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Explorer: America's First Satellite

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Background information on this program can be found in **Project Orbiter: Prelude to America's First Satellite** in the January 1998 issue of *SpaceViews*

The Satellite

The satellite that would be lofted by ABMA's (Army Ballistic Missile Agency) Juno 1 launch vehicle was the responsibility of Caltech's Jet Propulsion Laboratory (JPL), then directed by William H. Pickering. Development work on the satellite actually began back in December of 1954. The payload compartment, which remained attached to the last stage of the Juno 1 carrier rocket once in orbit, weighed only 8.23 kilograms (18.13 pounds) of which 5 kilograms (11 pounds) was actual instrumentation. The stainless steel tube that would carry the instruments was 15 centimeters (6 inches) in diameter and 81 centimeters (32 inches) long including the aerodynamic cone at the top. The total length of the satellite, with the spent fourth stage motor casing, was 2.03 meters (6 feet 8 inches) and it weighed 14.0 kilograms (30.8 pounds). Despite its diminutive size, especially compared to the first Soviet Sputniks, the satellite was able to carry a respectable array of scientific instruments due to America's lead in miniaturization.

The satellite was equipped with a pair of mercury battery-powered phase-modulated telemetry and tracking transmitters operating at a frequency of about 108 MHz like the Navy's Vanguard satellite. Each "microlock" transmitter had eight telemetry channels to relay data back to the ground. The primary transmitter, with a power of 10 milliwatts, used the satellite casing, with the aid of a dipole antenna gap toward the top of the satellite, as an antenna to transmit data to large military receivers. The backup 60 milliwatt transmitter used a four-wire turnstile antenna that could be detected using amateur radio equipment. A prototype of the satellite successfully tested an early version of the microlock transmitter on the maiden launch of Juno 1's forerunner, the Jupiter C, on September 20, 1956 during a suborbital test flight.

Picture of Explorer 1 (NASA)

The scientific payload of the satellite consisted of three instruments. The first, supplied by JPL engineers, was a set of four thermistors to measure spacecraft temperatures. This mission was to test passive thermal control techniques so that the payload could withstand the temperature extremes of space. First the stainless steel exterior of the payload was sandblasted so that micrometeorite impacts would not substantially change its surface properties.

Eight white aluminum oxide stripes were painted down the length of the payload section to reflect sunlight while still allowing heat to be efficiently radiated away. The thermistors, which were placed throughout the satellite, would allow the engineers to assess their efforts to control the satellite's temperature. The frequency drift of the transmitters subcarrier oscillator could also be used to independently check on the temperature. This data would then be used to improve the thermal design of future spacecraft

The remaining two instruments were concerned with characterizing the environment in orbit. First was a cosmic ray experiment designed and built by a University of Iowa team led by James A. Van Allen. This instrument consisted of a commercially-available Anton 314 Geiger-Muller tube that was 10.2 centimeters (4.0 inches) long and 2.0 centimeters (0.79 inches) in diameter. The instrument was similar to those Van Allen and others had flown during the previous decade on sounding rockets and high altitude balloons. The electronics of this Geiger counter were designed to handle counting rates five times higher than predictions based extrapolations of rocket and balloon data. Van Allen and his team hoped to determine if cosmic ray intensities continued to increase with altitude as had been observed in earlier experiments.

Next was a trio of detectors supplied by the Air Force Cambridge Research Center to detect micrometeorites. One sensor was a lead zirconate piezoelectric crystal microphone designed to detect the impact of micrometeorites against the satellite's metallic casing. This detector had an effective area of 0.23 square meters (2.5 square feet) and could detect a micrometeorite as small as 2 nanograms (75 trillionths of an ounce) travelling at 12 kilometers (7.5 miles) per second. The other pair made use of electrical resistance measurements to detect the effects of micrometeorite strikes. One consisted of a group of a dozen fine wire gauges, mounted on the fourth stage motor casing, that were electrically connected in parallel. The total resistance of this array, which had a total effective area of about 12 square centimeters (two square inches), would change when a wire broke from a the impact of a micrometeorite larger than 10 microns (0.4 thousandths of an inch). The last micrometeorite sensor consisted of metallic film deposited on a substrate whose resistance would increase as its surface eroded.

