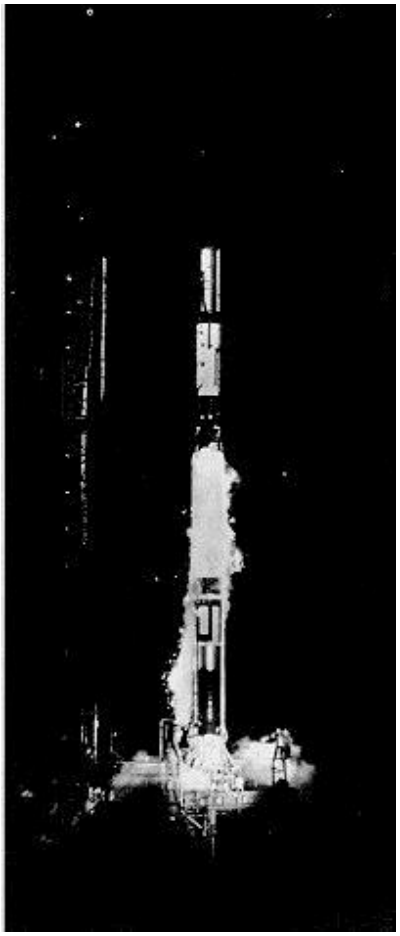
Diagram of Vanguard 3. (NASA)

SLV-7 lifted off on September 18, 1959 under the watchful gaze of the public. To the relief of all involved, this last launch was successful and Vanguard 3 was placed into 510 by 3,743 kilometer (317 by 2,326 mile) orbit around the Earth inclined 33.3 degrees to the equator. Until it finally fell silent on December 8, Vanguard 3 returned a wealth of new scientific data. Over two thirds of its 4,200 magnetometer measurements were deemed "prime data" to be used to characterize the Earth's magnetic field. Other instruments performed a comprehensive survey of the inner edge of the Van Allen radiation belt adding significantly to the understanding of this Space Age discovery. The flight of Vanguard 3 proved to be a fitting finale to the nation's first official satellite program.

The Legacy

While Project Vanguard had been officially "phased out" by NASA's first anniversary, the project left an invaluable legacy whose influence is still seen to this day. Even before the project's first successful launch, Vanguard's upper stages had been modified for use on the Thor-Able which launched the nation's first Moon probes (see **Operation Mona: America's First Moon Program** in the April 1998 issue of

SpaceViews). By the end of the Vanguard program, plans were already well underway to use these same stages with the Atlas-Able to launch NASA's new series of Pioneer probes to the Moon and beyond. The Thor-Able hardware would later be significantly modified to become the famous Delta launch vehicle whose descendants still fly today. The X-248 rocket motor would also be used in NASA's low-cost Scout solid propellant satellite launcher.



Lift-off of the SLV-7 carrying the last Vanguard satellite, Vanguard 3. (NASA)

The Vanguard satellite hardware itself would also prove to be valuable. Much of the hardware (e.g., telemetry systems, tracking beacons, miniature tape recorders, etc.) developed for the program had already been "borrowed" by other satellite programs and future satellite hardware would be based on this newly proven technology. Vanguard's network of tracking facilities would serve as the basis of NASA's worldwide tracking network. Management techniques developed run the project were also adopted by NASA. The list goes on and on.

Although Project Vanguard often gets pushed aside because of its poor flight record of only three successes in 11 attempts, it left a powerful legacy that immeasurably aided America's push into space.

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