Germany's Rocket Development in World War II

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Many important technological innovations came about during World War II as a consequence of each side trying to gain an advantage over the other. Examples of this include radar, sonar, the atomic bomb, and ballistic missiles. These missiles in the form of *the German V2* were first deployed on September 7, 1944. This paper will explain the events that led up to the deployment of this new weapon system. This paper will be largely a literature review as my research has relied primarily on Michael Neufeld's *The Rocket and the Reich*; it covers in detail many aspects of my research. In my assessment, rockets were originally conceived as a replacement for, and improvement on, long-range artillery. Their proponents hoped that the sudden deployment of these rockets could so demoralize the enemy as to bring about a quick victory. In the end, however, the V2s were much too inefficient a weapon to have any appreciable impact on the war.

During the few good years of the late 1920s, the Weimar Republic was in the midst of a spaceflight obsession. This fascination is described by Michael Neufeld in *The Rocket and the Reich*. In 1929, a movie about a voyage to the moon, *Frau im Mond* (The Woman in the Moon), was playing in Berlin. Newspapers were announcing the imminent launch of a high-altitude rocket that was planned as a publicity stunt for the movie. In the preceding years, various somewhat bizarre and dangerous demonstrations with black powder rockets attached to bicycles, automobiles, and even a railroad car were performed. Particularly headline grabbing were racecar stunts performed by the heir to the Opel car company fortune, Fritz von Opel. The catalyst for this fad had been the publication, in 1923, of the book *Die Rakete zu den Planetenräumen* (The Rocket into Interplanetary Space) by Hermann Oberth, a German living in Transylvania. In this book, Oberth had described various methods for achieving manned spaceflight. Of particular significance was his mathematical demonstration that a liquid fuel rocket using liquid oxygen and alcohol would be much more powerful than the conventional black powder rockets. Only after this work was discovered by Max Valier, an Austrian writer and supposed astronomer, did it receive any widespread attention. Valier began what can only be described as an aggressive public relations tour. He wrote numerous articles and delivered speeches in which he touted the ideas of Oberth. It should be noted that Oberth's ideas were not unique to him. The American Robert Goddard and the Russian Konstantin Tsiolkovsky had also come to many of the same conclusions. However, their work was hard to get access to; either being hidden in obscure publications or else written in rather ambiguous fashion. Unbeknownst to most people at the time, Goddard had successfully launched a liquid fueled rocket in 1926. By the late 1920s, space travel had ceased to be a crazy idea on the fringes of society. The rigorous theoretical work of Oberth together with the boisterous attention grabbing of Valier had made the concept acceptable to the German public.[1] All of the speculation and excitement about rocketry did not remain merely a phenomenon of popular culture.

Lieutenant Colonel Karl Becker of the German Army Ordnance Office had taken an interest in rockets. In particular, he was interested in the possibility of using solid fuel rockets as a delivery method for chemical weapons on the battlefield.[2] It is interesting to note that this idea had actually been discussed by Oberth in the 1929 version of his book. However, his delivery system consisted of a large intercontinental ballistic missile powered by liquid fuel. For his part, he felt that it would be impractical, because of the difficulty of targeting the missiles, for at least two decades.[3] There is some debate among historians as to whether the omission of rockets in the Versailles Treaty made the German army particularly interested in their use as weapons. Walter Dornberger, the head of the rocket development group from its inception, makes this argument in his article *The German V2*.[4] Neufeld argues that this was of secondary importance to the Treaty's prohibition on heavy artillery. He points to Becker's idea of using rockets in chemical warfare, which was prohibited by the Versailles treaty, as evidence that legality was not particularly important to him. In addition, he notes that the German army was conducting secret research into all sorts of banned weapons in Germany and other countries like the Soviet Union. It was thought that sufficiently powerful rockets could replace long-range and short-range artillery.[5]

