Jules Verne Inspired the V-2 and U.S. Moon Rocket

By Douglas G. Culy

How it all Started

The story of the V-2 rocket stretches behind and beyond its sneak attacks on London, encompassing development by space-flight dreamers, production by concentration-camp inmates, attacks from shifting hard-to-find sites, further development in Russia and the U.S., and motivating rockets to outer space. Building it, started before German leader Adolph Hitler's arrival; then it was ignored, later cancelled, and finally embraced by him; leading to Russia, the U.S. and China reaching space and the moon.

The inventors of the V-2 rocket, probably the 20th century's biggest aviation surprise, were inspired by early science fiction. France's Jules Verne (1828-1905), wrote an imaginative story and its sequel in 1865 and 1870: "From the Earth to the Moon" and "Around the Moon," that created space flight enthusiasts worldwide. He was not the first, much earlier the Greek Lucian of Samosata (120-180 A.D.) originally brought the subject up. Englishman H.G. Wells' "War of the Worlds" in 1897, was almost as exciting. Then, in Russia, Europe and the U.S., activity intensified on imagining, designing and building a rocket to get people to the Moon or Mars. At that time, manned rocket capabilities did not extend beyond the imagination of Jules Verne. This was in spite of his first mode of travel to space being in a cannon shell, using rockets only for directional control. Verne's books continued to be published long after his death, and he is the second most translated author in the world. He wrote five space-flight novels and more than 50 exotic travel novels. At least a dozen movies were made from Verne books.

Seventy years after Verne, the development of the V-2 rocket Vengeance weapon in Peenemunde, Germany, was done by people who mostly wanted nothing more than to follow Jules Verne to the Moon. This was amply reflected by their actions over many years. V-2 development, production and operation had different leaders, organizations and locations. This story focuses on how each came about. The V-2 was a tremendous technical achievement, with such advanced capability that few could imagine or anticipate its existence. But it was a poor use of resources. Its story traces from Russia to France to the U.S. to Germany, and eventually to the Moon with the U.S. and Russia (Russia getting there first).[1] The differences in technology and motivation resident in these countries made for an uneven pathway.

In Europe, Verne's followers were playing with powder rockets and dreaming of going to space. They were NOT dreaming of rockets as weapons, although such had been their use in Asia and Europe since the early 1200s. Early on, there were four noted space and rocket pioneers: the Russian teacher Konstantin Tsiolkovsky, American physicist Robert Goddard, French space-scientist Robert Esnault-Pelterie, and German-Rumanian writer and rocket enthusiast Herman Oberth.

In Russia, schoolmaster Konstantin Tsiolkovsky in 1878-79 had read Verne, analyzed various aspects of space flight, the control of rockets and their engines, use of dirigibles and other possible ways to get into orbit and travel in space. He also published interplanetary travel stories that inspired his fellow Russians, who built the rockets that he only imagined. Those first Russian liquid-fuel designs were imagined in 1898, and flown in summer 1932 at low thrusts, but halted during Stalin pogroms. Tsiolkovsky died in 1935.

In 1912 Esnault-Pelteri gave popular lectures in Paris on spaceflight with solid- and liquid-fueled rockets based on studies he began around 1907. That year, the *SS Titanic* used solid-rocket flares to signal its distress after hitting the iceberg and needing rescue. Esnault-Pelterie in the 1930s published his book "L'Astronautique" on space flight, and lived to 1957, knowing spaceflight was finally happening.

In 1909, Robert Goddard in Massachusetts was also inspired by Verne for space flight, and started with powder rockets in 1915 because they were much simpler to construct. Goddard soon found they had limited range because powder fuel was mostly binder that did not burn with much energy, while liquid fuels burned with significantly more effectiveness in producing thrust. In 1917-18 he worked for the Army, and proposed liquid rockets, which they did not respond to. Much later, Goddard made the world's first liquid-fueled rocket flight on March 16, 1926. He eventually filed 214 liquid-rocket patents. Most interestingly, some of Goddard's rocket flights were done at the Mescalero Ranch in Roswell, N.M., where extra-terrestrials were suspected of having landed just two years after his death, and the location of the Goddard Space and Rocket Museum. It is not too far from the military White Sands Proving Ground.

Europe's first liquid-fueled rocket was flown in Germany by Johann Winkler on February 21, 1931, five years after Goddard did it. However, Goddard's accomplishments were not well known because he was excessively private (his autobiography written in 1928 was not published until 14 years after his 1945 death).

Surprisingly, after WWI started, solid-fueled rockets got limited use on fighters, and liquid-fueled rockets were offered, but not built. Penalties on Germany for starting the war were spelled out in the 440 articles of the Arms Limitation Treaty of Versailles signed June 28, 1919, and were overwhelming in impact: Loss of Prussia and Alsace, disposal of much manufacturing capacity, a stunning fine to be paid in gold equivalent to two trillion dollars today, surrender of all military aircraft and almost all weapons and equipment, restraints on re-arming and limitations on use of civil aviation. Germany was also kept out of the League of Nations, formed on January 10, 1920 (but was admitted to the League on September 8, 1926). The U.S. Congress elected not to join the League, as the U.S. became very inward-looking, as had Europe. Europe endured several years of economic collapse and inflation, evolving into chaos in Germany followed by strong pacifism in its early Weimar Republic.

However, the Versailles treaty did not prohibit rockets or rocket-powered aircraft, this omission eventually opening the opportunity for work in this area. However, German institutions were not interested in pursuing rocket technology, and it took several years for the German economy to recover enough for rocketeers to gather. The biggest group, the Society for Space Travel (VfR), was started in 1927 for space travel devotees to build and fly rockets without worry about Allied inspections, which were still being conducted. Willy Ley, the foremost post-WW2 rocketry historian was a member. The VfR was headed by Herman Oberth (a German born in Rumania), whose book "Rocket into Interplanetary Space" was published in 1923. He, too, had been inspired by reading Jules Verne. Oberth was one of the early rocket builders (an enthusiast, not an engineer), and late in his life saw his goal achieved as von Braun's guest at Cape Canaveral, Florida. The VfR built and ran their liquid-fuel Kegelduse 15-lbt engine in 1930, finding no interest from the Army. Then, for a little more than a year, the VfR rented a Berlin storage facility from the Army, which they named "Rocket Flying Yard." In that year, the VfR did 270 static firings and 87 launches. The Army was still not impressed, and soon took their storage yard back. Then the worldwide 1929 Depression hit, and the by 1931 the club was on the verge of breaking up when things changed.

Another result of the Arms Limitation Treaty was to direct the interest of the German Army to rockets as field artillery, which had been tried before. Dr.-Engineer Col. Karl Becker, head of the Ballistics and Munitions Section, had worked on the Army's giant Krupp-built Paris Gun of 1918 (its 264-lb shell traveled 82 miles, entering and leaving the stratosphere before hitting a target). The V-2 was more a descendent of that gun than it was of Verne's rockets. The gun's barrel was about 131-ft long, made by inserting a longer 21cm-bore barrel into a shorter worn-out 34cm-bore barrel. After transport by rail, the gun was mounted on a turntable set on a 15ft-thick concrete pad poured for each location. Seven guns were built with replaceable barrels, as they were worn out after 60 firings. From various never-discovered locations, 303 shells were fired in France, with 183 hitting Paris (the Germans were that close to Paris!!).

