THE STORY OF EXPLORER I

Wernher von Braun Memorial Lecture
National Air and Space Museum
Smithsonian Institution, January 31, 1978
Washington

by

Ernst Stuhlinger, Huntsville, Alabama

Although Explorer I is much younger than most of us who have come here today to celebrate its twentieth anniversary, its roots can be traced back in history much further than most of us can trace their own personal roots. The story of Explorer I began at the time when science succeeded in establishing a firm place in the affairs of man, almost five hundred years ago. I am convinced that Nicolaus Copernicus, who clearly perceived the orbital motions of the moon around the earth, and of the planets around the sun, also understood that a projectile, if given enough velocity in a horizontal direction above the altitude of the highest mountains, would orbit the earth. Kepler, who discovered the relationship between orbital velocity and distance from the center of gravity a hundred years later, must also have been aware of the possibility, at least in principle, to establish artificial moons. Again a hundred years later, Isaac Newton formulated the conditions for a man-made satellite on the basis of his immortal laws of mechanics. - If you set up a cannon on the top of a high mountain on the equator, he said, and if you shoot due east with a muzzle velocity of about 8000 meters per second, the bullet will go around the earth and hit you from the rear. - Whether Newton anticipated that this high muzzle velocity would really be obtained three hundred years later with the help of rockets, is not known. However, for the rocket and space pioneers of the late nineteenth and the twentieth century, it was a familiar thought that man-made rockets would one day be capable of launching earth-orbiting satellites. Esnault-Pelterie in France, Tsander and Tsiolkovskii in the USSR, Ganswindt and Oberth in Germany, Goddard in the United States--they all had their designs and recommendations for satellites. Many of those who worked on rocket projects during and after World War II undoubtedly had their minds from time to time wander off, lured by the siren song of space, and they compared the velocity of their rockets with the magic number of eight kilometers per second needed to achieve orbit.

Wernher von Braun had his first orbital encounter at the age of thirteen after he had bought Oberth's famous book "Rocket Flight to Interplanetary Space," published in 1923. Although he was discouraged and dismayed by the jungle of mathematics in that book, he grasped the logic of Newtonian mechanics; he also realized that if he ever wanted to understand more of the mysteries of space flight, he had to do his homework in mathematics. In 1930, when he was eighteen years old, Professor Oberth employed him as an assistant in the city of Berlin. Young Wernher helped with an exhibition of rockets and futuristic space vehicles; he told the visitors all about rockets, satellites, and space probes, and he assured them that manned flights to the moon will become possible in the near future.

Ten years later, rocket development work was well underway in Peenemuende. Progress was fast, and the possibility of reaching out into space became real. However, the Peenemuende Project was not the time or the place to think of space flight. A harmless, but imprudent remark by Dr. von Braun to the effect that rockets should rather be used for space flight and not for military purposes led to his arrest by the GESTAPO; it took General Dornberger, Commander of Peenemuende, two weeks to have him released from jail. Talks about satellites and space flight were simply taboo in Peenemuende. But, the basic laws of propulsion and guidance apply to space vehicles as well as they do to ballistic missiles, and when Dr. von Braun arrived in the United States after the war, a flood gate opened for all the ideas, plans, calculations, and sketches which had accumulated during previous years in his restless and productive mind. He talked, presented, and wrote about gigantic space stations orbiting the earth, about expeditions to the moon, and about a manned landing and return flight to the planet Mars. While he allowed his thoughts to roam weightlessly through the universe, he was very careful, in a characteristic von Braun manner, to retain a firm foothold in the real world of rocket engines, shop capabilities, and budget cycles. When the first opportunity for the launching of a small satellite arrived, Dr. von Braun grasped it, and he did not let loose until America's first satellite, Explorer I, was in orbit. That opportunity came in the early fifties. In 1950, after von Braun and several hundred of his coworkers had moved from Fort Bliss in Texas to Huntsville in Alabama, work on the Redstone guided missile began. The Redstone was a single-stage rocket for a heavy nuclear warhead and a range of 200 nautical miles; its alcohol-fueled engine, developed by North American Aviation, came from the Navajo Project. Development work on the Redstone progressed rapidly, and von Braun soon was convinced that it would lead to a successful missile project for military use. I remember well that in the summer of 1951, he said to me: "With the Redstone, we would be able to do it." - "Do what?" I inquired. "Launch a satellite, of course!" - He then explained that two or three upper stages, consisting of solid propellant rockets, would be needed to generate orbital velocity, and that these upper stages would be fired horizontally in quick succession at the apex of the Redstone's parabolic trajectory. This was a fantastic plan; it took the earth-orbiting, man-made satellite suddenly out of its dreamworld and made it a part of real life. However, almost six years were to pass before this plan materialized. After all, von Braun and his Army team worked on a military project of high priority which did not tolerate any side-tracking into projects that were not essential to the military effort.

