The German V-2

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THE DESIGN FEATURES and performance data of the V-2, one of the outstanding innovations of the last war, are well known and have been described extensively in many books and articles.[1] Less well known is the inside story of this weapon—how the Germans came to build it, what inspired them, how they succeeded, and especially why this weapon, in spite of all efforts, failed to become what its creators intended.

In the fall of 1929, the Research and Development Department of the German Army Board of Ordnance, under its chief, Colonel Professor Dr. Karl Becker, began to investigate jet propulsion as a possible means to propel an explosive carrier.[2] They uncovered more fiction than fact, no exact data from which they could come to any conclusion. What they found was technically unconquered land hidden in a foggy, sometimes stormy, atmosphere.

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[1] See Walter Dornberger, *V-2* (New York, 1954); W. J. Craven and J. L. Cate, eds., *The Army Air Forces in World War II*, Vol. III (Chicago, 1951), pp. 84-85, 525-46; British Ministry of Supply, *Report on Operation "Backfire"* (London, War Office SPOG/500/12, January 1946); U. S. War Department, *Handbook on Guided Missiles of Germany and Japan* (Washington, February 1, 1946); L. E. Simon, *German Research in World War II* (New York, 1947); U. S. Army Air Forces, *The Story of Peenemuende—Interviews on German Rocket Research* (Washington, 1945); J. M. J. Kooy and J. W. H. Uytenbogaart, *Ballistics of the Future* (New York, 1948); and W. G. A. Perring, "A Critical Review of German Long Range Rocket Development," *Journal of the Royal Aeronautical Society* (July 1946).

[2] Alfred R. Weyl, *Guided Missiles* (London, 1949).

On the other hand, the time was ripe. Since the early 1920's, with the development of inexpensive, mass-produced light metals, highly efficient oxidizers which could be handled, and reliably accurate electronic equipment, three fundamentals were available for the revival of the ancient art of rocketry.

The history of technology proves that when the time is ripe, people are thinking about or working on the same problems in almost all civilized countries. So we see in 1930, private groups, inventors, and engineers in many countries were working on rocket propulsion, even designing and fusing first samples of liquid-fuel rockets. Experimenting in the United States was Professor Robert H. Goddard, in Romania Professor Hermann Oberth, in Russia Professor Konstantin E. Ziolkovsky, in Germany Max Valier, Engineer Johannes Winkler, Rudolf Nebel, and others.

One thing was common to all of them—their funds were extremely limited. In part, they had excellent ideas, imagination, and even skill, but they failed to perceive the development costs and the amount of hard work required before attaining convincing results. As late as 1941, Professor Oberth, the outstanding rocket theorist, who had no knowledge of the German efforts in this direction, suggested a 200-mile range single-stage rocket for whose development he asked $10,000. These men lacked one thing—none had a financially strong sponsor. Eccentric inventors with new ideas usually do not get such sponsors.

Role of the German Army

Why, then, did the German Army become a sponsor of rocket development? The answer is to be found in another question: Why should it have been different with the rocket than with atomic energy, with the airplane, or with most other revolutionary technical inventions? The big boom in aircraft development began from the moment the armed forces all over the world became interested in it, not as a means of transportation for peaceful purposes, but as a weapon carrier. The rocket, too, had to find its way into modern technology by its first application as a carrier of explosives. Private industry or government would not have spent hundreds and hundreds of millions of dollars for a new technical idea which, in the foreseeable future, would not produce any profit. The Germans were looking for a new superior weapon system which was not prohibited to them by the Treaty of Versailles.

It remains to be explained why the German Army later became its own contractor in the rocket field, doing the research and development work in a military installation without letting big private industry in on this new business. Up to 1930, all development divisions of the German Army carried on their developmental work, as in the United States, with the assistance of competent industries. Only for the development of solid and liquid-fuel rockets did the Army set up its own engineering staff and its own workshops and facilities. There were two reasons: (1) no competent industry was interested; and (2) secrecy. If the German military wanted a truly secret weapon, they had to develop it within military facilities where strict security regulations could be enforced.

