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## **THE VANGUARD PROGRAM**

**Date:** September 9, 1955 to September 18, 1959

**Type of Technology:** Rocket Booster

**Country:** The United States

*Destined to be remembered for its failed attempts to launch the first U.S. man-made satellites, the Vanguard program generated important developments in rocket propulsion, satellite design, and satellite telemetry and tracking and eventually succeeded in launching three Vanguard satellites.*

### *Principal personages*

JOHN HAGEN, Program Director of Project Vanguard, Naval Research Laboratory.

DR. JAMES A. VAN ALLEN, Professor of Physics, Iowa State University.

WILLIAM H. PICKERING, Director, Jet Propulsion Laboratory (JPL), California Institute of Technology.

MILTON W. ROSEN, Technical Director of Project Vanguard, Naval Research Laboratory.

HOMER E. NEWELL, JR., Naval Research Laboratory.

DONALD J. MARKARIAN, Vanguard Project Engineer, Glenn L. Martin Company.

THOMAS K. GLENNAN, Administrator, National Aeronautics and Space Administration.

### **Summary of the Program**

Project Vanguard consisted of fourteen multi-stage launches, including test vehicles, with the stated purpose of placing the United States' first man-made satellite into Earth orbit.

In the early part of the twentieth century Robert H. Goddard designed, tested, and successfully launched both liquid- and solid-fueled rockets. Rocket designers in the United States, the Soviet Union, Germany, and Austria were busy throughout the 1920's, 1930's, and 1940's developing the skills and technology that would later be used by rocket scientists of the post-World War II era. After World War II, a global awareness of the effective use of rockets forced the U.S. military to alter the scope and direction of their ballistic missile research. After the May 1945 surrender to the Allies of roughly 120 German rocket scientists at Peenemünde – led by Wernher von Braun - the academic research community, industry, and military of the United States became engaged in dissecting, modifying, and eventually, using German V-2 rockets for basic research. The U.S. Army, Air Force, and Navy were independently developing sounding rockets (rockets capable of sub-orbital flight) and spacecraft capable of orbital flight (research satellites). Because of the outbreak of the Korean War, however, military research was largely aimed at accurate delivery of nuclear or conventional weapon payloads.

On September 9, 1955, with the backing of the President Dwight D. Eisenhower, the Department of Defense authorized the Naval Research Laboratory to administrate a far-reaching

program to design, build, and launch at least one artificial satellite during the International Geophysical Year, or IGY - a period of a year and a half running from July 1, 1957, to December 31, 1958. The United States' participation in the IGY, an international peacetime research effort, was problematic, because only military agencies had the hardware, financial backing, and manpower necessary to launch a satellite. Nevertheless, with the support of the Department of Defence, the Bureau of Aeronautics, the Office of Naval Research, the National Academy of Sciences, and the National Science Foundation, the NRL began implementing Project Vanguard. The NRL was backed by the Glenn L. Martin Company (GLM), Aerojet General Corporation, Grand Central Rocket Company (GCR), Allegany Ballistics Laboratory, General Electric (GE), International Business Machines (IBM), Minneapolis-Honeywell, and a myriad of American universities and research facilities.

The planning and construction of the Vanguard launch vehicle's main-stage was facilitated with testing in the late 1940's of the Viking rocket built by GLM for the NRL. Nurturing a working association with one of the nation's largest rocket builders, it was only natural that the NRL turn to GLM for help with the development and deployment of Vanguard test vehicles and satellite launch vehicles. Unfortunately, GLM also won a contract with the Air Force to construct the Titan missile, thus diluting the manpower it could expend on the Navy's Project Vanguard.

Despite these problems and others involving questions of responsibility and decision making, the NRL and GLM effort was successful. Rocket design specifications were completed by February, 1956, but again, disagreement between the NRL and GLM resulted in amendments and delay. The early Vanguards, Viking M-15's manufactured by GLM were modified Viking M-10 missiles with a GE first stage motor, an Aerojet Aerobee-Hi liquid-propellant second stage, and a GCR solid-fuel upper stage. Here, the spectre of the military dissipated, as the Viking missile was a renowned research vehicle that had long been used for atmospheric sounding.