The Army-von Braun team was not the only place where thoughts of a satellite project began to crystallize. The Naval Research Laboratory, in 1945, requested the Guggenheim Aeronautical Laboratory at the California Institute of Technology, directed by Theodore von Kármán, to study possiblities of artificial satellites. Results of this NRL study showed that a satellite project would be too costly for the Navy; a plea to the Air Force for cooperation found no response because the Air Force had its own satellite study underway, Project Rand, which was supported by North American Aviation and Northrop. The Navy study proposed a single stage, liquid hydrogen-liquid oxygen rocket of 50 tons take-off weight. A multi-stage rocket was proposed in the Air Force study. In the fall of 1947, the Committee of Guided Missiles in the Joint Research and Development Board, chaired by Clark Millikan, tried to coordinate Navy and Air Force studies. The Committee recommended that military uses be established for satellites before an expensive satellite project was initiated. Both study efforts were terminated around 1948, and little public debate of satellites occurred during the following years. The Guided Missiles Committee recommended, though, that the Army-von Braun team, supported by the General Electric Company, should provide continuing analysis of problems related to the development of earth satellites.

Three British space enthusiasts, Gatland, Kunesh, and Dixon, published a satellite paper in 1951. In the same year, a Russian scientist and student of space flight, Tikhonravov, wrote that the USSR "would be able to launch a satellite." Wernher von Braun published an article on satellites in 1952, and Fred Singer, presently professor of environmental sciences at the University of Virginia, proposed Project MOUSE (for Minimum Orbital Unmanned Satellite of the Earth) in 1953. Another Russian scientist, Academy President Nesmeyanov, wrote in 1953 that "the creation of an artificial satellite is a real possibility."

In the meantime, some advocates of a satellite project in the United States began to coordinate their capabilities and aspirations in a person-to-person campaign. Members of the Army and the Navy study teams, and some of their supporters at industry, established working contacts. On June 25, 1954, Frederik C. Durant III of the A. D. Little Corporation called together in Washington a small group of experts, including Bill Bollay, Commander George W. Hoover, Alexander Satin, S. Fred Singer, Wernher von Braun, Fred L. Whipple, and David Young. That historic meeting came probably closest to what could be called the birth of Explorer I; at that time, the future satellite was simply called "orbiter." The group decided to recommend an immediate satellite program with the Redstone as booster and three upper stages of Loki rockets. This four-stage rocket would be able to launch a 2.3 kg (5 lb.) satellite. If scaled-down Sergeant rockets replaced the Loki rockets, a 7 to 9 kg (15 to 20 lb.) satellite could be orbited. Official blessing was given to the proposal by Rear Admiral Frederick R. Furth, Chief of Naval Research. More meetings of the Orbiter group followed in Washington, in Huntsville, and at the Cape in Florida. The little community had grown to about thirty die-hard believers; it included Austin Stanton, Colonel Nickerson, and several of von Braun's coworkers. Study objectives were assigned to various members, and technical details of the project quickly took shape. In September, 1954, Dr. von Braun wrote a paper "The Minimum Satellite Vehicle Based Upon Components Available from Missile Development of the Army Ordnance Corps" which offered exact data for design and performance of the four-stage satellite vehicle. Maj. General H. N. Toftoy, Commanding General of the Army establishment in Huntsville, approved of the study project, provided that the Chief of Ordnance, Maj. General Leslie E. Simon, gave his permission. General Simon's approval was readily obtained. Further indirect support for the project was provided on October 4, 1954 by a special committee of the International Geophysical Year in Rome which recommended inclusion of satellites in the IGY program of the United States. The National Academy of Sciences and the National Science Foundation accepted this recommendation, and on July 29, 1955, President Eisenhower announced US plans to launch one or more satellites during the IGY.