Their obvious success was proof of the correctness of their thinking at that time. Hardly anyone in the world, not even most of the top officials of the Third Reich, knew before the spring of 1943 that such a development was under way at the Army Experimental Station at Peenemuende. Yet, by 1945 the Germans had a rocket lead of approximately ten years.

But in the early 1930's there was no such thing as Peenemuende, only confusion. On the one hand, theorists and university professors quarreled about the sixth decimal behind the comma in the calculation of a flight path to Mars and Venus. On the other, a branch chief in the Board of Ordnance made a written report to his supervisors in 1931 that a liquid fuel rocket could never take off from the ground on its own. He came to this conclusion—which almost killed the development of liquid propulsion for rockets—from early test results. The ballistics branch of the Army's Board of Ordnance at that time experimented with a combustion chamber which produced 60 lbs. thrust. But the weight of the power plant package with its tanks was 400 lbs., and such a device presumably could never take off.

Rocket development in Germany owed its later progress to the initiative and foresight of the chief of the development department of the Army Board of Ordnance, Major General Karl Becker, at that time one of the outstanding ballisticians of the world. (In the spring of 1940, he committed suicide after a quarrel with Hitler). General Becker established in 1930 the first goal in the field of modern military rockets: to make a saturation weapon out of solid rockets and to find out what could be done with a first prototype of a liquid-fuel rocket.

When the German military realized they could not get industry to do the development job for them, nor induce different groups of inventors to concentrate on hard study and work and forget about publicity stunts, the Board of Ordnance was forced to start initial work on a small scale in a corner of Kummersdorf, an Army proving ground near Berlin.

At that time, four men formed the nucleus of an enterprise which later, in 1943, employed almost 17,000 men in Peenemuende alone: a 19-year old student, later Chief Engineer at Peenemuende, Wernher von Braun, now NASA's director of booster development at the Marshall Space Flight Center in Huntsville, Alabama; a young technician with some experience in liquid-fuel rocket powerplants and especially in the handling of liquid oxygen, later chief designer at Peenemuende, Walter Riedel, now in England; a highly skilled foreman, later chief of the experimental shop in Peenemuende, Heinrich Grunow; and myself, at that time Captain in the German Board of Ordnance and assistant in the ballistics branch.

The first rocket static test stand was built at this proving ground in the fall of 1932; it was a test stand for a maximum thrust of 3000 lbs. only. It was in this test stand that the first hot run with a 600 lb. combustion chamber was tried the day before Christmas 1932. This attempt ended in a big explosion, and it took three months to repair the facility.

How did it happen? We weren't so wise at that time as we are now. We tried to ignite the liquid propellants, oxygen and alcohol, gorging out of the nozzle by a torch on a long stick, held near the nozzle mouth. The fuel ignited all right, but the static test stand was completely destroyed.

It would be foolish to think that at that time the Germans had any definite idea about what would later evolve from their work. Yes, the initial, small group dreamed about long-range rockets and space ships. But they did not know and they did not care what would happen later. They just started with a power plant. From 1932 until 1945, they never received any specific written requirement of any kind for a weapon system from their military superiors or anybody else. Later on, this group had to make up their own minds how a military rocket should perform. I can assure you, if we had known at that time, what amount of work, what trouble, what desperation—but happiness too—was hidden in the lap of the future, we would have stopped our work immediately. We approached the rising problems with the courage of the innocent and the dumb. A step in any direction was a step on virgin soil. As we progressed we enjoyed our work more and more. Everyone became enthusiastic. There was no obstacle which we would not try to overcome. We learned to know the feelings of great inventors who see their dream finally take shape and come true.

In this connection, I would like to correct an error which you find in a number of stories about the V-2, namely that the V-2 was Hitler's devilish idea, designed to conquer the world. Up to 1943 Hitler had absolutely nothing to do with the rocket program. In September 1944, he named the first operational rocket: "Vengeance Weapon 2" (V-2). *We* called the rocket the A4. The A4 was the first weapon version of a long line of experimental rockets, which were developed by my division in the Army Board of Ordnance. Hitler never saw the A4 except in movies, nor had he ever been in Peenemuende. He simply was not interested. We could not understand it, because he was very much interested in the technical details of all other weapons. He had a phenomenal memory for all types of guns and for any kind of weapon; he knew their performance data, weight, and number better than any expert, but he was not interested in our work. My only explanation is that he put great store in his intuitions and dreams. Since he had dreamed that such a weapon would never be fired against England, he had made up his mind that it was unwise to put effort and money into such a project.