By 1930, a rocket looked better to the Army than a gun. After conceiving a large artillery rocket to attack battlefield rear areas and cities as did the Paris Gun (its shells had impacted Paris just as the V-2 would hit its target cities), Becker designed and built a simple solid-fuel rocket with no explosive in 1929-30. This experience convinced him that ethyl alcohol would be a safer as well as more effective fuel. He ran his liquid-fueled engine on July 23, 1930. Within a month, Walter Dornberger, a WWI veteran army captain, two-year prisoner of war in France, and recent graduate of Berlin University in Mechanical Engineering, was assigned to work on both solid- and liquid-fueled rockets for Becker. Dornberger became the one of the co-fathers of the V-2. Their plan was to use the popular rocket societies to get something done with only the very modest amount of financing available from the Army…of which Dornberger's group would get next to nothing.

The story now follows Baron Wernher Magnus Maximilian Freiherr von Braun, the other co-father of the V-2, displayed unusual abilities and interests from the age of four years; mastering five languages, the piano and earning glider and powered pilot licenses before turning 18. He joined the VfR in 1929, age 17, having been fascinated by space flight since he was eight years old. His enthusiasm and intelligence resulted in him soon becoming their most influential member. After he finished his B.S. in Mechanical Engineering in 1932, and a 1933 M.S. in Aeronautical Engineering, he started on a Doctorate in Physics and wanted to discuss a successful rocket in his thesis. VfR's rockets were small, and not able to fly far or carry much; after von Braun's arrival, they increased in size and capability.

In December 1930, the Army set up a small rocket test area in their big proving ground in Kummersdorf, a suburb of Berlin. Dornberger was now a colonel, with half of his budget was for solid-rocket development, and half for liquid rockets. The Army's goal was for a solid rocket with a range of six miles, for a liquid rocket with twice this range and 10 times the weight of the artillery shell fired by the Paris Gun. Dornberger and Becker surreptitiously attended VfR meetings, liking the work being done, but were appalled at the lack of organization

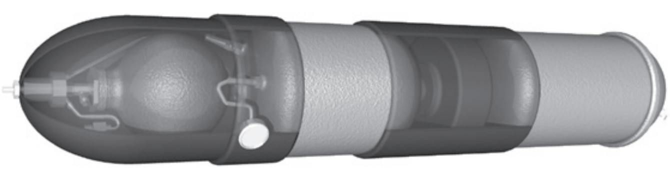
Lt. Gen. Dr. Walter Domberger and Wernher von Braun surrendering to the Allies in May 3, 1945. Both would eventually come to the United States as part of OPERATION PAPERCLIP. (USAF photo) and record keeping. Even so, an Army liquid-fueled rocket was surprisingly contracted to VfR… for a measly $234. Von Braun and a VfR friend demonstrated it to the Army in June 1932. Their "Two-Stick Repulsor/MiRak I" liquid-fueled rocket carried a parachute, a flare, and was 14 ft long. It crashed on launch without releasing its payload. In spite of that result, the Army made VfR an offer to hire anyone who would do organized work for them and keep quiet about it, secrecy being paramount…and Dornberger got von Braun in October 1932 as a civil-service employee, with the job of Technical Director. To be assigned that high of a position for a 20-year old signified that Dornberger sensed von Braun's special abilities. The Dornberger/von Braun partnership was to create a hateful weapon, last many years, and put man into space.

The German Air Force had a big budget, and its Wolfram von Richthofen (cousin of WWI ace Manfred) became aware of the Kummersdorf effort and allocated significant funds in late 1932 to support Army work there. The Air Force wanted rockets to assist takeoff and to propel a fighter. This motivated Becker to provide even greater Army funds for a bigger, better liquid-fuel rocket. Joint funding reached several million dollars. This funding fueled the need for obtaining a larger and more secret facility. Kummersdorf then began to investigate rocketry in general. After the first three research rockets, the focus moved to weapons. Later versions had major transport goals, the largest of which could travel as far as from Europe to America. These more ambitious projects were not built, as they looked too far into the future, and Allied bombing had by then significantly reduced German capabilities.

This rocket model series, called "Aggregat" (grouping), were serially identified with the numbers A-1 to A-12, the later ones not getting beyond the paper stage.

The A-1 was actually the subject of von Braun's doctoral thesis on rocket burner combustion. Work started on it in late 1932, fabrication began in the Summer of 1933. The A-1 did not achieve flight because front-end heaviness caused a simultaneous nose-over on the first liftoff attempt (probably in early 1934). It was only 55 inches long, weighed 330 lb, and had a 660-lb-thrust (lb-t) liquid rocket engine that ran for 16 seconds using liquid oxygen (LOX) and alcohol. Even with this failure, Von Braun was granted his Doctorate June 1934.

The A-2 was a replacement for the A-1, the same size, using the same engine. It was revised to move its heavy flywheel stabilizer from the nose to mid-fuselage. Construction was started in early 1934, with launch near the beginning of that December. Two were built, and both were flown from the island of Borkum at the mouth of the Ems river…150 miles West of Peenemunde, crashing on first flight; but they did get into the air.



von Braun's second rocket design, seen here in cut-away, was still finless, relying on a gyroscope for stabilization.

The new Nazi government had become aware of the rocket effort, and made much more money available for the Aggregat program, starting with the A-3. This was the first rocket built with a pressure-fed engine, controllable exhaust vanes, gyro-compass stabilizers, accelerometers, instruments in the nose, and carrying a parachute. It was the biggest rocket to date. The University of Aachen evaluated rocket aerodynamics in its very small wind tunnel before A-3 design started early in 1935. Soon, many universities were helping design the A-series rockets. By this time, Dornberger and von Braun realized the Kummersdorf facility flight range was too small for the A-3, in addition to the need for more seclusion. Von Braun had made Dornberger aware of the island of Usedom with the tiny fishing village of Peenemunde on the North German coast of the Baltic Sea near where von Braun grew up. The Air Force, also learned about Usedom, and purchased Usedom on April 26, 1936. They immediately began developing it, eventually expanding the site with an airfield, manufacturing shops and test laboratories including wind tunnels. At that time it was the largest aircraft test facility in the world. Four A-3s were built there, and first flight was on December 4, 1937, for 40 seconds from the island of Griefswalder Oie, offshore from Peenemunde. All four had problems with their guidance and control systems not having sufficient effect, largely because the rocket's drag was too high for the guidance system, as well as experiencing engine failures. These problems were unrelated to those caused by the island's mice population eating insulation on the site's electrical wiring, and by workers being sidetracked to hunt pheasant. A-3 length was 22.1 ft, diameter was 2.2 ft, weight was 1,650 lb, and its engine generated 3,300-lb-t for 45 seconds.

Early thinking at completion of A-3 design about the next project, to be designated A-4, was that it had to be a field-artillery weapon carrying a one ton of explosive (like the Paris Gun), but small enough to be carried on a train car through railroad tunnels, and have a strike dispersion goal for half of its hits being spread less than two percent (twice as demanding as that demonstrated by the Paris Gun).