Dr. von Braun was very happy about all this progress, but he felt that one important element was still missing in Project Orbiter, a representative of science. He asked me to establish contact with a scientist who might be interested in joining our project, and who would lend scientific credibility to our endeavor. In 1946 and 1947. I had been fortunate to meet several of the upper atmosphere physicists who had accepted an invitation by the Army to place instruments for the observation of atmospheric components and radiations into the nosecones of captured V-2 rockets that were launched to high altitudes at the White Sands Proving Ground in New Mexico. One of these young scientists was Dr. James Van Allen, professor of physics at the State University of Iowa. He spent a sabbatical year at Princeton University during 1954; I met him in his study, and I vividly described to him our plans for an eight-kilogram satellite on top of a modified Redstone. This satellite, I emphasized, was almost ideal as a carrier for Geiger counters which could measure cosmic radiations. Dr. Van Allen at that time was already known internationally as an expert in cosmic radiation.

While I talked, Dr. Van Allen did not show any reaction as he was sitting in the corner of his sofa. The only sign of life was his pipe which produced enormous quantities of smoke. After I had finished, he simply said: "Thanks for informing me. Will you keep me posted on your progress?" - This extremely scant response was a surprise, and I was convinced that I had done a very poor selling job. But we did keep Dr. Van Allen posted. Unfortunately, our news for him were not too good--until November 8, 1957.

In October, 1955, Dr. Richard Porter of the General Electric Company became chairman of a panel responsible for the technical planning of the IGY satellite project. Before this panel was established, however, the fledgling Project Orbiter which had begun its life with so much hope and promise came to an unexpected and untimely end. In an effort to focus as much professional expertise as possible on the project, the Orbiter team had invited Air Force participation through the Assistant Secretary of Defense, Donald A. Quarles. Rather than accepting the invitation, Dr. Quarles established an ad hoc committee under Homer Joe Stewart, physics professor at CALTECH, which was to compare the Army-Navy Orbiter proposal with two new satellite proposals. One of them, the Vanguard proposal, had been submitted by other members of the Naval Research Laboratory. The third satellite proposal was an Air Force project; it was based on the Atlas missile as a carrier. That proposal, however, was quickly discarded by the committee because the Atlas rocket was still in an early stage of development. The proposed carrier rocket for the Vanguard project consisted of a modified Viking rocket as first stage, an improved Aerobee as second stage, and a new solid propellant rocket as third stage. A satellite capability of 22 kg (50 lbs.) was promised at a total cost of $11 million. On September 9, 1955, the Stewart Committee cast a majority vote for Vanguard and against Orbiter. Dr. Stewart, and two other committee members, had voted for Orbiter. There may have been several reasons why Project Vanguard won over Project Orbiter in this committee decision. The Orbiter satellite was to be launched with a military rocket, the Redstone, while Vanguard used only rockets that had been built for high altitude research.

The Viking rocket, developed at the Naval Research Laboratory by Milton Rosen and Ernst Krause in close cooperation with the Glenn L. Martin Company, had accomplished twelve successful flights between 1949 and 1955; Aerobee rockets, which have been used extensively for many high altitude flights since the late forties, had been developed by the Applied Physics Laboratory at John Hopkins University and built by the Aerojet Engineering Company. To many of the Stewart Committee members, it seemed preferable to base an American satellite project on strictly non-military rockets. These committee members may not have been sufficiently familiar with the inherent problems of a complex technical system to appreciate the advantage of a project which uses proven components and a large, experienced, and well integrated development team, in constrast to a project whose components require substantial modifications and a great deal of systems engineering, and which must be accomplished by an adhoc team assembled only for this specific project.

After the committee had decided for Vanguard, John P. Hagen, radio astronomer at NRL, became program director of the new project; Milton Rosen served as technical director. Von Braun's Army team was told to stay out of the satellite business. For most of the members of the Army-Navy Orbiter group, these were sad times. Not so for Wernher von Braun! Inspite of the bad tidings, he kept his beaming optimism. Some time before the fateful decision against Project Orbiter, Dr. von Braun had already initiated a program to test scaled-down nosecones of future intermediate range ballistic missiles during re-entry into the atmosphere after a high altitude flight. The most practical vehicle for such re-entry tests would be a Redstone rocket, equipped with two upper stages consisting of clustered solid propellant rockets. It just so happened that the combination of a Redstone rocket with two upper stages, needed for nosecone re-entry testing, showed a striking similarity with a rocket capable of launching a satellite; as the only difference, the satellite launcher carried a third solid stage with a satellite instead of the heavy re-entry nosecone. Development and testing of re-entry nosecones was part of Dr. von Braun's assignment to build an intermediate range ballistic missile, the Jupiter, at the Army Ballistic Missile Agency in Huntsville.