According to Neufeld, Becker received permission to start a small research project into solid fuel rockets in late 1929. Many of his assistants on the project came out of a program for training officers in engineering that Becker had founded. He had established the program in response to what he felt was an anti-technology spirit in the German Imperial Army Officer Corps. The new leadership of the Army after World War I helped make this program possible. Becker had received his doctorate from the applied physics institute at the Technical University of Berlin. This institute had formerly been the artillery laboratory of the Prussian army, but had metamorphosed to remain legal under the Versailles Treaty. The institute basically functioned as a master's degree program in mechanical engineering, not surprisingly with a focus on artillery. Three products of this program; Walter Dornberger, Leo Zanssen, and Erich Schneider, were important figures in the beginning of this research.[6] The eventual outcome of this solid rocket research was the introduction of the so-called *Nebelwerfer*. It was basically a system that launched multiple rockets to bombard an area, similar to the Russian Katyusha. It would appear that the name *Nebelwerfer* (fog thrower) was intended to disguise the true nature of the weapon to circumvent

Versailles' restrictions.

While the army was conducting early research into solid fuel rockets, amateur rocket groups were doing their own research into the liquid fueled variety. Neufeld describes their activities. Oberth and Valier had attempted quite early to find a source of funding for research to convert the theoretical knowledge into practical use. They expected to be able to find a corporation or a wealthy benefactor who would be interested in furthering spaceflight. Neufeld argues that these men had the romantic image of the independent inventors of the late nineteenth and early twentieth century in mind. They really had not comprehended the enormous costs that came with research into such revolutionary technology. The author makes an important observation that only a government-backed military industrial complex has the resources to finance such an undertaking. Despite these miscalculations, however, amateur groups did play a role in early developments.[7]

In the early 1930s, the most noteworthy of these groups was the *Raketenflugplatz* (rocket launch site) *Berlin*, whose origins lie with the rocket launch planned to coincide with the premier of *Frau im Mond*. Oberth, who was acting as science advisor for the film, came up with the idea which was to be financed by the movie studio. In attempting to make up for his lack of engineering experience, Oberth joined up with Rudolph Nebel. Neufeld describes Nebel as a con artist rather than a proper engineer. The effort was a failure, which ended with Oberth returning home to Romania after a nervous breakdown. Nebel, together with the remaining members of another group, the *Verein für Raumschiffahrt* (Society for Space Travel), decided to start a group for liquid fueled rocketry as a way to continue Oberth's work. The starting materials were, in fact, the parts for the rocket that never flew. Nebel managed to secure workshop space and potential certification for the rocket from the Reich Institution for Chemical Technology. The Army Ordnance Office also provided the equivalent of $1, 200 for the rocket launch; a precursor of their future role. Oberth returned from Romania and the group succeeded in launching a small, 7 kg thrust rocket. After the successful launch on July 23, 1930, Nebel received permission from the Defense Ministry to use an ammunition dump to conduct further tests. The *Raketenflugplatz* officially opened on September 27, 1930. Karl Becker's office had actually helped to arrange a three-year lease on the location. However, this relationship with the Army Ordnance Office only lasted for about six months.[8] They could not tolerate Nebel's ceaseless fundraising attempts which consisted of writing what were described as "sensationalistic articles in newspapers and magazines." because this publicity conflicted with their desire for secrecy.[9] The *Raketenflugplatz* successfully launched many other rockets and even demonstrated a 50 kg thrust rocket engine.[10] While these developments were under way, the Army Ordnance Office had themselves begun more serious research into liquid fuel rockets.