Hitler visited Kummersdorf in 1938, saw the A-3, and was told about the upcoming A-4 artillery rocket; but was not impressed. The Air Force bowed out of the big rocket effort in 1939 because they wanted to spend their budget on the V-1 pulse-jet drone (Vengence Weapon 1 was applied to the Fiesler F-103 Buzz Bomb); but retained the larger western part of the Peenemunde site for developing it. V-1 first flight was at Peenemunde December 1942; its program was partially motivated by Dornberger's suggestion that the A-4 was better than the bombers at terrorizing Britain. Both carried the same size warhead, but the V-2 took 3,500 manhours to build, versus 900 for the V-1. In May 1943, Speer had a formal review to decide on V-1 versus V-2 program continuation. This review resulted in both programs getting go-aheads.

All engines for the Kummersdorf (and later Peenemunde) rockets were designed and built in-house, growing in parallel with the needs of the rockets. Their thrusts were: 330, 660, 2,200, 3,300, and 56,000 lb. The jump from 3,300 lb-t to 56,000 lb-t (and to their corresponding flight length) was too great a challenge for Kummersdorf, causing the selection of the much larger Peenemunde site, and requiring many more months of effort before reaching flight capability.

Building the Prototype A-4/V-2

Studies leading to the bigger A-4 (later named V-2) were started in Fall 1935 when Dornberger decided the time had come to produce Becker's field artillery rocket to hit targets behind enemy lines. Early consideration was on the burner and guidance system. Prior to going ahead with the A-4, because of the guidance problems demonstrated by the A-3, the team decided to build a smaller demonstrator of artillery goals, the A-5, and its design was started in mid-1937, featuring improved aerodynamics and looking like a scaled A-4.

Length was 19.1 ft, diameter was 2.8 ft, and gross weight was 1,900 lb. It was to hold a 50-lb payload. The A-5 had the same 3,300-lb-t engine as the A-3 (but positioned more to the rear), and had larger tail fins of about 14 sq-ft area each (span from tip to tip of 77.5 inches). It cruised at 900 mph for a range of 16 miles in 45 seconds. More than 30 A-5s were built, the first being launched in August 1938 without a guidance system; first flight with its guidance system was in October 1939, most had been flown by the end of 1941, with the last A-5 launch in mid-1942. Development effort on the A-4 was restarted in earnest after the successful test of the A-5 guidance system. Dornberger was a General by then, and given an Honorary Doctorate in Engineering.

A-4 preliminary design was completed in 1938, with its development effort slowly starting at Dornberger's initiation and direction, and accelerating after first flight of the A-5 that August. Although A-4 funding was halved by Hitler when WW2 started, Peenemunde expansion continued; but was placed under Reich Munitions Minister Albert Speer's control. The A-4 design manager was Walter Reidel. Hitler was quite aware of the A-4 by that time, but did not see it as a useful weapon. Speer had been immediately greatly impressed by the youthful vitality of the team.

The A-4's engine design was supervised by Walter Thiel, hired at Kummersdorf in 1936, at age 26, with only one year of work after his 1935 doctorate in engineering. Thiel immediately started design studies for a better-optimized engine than the A-3/A-5 had (its combustion chamber had 50-percent losses). He worked at Kummersdorf until 1940, so early work on the A-4 combustor was limited by cell capacity to 8,000-lb-t. Thiel changed the combustor design from a long cylinder to a much shorter spherical chamber, added pre-mixing cups, increased combustion pressure, and adjusted ignition timing…reducing losses. The engine's graphite rudders were more effective at takeoff/climb-out speeds than were the fin's metal rudders. The design problem and task were shared with many of Germany's engineering schools and a few of its industrial concerns; with some professors taking jobs at Peenemunde. A three-pre-cup burner design was considered until von Braun said to use the same pre-cup size as in the A-3/A-5 engines, which resulted in 18 pre-cups in the A-4, the definitive configuration. This configuration had much-improved combustion stability, hence chamber reliability. Four rings of small holes drilled around the combustor liner provided film cooling from seeping alcohol, where the initial approach had been to use excess fuel flow to cool. The large alcohol flow between the inner and outer combustor liners provided regenerative cooling, but also made fuel pumps necessary to provide more fuel pressure. Flows were 120 lb/sec of 25% water-75% alcohol, 150 lb/sec of -297-deg-f LOX, pumped with +725 deg-f steam. The pumps warped and cavitated, these problems not solved until January 1943, requiring 20 A-4 flights to do so. High-frequency engine vibrations persisted. General but significant problems with bearings, seals, and gaskets were dealt with as a matter of course. Valves, controls, and gages presented so many problems that their development had to be done at Peenemunde; many not being solved until 1942. The oxygen control valve was made to open in two steps, so that combustion quality at low thrust could be observed statically before committing to flight. A 15-degree exhaust nozzle divergence angle was set after evaluating several angles. Initially, the warhead was exploded by radio control, but this was changed to programmed command in later models. A-4 design benefitted much from extensive use of Peenemunde's new supersonic wind tunnel. The warhead's Amatol explosive filling was chosen because it would not be set off when the nose glowed red from re-entry friction.

After the move to Peenemunde, the initial form of the A-4's engine was first run March 21, 1940, making much less power than needed, and setting off a major development effort to resolve burn-throughs, pressure fluctuations, poor mixing, and pump cavitation. By the time the first lot of 80 test engines had been built, the combustion chamber inner and outer liners had been modified. They were made from short-life low-carbon mild steel. In the latter part of the program the combustor was greatly simplified in Peenemunde to have only one pre-combustion space, but developing it took too long to incorporate in the production design. Drawings of this simplified engine were widely distributed, and are included in many descriptions of the A-4/V-2. So, it can be concluded that the one-pre-cup engine was built and run in Peenemunde.

Sadly, General Becker, the conceptual grandfather of the V-2, committed suicide in Spring 1940 after arguing with Hitler, and so was not able to see the V-2 used.

Obviously, Dornberger regarded the A-4 as much his baby as did von Braun; and his vision for it also went as far as going to the Moon (he having said as much to the team in group meetings), but Dornberger's goals also included Army goals of secrecy and isolation. The expanded Peenemunde facility was ready to use by early 1939, the Army spending $70 million on building their part of it (Peenemunde East). The A-4 project was not fully staffed until August 1939. Funding was halted in February when Hitler's success in Poland led him to stop projects lasting more than a year, and he felt the A-4 would not be needed. After Hitler had reduced and then stopped funding the large expenditures at Peenemunde, he resumed financial support later in 1940 when, after the short but intense Battle of Britain, he realized that the war was going to persist, and the A-4 could be a useful weapon.