Besides struggling with the technical complexity of this weapon, we therefore, until 1943, had also to struggle against this dream of the Fuehrer. Not until July 1943, when we finally convinced him with facts, did he see any usefulness in our rockets, and then not as a weapon but as a war-preventive means. "Why didn't I believe in the success of your work?" Hitler asked me. "If we had had this weapon in 1939, we never would have had this war. Now and in the future, Europe and the world are too small for a war. With such weapons available war will become unbearable for the human race."

Some hours later, he told me, "I have to apologize only to two people in my life. One is Field Marshal von Brauchitsch. I did not listen to him when he pointed out over and over again the importance of your development. And the second is you. I did not believe in any success for your work."

Evolution of the V-2

Now, I would like to describe how the A4 concept was actually conceived. In the Board of Ordnance rocket development started in 1930, before Hitler came to power. At that time it was very difficult to obtain money and facilities. It was a constant struggle, and only through the support of General Becker, who allocated money from other divisions, could work continue. As this brainchild of Becker's grew rapidly, requiring more and more money, new ways to raise funds had to be found. Becker told me in January 1936, "If you want more money, you have to prove that your rocket is of military value."

Up to that time only a powerplant had been developed, and a small rocket in two versions had been assembled, the A1, which shortly afterwards was modified into the A2. The latter was a sounding rocket, which was first launched in December 1934 to an altitude of 1½ miles. A new project, the A3, was another experimental rocket which, it was hoped, would break the sonic barrier.

We knew from the beginning that if we really wanted to develop big operational rockets we would have to have our own research and development center; it must be large and self-sufficient, with all laboratories, wind tunnel, work shops, and test facilities at a remote spot, far away from any large city, near the seashore, so we could test-fire over the sea. By December 1935, we found such a place near Peenemuende, a very small fishing village on a large island in the Baltic Sea. Planning such a station, we had to fix the requirements for big test stands. Now we had to think about what we really wanted to put into operation. We proposed liquid-fuel propelled rockets for use as jato's (jet assisted take off rockets for aircraft), rocket powerplants for airplanes, and powerplants for heavy shells with short range, but the big rocket was only a somewhat hazy dream.

One day, in March 1936, I sat with von Braun and Riedel in our small office on the proving ground near Berlin, talking about the size of the planned test facilities at Peenemuende. After listening for an hour to their fumbling around, I planted my fist on the table and told them what I wanted and how this rocket should look.

I am an old long-range artillerist. And, the most famous gun until 1936 was the Parisian gun, dating from the end of the first World War. This gun fired 22 lbs. of explosives over a range of 78 miles, but it was too heavy in the firing position and was terribly inaccurate. This weight in the firing position, necessary for long-range guns, had to be eliminated by using a single-stage rocket to be launched vertically and to be programmed later on into an elevation angle of 45°. This rocket should carry 100 times the weight of the explosives in the shell of the Parisian gun and have a range twice that of the gun, or 156 miles. The accuracy of the rocket should be three tenths of one per cent of the range, compared with four to five per cent of conventional guns. This rocket should be small enough to be shipped in one piece on normal roads, even through small villages, without jamming traffic, or on one single railroad car, through all European railroad tunnels. Thus, the over-the-fins diameter of not more than nine feet and the overall length of not more than 42 feet was established. It was quickly calculated that a burn-out speed of 3,600 miles per hour could do the job. Finally, after years of jumping in all directions, a mission for a large rocket was found.

During the next few days, thrust, combustion time, and mass ratio were calculated. Much thought was given to the overall configuration, to guidance and control, and to structural problems. With these calculations and considerations, troubles began. There was no solution to all our problems. We had violated one of the fundamental laws of realistic engineering: "Don't project your thinking too far into the future." What was needed was 55,000 lbs. thrust for 65 seconds, and the biggest combustion chamber at that time had a thrust of only 3,300 lbs. A kind of radio control had to be developed which would allow cutting off the thrust at the right moment with an accuracy of 1/1000th of the velocity. We did not know at that time what an accelerometer looked like nor did we have the faintest idea about an integrating accelerometer. There were thousands of major problems for which there was no answer at that time.