Kerosene and liquid oxygen were used for the first stage of the Vanguard rocket, which generated 120,096 newtons of thrust. The fuel and oxidant were supplied to the engines by a hydrogen peroxide decomposition technique, which produced superheated steam and oxygen to drive turbine-driven fuel and liquid oxygen pumps. Helium gas supplied pressure for the fuel tanks. The second stage produced 33,360 newtons of thrust with a mixture of white fuming nitric acid and unsymmetrical dimethylhydrazine, an explosive rocket fuel. The third stage was powered by a solid-propellant motor and generated roughly 13,344 newtons of thrust.

With the development of the transistor and miniaturized electronic circuitry, satellite instrumentation design programs at the NRL, JPL, and university campuses swung into full gear. Satellites were prepared under the directorship of the National Academy of Sciences. Meanwhile, NRL telemetering and tracking systems were in advanced stages of development. The deployment and success of the Minitrack system was a result of rigorous testing and research; this highly accurate tracking system formed the backbone of satellite tracking during and after the Vanguard era. GLM developed computer programs and balanced weight against the anticipated flight trajectory. IBM offered the NRL free computer time at the Massachusetts

Institute of Technology. Because of loans and contracts, both optical and electronic tracking and telemetry stations were built and manned largely by civilian personnel.

As originally planned, Vanguard test vehicles – numbered TV 0 through TV 5 – would precede the production of Vanguard model satellite launch vehicles that would be used for missions SLV 1 through SLV 6; there would be a total of twelve launches. Because of engineering changes in payload shape, weight, and size, a moderate degree of launch failure, and the globally transmitted 20- to 40-megahertz beep of Sputnik 1, the original Project Vanguard firing schedule was accelerated and ultimately expanded to fourteen attempts with the launches of two backup test vehicles, TV 3BU and TV 4BU. In all, three highly-successful satellites were placed into earth orbit, and abundant new geophysical, atmospheric, and near-space data were gathered for processing and analysis.

The first Vanguard launch, TV 0, occurred on December 8, 1956, and successfully tested the Viking 13 first stage and the telemetry and tracking systems, which reached an altitude of 203.5 kilometers and range of 157 kilometers. TV 1, or Viking 14, followed on May 1, 1957, and after a test of third stage propulsion reached a range of 726 kilometers with a 195-kilometer peak altitude. Sputnik 1, launched October 4, 1957, interrupted the proposed Vanguard test launch schedule; TV 2 restored confidence in the project with a better-than-expected performance, involving the three-stage Vanguard prototype with inert second and third stages, on October 23, 1957. The Soviet Union launched the space dog Laika into space on Sputnik 2 on November 3, 1957. The Vanguard TV 3, a three-stage missile complete with the United States' first man-made satellite was fired on December 6, 1957, but to the amazement of all spectators, toppled and exploded on the launchpad. This failure was a crushing blow to American pride, but it was also a stimulant for more careful engine system tooling and rocket construction techniques by GE and GLM, respectively, in preparation for future Vanguard firings.

In the interim, the United States Army Ballistic Missile Agency (ABMA) at the Redstone Arsenal in Huntsville, Alabama, had been researching modified German V-2 rockets with the assistance of the California Institute of Technology's Jet Propulsion Laboratory. On January 31, 1958, the ABMA-JPL team launched the Juno 1, a four-stage version of the Jupiter C rocket, which carried the first U.S. satellite, Explorer 1. Project Vanguard's second attempt with TV 3BU, ended in failure on February 5, 1958, when a control system problem resulted in loss of attitude control and eventual breakup of the TV 3BU Vanguard after fifty-seven seconds of flight.

Finally, on March 17, 1958, TV 4 placed Vanguard 1 into orbit with an apogee (the point farthest from Earth) of 3,966 kilometers and a perigee (the point nearest to Earth) of 653 kilometers. Vanguard 1 was designed to measure Earth's shape and atmospheric density. It is expected to orbit, with its third-stage motor casing, for more than two centuries. The 25.8-kilogram, 16.26-centimeter spacecraft fulfilled the Project Vanguard goal of launching an artificial satellite within the IGY. The TV 5 launch attempt on April 28, 1958, failed to orbit a 50.8-centimeter, spherical, 9.8-kilogram X-ray and environmental satellite because of second-stage shutdown problems.

The first production version of a satellite launch vehicle, SLV 1, was, on May 27, 1958, to carry a satellite nearly identical to that destroyed during the TV 5 attempt. Again, during second-stage burnout, attitude control problems arose that resulted in firing of the third stage at an angle unsatisfactory for orbit. On June 26, 1958, SLV 2 encountered second-stage propulsion system shutdown after eight seconds. Failure to achieve orbit also plagued the SLV 3 launch on September 26, 1958, when the second stage underperformed.