Becker and others had, by this point, developed a longer term plan for liquid fueled rockets. According to Walter Dornberger the idea was to improve upon the Paris Gun. This extremely large artillery piece was the pinnacle of artillery technology. It was capable of launching an approximately 100 kg shell roughly 80 miles.[11] However, it was very inaccurate and was extremely hard to maneuver due to its immense weight.[12] Neufeld adds that this gun only launched 320 shells before its specially built barrels wore out. Rockets would be better because they did not require barrels and all the other support equipment. Becker, as Neufeld relates, hoped that the surprise deployment of these weapons could potentially lead to a collapse of enemy morale and, consequently, a quick victory. The fact that the planned rockets would be more powerful and based on a previously unseen technology would increase that shock value. However, they would have to be developed in absolute secrecy.[13]

The Army Ordnance Office had left liquid fueled rocketry on the back burner after their short-lived relationship with the *Raketenflugplatz*. On October 16, 1931, Karl Becker wrote to the Heylandt Company inquiring about their liquid fuel rocket motors. These rockets had come into existence from experiments by Max Valier who attached liquid fuel rockets to race cars. Valier had actually died in one of these failed experiments. Despite this deadly accident, Arthur Rudolph, the future chief engineer of the factory at the Peenemünde research facility, continued these experiments despite the wishes of his superiors. They eventually produced a rocket with 160 kg of thrust. Instead of purchasing this rocket car combination for research by the Ordnance Department, as he originally intended, he decided on a study contract with the company to figure out the proper shape for a rocket exhaust nozzle. For the first time, the Army Ordnance Office had begun systematic research. The study, completed in April 1932, showed that the current shape of the nozzle, based on the assumption that long and narrow was best, was inefficient. A second contract was agreed upon in October, 1932, for the construction of a 20 kg rocket fueled by liquid oxygen and alcohol.[14] Despite these new approaches to research, the Army Ordnance Office had not given up on amateur groups.

On April 23, 1932, Karl Becker wrote to Nebel with an offer. Nebel would receive 1,397 marks if he could successfully launch a rocket that would deploy a parachute and a flare at the height of its flight. The test was to take place in secret at the Army Ordnance testing ground at Kummersdorf near Berlin. This testing ground had only recently come into existence. Nebel began to make claims far in excess of what had been requested. However, by the time of the test on June 22, these estimates had been cut in half. The attempt was a failure; the rocket managed to take off but quickly turned to flying horizontally and subsequently crashed less than a mile away. The Army observers were not impressed. The report on the launch states that further work with Nebel is impossible because he makes promises despite knowing

better. Nebel's attempts to convince the Army Ordnance Office that the test was not a failure were fruitless.[15] This would be the final time the Army would attempt to work with him. However, the failure of this test had a positive outcome for the Army's rocket research. It was at around this time that members of the *Raketenflugplatz* began to work in the Army's research program.

Arguably the most famous of the German rocket scientists, Wernher von Braun, visited with Karl Becker shortly after the failed test. Von Braun would go on to become technical director of the rocket research effort. During this visit, Becker offered von Braun the opportunity to continue research for the Army, albeit in secrecy. This offer sparked intense debate among the members of the *Raketenflugplatz*. Some didn't want to do it because it conflicted with their idealistic view of spaceflight. Others, like Nebel, didn't like the idea of having to do research in secrecy. In contrast, von Braun did not have any of these qualms. Michael Neufeld argues that this willingness was due to his conservative, aristocratic upbringing. Because of this upbringing, von Braun had no problems with working inside the military. For him, military funding was a necessary step on the road to space travel. Von Braun became a doctoral student under a physicist who ran a program in the Ordnance Office; his doctoral thesis was on liquid fueled rocketry. At the same time, on December 1, 1932 he began working at the Kummersdorf weapons range.[16]