In addition, I should like to mention one more problem for whose solution we had to break through conventional scientific thinking. At that time it was allegedly a proved fact that an aerodynamically-controlled body could not fly stably at supersonic speed, yet a Mach 4.5 fin-stabilized body was anticipated. [Mach number, after Austrian Ernst Mach (1838-1916), expresses speed of a body with respect to the surrounding air relative to the speed of sound. Hence, Mach 4.5 is a speed four and one-half times the speed of sound (Ed.)].

The question may be asked: who is the actual inventor of the V-2? There is no single inventor who had a brilliant brainstorm leading to the V-2. Invention and development of modern, complicated machines such as guided missiles, which comprise in their design and performance all branches of science and technology, bring into being a new type of collective inventor, the team. Modern invention is hard, scientific, and technical work by a whole group of intelligent, dedicated people. It is a matter of progressing step by step, examining the testing in different institutes and facilities, weighing the feasible against the hoped-for in many proposals. Last, but not least, it is the successful perseverance of all workers, of their unshakable faith, of sufficient means, of luck, and of one single, hard will to fulfill the task.

There were at least a dozen outstanding people working at that time in Peenemuende, each an expert in his special field. Without a single one of them, modern rocketry would certainly have been delayed for decades. Therefore, if an inventor has to be named, I should call him: The Peenemuende Team.

Rocket propulsion is not an invention of modern times. It can be found in nature. Human beings used this type of propulsion for hundreds of years. When Sir Isaac Newton fixed his third law of motion, propulsion by reaction had been theoretically proved as one of the few possible drives for space craft. The basic principles were well known for centuries, but the time was not yet ripe to start the development of big rockets until the three fundamentals, as I mentioned before, were available. So, all over the world, between 1900 and 1920, rocketry was revived, this time on a big scale.

Professor Goddard was one of the first who realized the new possibilities. There were others, in different countries, even in Germany. Naturally, the German Board of Ordnance studied all available literature. But what was available? A few books, some articles in trade papers, and much wishful thinking. Technical facts and data could not be found. Almost 90 per cent of Goddard's patents were, we later learned, not available, and the Germans never saw them. This is particularly true regarding the use of jet rudders, film cooling, stabilization, and control.

It is my view that any group of interested and skilled people, no matter from what country in the world, which had to handle the same problems that we had to handle in Germany, under the same conditions, and which had to solve the pending task by conscientious, hard labor, necessarily would have come to the same solutions.

We had transferred our activities from this small proving ground near Berlin to Peenemuende on the Baltic Sea. In August 1936 we broke the ground and in May 1937 we moved in with approximately 300 men. Peenemuende was a self-sufficient research and development center for rockets. It remained such a center until January 1945, when its personnel and mobile facilities were transferred to Thuringia. It was a research and development center in the good and bad sense of the word. The V-2 was never mass-produced in Peenemuende, only the first blocks of experimental rockets were manufactured. All in all, only 250 V-2's were built in Peenemuende.

During the preparations for mass-production, it was not easy to stop scientists from thinking and creative engineers from inventing, otherwise they would not be scientists and creative engineers. They always had new ideas and they felt production should wait until they were ready. A lot of technical knowledge, common sense, and experience must be expected from the chief of such an organization to guide these people, to determine the correct moment to freeze development, and to start production. This transition period, from development to mass-production, was by far the most trying in the entire program. There were no qualified people available for that, and the job had to be accomplished with people not qualified for this task. In fact, we had to release about 60,000 design changes from the moment we thought we were ready to freeze the design for mass production until the end of the war.[3]

Peenemuende

Peenemuende was set up in two main parts. In one part the Air Force established a large airfield and test facilities for the V-1, the glide bombs, jato's, Me-163, Me-263, and later for air-to-air and ground-ground remote controlled anti-aircraft guided missiles. The other part, by far the bigger one, was for the Army. Three hundred million marks were spent altogether by the Army to establish and operate these facilities. At its peak, the Army Experimental Station occupied an area of approximately 18 square miles and employed about 17,000 engineers and workers. The most significant factor in the successful development of the rockets proved to be that the research institutes, the engineering departments, the static test facilities, the oxygen generating plants, the work shops, and the launching sites were all at the same location and under one management. No time losses could occur.