Preparing for Launch

The rocket that would attempt to launch America's first satellite was designated Round 29 by ABMA. This rocket was the backup for Jupiter C Round 27 which flew the design's maiden flight in 1956. Since this flight made use of the Juno 1 launch vehicle configuration (save for a dummy fourth stage), Round 29 was the easiest to modify for a satellite launch. The modified Redstone first stage was flown to Cape Canaveral from the Redstone Arsenal in Alabama in a C-124 Globemaster cargo aircraft on December 20, 1957 only six weeks after von Braun received authorization to proceed. After its arrival, the first stage was moved to the Army missile firing laboratory's Hangar D where it was checked out and integrated with the upper stage rocket cluster which had been checked out earlier at JPL’s spin-test facility on the Cape. By January 13, 1958 the Rocketdyne A-7 powerplant had been checked and final preparations were begun.

The U.S. Air Force, which operated the Cape Canaveral's test range, assigned January 29, 1958 as the beginning of a three day period for the ABMA satellite launch attempt. If the launch of the Juno 1 was delayed beyond this, it would have to wait until after the Vanguard TV-3BU satellite launch attempt which was being prepared only a kilometer and a half (one mile) away in Hangar S. To help even the satellite's exposure to sunlight during the first days in orbit, the launch window was set to extend from 10:30 PM to 2:30 AM Eastern Standard Time.

In order to avoid alerting the press to the impending launch, the Juno 1 was erected under cover of darkness on Pad 26-A. By dawn, the gantry was in position so that the upper stages were covered. To observers on the beach, Round 29 looked like just another Redstone missile test. On January 24, 1958 the press finally started receiving daily briefings on the upcoming launch on the condition that no information would be released until after launch. Amazingly, both the Army and press corps kept the agreement. With the successful completion of a flight simulation test on January 28, America's second attempt to send a satellite into orbit was ready to go.

While all the hardware was ready, Mother Nature refused to cooperate. Weather reports on January 29 were not promising and indicated a wind speed of 270 kilometers (168 miles) per hour at altitudes of 11 to 12 kilometers (36,000 to 40,000 feet). The threat of lightning, which could prematurely set off the upper stage rocket motor igniters on the pad, combined with the buffeting from the upper level winds made a launch impossible. The next day the winds had hardly died down and it was a cool and cloudy day on the ground. Hoping for improved conditions later in the day, the 11 hour countdown started at 11:30 AM and the Redstone was fueled. With wind speeds reported to be 349 kilometers (217 miles) per hour at 12 kilometers (40,000 feet), the countdown was finally halted at 9:00 PM. As the night wore on the winds slackened somewhat but not enough for a launch. Although there was some concern that the modified Redstone's corrosive Hydyne fuel might degrade the seals in the launch vehicle's plumbing, the rocket was left fueled for one last launch attempt on January 31 when conditions were predicted to be better.

Juno 1 launches Explorer 1 on January 31, 1958 (NASA)

As hoped, conditions on the 31st were good enough for a launch attempt. That night about one hundred reporters gathered at a hastily assembled grandstand 2.3 kilometers (7,500 feet) from Pad 26-A near Hangar D. Range Safety officers would not allow them any closer. With 15 minutes to go before launch, the pad area was cleared. Three minutes later the upper stage cluster was set spinning at 550 RPM as programmed. After a rapid paced series of events the count reached "Zero" and the firing command was given. This was followed by a series of events culminating with the ignition of the main engine 14 seconds later. Finally at 10:47:56 PM EST on January 31, 1958 (T+15.75 seconds), the first Juno 1 leapt from the launch pad and into the night sky.