When the Nazis came to power in January 1933, the situation began to change for the rocket program. Their budget was able to steadily increase with the government's renewed focus on armaments. This budget inflation only intensified when Germany's rearmament became public in 1935. Because they were the development branch of the largest armed service, the budget of Army Ordnance increased rapidly. However, this new environment also came with new pressure. In order to have a new, large share of the military budget, they were going to have to prove that the rocket was militarily useful. But, doing so did not come without consequences. A meeting intended to get this point across was met with great enthusiasm. Some officers wanted to immediately weaponize the rockets that the Army had developed. The leaders of Army Ordnance did not like the idea. Their plan was to develop a large ballistic missile for sudden deployment; unleashing the technology too early would diminish its shock value. Von Braun was able to convince the others that the rockets were not quite ready for military use. Army Ordnance continued with its development and received a budget of a half-million marks to expand their weapons range at Kummersdorf. Even this expanded weapons range would be inadequate, because of ideas for joint projects with the Luftwaffe.[17] The prime motivation was to combine rocket engines and aircraft. People in the German aircraft community knew that propeller aircraft were reaching their theoretical limits. It was also predicted that contemporary anti-aircraft artillery and aircraft would be unable to defend against high altitude, high speed bombers which necessitated a high-speed interceptor. At the time, rockets were the only technology capable of powering such an interceptor.[18] Various agreements were made for the Luftwaffe and the Army to participate in these developments. This partnership led to the idea of a joint "experimental research establishment".[19] In early January 1936, it was decided how the center would be structured. On April 1, the center received approval and the land was purchased the next day. The selected site near the small community of Peenemünde on an island on the Baltic coast had been suggested by von Braun's mother.[20] Von Braun, at age 25, became the head of the Army's part of the site when it opened in May 1937. Most of the operations were moved to the new location within a year.[21]

When World War II began, things once again changed for the rocket program. They now came up against shortages of vital materials and labor. These shortages were compounded by a confusingly organized war economy that led to conflict between various branches over all sorts of issues. The result of this disorganization was that Hitler himself had to get involved to sort out questions of priority. One consequence of Hitler's involvement was that Army Ordnance started to promise that the missiles would be mass-produced very soon and help affect the outcome of the war.[22] In the attempt to bring these ideas to fruition, planning began for the construction of a production facility for ballistic missiles. Dornberger had already had the idea of a production facility at the end of 1937. Von Braun and other engineers tried to talk him out of it because the technology was not yet ready for mass production. The rocket he wanted to build, the A4, barely even existed on paper. Only in late 1938, after the successful launch of unguided A5s, did the Army Commander-In-Chief Walther von Brauchitsch authorize the purchase of land to expand Peenemünde because it was "particularly urgent for national defense."[23] The A5 itself was a variant of the rocket designed to test guidance systems.[24] But, building the facility in Peenemünde came with all sorts of problems. Its location on a sandy island meant that aboveground bunkers, which were more expensive, would have to be built. The sandy soil coupled with the fact that saltwater seeped into the freshwater would make water and sewage systems problematic. All these problems were compounded by the remote location of the island.[25] Dornberger would run into more serious problems than this less than ideal location. Getting the needed resources, both in terms of labor and material, meant getting involved in Nazi bureaucracy.

Before discussing how Nazi bureaucracy affected the rocket program specifically, a more general description of Nazi bureaucracy is necessary. Michael Neufeld characterizes Nazi bureaucracy very eloquently, calling it a "collection of warring bureaucratic empires".[26] For starters, there was no clear protocol for establishing priority of projects. There were numerous people who

were in some way responsible for the economy, but few were actually effective. Hermann Göring was the head of the four-year plan, supposedly responsible for the whole German economy. However, as head of the Luftwaffe he didn't really have the time or the expertise to fulfill that responsibility. The actual economics minister, Walther Funk, who was responsible for the civilian economy, was himself beholden to Göring. The man officially in charge of military production and priority questions was General Georg Thomas, head of the Economics Office of the Armed Forces High Command (OKW). To this long list of personalities should be added General Wilhelm Keitel, head of the OKW. The closest thing to a priority list was a document signed by Göring which gave construction projects for the Navy's U-boats, the Army's rocket program, and the Luftwaffe's airplane production top priority.[27] More important, for a short while at least, was rationing of coal and steel resources. Only on July 18, 1940, did Göring attempt to create a better system. The system was essentially a combination of the rationing and his construction list. At first, there were two priority levels, I and II. A month later the top level was split into two, 1A and 1B. On August 20, Hitler personally added a "special level S" for projects related to Operation Sealion. Early 41 saw the birth of a fifth priority level "special level SS", no relation to the organization. By February, all levels below the special levels were eliminated. So, after six months of constant reorganization, the priority level system had come to exactly where it started with only two tiers. Neufeld sums up this evolution of priority levels as "priority inflation". The various branches attempted to crowd their projects into the highest priority until they were not enough resources to go around. This political maneuvering created absolute chaos. Because the OKW did not have the ability to rein in the various branches and Hitler didn't want to make tough decisions, new priority levels were simply created. But, that never solved the problem for very long.[28]