Peenemuende, although a military installation, was set up like a private enterprise. And even with 4000 soldiers with engineering background, Peenemuende was organized like a private factory. The chiefs of all departments, divisions, and branches were civilians. With the exception of some accounting and administrative military personnel for the base, the only military office was that of the Military Commander, who was at the same time military and technical chief.

Why were those 4000 soldiers at the Research and Development Center? The reason was lack of support of the rocket program by the Armament Ministry and by Hitler himself. During the war, both were responsible for manpower and raw material distribution. Although the experimental station in Peenemuende was fully supported by our military chiefs right up to the Chief of the Army High Command, we could get no personnel and no materiel from the high offices of the Reich. In November 1939, Hitler dropped Peenemuende from the priority list. To continue work, I asked the Chief of the German Army High Command to release from his front-line troops several thousand soldiers with engineering background on whom the authorities of the Reich could not lay their hands. I got them.

Within the factory these soldiers were civilians and received the same pay as civilian employees. Outside the plant they were front-line

[3] Wernher von Braun, "Survey of Development of Liquid Rockets in Germany and Their Future Prospects," *Journal of the British Interplanetary Society* (March 1951), pp. 78-80.

troops on temporary duty inside Germany. These soldiers became the backbone of Peenemuende, and later on, when the A4 troop formations were established, they were the skilled nucleus of these troops, trained during long years at Peenemuende. By July 1943, when Hitler finally acknowledged Peenemuende, enough manpower was allocated to finish the development and to start mass production.

An article in *Fortune Magazine* about the RAND Corporation, stated that Hitler, by looking into his crystal ball and supporting the V-2 program, had essentially contributed to the defeat of Germany.[4] Had Germany put the same amount of effort into the manufacture of airplanes as it did into the V-2 program in order to achieve air supremacy in Europe, the article stated, the outcome of the war would have been different. Such a statement is very debatable and may lead to false conclusions. The historical facts are these:

(1) Hitler did not support Peenemuende at all, not until it was too late (July 1943). American aircraft production at that time could never have been rivaled by Germany's aircraft production. It was only a question of time before the Allies would have air supremacy over Europe and Africa.

(2) Up until the end of the war it was not aircraft production that caused the Germans trouble. Underground factories in aircraft production ran full blast up to the final days. What was lacking was fuel, not airplanes. Germany could not protect the oil fields under its control nor the factories producing synthetic gasoline. They were destroyed by bombing from the air. Lack of foresight about the effectiveness of subsonic and supersonic anti-aircraft missiles and high-speed interceptors kept the development of these defensive weapons back for at least two to three years. Then it was too late. From 1938 until 1942 such weapons were proposed by the Army Experimental Station; even in 1942, when such a proposal was again presented, the Air Ministry replied that air defense would be handled by German fighters and anti-aircraft guns.[5]

(3) The V-2 was developed as an artillery weapon with high accuracy to surpass the range of long-range guns. In 1940 and 1941, when a German bomber could not fly over England more than three times before being shot down, the question of whether such a weapon as the V-2 could take over some tasks of the bombers became urgent. The advantage of a big long-range rocket, costing only about $38,000, became evident when com-

[4] *Fortune Magazine* (August/September 1946).

[5] Sir Philip Joubert, *Rocket* (New York, 1958).

pared with the $1,250,000 cost of a bomber, not to mention the loss of its crew.[6]

(4) What would have happened if, starting in 1942, the Germans had fired such long-range rockets against England in increasing number, with greater range and accuracy; or if the German High Command had followed our advice to develop and mass-produce anti-aircraft guided missiles in sufficient quantities so that they could go into action in 1942? It can be assumed that the outcome of the war would have been quite different; at least, there would not have been the devastating bombing of German cities, industries, and the synthetic gasoline generating plants. Germany would have kept air supremacy over Europe not with fighters and bombers but with anti-aircraft guided missiles and long-range missiles. Under their protection a new, powerful bomber fleet could have been built up in order to carry the war over enemy territory.