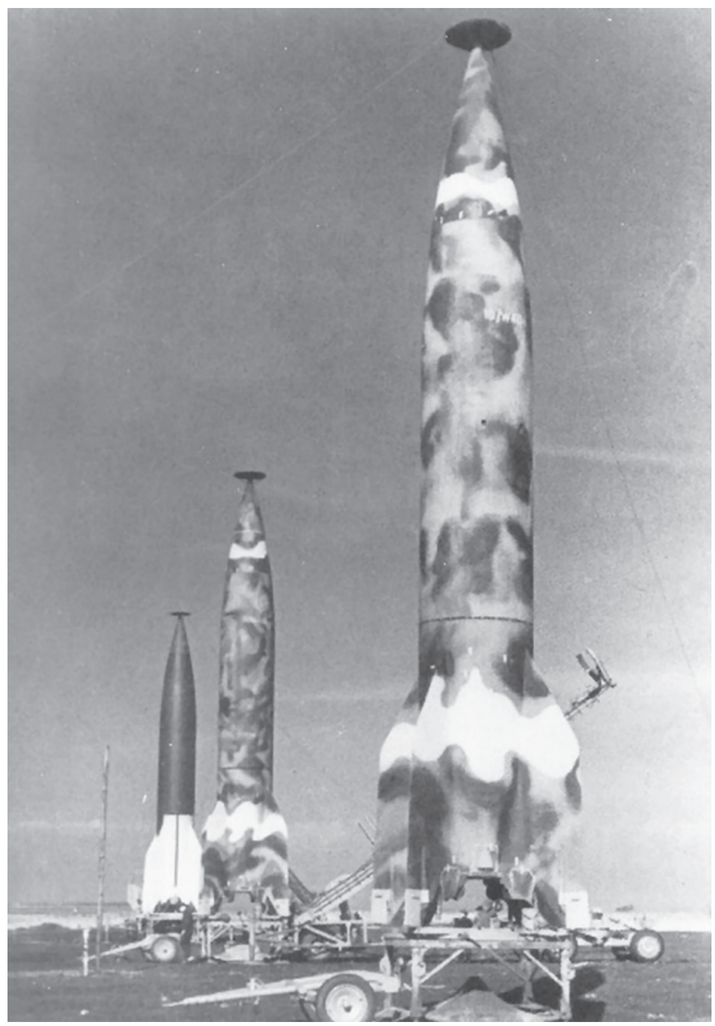
Although the primary design problem of the A-4 was its engine, much new technology was found to be needed for most functions in the rocket, and the first manufacturing drawings of the A-4 were not completed until early 1941. These new technologies were: graphite rudders in the exhaust flow, aerodynamic rudders on the fins, two improved gyroscopes for control of pitch, yaw and roll, a complex fuel pumping system for main fuel, turbo-motors for the main pumps and special fuel (sodium permanganate and hydrogen peroxide) for the turbo-pump motors…these were the most difficult to manufacture of all A-4 parts. An accelerometer to control motor output for the turbopumps was not added until "A-4C" revision was issued in April 1944. The technical sophistication of the A-4 belied its low-cost goal.

The A-4 was 45 ft 10 in. long, 5 ft 7 inches in diameter, the 77.5-sq-ft fins acting like wings to stabilize horizontal flight. Its empty weight was 6,540 lb, and takeoff weight was 28,440 lb. The maximum payload (warhead) was 2,200 lb, and full fuel weighed 19,700 lb. The same liquid-oxygen/ethyl-alcohol blend used earlier was also in the A-4, in spite of its instability causing short storage life in parked rockets. Facilities for making LOX were a necessary addition to Peenemunde and all A-4/V-2 launch sites, fixed and portable. Fuel load was calculated for the intended mission (Brussels, Paris, British Coast, London), and the controls were then set to stop the engines at the planned duration (about 55 seconds burn time, although 68 seconds was ultimately possible with maximum fuel). Maximum range was 240-270 miles. Maximum speed was Mach 5.35/over 3,300 mph at altitude (about 5 minutes flight time).

Hitler again slowed work on the A-4 in March 1941 when he decided to attack Russia. Operating under low priority, manufacture of its long-lead parts had been started more than a year before, and assembly of the first A-4 did not start until early 1942. Its first flight attempt on March 18, 1942 crashed before takeoff was completed. The second try on June 13 took off, but failure of the guidance system caused the A-4 to veer out of control soon after, when flight became non-vertical. However, the big problem of taking off had been solved. The next launch on August 16 exploded at 47,000 ft. The first totally successful launch of the A-4 was on October 3, 1942; this in spite of the March 1941 priority cut that was not restored until July 7, 1943. At a banquet that night, Dornberger said "We have proved rocket propulsion practicable for space travel…so long as the war lasts, our most urgent task is the rapid perfecting of the rocket as a weapon. The development of possibilities we cannot yet envisage will be a peacetime task."

Fear of losing the war emerged after the Russians started pushing the Germans out of the Kursk area, and a higher priority given, the same as that of the tank program. By then, when Dornberger and von Braun were briefing Hitler about the program, he took it seriously, visualizing hitting London again. Hitler then told Speer to push the A-4 program as hard as he could. Listening, Josef Goebbels, Propaganda Minister, suggested "Vengeance Weapon 2" title for the A-4; and it stuck. Vengeance weapons were to extract revenge on the Allies for the saturation bombing of German cities going on then. At this time, Hitler granted to von Braun the honorary title of 'Professor,' which is a notch higher than 'Doctor.' A-4 flight testing showed its initial cruise speed and range were deficient; and many prototypes were needed to solve each problem because only four datums could be observed and recorded on any one flight.

British reconnaissance in Spring 1943 found the rocket and jet plane activity at Peenemunde, and focused bombing of residential and manufacturing facilities was started the night of August 17 by 640 RAF aircraft, and continued later that month by U.S. Army bombers. 800 workers were killed that first night, including Dr. Thiel, the engine designer, and one other engineer. Operations were delayed about a month, but normal development activity continued there, some special-parts manufacture was moved off-site, and production was moved from above-ground factories to an underground location. A-4 flight testing was moved to the Blizna, Poland facility. Not until Spring 1944, could 24 datums could be recorded. The tenth A-4 exploded violently on the launch, and on June 30, 1944 control of one was lost just after takeoff, and it crashed at a nearby airfield. Early flights showed dispersion was many miles, because the control system was affected by the static electricity charge from air friction accumulated during flight.



Three V-2s on launch stands ready for launching. The near two painted in camaflouge while the distant one is painted in typical test color markings. (IVM/U.S. Army Archives via Rare Historic Photos)

Eventually, 250 A-4 prototypes were built at Peenemunde before first flight of the production version, V-2, was achieved. There were 65,000 drawing changes in the 23 months between first flight of the A-4 and initial operational capability (IOC) of the V-2 (A-4C) in September 1944. Design changes before first flight have not been recorded. This date was two years later than it could have been; but that is also the story of several of Germany's other advanced weapon developments, which benefitted Germany's opponents and victims by probably shortening the war because these weapons used critical resources and were too late to be effective.

There were at least A-, B-, and C-designated versions of the rocket before production ended. The 'A' design probably defined the first 80 prototypes, still needing many changes in the engine and controls. The 'B' version was the remainder of the first 300 A-4s, awaiting a few engine and control improvements, and used only at Peenemunde and the remote Blizna, Poland, test-firing site. Fabrication of the 'C' design (V-2) was started in April 1944 embracing all the design changes to that point for production. In August that year, a modified 'C' design was built for test of 80 further-improved examples in Poland. This may have included the single-cup combustor, and would have become the 'D' version. The source of the problem of exploding at re-entry was not discovered until the testing of these last examples. The fix being a steel collar at the warhead attachment. Satisfactory dispersion was not achieved until Blizna testing.