With passage of the Space Act of 1958, the civilian National Aeronautics and Space Administration (NASA) was created to direct the U.S. space program. Vanguard 2 was successfully placed into orbit by NASA on February 17, 1959, with the launch of SLV 4. Weighing a total of 32.4 kilograms, the 10.7-kilogram payload and 21.7-kilogram third-stage motor casing attained an initial orbital apogee of 3,319 kilometers and a perigee of 556.7 kilometers. The Vanguard 2 payload, destined to orbit for roughly two hundred years, is a 50.8-centimeter spherical satellite that measures cloud distribution and the terrestrial energy cycle budget.

SLV 5 was fired on April 13, 1959; it attempted to launch a 33-centimeter satellite magnetometer and 76.2-centimeter expandable sphere. Problems arose during the separation of the second stage and resulted in an aborted flight. SLV 6 was fired on June 22, 1959, but again, a second-stage failure sabotaged the launch with a rapid drop in fuel tank pressure, faulty ignition, and explosion of the helium tank because of overheating. The 50.8-centimeter satellite on board, designed to measure solar radiation and its reflection from Earth, failed to orbit.

NASA decided to use a spare backup launch vehicle, TV 4BU, in a final attempt to launch a third Vanguard satellite. Using a new solid-propellant third-stage motor, built by Allegany Ballistics Laboratory, the rocket successfully launched Vanguard 3 on September 18, 1959. The final Vanguard weighed 42.9 kilograms and included a 23.7-kilogram payload and 19.2-kilogram motor casing. The initial orbital apogee was 3,743 kilometers, and the perigee was 510 kilometers. The payload included a magnetometer, an X-ray device, and environmental measuring systems. In large part, Vanguard 3 fulfilled the agenda of previous unsuccessful Vanguard launch attempts.

### **Knowledge Gained**

With the end of NRL control of Project Vanguard in late September, 1958, and the creation of NASA in October, many key Vanguard personnel joined the NASA staff. As such, the knowledge gained during the Vanguard era was applied toward all subsequent U.S. space ventures. Growth in the fields of vehicle engineering, construction, fueling, and launch were predictable outcomes of Project Vanguard. The three Vanguard satellites that were successfully launched investigated energy fields in boundary between Earth's atmosphere and space and carried out Earth-directed research.

Vanguard 1 achieved a high-apogee orbit and provided a tracking signal until 1965 thanks to its pioneering use of solar cells. By analyzing changes in orbital acceleration, the satellite detected a bulge in the atmosphere caused by solar heating and recorded a bulge in the

Southern Hemisphere of Earth itself, thus confirming that Earth is non-spherical shape and Earth's interior is inhomogeneous.

Vanguard 2 performed an experiment that measured variations in cloud-top reflectivity. The results were not conclusive, but they contributed some data and perfected meteorological techniques used in later missions. Vanguard 3 was a 50.8-centimeter sphere with sensors for solar X-ray and Lyman-alpha radiation measurements, environmental sensors, and a 66-centimeter projection supporting a magnetometer. Because of the Van Allen radiation belts, the radiation detectors were overloaded and failed to provide accurate data, but accurate temperature monitoring was accomplished over seventy days. Measurements of interplanetary cosmic dust showed a variable but significant influx of particulate matter estimated at 9,072,000 kilograms per day. The magnetometer provided accurate measurements of the Earth's magnetic field, plus data on magnetic disturbance events and upper atmosphere lightning ionization.

### **Context**

The technological impact of Project Vanguard has permeated every aspect of manned and unmanned space exploration and discovery. First and foremost, Project Vanguard developed budgeting, command, and scheduling techniques for effective launching of missiles. Advances in missile guidance, tracking, telemetry, and antennae systems, developments in electronic miniaturization, and solar cell and mercury cell use in satellites were made possible by Project Vanguard. The use of fiberglass casings and the eventual design of the Air Force Thor-Able booster and NASA's highly successful Delta and Atlas launch vehicle are all direct descendants of Viking and Vanguard technology.

In addition, the Vanguards provided new views of the Earth's geologic cycles, thus promoting environmental awareness. The subsequent research in electronics, computers, communication, and optics has changed the quality of human life. Finally, Project Vanguard demonstrated that the American military-industrial-academic complex was capable of far-reaching outer space missions.

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### **Cross-References**

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