Until the late fall of 1939, it was expected that the big rocket could be developed without the help of universities and industry. After war broke out, time became all important. Many universities and institutes, which were threatened with closure, and industries were given a list of some hundred specific problems requiring urgent solutions. The response was overwhelming, and through the resulting cooperation large strides were made. By June 1942, the first rocket was launched, although it proved to be a flop. By October 3, 1942, with the third missile on the launcher, all records in range, altitude, and speed had been broken. The feasibility of big liquid propelled rockets had been proved.

However, even after this success, not everything went well. We went from success to failure and back again. In July 1943 we had four explosions in a row on the launching pad. We learned the hard way that such an automatic weapon is as good, bad, or even worse than its smallest, most insignificant component part. Even the tiniest failure of a part resulted in total loss of the missile. And most of the time we had no idea what caused the failure. Telemetering equipment was not available before the end of 1943, and then only for a few important check points. Therefore, we had to rely on long and thorough testing of all component parts and of the completely assembled missile under simulated flight conditions. It was also learned that reliability, based on simplicity and foolproofness, should be the first and principal law in the development of these new weapons.

[6] Rudolf Lusar, *Die deutschen Waffen und Geheimwaffen des 2. Weltkrieges und ihre Weiterentwicklung* (Munich, 1962), p. 157; David A. Anderton, *Aviation Week* (September 24, 1957), p. 130.

Air Attacks on Peenemuende

Development was in its final phase, and the underground facilities for mass-production at Nordhausen in Thuringia were almost ready for operation, when the famous British air attack on Peenemuende occurred in the night of August 17-18, 1943. We knew it could be expected and we were prepared as best we could.

In the spring of 1943, the British Government received for the first time factual intelligence reports that rockets were being developed in Peenemuende.[7] The characteristic vapor trail in the air during the launchings could not be avoided and could be seen from Sweden. In addition, German propaganda boasted too much about all the coming wonder weapons. The Royal Air Force photographed the entire German Baltic seashore from Denmark to Poland, and in spite of all camouflage, the type of activity at Peenemuende was revealed by these pictures.

After two months training, about 600 British bombers began their attack on Peenemuende during a full moon. By radar they found the location, which was covered by thick, artificial fog. In one hour they dropped more than three million pounds of explosives and an enormous quantity of incendiary bombs. Only 47 bombers were shot down. The day before, the heavy anti-aircraft defense of Peenemuende had been withdrawn by an order from Hitler. Peenemuende lost 735 lives that night, 210 Germans, mostly women, girls, and children, and more than 500 foreign construction workers in a big camp between Peenemuende and Zinnowitz, the next town on the shore. At first the damage looked extensive, but soon it was discovered that the vital buildings—the electronic division, wind tunnel, oxygen generating plants, the 12 big static test stands, and big work shops for the test series—were not hit at all. Only wooden barracks and replaceable buildings in the plant were destroyed. The living quarters of our workers and employees were wiped out. But after four weeks of clean-up work, Peenemuende worked full-time again. Most of the vital equipment and production drawings had been moved to other places in the neighborhood before the attack.

The air attacks on Peenemuende continued with four day-time raids by the United States Air Force during 1944. They consisted mostly of pin-point attacks on unfinished static test facilities. No vital damage and no casualties were incurred. The completion of the work to be done on the long-range rocket could not be prevented, nor could

[7] Terence Robertson, "The War Against Von Braun," *MacLean's* (Canada, March 1962), pp. 17-21; cf. Thomas F. Dixon, "Solving the V-2 Mystery in 1944," *Airpower Historian*, Vol. X (April 1963), pp. 46-49.

the later incessant bombing of the launching sites at the front delay its entry into action. In the case of the V-2 offensive, the bombing neither delayed it nor reduced it to any extent.[8] However, it was decided to be careful, and during the following months no rockets were launched from Peenemuende at all. The impression of complete annihilation was created. By order from Headquarters, experimental firing was moved to Poland, where the rockets were fired over ground.