The team's persisting interest in space flight resulted in neglecting the development of support equipment for weaponizing the A-4; and equipment design was not begun until mid-1943. More than 30 different pieces of equipment were needed. The more important of these were:

1 Armored fire control vehicle – half-track
1 Transporter/erector trailer – Meilerwagen (3)
2 Launch platform – trailer-mounted
3 Trailer—moving the missile (3)
4 LOX tank trailer (2)
5 Alcohol tank truck (2)
6 Sodium permanganate tank truck
7 Hydrogen peroxide tank trailer
8 Pump trailer
9 Large 16-ton crane
10 Conventional surveyor's theodolite
11 Cable trailer
12 Power supply truck
13 Control compartment truck
14 Radio truck
15 Support disk with cables for warhead tip
16 Railroad flat car for transport/launch
17 Ten-car train for residence

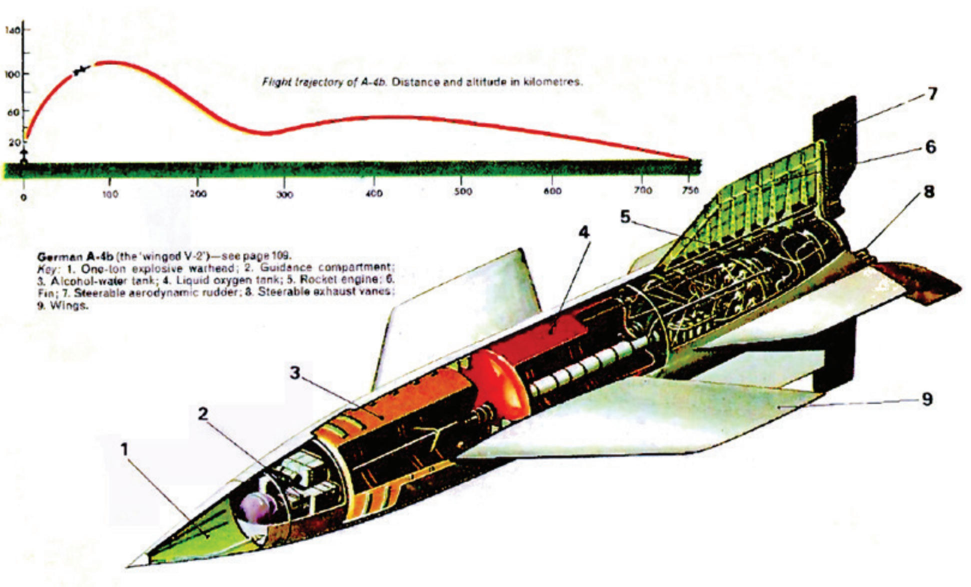
Industry response to this need was quick, but was another factor in determining V-2 IOC. The theodolite was used to get alignment in azimuth with the great-circle direction of the target.

The rocket team's barely concealed space interest also resulted in the arrest of von Braun and several of his associates on March 5, 1944, by the Gestapo for talking about space flight when they should have been discussing the A-4 as a weapon. It took several weeks for Dornberger and then Armament Minister Speer to convince Hitler of von Braun's essential status in the program. The increasing focus on production forced Speer to take more interest in the A-4/V-2. Just before von Braun's arrest, Speer persuaded the head of the German arm of General Electric Corp. to visit Peenemunde to review the A-4 program and take over management of the overall advanced weapon program.

The 89th prototype was flown in June 1944, accidentally landing in Sweden, resulting in Britain getting its first relatively complete V-2 to examine.

A winged A-4, designated A-4b, was studied at Peenemunde in 1940 to increase A-4 range by a factor of almost three. It started as the A-9, but was re-named A-4b and simplified in design to be more basically an A-4 so as to get more Army support. It had swept-back wings, with span of 20 ft 4 in, 223 sq-ft wing area, and its fins extended with rudders, with gross weight increased to 28,600 lb. Three demonstrators were built, the first flown in January 1944, the second soon after, with the third crashing. Maximum speed was measured at Mach 3.0. Range was expected to be about 500 miles. That late in the war there was no willingness by the Army and Hitler to do it.

A Photo illustrating most of the support system required to transport, prepare and launch a V-2. (IVM/U.S. Army Archives via Rare Historic Photos)



Cut-away of the A-4b, a winged V-2, was designed to increase the rockets range by about a factor of three (to about 500 miles). Examples were test flown but came too late in the war to enter production.

The A-6, not built, was planned to be an A-5 with a ramjet engine, flying at 1,000 mph for 15-to-20 minutes.

The A-7, also similar to the A-5, half the length of the A-4, 5.91 m long, 0.38 m in diameter, weighing about 2,200 lb. It was designed to use a hypergolic fuel, and two were built without engines, flown with wings as gliders in 1940-1943.

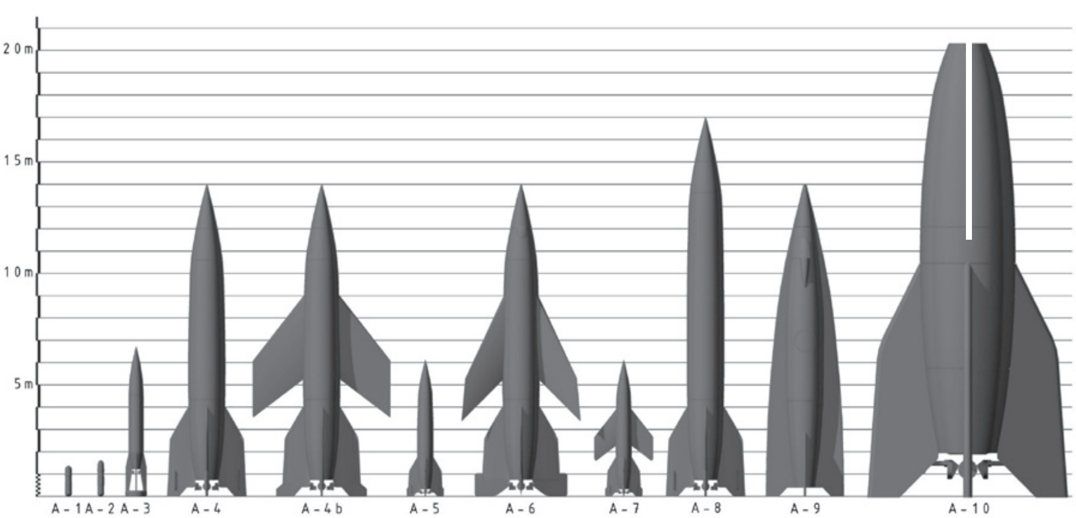
The A-8 was to be A-5 size, to use a more storable fuel, but was not built. It was the last completed Peenemunde detail design, done in September 1944.

The A-9 and A-10 were layout designs only. The A-9 would be slid into four slots occupying half the length of the A-10. The intent was for the A-10 to boost the A-9 up to the edge of space at 2700 mph, so that the A-9 could then fly to distant targets such as New York City. This project was started in very early 1940, with layout design being finished before the end of that June. It was re-examined late 1944; but circumstances at that time prevented taking it much further. The A-10 was to have six of the engines used on the A-4, and was to be 65 ft long. The 1965 movie, "Operation Crossbow" starred the A-9/A-10 (with static engine runs) as well as V-1s and V-2s taking off from Peenemunde (maybe Mittelwerk too).

The A-11 was to be the third-stage booster rocket for the A-9/A-10 combination, to put it in outer space. With the realization of this idea, the dream of going to the moon would have been close to happening. At this point in the war, it is hard to imagine the rocket team having the time to think of such a vehicle; but a special group led by Ludwig Roth operated sub rosa throughout the war to do such dreaming in spite of being officially stopped in 1943.

The A-12 was to be a significant enlargement of the A-11, to carry 30 tons of payload to outer space. This concept in 1944 was proof that von Braun and company remained very psychologically committed to space flight.