This changing priority system profoundly influenced the rocket project. When the new priority system was established in July 1940, the Peenemünde project was not even mentioned. Only after two weeks was it again at the top priority. After two months of changing priority lists, the program found itself in the third tier. Dornberger was able to have it moved up one level in two weeks. In February 1941, when the priority level system had stabilized, the development side of the program was put in first place, the production plant in second place.[29]

On top of the chaos of these priority levels, the war economy was also subjected to Hitler's strategic whims. Both he and Göring seemed to think the economy could be reoriented as quickly as their military plans. In 1939, Hitler gave priority to the Navy's "Plan Z" for a large battle fleet against the British.[30] During the Battle of Britain, emphasis was given to the Luftwaffe. Long before that was even over, emphasis went to the Army and Panzer divisions for the Russian campaign.[31] Very shortly before Operation Barbarossa, Hitler, brimming with confidence of an early victory, again shifted emphasis to the Luftwaffe and Navy for use against the British.[32]

Adding to all this chaos was the frequently used tactic of referring to "Führer orders"; whether these orders were real or not was completely irrelevant. Officials would often concoct these orders based on a favorable comment made by Hitler.[33] Not surprisingly, no one dared to question the validity of Hitler's "orders".

The main effect of the chaotic bureaucracy on the missile program was in terms of acquiring the necessary resources. Dornberger responded to each new threat to the program with a mixture of warnings and promises. The first obstacle that had to be overcome was the tremendous expense for the development plant, 180 million marks. In return for this investment, the military was to receive 1,500 A4's per year. In an attempt to secure the funding and other resources, Dornberger tried to convince Hitler of the usefulness of the rockets. However, Hitler was not very impressed with what he saw during his visit to Kummersdorf in March, 1939; Hitler would never visit Peenemünde.[34] Neufeld repeats a comment by Albert Speer that Hitler only understood technology from World War I.[35] In *The German V2*, Dornberger writes that Hitler could remember tremendous details concerning weapons but he did not follow the rocket developments very well.[36] When the war broke out, the Army Commander-In-Chief Walther von Brauchitsch issued an order that the program should continue with all means. However, this protection came with strings attached. Production of the missiles was to start in late 1941 instead of 1943. This accelerated schedule meant that the program had to deal with unrealistic timelines in addition to all the other problems.[37] A more significant problem was that all programs were subject to steel quotas. The new deadline for production meant that the program needed more steel to build the factory. The Army Commander-In-Chief tried to give the program steel from his own supply in addition to what they were already getting. However, Keitel, head of the OKW, wanted to get Hitler's permission for this allocation which was denied. The presentation to Hitler by Dornberger on November 20 did not change this decision. Hitler would not agree to an early expansion of the program. Dornberger's response was to fervently argue for the production plant. Most importantly, he pointed out that, compared to his plan, production of missiles would be severely cut and delayed. If production was somehow still able to start in September 1941, they would only be able to produce roughly one thousand per year. He also tried to argue that there was an international missile race taking place that Germany should not lose. None of these arguments helped; in March they were informed that they would only receive 80% of their steel quotas for the next quarter.[38] In the midst of all this chaos, Karl Becker committed suicide on April 8, 1940 due to the stress.[39]

In late June 1941, a memo by Dornberger, written in response to a renewed attempt to curtail Army

construction, presented a new argument. Essentially, because there was no defense against the missile, it would be an effective psychological weapon against London and other cities. On August 20, 1941, in a meeting with Hitler organized by von Brauchitsch, Dornberger finally succeeded in getting the Führer's support for the rocket program. As a result of this, both the development and the production sides of the program were given top priority.[40] However, with Hitler's support, the program became a lucrative target for power-hungry officials. Difficulties arose when Speer's Armaments Ministry tried to rapidly begin production of the rockets. More ominously, the program became involved with Himmler's SS through the use of slave labor.