After the first successful launchings of a radio-guided ballistic missile in 1937, we had started looking seriously into the future. Up to that time it had not been proved that a ballistic rocket, built more or less according to well known design principles, could operate in space. For many years from that date, the advanced planning and preliminary design departments were busy with drafts and first lay-outs for intercontinental missiles (the A9/A10), winged missiles to increase the range (A4B), and bigger load-carrying rockets for the establishment of space stations, circling the globe. It was a difficult decision for me to stop this future planning in the fall of 1943, after the attack on Peenemuende. It was found out, by firing over land, how many problems still had to be solved before the V-2 could become operational.

Until the attack, we had fired only over water, along the shore where the tracking stations were established. The colored spots in the gray Baltic Sea, originating from dye-bags carried with the missile, were regarded as the presumable impact point of the complete missile.

Test and Actual Firings

Now came the usual set-backs as the first production series were tested and experimental firings increased. Up to ten missiles a day were fired from three launching tables for training purposes and also to put the finishing touches to the missile. Ten per cent of these stopped short after launch, the thrust failed, and the missile dropped back on the launching site, causing much damage. Twenty per cent exploded in the ascending branch of the trajectory, and forty per cent exploded two to three miles above the ground after travelling over the entire course without any trouble. For a long time, no reason could be found for these failures. From the small amount of telemetering data available at that time, we could determine only what happened after the primary failure had occurred.

Finally, after many test firings, the reasons were found. Though minor, they had big consequences. First, a dropping relay caused by resonance vibrations; second, a loosening of fittings in the propellant

[8] Sir Norman H. Bottomley, *Flight* (London, February 25, 1948), p. 226.

pipe lines, also caused by vibration and a weak spot in the design and structure of the outer skin at the ogival forward section. When the missile re-entered the atmosphere, some fluttering of the skin, already weakened by air friction heat, which increased the temperature to approximately 600° centigrade, occurred. The skin burst, air rushed in, and the missile blew apart. However, this was found out only in the last months of the war. A rivetted cuff around this section improved the situation noticeably.

But before these problems were solved, the rocket was already deployed. On September 6, 1944, the first rocket was launched against a military camp near Paris. Two days later, the first V-2's were fired against London and targets in the southern part of England. Altogether, 3,745 of these flying laboratories were successfully launched between September 6, 1944 and March 27, 1945. Some 1,115 fell on England, 2,050 on targets on the Continent. For development, improvement, and training of the troops 580 rockets were used. Of all launched rockets, 74 per cent went within a target circle of 18 miles, from these 44 per cent within a six mile circle. In November, December, and January, an average of 140 missiles a week were launched. Twenty-five percent of all missiles were beam-riders during the powered part of the trajectory, resulting in a lateral dispersion in the impact area of only ± one mile.

During the deployment at the front, the losses in the firing positions by enemy action were nil. Some casualties occurred among the supply formations. Never was a single rocket intercepted by enemy action, nor did we discover any radio counter-measures. It may be that the well-known erroneous shot to Sweden in June 1944 led British intelligence in the wrong direction. That time an A4 was used as a carrier for the radio guidance equipment for the supersonic anti-aircraft rocket "Wasserfall." This missile went out of control and dropped on Swedish soil, thus prematurely revealing this secret weapon.[9]

The lack of casualties on the launching sites may be explained by the rocket's mobility. The missile could be launched from unprepared, hidden firing positions, out of a forest, out of a burned-out barn, or from side roads. The firing position could be changed after each shot. But it was not necessary. One beam-rider regiment stood in one firing position near Zwolle in Holland for four months without ever being attacked.

Besides technical trouble, there were plenty of other worries. The Peenemuende group were considered utopians and fantasts, even among

[9] See Dixon, *loc. cit.*

the upper echelon of the Reich. But from the moment success was evident, their product was no longer considered the work of some crazy Army people, but the deed of the German intellect and belonged to the German people. Then the Ministry of Ammunition wanted to take over, big industrial concerns wanted the lead, party organizations and the SS claimed the rocket for their own personal benefits, or at least wanted to share in the rewards. This struggle worried us for years after the first successful launchings. Partly we lost, partly we won. But this situation was far from being helpful.