During 1943-45, the team developed a rail-car launch system for the V-2, not used; and in their spare time, the team developed the Wasserfall and several smaller missiles that entered or almost entered production; but none entered service. During 1942-45, the team developed a submerged A-4 and smaller missiles -- none fielded. Near production, the Wasserfall ground-to-air rocket, started December 1942, first flown February 1944, was to down B-17s, and would have been a more effective use of funds. Speer regretted not emphasizing it instead of the V-2.



The Aggregat *series (German for "Aggregate") was a set of ballistic missile designs developed in 1933–1945 by a research program of Nazi Germany's Armed Forces (Wehrmacht). Its greatest success was the A4. (Wikipedia commons)*

Other manufacturers developed 11 missiles (anti-aircraft, anti-tank, and anti-ship rockets), most not making it to attack status. The Henschel Hs 293 air-to-air missile used the same fuel as the V-2 turbopumps, was produced in the hundreds, and was in service from August 1943 until April 1945.

By the beginning of 1945, 4,450 people were employed at Peenemunde, about 900 being engineers and scientists.

Producing the V-2 and Going to the Moon

Even though IOC of the V-2 was not achieved until September 1944, its production design was started at the October 1942 first successful flight; indicating the underlying urgency in the program. This effort focused on simplifying the structure and lowering costs, and the production V-2 unbelievably cost less than a torpedo (probably only because of so much prisoner/slave labor), and much less than a bomber. Henschel, Zeppelin, and the Peenemunde factory were designated to produce it. Munitions Minister Speer persuaded Hitler to sign the production order for the V-2 December 22, shortly after first flight. This was two years later than it might have been if Hitler had not waffled so much in wanting it.

At that time, expected V-2 production monthly material requirements were 24,000 tons of iron and steel, 5,200 tons of aluminum, 477 tons of copper, 244 tons of alloying metals, and 3.2 tons of silver. These were a big fraction of total German aircraft production needs at that time. Priority was given to parts delivery for the revised design in the Summer of 1943. Another 50 A-4Bs were built at Peenemunde and tested in Poland for the production program. Hitler did not become serious about the V-2 until July 7, 1943, when he saw movies of A-4 takeoffs the previous October. These movies were shots of one successful takeoff taken with multiple cameras.

In the Fall of 1943, the team proposed to tow five V-2s, each in its own tube, behind a submarine until close enough to attack New York City. For launch, the tube was to be sunk on one end for it to be brought to vertical before firing. One was built and partially demonstrated. In January 1945 the team demonstrated at Peenemunde a V-2 vertical launch from a railroad flatcar.

Hitler had wanted to use German labor for V-2 production, but Rudolph and/or Himmler persuaded him that prisoner labor would cost much less. At about this time, Speer assigned control of the facility building program to Maj. Gen. Dr. Engineer Hans Kammler, a ruthlessly ambitious Civil Engineer who had sought government service right out of school, got unhappy with the Army, and transferred to the SS. There he became quite successful, had built several concentration camps to house Jewish prisoners, and then got assignment to V-2 production. He established significant new goals for it. More than any other person, Kammler defined the service use of the V-2, and he made many enemies in doing so.

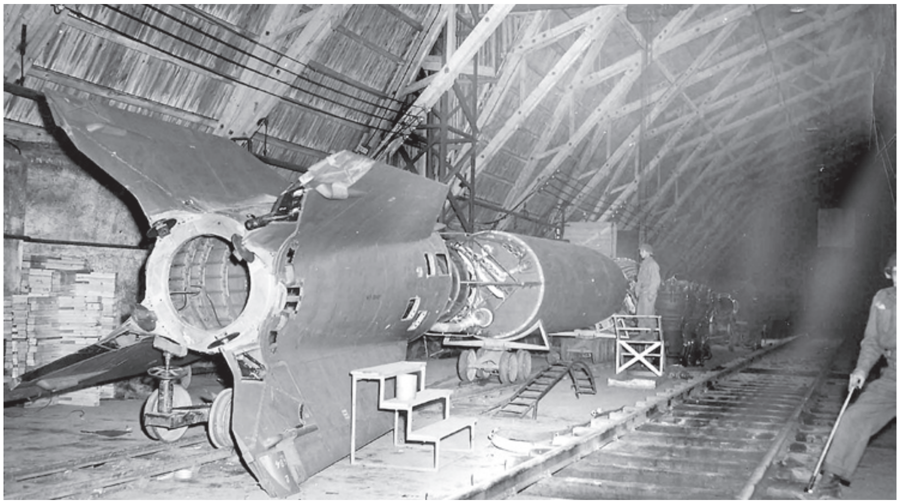
Prior to this, A-4 development manufacture (actually semi-production because of the quantities) at Peenemunde going on since 1942, had to take place with drawing changes after every flight, because each one showed new problems and necessity for changes. Over 5,000 manufacturers were lined up for A-4/V-2 assembly; that number resulting from the desire for triple back-up in suppliers. Manufacture of detail parts remained widely spread throughout Germany, with some in France and Switzerland. A card indexing system was used in managing this group of suppliers and sub-contractors, which was most likely an IBM system (IBM punch card system was introduced in 1928) since its International arm operated in Germany all during the V-2 era.

The first launch from the Blizna, Poland, remote 400-man test facility was on November 5, 1943. By March 31, 1944, after testing 57 production versions there (built at Peenemunde) 31 had failed on takeoff, 19 failed in the air, and only four out of the remaining seven hit the target area. Von Braun and Dornberger went to Blizna to find the cause. On advice from Dornberger, von Braun positioned himself in the hole of an earlier crash… and survived, but saw the problems. Reasons were stray voltages to the controls, weak skin alloy, and overheating on re-entry. Ultimately, 600 V-2s were used in troop-training there. After finding and fixing most A-4/V-2 structural problems that caused these failures (requiring working on fuel tank insulation with fiberglass and adding a reinforcing ring for the skin of the upper fuselage, which took until August 1944), IOC for the V-2 was finally obtained September 1944…unfortunately (or fortunately for the Allies) after the D-Day Normandy Landings. 1,588 had been produced by this time, and the Russian army was advancing through Poland, taking Blizna.

With the RAF bombing of Peenemunde in April 1943, Kammler took (not given it) V-2 program control; this event causing Army generals Metz and Heinemann, newly reporting to him, to ask for reassignment. Kammler kept detail part production outside of Peenemunde, and re-directed final assembly to the Mittelwerk (deep under the Harz mountains) in August 1943. The Mittelwerk had been in existence since 1917, first as mines, then for storage.

In September 1943, Kammler relieved Dornberger of direct responsibility for the missile program, but let him maintain technical consulting and control. They hated each other. Extending the Mittelwerk tunnels started then, which was very hard on the workers. Concentration Camp Dora was not yet built, so the diggers had to live in the tunnels, with starvation and unhealthy conditions killing thousands. V-2 production used 1,200,000 sq.ft. of Mittelwerk floor space, comprising two long main tunnels 35-ft wide, 25-ft high, 500-ft apart, and connected by 47 cross tunnels 30-ft wide and 22-ft high. The first production V-2s were delivered New Year's Eve 1943, but were not operable. Delivery was started in spite of the contract not being formally issued until the next month, and at least 1,400 had accumulated at Army sites by the time of first launch. Because of the problems created in productionizing the V-2, output from the Mittelwerk was initially slow, and got slower when first usage found design weaknesses that needed to be fixed: January 1944-80 V-2s, Feb.-86, Mar.-170, Apr.-253, May-437, June-132, July-86, Aug.-374, Sep.-629, Oct.-628, Nov.-662, Dec.-613, Jan.1945-690, Feb.-617, Mar.-490, for a total of 5,737.