Michael Neufeld devotes more than a chapter to the issue of slave labor. The rocket program had always had problems getting a workforce. The original idea of having everything done at Peenemünde had been replaced with the facility assembling parts from other suppliers. This change meant that more unskilled workers could be used. By April 1943, about three thousand foreign workers were working at Peenemünde. Prior to this date, their use has been restricted due to the secrecy of the project. In 1943, the plan was to use Russian forced labor in production, which was in keeping with the general trend in German industry. In early April, it was suggested that Peenemünde should use concentration camp labor in production. Arthur Rudolph visited the Heinkel aircraft factory which was using such labor and wrote a memo saying how well the idea works. On June 2, a formal request for concentration camp labor was made and two weeks later the first inmates arrived at Peenemünde.[41] It should be noted that on July 7, Hitler actually ordered that no foreign workers should work on the missile project for secrecy reasons. It is quite interesting that this order was essentially ignored. It was expected that missile production would start at Peenemünde in August.[42] But, the war would change that plan and the whole missile program. On August 22, 1943, the British conducted a major air raid on Peenemunde.[43] In response, Himmler convinced Hitler that missile production should be moved to underground locations with an accompanying increase in the use of concentration camp labor. On August 26, a series of tunnels near the city of Nordhausen in Thuringia in central Germany were selected as the main production site for the A4s. These tunnels had originally been built for underground fuel and chemical weapons storage. The first concentration camp inmates arrived at the site, soon to be known as Mittelwerk, two days later. The first task of these prisoners was to blast the tunnels deeper into the mountain.[44] By November, there were about eight thousand prisoners living in the tunnels.[45] Within a year, the total population of the facility was 13,500.[46] In October, the Mittelwerk Company was finally given a contract to produce 12,000 missiles at 40,000 marks each for a total of 480 million marks. The conditions for the laborers were horrendous. Even the construction of rudimentary facilities typical of a concentration camp was delayed. The tunnels never got warmer than 69°F, the constant noise of blasting made sleep impossible, and there were no toilet facilities to speak of. As a result, there were epidemics of dysentery, tuberculosis, and pneumonia. Between December 1943 and March 1944 about 2,500 inmates died; between twenty to twenty five per day. Under these conditions, the first A4s were produced at the end of December, although they were all so poorly built as to be unusable.[47] In total, a bit fewer than six thousand missiles were built in Mittelwerk.[48]

3,200 A4's were launched between September 7, 1944, and March 27, 1945. Most of them were fired against Antwerp, and, to a lesser extent, London. After the missiles were deployed for the first time, they were given the name V2, which stands for vengeance weapon two, by the Nazi propaganda ministry. However, the missiles had an almost negligible impact on the war. Michael Neufeld very clearly demonstrates this fact by pointing out that more people died producing the weapons than were killed by them. Only five thousand people were actually killed by the weapon. More civilians were killed in individual raids on Dresden and Hamburg. Why did the missile not have the strategic effect hoped for? To begin with, the missiles were too inaccurate to hit any specific target.[49] The one metric ton warhead could therefore not be utilized efficiently. Compounding the inefficiency were the very insensitive proximity fuses. The low sensitivity was a compromise decision to deal with the tendency of the missiles to explode during descent; using such fuses would ensure that an explosion did not set off the warhead prematurity. However, this compromise meant that, exactly as Hitler had predicted, the missile "thr[e]w up a lot of dirt".[50] Even if the missiles could have been accurately targeted, the combined explosive power of all the warheads was less than a single air raid. In terms of the effect on the enemy psychology, the V1s were actually more effective because of the noise they made. They also diverted more military resources because they could actually be stopped.[51]