Hopes and Failures

It must be explained, also, why the V-2 failed to become what official German propaganda hoped and the Allies feared.

(1) This new rocket, from a military viewpoint, was intended as an important addition to the already available military arsenal to increase the range of the artillery and to provide some advantages which could never be obtained by heavy guns.

(2) This new weapon, with its 1,650 lbs. payload of explosives could only have the effect of a normal bomb of the same size. The German Board of Ordnance was completely aware of that. It was never intended to develop this weapon with an annihilating effect; there was no nuclear warhead development in Germany. The pretense of the German propaganda machine that the outcome of the war could be changed fundamentally by these so-called wonder weapons, accepted so readily by the Allies, put the German Board of Ordnance in a very difficult position. It also aroused hopes in Germany which the creators of this modern rocket never intended. Anybody trained in weapon technology could see that this weapon was a new and outstanding weapon, as were so many others during the last war, and only a useful combination of all of them could turn events decisively.

(3) The deployment of this weapon occurred at least two years too late. The war in 1944 could not have been won by firing 900 V-2's per month as planned, on mainly two targets, not even with the combination of all so-called "vengeance weapons." Lack of foresight and knowledge of U. S. potentialities in aircraft production prevented the German leadership from giving early and sufficient support to this program in order to help win the war in Western Europe before the masses of the American Air Force could go into action. General Eisenhower wrote in his memoirs, *Crusade in Europe*, if the V-2 weapon would have gone into action six months earlier, the landing in Normandy would have been almost impossible.[10]

[10] Dwight D. Eisenhower, *Crusade in Europe* (Garden City, N. Y., 1952), p. 294.

(4) The weapon was not fully developed when it was forced into action by a decision of Hitler:

(a) The high drift rate of the gyro axis, which could not be improved further at that point of the war, did not allow an accuracy of three tenths, of one per cent of the range, as had been specified in 1936. However, the dispersion of the A4 was much better than that of any other weapon built up to 1945, considering the range.

(b) The airbursts, which we still had when the A4 went into action, did not allow the use of highly sensitive fuses which could detonate the missile on the first slight contact with the ground. Instead, we had to use a very insensitive fuse which withstood the stresses of a possible airburst. Therefore, the result was mostly a big hole in the ground.

(c) The development of a proximity fuse, which could detonate the rocket 30 to 60 feet above ground, could never be completed in Germany so that it could be mass-produced.

Nevertheless, a new weapon system was used for the first time in history. In spite of its imperfection, this will always remain one of the outstanding technical achievements of modern times. By wrong timing and lack of support it came too late to play a decisive military role in the last war.

In Retrospect

When we forget for a moment what was expected from this technological newcomer in the weapon field on both sides, then this new weapon was the first operational sample of a new generation of weapon systems—ballistic long-range rockets—which, in their achieved perfection decades later, are bound to determine the future of mankind.

It is self-evident that in technical pursuits, the first idea put into practice can never be perfect—and can never mean the end of the work. Mistakes are made, difficulties are not completely overcome. Complicated early solutions are not replaced by simple and reliable ones. And above all, the new device does not make the impression of a perfect, rounded-off, and finished product. Criticism from hindsight comes easy at this stage. However, the first application of a big rocket power plant in a supersonic carrier, flying through free space, is now recognized in its pace-setting importance to the history of rocket technology.

Those looking at the V-2 rocket only as a weapon system should not forget that rocket propulsion proved for the first time its possible application for future space flight. For this future—the utilization of space for mankind—the Peenemuende crew worked as well. In March 1944, the director of engineering of Peenemuende, Professor von Braun, and two of his leading men were put in jail by the German Gestapo because they had thought and talked too much about space travel and not about the rocket as a weapon. Therefore, they allegedly committed sabotage. It was not easy to get them freed. They were released only by explaining to Hitler that everyone working on the big rocket was indispensable to the V-2 program and had become a space fanatic who looked at the V-2 only as a first step into the future of space travel.