When the V-2 began production, the need for more manpower at all factories was immediately realized, and pressure was placed on the French, Russian and Italian prison labor force. Their high death rate caused use of Jewish prisoners to be started. Maltreatment of nearly 60,000 of these prisoners resulted in much higher death rates, and soon brought the realization that more-experienced workers were needed. So, in the last months of the V-2 program, workers were brought in from other sources. By war's end, prison labor on the V-2 was less that 40 percent of what it had been. Production at Mittelwerk had skilled labor requirements such that employment of Germans there increased from 3,400 in



Due ot Allied bombing most of the production of the V-2 was moved underground and employed slave labor. U.S. soldiers inspect a German V-2 rocket at the factory in Kleinbodungen, Germany, 1945. (IVM/U.S. Army Archives via Rare Historic Photos)

July 1944 to 4,900 in March 1945, while the use of prisoners decreased from 8,400 in July 1944 to 6,900 in March 1945.

Twenty-car trains moved whole V-2s from the Mittelwerk to Army storage sites initially, and later directly to launch sites, usually one rocket per flat-car. Every train got through, although some were damaged by fighter attack. Sometimes, train-loads of components were shipped to remote locations for assembly closer to launch sites.

Construction of large V-2 launch facilities had already started in late 1942. The team recommended use of mobile launchers, but Dornberger wanted bunkers; Hitler, being impressed by how well their submarines had endured bombing of the bunker-like French submarine pens, agreed with Dornberger. Four large concrete bunkers were started in France to launch V-2s, but were over-run by U.S. troops without any flying from them. These could store 30 V-2s at a time, after assembling them from train carloads of components.

The bunkers had to have facilities for liquifying oxygen, because of its instability in transport. Total German LOX manufacturing capacity limited daily launches to 30 for offensive use while allowing about seven for necessary experimental use.

Supplies of ethanol were barely sufficient for production needs, and for a while methanol was substituted; an unexpected outcome of which was the poisoning of several soldiers who had been stealing drinks. Ethanol fuel for the V-2 in Germany, where alcohol was drunk more than water, was immediately noticed and taken advantage of by operators. Some drunkenness occurred and was strongly reacted to by the hierarchy. One engineer observed that the amount of alcohol in one V-2 was equivalent to 66,130 dry martinis. Available potatoes for ethanol were quickly decreasing as Russia overran Eastern Germany. Supplies of fuel for the turbo-pumps were sufficient.

Kammler situated his headquarters near V-2 launch sites close to the Channel Coast, and his influence resulted in the SS starting its own missile launch unit. Kammler hyperactively moved back and forth between Mittelwerk and the coastal bunkers as the situation changed. Some bombing of bunkers was done with remote-controlled B-17s guided by a B-34 (Program Aphrodite). One of these, piloted by Joe Kennedy, the future president's brother, exploded in England, with so much damage to a town that the program was cancelled. When Allied troops moved into Normandy, the bunkers were captured. After the mobile V-2 sites were pushed back into Germany, Kammler saw the end of the war coming, asked for re-assignment to manage the Luftwaffe fighter program, and then disappeared on a trip to Eastern Europe at war's end.

The first V-2 launch from a mobile unit was on September 6, to hit Paris, but failed on takeoff. The next attempt, on September 8, succeeded, and on the same day, a unit in Belgium launched the first missile attack on London. The mobile launch units needed four days to assemble and set up a V-2, and fuel, LOX, and all of the support equipment that had to be there. Four hours were needed for fueling and LOXing readiness for takeoff. Launch rate towards London did reach more than 15 per day during February and March 1945 because fuel availability was relatively better than rocket supply, which had grown with difficulty from five a day at first, and seven per day late in 1944. The breakdown of Germany's rail system resulted in much of 1945 hardware production not getting to launch sites, being left at the factory and storage depots.

The last experimental A-4 was launched at Peenemunde February 19, 1945. The team had started to leave on January 31 in recognition of the nearness of the Russian troops signaling the end of operations there. Most of them preferred to be captured by U.S. forces. The last ones departed February 22. Von Braun's last trip there was on February 27, and on March 17, Hitler ordered all critical facilities to be destroyed (this order was not fully obeyed). Mittelwerk was continued in production as long as possible, until being overrun by troops.

On March 11, 1945 eleven V-2s were at last used for the original purpose it had been created, in a defensive action attacking the Ludendorf bridge near Remagen, Germany, after it had been taken by U.S. soldiers. This was not a successful operation. The last launch of a production V-2 at a target was March 28, with five more being launched (ditched) soon after into the North Sea from Schleswig-Holstein. Overall, 3,308 V-2s were launched.

Program cost had come to the equivalent of $1.9 billion, a major drain of German resources in both financial and material terms. The development portion of this was approximately $745 million, but development really had not yet been completed when production started. There were 5,940 production V-2s built right up to the surrender of Germany, most with slave labor in the Mittelwerk tunnel facility. Of these, 1,403 were counted as having landed in Britain (517 in London), 1,610 landed in Belgium (1,265 in Antwerp), 19 landed in Paris, with 137 landing elsewhere, and there were at least 139 V-2 launches that did not reach their targets. A large number were not flown, being left sitting around at the factory and launch sites.

The bottom line was that one-third fewer people were killed in the rocket's targeted areas than were killed in its manufacture; and a typical British night bombing raid killed almost ten times as many people as were the total killed by all V-2s. Also, Germany built less conventional aircraft and other military equipment, since the V-2 required metals and electronics when the Luftwaffe and Wehrmacht needed replenishment. Because sources of gasoline and diesel fuel for Germany were being bombed out or captured, Germany's overall equipment (planes, trains, trucks, and boats) operating capability was also greatly reduced, and much war fighting gear produced during 1945 sat idle. So, the Allies benefitted tremendously from V-2 production's capture of resources. Few histories of WW2 mention the material usage for A-4s/V-2s being a major drawdown on overall German weapon availability after mid-1943.

U.S., British, and Russian teams were looking for V-2s and V-2 engineers even before German surrender. Initially, when the team (now think Space Society) members were captured, they pleaded ignorance of what the SS had been doing. The need for their skills was such that they were within the next year working on helping the Allies understand the V-2.

In spite of the large numbers of V-2s laying around assembly facilities and launch sites, the U.S. teams were forced to find parts stashed in many places so as to be able to send back to the U.S. the equivalent of 100 brand-new V-2s that had been asked for. When the requested 100 rockets made it to the U.S., most, but not all, were tested at White Sands Proving Grounds in New Mexico. Later ones were modified to have five feet more length of the nose payload space. A few were not flown, having become obsolete. The team were stationed at Fort Bliss, Texas, close to White Sands. Just as the V-2 was initially a German Army program, the U.S. Army had initial control of it after WW2, and the team eventually became Army employees.

The U.S. flew its first V-2 June 13, 1946, and its last one in 1952. These flights studied atmosphere composition, pressure and temperature at 100 miles altitude, occurrence of micrometeoroids, solar radiation and cosmic rays.