On the day when Project Orbiter was cancelled, Dr. von Braun told his coworkers: Let's go full steam ahead with the re-entry test vehicle! Dr. Pickering, Director of the Jet Propulsion Laboratory, and Dr. Froelich, his close associate, visited Huntsville shortly afterwards and pledged their full cooperation in the development of the composite re-entry test vehicle. JPL had been actively involved in the development of high altitude rockets for years, and some of its members were quite familiar with the possibilities of launching satellites with multi-stage rockets. The joint work of the von Braun group and JPL proved highly successful; in September, 1956, a Redstone rocket equipped with two upper stages, called Jupiter C, reached an altitude of 700 miles and covered a range of 3300 miles. Two further flights during 1957 performed equally well. The fiberglass nosecone of one of them was recovered from the Atlantic Ocean; it was shown by President Eisenhower on television, and it proved that the ablation technique would be successful in protecting warheads during atmospheric re-entry. For this long-range flight testing, the original Redstone missile had been uprated for higher performance. The propellant tanks were elongated to increase their capacity; the alcohol fuel was replaced by the more powerful Hydyne[1], and the container for hydrogen peroxide for the turbopump system was enlarged to allow a longer burning time. The two upper stages of the Jupiter C re-entry test vehicle consisted of eleven and three scaled-down Sergeant rockets, prepared and assembled by the Jet Propulsion Laboratory.

In February, 1956, Major General John B. Medaris assumed command of the newly created Army Ballistic Missile Agency in Huntsville. He quickly proved a highly efficient and competent leader. Under his command, development of the IRBM Jupiter program, including the re-entry test vehicle Jupiter C, progressed rapidly. Not so good was the progress of the Vanguard satellite project. Building a three-stage, high-performance satellite carrier out of three different rockets proved to be more complicated than previously thought. Basically, the project plan was sound, and the members of the project were certainly very competent. The inherent weakness of the project was simply the fact that it did not utilize any experience or help from the ballistic missile program. After several Vanguard failures on the launch pad, the Army offered in April of 1956 a series of 6 satellites, the first to be launched in September of that year. The Army even offered to make this satellite series a part of the Vanguard program, but the Navy remained firm in its decision not to accept any help from the Army-JPL team.

In the meantime, signs of Russian satellite activities became more and more evident. On April 15, 1955, the Academy of Sciences in the

1) Hydyne = Unsymmetrical Dimethylhydrazine

USSR was given the assignment to coordinate the development of meteorological satellites. In July of that year Russia publicly announced the existence of a satellite program, and in August, Professor Sedov stated at the IAF Congress in Copenhagen that artificial satellites will be launched within two years. Satellites were mentioned repeatedly in public pronouncements during the following year; in June of 1957, Nesmeyanov stated that a satellite launcher and its payload were ready, and that a launching should be expected within months. Around the same time, Lloyd Berkner, USA member of the IGY Committee, received information of an impending sattelite launch by the USSR. On September 18, 1957, Radio Moscow stated that a satellite would be launched soon; transmitter frequencies of the satellite were publicly announced on October 1, 1957.

A few people in the United States followed these developments with grave concern. The crisp statements of the Russians, the depressing plight of the Vanguard Project, the tied hands of the Army-JPL team, and the almost complacent disregard of most Americans for the possibility that our country may be outranked by the USSR with a brillian technical accomplishment--all this added up to the gloomy forebodings of a major shock.

This shock came on October 4, 1957, when Russia proudly announced that Sputnik I, a 184 lb. satellite, was in orbit, and that anybody with a little radio receiver could hear its gentle, but insistent beep-beep every 96 minutes.