As my paper demonstrates, the technological developments that transformed rockets from small experiments to large military missiles obscure the fact that these weapons were not going to be able to affect the war. If missiles cannot hit a specific target, they are not cost effective. Poorly guided, conventionally armed ballistic missiles are ineffective, as has been demonstrated throughout the military history, most recently during the Gulf War. To illustrate a contrast with precision weapons, the laser guided missiles used by the Americans in 1991 were able to deliver their payloads to a specific building with few unintended deaths. Conducting a large-scale strategic bombing campaign, such as the campaign conducted against Germany during World War II, is simply not an option with missiles because of their tremendous expense. Furthermore, accurate guidance was simply not feasible for the Germans. The requisite

electronics simply did not exist. Therefore, as Dieter Hölsken, a V2 historian argues, the V2 was developed too early in technological terms, rather than too late in the war, to affect its outcome. Neufeld's main argument is that the V2 failed because it was conventionally armed. Had it been combined with a nuclear warhead, it would have been the revolutionary weapon the Germans had hoped for.[52] Even if the Germans had had this insight, however, the German rocket was not powerful enough to lift the nuclear weapons of the era; the bombs built by the Manhattan project weighed four times as much as the V2's warhead.[53] Such weapons would come into existence within fifteen years after the end of World War II.

Notes:

[1]Michael J. Neufeld, Rocket and the Reich: Peenemunde and the Coming of the Ballistic Missile Era. (New York: Simon & Schuster, 1994), 6-8.

[2]Neufeld,6.

[3]Neufeld,8.

[4]Walter R. Dornberger, "The German V-2," Technology and Culture 4, no. 4 (1963), 394.

[5]Neufeld,6.

[6]Neufeld,8-9.

[7]Neufeld,9-10.

[8]Neufeld,11-14.

[9]Neufeld,14.

[10]Neufeld,15.

[11]Dornberger cites a figure of 10 kg in his article, which Neufeld repeats. However, other sources give a figure of roughly 100 kg. Given the size of the Paris Gun, 21 cm, it is much more likely that it fired a 100 kg shell. In fact, other sources confirmed a shell of this size.

[12]Dornberger,398.

[13]Neufeld,16.

[14]Neufeld,16-19.

[15]Neufeld,19-21.

[16]Neufeld,21-23.

[17]Neufeld,41-43.

[18]Neufeld,45.

[19]Neufeld,46.

[20]Neufeld,45-49.

[21]Neufeld,55.

[22]Neufeld,111-113.

[23]Neufeld,113-114.

[24]Neufeld,282.

[25]Neufeld,114-115.

[26]Neufeld,24.

[27]Neufeld,120.

[28]Neufeld,128-131.

[29]Neufeld,128-131.

[30]Neufeld,117.

[31]Neufeld, 128.

[32]Neufeld,136.

[33]Neufeld,118.

[34]Neufeld,116-118.

[35]Neufeld,140.

[36]Dornberger,397.

[37]Neufeld,119.

[38]Neufeld,122-125.

[39]Neufeld,127.

[40]Neufeld,136-140.

[41]Neufeld,184-189.

[42]Neufeld,195.

[43]Neufeld,197.

[44]Neufeld,200-203.

[45]Neufeld,209.

[46]Yves Beon and Michael J. Neufeld, Planet Dora: A Memoir of the Holocaust and the Birth of the Space Age. (Boulder, CO: WestviewPress, 1997), XX.

[47]Neufeld,209-213.

[48]Neufeld,263.

[49]Neufeld,263-264, 273-274.

[50]Neufeld,220-223.

[51]Neufeld,273-274.

[52]Neufeld,274-275.

[53]Neufeld,139-140.

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