Seventy seconds after launch the upper stage cluster's spin rate was automatically increased to 650 RPM to avoid resonant vibrations that could shake the ascending rocket to pieces. After another 45 seconds the spin rate was increased again to its final value of 750 RPM. Finally 2 minutes and 36.7 seconds after launch the Redstone shut down just a fraction of a second early. Six seconds later the instrument section with the spinning upper stage cluster separated from the now-spent Redstone and continued to coast towards the apex of its trajectory for another four minutes. Six minutes 43 seconds after launch, at an altitude of 362 kilometers (225 miles), the second stage rocket cluster was ignited on ground command. After 6.5 seconds the third stage cluster ignited followed 6.5 seconds later by the final stage.

Telemetry received on the ground indicated that the satellite had probably reached orbit but they would have to wait until 12:41 AM EST when the satellite made its first pass over JPL's tracking station in Earthquake Valley, California for confirmation. Although the signal was received an agonizing eight minutes after the predicted time, it was finally detected confirming the success of the launch. America's first satellite, called Explorer 1, was in a 360 by 2,534 kilometer (224 by 1,575 miles) inclined 33.24 degrees to the equator. America was finally in the Space Race and von Braun and his team managed to do it six days before their 90-day deadline was reached.

Exploring the Unknown

Explorer 1 continued to transmit data until May 23, 1958 when its batteries were finally exhausted. During its 112 day active lifetime in orbit, its instruments returned some interesting data. The microphone used to detect the small micrometeorites recorded 153 impacts during a total observation time of almost 22 hours. While a slight change in resistance was noted, none of the wire gauge detectors were unambiguously broken by a micrometeorite.

Most interesting of all were the results of Van Allen's cosmic ray experiment. Starting at the perigee altitude of 360 kilometers (224 miles), the cosmic ray counts increased with altitude about as expected. Above altitudes of about 1000 kilometers (600 miles), however, the Geiger counter mysteriously fell silent. Once the satellite fell below 600 kilometers altitude as it returned towards perigee, the instrument started returning data once more. Since the other instruments continued to transmit normally, it was suspected that the cosmic ray experiment's behavior was a symptom of a problem in the instrument or its telemetry channel. A second satellite was needed to make more observations.

JPL engineers prepared a second satellite for launch. Explorer 2, which carried a payload of 8.55 kilograms (18.83 pounds), was virtually identical to its predecessor. On March 5, 1958 Explorer 2 lifted off from Cape Canaveral on top of Juno 1 Round 26. Unfortunately for the first time in the Jupiter C/Juno 1 program, the launch vehicle suffered a major malfunction during flight. The final stage of the upper stage cluster did not ignite and the satellite failed to reach orbit.

Already in the pipeline was yet another satellite that was being quickly prepared for launch as part of ABMA's now expanded $16 million, four-satellite "Project 416". While similar in appearance to the first two Explorers, the new satellite possessed a slightly different mix of internal equipment. Deleted to keep the total payload weight down to 8.42 kilograms (18.53 pounds) were the micrometeorite microphone, the turnstile antenna, and all but two thermistors. A miniature tape recorder was now carried to store cosmic ray data when the satellite was out of range of tracking stations. This device could record an entire orbit's worth of radiation data and transmit it upon ground command in five seconds. The scaling circuits of the cosmic ray experiment were also modified to slightly increase the maximum count rate.

On March 26, 1958, just nine days after the first successful Vanguard launch, Explorer 3 was lifted into orbit by Juno 1 Round 24. Due to a large deviation in its injection angle, the satellite ended up in a highly eccentric 188 by 2,801 kilometer (117 by 1,741 mile) orbit inclined 33.5 degrees to the equator. The low perigee caused the satellite's orbit to decay faster than planned and limited the spacecraft's useful lifetime to 93 days. Despite the shortened mission, the cosmic ray experiment experienced the same lack of particle counts at altitudes above 1000 kilometers (600 miles). Dr. Van Allen immediately began to suspect that the radiation counts were not falling to zero but instead became so high as to saturate the instrument's electronics.