On that day, the newly appointed Secretary of Defense, Neil McElroy, happened to be on a visit in Huntsville. His hosts, General Medaris and Wernher von Braun, were quick to point out the tremendous impression this little satellite made on the world, and the most urgent need to prove the technical prowess of this country by launching an American satellite as quickly as possible. Secretary of the Army Wilbur Brucker repeated his offer: six Army-JPL satellites for 12.7 million dollars. It took the Stewart Committee three weeks before it finally endorsed the ABMA satellite project plan, and it took another two weeks, another Vanguard failure, and another USSR satellite--the 1120 lb. Sputnik II with the dog Laika onboard--before the Secretary of Defense authorized the preparation of two Army satellites; but even these should not be launched before March 1958, and not unless Vanguard failed again. This uncertain trumpet call was not what General Medaris was willing to accept. He requested more definite orders, and with the help of William Holaday, the "Missile Tsar" in the Defense Department, he received the go-ahead signal for a satellite on November 8. Dr. von Braun was ready to promise a launch date 60 days later, but General Medaris, with a fatherly gesture, simply said: "Wernher, let's make it 90 days." Eighty-four days later, the Army's satellite was in orbit, but these 84 days were filled with a most intense work program. Several three-stage Redstone re-entry test vehicles (with two upper stages), which had been built during the previous year, were sitting in the hangar and waited for a satellite assignment. However, General Medaris had to promise to the Department of Defense that his Army Ballistic Missile Agency in Huntsville would not work on a satellite project. When this taboo was finally removed in November, one of the re-entry test rockets had to be transformed into a real satellite launcher. A third solid propellant stage, consisting of a single rocket, had to be built and mounted on top of the second stage structure; an attitude control system with gyroscopes and compressed air nozzles had to be designed, built, tested, and integrated in the instrument compartment of the Redstone; this compartment, together with the three upper stages and the satellite, had to be prepared for separation from the Redstone a few seconds after burnout, and while this cluster coasted upward toward the apex of its parabolic trajectory, it had to be turned into an exactly horizontal position. A special instrument, called apex predictor, had to be designed, built, and integrated in the rocket system; it had to generate the ignition signal for the first of the three solid stages at apex in such a way that the third stage would take off horizontally at the exact moment of apex. Good insertion of the satellite into its orbit, and consequently a long lifetime of the orbiter, could be expected only when this ignition sequence worked properly. Finally, the satellite had to be designed, built, and equipped with at least some space physics instruments which would make a worthwhile scientific endeavor out of the satellite launch.

The Vanguard Project had established a number of radio tracking stations around the earth which would be capable of receiving signals from the Vanguard's transmitter. When the Army satellite project was activated, this system, called Minitrack, was considered for use by the Army satellite. However, Eberhardt Rechtin at JPL proposed another system, called Microlock, which was smaller, lighter, more sensitive, and more accurate. Its signals could be received by the existing Minitrack stations. Dr. Van Allen from the State University of Iowa had built a cosmic ray experiment with two small Geiger counters for Vanguard.

With great foresight, he had given his instruments dimensions which fitted also into the long and slender body of the Army satellite. Dr. Maurice Dubin prepared a small meteoroid detector. All these instruments, including two telemetry systems for signal transmission to earth, were battery powered. The shell of the satellite, made of stainless steel, was attached through a fiberglass ring to the casing of the third rocket stage, and through another fiberglass ring to the steel nosecone. The fiberglass rings served as antenna gaps for two radio transmitters. The satellite had been designed by Joseph Boehm at ABMA; the attitude control function to turn the instrument compartment with the upper rocket stages into a horizontal position during the coasting flight was a product of Walter Haeussermann's guidance and control division, also at ABMA. Throughout the satellite project, cooperation between ABMA, JPL, and the numerous contractors behind the Redstone was very close, and, inspite of the hectic pace of the project, very pleasant. The Chrysler Corporation was prime contractor for the Redstone. The Ford Instrument Company in Long Island, New York, was responsible for the overall guidance and control system. To the amazement of some outsiders, there was no "roles and missions" document which would have spelled out what each member of the big family was supposed to do and not to do. There were many discussions, of course, but they aimed at the problems to be solved, and not at prerogatives, demarcation lines, or privileges. There was a job to be done--everything else was secondary.