Flight activity expanded to extending rocket usefulness, including launch by the Navy from the U.S. aircraft carrier Midway, and as the boost stage of two and three-stage rockets (the WAC-Corporal in 1949 being the first one to top-off a V-2). The Air Force's 1946 MX-774 derivative of the V-2 was dropped as insufficiently advanced. In another year, the team was working directly on space flight, as had been their original goal 20 years earlier in Germany. There, team member Ludwig Roth said about the New-York-Bomber studies, "We did not fly this bomber, but it got us here anyway".

In 1950, 121 members of the team were transferred from Army Fort Bliss to its Redstone Arsenal near Huntsville, Ala., to support the now burgeoning space effort. By 1956, von Braun, having risen to Program Manager of the 4,800-man Development Operations Division, had placed his team in most of the responsible positions at Huntsville, and was himself the most visible spokesman ("Doctor Space") for the U.S. space program, touting the Redstone, Atlas, Jupiter and Saturn rocket programs and Explorer satellites. Initially, the V-2 had a significant role in their design, but this rapidly decreased as greater capability and newer technology came available.

In April 1958, NASA was created by President Eisenhower, and it was given responsibility for von Braun's division. This was capped off much later, on July 16, 1969, at the liftoff of the Saturn V three-stage rocket for the Apollo 11 mission to the moon. There, two of the original German rocket team were von Braun's guests at its Florida takeoff site: Rudolf Nebel and Hermann Oberth, courtesy of von Braun, had special seats at the Kennedy Space Center at Cape Canaveral and watched the launching of the first men to land on the moon. Oberth had retired to Rumania after the war, and continued studies of going to space.

The British in the words of team member Dieter Huzel "wanted to become familiar with the other end of the trajectory"; i.e., they focused on launching and operating the V-2, while America learned to develop it. They found many V-2s in deteriorated condition or missing guidance parts, but were given 12, prepared eight, and launched three in Cuxhaven, Germany, in October, 1945, with much German help (including Dornberger's). Present were Dr. Theodore von Karman from Cal Tech, and other Americans and Russians, as well as the press. The British-held prisoners from Peenemunde assembled the only V-2 Operating Manual (none being allowed distribution during the war to maintain secrecy). Only 20 Peenemunders chose to go to Britain, but Dornberger was imprisoned there from 1945-1947. The drastic shrinkage of the British economy immediately after the war thwarted their interest in missiles and space for a long time.

Finding V-2s was eye-opening for Russian rocketeers, since their work halted in 1932 had been barely restarted by 1944. Because Russia occupied that part of Germany where most V-2 parts were manufactured, they were able to capture 2,100 Peenemunde employees, some holding undisclosed ideas for improving the V-2. The Russians found 50 V-2 engines in freight cars, rebuilt Peenemunde, and got Peenemunders to assemble 30 V-2s by September 1946, achieving greater engine thrust by more carefully fitting parts, still using the 18-pre-cup combustor. Forty engine runs were made evaluating improved fuel/combustion systems. That month, Russia moved the

Russian R-1 being prepared for launch. (Meilerwagen copy) factory and surprised, unwilling Germans to Kapustin Yar, Russia; there, kept isolated from Russian engineers, the team remainder developed their own V-2s as R-1s. Its first flight was October 18, 1947, and the first flight of a production unit was October 10, 1948. The next step, the R-2, had accessory and component design and location suggested by the team, lowering weight, increasing performance and still using the 18-pre-cup-combustor. Development was focused on improved oxygen injection, using higher alcohol concentration, and shortening the engine. Apparently, the Russians never used the single-pre-cup combustor in their early V-2-derived designs. 1,545 R-1s and R-2s were produced in 1949-55.

After contributing much new technology to Russia (that for fuel injection being most beneficial), and inspiring Russian designs, the Germans were strangely isolated from the Russian developments, and sent back to Germany (East) between 1950 and 1958.

The Russians immediately started designing larger rockets, first to serve as weapons, and then to access space. They did so well that the first earth orbiter was put up by Russia. Their R-7 rocket (called by NATO the SS-6 Sapwood) used for these efforts was a direct descendent of the R-1, and still used German technology. 1957's Sputnik was first in space, using the R-7, and the Russians then earth-orbited Yuri Gagarin, and put the unmanned Zond 5 first on the Moon (but were not to put a man on the moon). Eight R-7s crashed before its first successful flight, this being only a month before Sputnik. The Russian effort was also led by an inspired (having read Tsiolkovsky) rocketeer, Sergei Korolev, who was at the Cuxhaven demonstration, and had sufficiently established their program that his passing in January 1966 did not slow it down. Russia in turn gave R-2's to China in 1956, it building a copy as the DF-1, which was the last V-2 derivative. China operated it for only a short time.

American rocket engines were initially independent of the V-2. The American Interplanetary Society was founded on April 4, 1930, by another bunch of Jules Verne's readers. Their first rocket was run on November 12, 1932, and on April 6, 1934, they changed their name to the American Rocket Society (ARS). The first ARS rocket engine was run in 1938. In December 1941, a few ARS members spun off Reaction Motors Inc., and in 1947 their engine pushed the Bell X-1 to supersonic speed, then evolving into a missile engine. The development of the Matador missile caused North American Aviation to form its Rocketdyne Division, which initially focused on the V-2.

Von Braun's 20+ years with NASA gave us the Saturn V, which put our men on the Moon (even if after Russia went around it unmanned). Kraft Ehricke said "Most of the V-2 development problems recurred in the later U.S missiles and rockets." Three weeks after Gagarin's orbit, Alan Shepard did it using a Redstone, and three weeks after that, on May 25, 1961, President J.F. Kennedy challenged a joint Congress session: "Before this decade is out, this nation should land a man on the Moon and return him safely to Earth." The U.S. Space Command was formed on September 1, 1982, and the U.S. Space Force was created December 20, 2019.

A U.S. movie with German star Curt Jurgens playing von Braun, "I Aim at the Stars" was made in 1959. Von Braun was not liked by everyone. His close friend, author Arthur C. Clarke, in discussing Peter Sellers' role in the 1963 movie "Dr. Strangelove" that mocked von Braun, said that "Sellers was out to get him".

V-2 being prespared for launch at White Sands with dignitaries in foreground. (USAF photo)

In March 1970, von Braun moved to NASA headquarters, hoping to be even more effective there. Feelings of upper management at NASA ranged from jealousy of his fame, competition from managers from other Centers, hatred from his being a Nazi, and irritation with his grandiose ideas of what NASA should do. Instead, he was ignored and not accepted by the Washington, D.C., crowd. Von Braun mourned at home for a while, but quit NASA in May 1972. Von Braun had made friends in Industry, and was offered and accepted a job with Fairchild Aircraft that July.

He had ignored suspicious colon polyps in 1970, contracted kidney cancer in 1973, and experienced rectal bleeding in August 1976. Von Braun left Fairchild then, and died in Virginia in 1977.

Released from British prison in 1947, Dornberger came to the U.S. as a part of "Operation Paperclip" and worked for the USAF until 1950, then moving to Bell Aircraft. He had significant involvement in Bell's proposals for the X-15, X-20, and pre-Space Shuttle activities, reaching Vice President. Dornberger retired in 1965 to Mexico, staying in contact with von Braun until his passing, and himself dying in 1980 on a trip to Germany. ✈

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Endnotes

1 Russia's Lunar 2 was the first man-made object to land on the Moon on September 13, 1959