Van Allen's discovery of what appeared to be a belt of trapped radiation encircling the Earth, and not cosmic rays from deep space, was of major importance. Decades earlier a Norwegian geophysicist named Carl Stormer predicted the existence of zones above the Earth where charged particles could become trapped between magnetic field lines. The problem at the time Stormer developed his theory was that there was no mechanism known to allow particles into this trap. Van Allen's findings demonstrated that these zones of "soft" radiation actually did exist and that somehow nature found a way to let particles into the trap. Van Allen's remarkable discovery was formally presented on May 1, 1958 during a landmark talk to a special joint meeting of the National Academy of Sciences and the American Physical Society in Washington, DC. The detection of what later became known as the Van Allen Belts was the first major discovery of the Space Age.

Explorer team members, including Wernher von Braun (right) celebrate the successful launch (NASA)

The Last ABMA Satellites

The instrumentation of the last satellite in ABMA's Project 416, Explorer 4, was totally devoted to studies of the Van Allen belt. The final stage of this satellite's launch vehicle, Round 44, was modified to make use of a new high performance propellant that increased the useful payload for this and subsequent Juno 1 flights from about 8.4 kilograms (18.5 pounds) to 11.70 kilograms (25.76 pounds). The sensors on this satellite included a pair of Anton 302 Geiger-Muller tubes which, with a diameter of 7 millimeters (0.28 inches) and a length of 9 millimeters (0.35 inches), were smaller than the Anton 314 tubes carried by earlier Explorers. One of the tubes was shielded with one millimeter (0.04 inches) of lead to help reduce the particle count rate and filter out low energy particles. The Anton 302 tube was subsequently carried by many satellites and space probes thus allowing direct comparison of the data.

Also carried were a pair of photomultiplier tube-equipped scintillators mounted behind windows drilled into the satellite's casing. These detectors allowed for the detection and differentiation of various types of radiation as well as allowing an estimate to be made of their energies. The smaller sizes of the detectors meant that the count rates would be reduced to levels that could be more easily handled by the satellite's electronics.

Explorer 4 was successfully launched into a 262 by 2,210 kilometer (163 by 1,374 mile) orbit inclined 50.1 degrees to the equator on July 26, 1958. During its 455-day mission, Explorer 4 was able to produce a much clearer picture of the structure of the inner portions of the Van Allen belt as it bobbed in and out of the belt a dozen times a day. It also made observations of man-made radiation the was injected into the belts as a result of a trio of one- to two-kiloton nuclear bombs detonated at an altitude of 480 kilometers (300 miles) over the South Atlantic Ocean between August 27 and September 6, 1958. Called Project Argus, this was an ARPA (Advanced Research Project Agency) sponsored project to determine the effects of high altitude nuclear detonations not only on radiation levels in the belt but on long distance radio communications and radar.

By this point in history, however, the ABMA satellite program was winding down. With the upcoming creation of the National Aeronautics and Space Administration (NASA) in October of 1958, it was anticipated that all ABMA space-related projects would be transferred to the new civilian agency. But before this happened, the Army would make two more satellite launch attempts. The first was Explorer 5 launched on Round 47 on August 24, 1958. It carried a payload similar to its predecessor to make observations of the upcoming Project Argus nuclear detonations. Unfortunately it failed to achieve orbit when the upper stage fired in the wrong direction resulting in a collision with the instrument compartment.

The final ABMA-launched satellite made use of Round 49 on October 22, 1958. Initially designated Explorer 6 but later renamed Beacon 1, this satellite carried an inflatable balloon and a small solid rocket motor to circularize the payload’s orbit. Once in orbit, the satellite would be tracked optically to determine atmospheric density at high altitudes. Unfortunately the mission failed during launch when vibrations induced by the spinning upper stages allowed the payload to break free. With this rather anticlimactic failure, the Juno 1 launch vehicle, with three successes and three failures, was retired making way for the larger Juno 2. This rocket would be used to send larger Explorer satellites into orbit as well as push the frontiers of space exploration out to the Moon and beyond.

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