In order to equalize any differences in performance of the solid propellant rockets of the first two upper stages, the total cluster of rockets and satellite was spinning around its longitudinal axis

was put into a large cylindrical container which at a rate of 550 RPM. This spinrate increased to 750 RPM during ascent of the Redstone, in order to avoid resonance with the natural frequency of the Redstone. This frequency changed gradually as the tanks emptied during ascent.

The correct moment of apex was computed during the ascending part of the flight in the following way. By measuring the altitude and the vertical velocity of the launcher at the time of burnout of the Redstone, the initial data of the coasting portion of the trajectory were known. With these data, the flight time to apex could be calculated with Newton's laws. Three independent methods to determine the burnout data were applied: radar observations, Doppler measurements, and an onboard accelerometer with integrator oriented in the vertical direction. Radar and Doppler data were available in the ground stations; the onboard data of the accelerometer were telemetered to ground. For each of these measurements, nomograms had been prepared which provided the time to apex as quickly as the observational data could be entered. From these three apex time determinations, a weighted average was formed with another nomogram and a simple sliderule, and this "most probable apex time" was set in the apex time predictor. This instrument consisted of a long threaded shaft, driven by a synchronous motor which started to run at the moment of ~~burnout~~ Lift-off. The turning shaft slowly moved a block with an electric contact point. Shaft and block represented a kind of "linear clock." A second block with a matching contact point, sliding in a groove parallel to the shaft, was set by hand on the point which corresponded to the calculated apex time. As soon as the shaft-driven block had reached the fixed block, the two contacts touched, and an electric circuit was closed, producing a radio signal that triggered the ignition of the first solid propellant stage at apex.

As a matter of precaution, the contacts on the two blocks were bridged over by a hand-operated button, and long before the launch the decision had been made that the button should be pressed at the time when the two contacts were seen to touch each other. The hand button would then generate a signal at the right moment even if the two contacts should fail to function properly.

By today's computer age standards, this was a quite primitive system, but it worked very well. The trajectory experts had told us that the lifetime of the Orbiter may be as long as 10 years, provided that we accomplished ignition of the first solid stage at exactly the right moment. - As it turned out later, Explorer I stayed in orbit for twelve and a half years!

As an additional precaution, we had a hand-held stopwatch, and we made the burnout signal audible over a loudspeaker. We also had calculated a "most probable" coasting time from burnout to apex, based on the anticipated performance figures of the Redstone. The stopwatch was hand-started when the burnout signal arrived over the loudspeaker. Had anything gone wrong with the signals needed for our apex computer, we would have pressed the ignition button when the stopwatch indicated the precalculated apex time, hoping that ignition would occur at about the correct moment. Fortunately, the signals for the computer did arrive correctly, and we did not need to read the stopwatch.

The Restone with upper stages and satellite was shipped from Huntsville to Florida by C-124 aircraft in December. Reporters were informed of the upcoming event, and they were invited to the launching, but with the understanding--by word of honor--that they would not write about the satellite in case of a launch failure: no fire, no story! Very fortunately, there was no need to put their fortitude to this test. However, General Medaris did not doubt that everyone would have kept his word.

Launch was set for January 29. The weather gods were not favorably inclined toward our project; they blew with high-altitude winds of 170 miles per hour, too much for the long, slender rocket. On January 30, wind speed increased to 205 miles per hour. The next day, winds had slowed down to 157 miles per hour, and General Medaris authorized the launching. At 10:47:56 in the evening of January 31, the Redstone satellite rocket lifted off from its launch pad.

Burning time of the Redstone was 157 seconds. Our computations and nomograms gave a coasting time from burnout to apex of about 247 seconds. Considering a burn time of 6.5 seconds for each solid rocket stage and a delay of 1.5 seconds between stage firings, the ignition signal had to be given at about 224.5 seconds after burnout. Our little apex predictor worked well, and the ignition signal was generated by each of the two redundant contacts (one automatic, one by the hand-pressed button) almost simultaneously.

As soon as the ignition signal had been radioed to the spinning rocket cluster at apex, the microlock tracking signal indicated that the three solid stages had indeed fired as planned, and that the satellite had quickly disappeared in an easterly direction. Several minutes later, a ground station in the Bahamas picked up the signal, and the hope increased that it may really be in orbit. General Medaris asked Al Hibbs what its orbital lifetime will be. Even for a member of JPL, it took some boldness to answer that question on the basis of the meager data available a few minutes after launch, and Al began to say: "The probability for a 90 percent confidence...." but the General, impatient under the pressure of events, wanted a clear answer. "Ten years, Sir," Al said, and General Medaris was satisfied. Al could have been bolder by 25%, as we learned twelve and one half years later.

After that, a long hour of waiting began. Not before the satellite had completed its first orbit and appeared over the Goldstone tracking station in California could we be certain that it really orbited the earth. Dr. von Braun, Dr. Pickering, and Dr. Van Allen (waited patiently) ~~were~~ at the Pentagon in Washington, together with the Secretary of the Army Wilbur Brucker. The satellite was expected to complete a full orbit in about one hundred and seven minutes. The Goldstone antenna, therefore, should have received a signal around 00:26, Washington time. Dr. Pickering, a little nervous by then, anxiously telephoned Pasadena and asked: "Do you hear her?" - "Negative," was the answer. Two minutes later, he repeated his question, and again received a negative answer. "Why the hell don't you hear anything?" he blurted out, but the man at the other end really could not answer that question. Secretary Brucker then asked calmly: "Wernher, what happened?" - Wernher stared at his watch. Beads of sweat appeared on his forehead. Contrary to his usual quick response, he remained silent.

In the meantime, Brig. General Jack Barclay and Eberhard Rees, deputies of Maj. General Medaris and Wernher von Braun, were sweating it out at ABMA in Huntsville, Alabama General Medaris, Center Director

Kurt Debus, Hans Gruene, Bob Moser, and other members of the Von Braun and the JPL teams had joined a group of reporters in a small auditorium at the Cape in Florida. All of them were waiting for news from California. There was great silence in the room in Florida, but the air was filled with tension. General Medaris looked alternatingly at his watch and at a clock on the wall. Neither Al Hibbs nor Jack Froelich said a word; it was really an unusual situation. And then, at about a quarter to one o'clock, there was a voice from the rear: Chuck Lundquist, a young scientist from Huntsville, entered the room and shouted: "Goldstone has the bird! It is in orbit!" - After that, nobody could hear anything, because everybody congratulated everybody at the top of his voice. In the Pentagon, Wernher von Braun took a deep breath. "She is eight minutes late. Interesting," he said.

Soon after the little satellite had begun its life in orbit, it was officially named Explorer I. Its instruments worked well, but their readings puzzled Dr. Van Allen and his coworkers George Ludwig, Carl McIlwain, and others. The Geiger counters showed only a low radiation count, and they even quit counting periodically on their way around the earth. This strange behavior was soon recognized as a saturation effect, caused by an unexpectedly high radiation density, and Dr. Van Allen was led to the discovery of the radiation belts which bear his name.

Sputniks I and II, after circling the earth for a few months in solitude, had received a brother in orbit. More satellites followed; the Vanguard Project achieved a first success on March 17, 1958, when a grapefruit-sized satellite was placed into a high orbit.

When Dr. Van Allen and I met a few days after the launch of Explorer I, he asked me whether I remembered our meeting in Princeton four years ago. Of course, I did. - "There I was sitting behind the smokescreen of my pipe", he said, "listening to what you were telling me, and I said to myself: Either, these guys are crooks. Or, if they are not, they have something absolutely fantastic on their mindes, and even on their hands. - At that time, he added I did not know the correct answer. Now, I do!"

With Explorer I, the two Sputniks had received a brother in orbit, after circling the earth for a few months in solitude. More satellites followed; The Vanguard Project [illegible] achieved a first success on March 17, 1958, when a small satellite was placed into a high orbit. Sputniks, Explorers, Vanguards, Discoverers, Tiros, Echo, Transit, Midas, Samos, Vostok, Mercury-Atlas, Cosmos, Telstar, Relay, Syncom, Salyut, Gemini, and a host of other satellites up to Skylab, Apollo-Soyuz, HEAO and IUE established their orbits around the earth during the following years. Some enjoyed only a short period of weightless life in space, others, such as the Lageos satellite, may stay in orbit for thousands and even millions of years. By 1976, about 2000 satellites and space probes had been launched successfully; 1100 of them were built by the USSR, 700 by the United States, and 200 by various othe nations. Many of the satellites had astronauts onboard.

For Wernher von Braun, this fabulous evolution was always a source of great happiness, and he often said: "Man has firmly established his foothold in space. He will never give it up again."