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GERMAN MILITARY HISTORY 1914–45

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The 'Big Ben' Rocket Campaign

Germany's lethal V2 rocket assault against Britain, 1944 - 45

COVER STORY

‘Big Ben’ 973

All images via the author unless otherwise credited.

■ **Londoners get a close-up view of the weapon which had terrorised them for seven months: the V2 rocket. In September 1945, this V2 was brought to Trafalgar Square for public exhibition.** *(Colour by RJM)*

An unusual project to archaeologically investigate the impact points of V1 and V2 weapons in the UK is ongoing by brothers **Sean and Colin Welch** of the ‘Crater Locator’ team. Here, they look at a 1945 V2 rocket impact site in Kent.

There was no warning of the approaching V2 missile. Travelling at 1,100 metres per second, it plunged into an orchard at Chainhurst Farm, Marden, Kent, and exploded leaving a crater 37 feet across and 10 feet deep. It was 02:19 hours on Friday morning, 9 March 1945. The target was London, but this missile was a long way off-course.

Despite the inexorable course of the war at this-point-in-time, the V2 campaign against London was a troubling one for the British authorities. Initially, the government passed off the first few as ‘gas explosions’, but when this story could no longer be contained, the truth was revealed. Officially, in Britain, the rocket strikes were known as *‘Big Ben’* incidents.

SUCCESSFUL LAUNCH

The development of a liquid fuelled rocket by Germany surprisingly came from the terms of the Treaty of Versailles of 1919. The Allies recognised that peacetime Germany would still require the means to defend itself and restricted the number of troops and type of weapons it was armed with so that it could not become an aggressive power. The

■ **A V2 test launch, possibly at Peenemünde. The first successful launch of an A4 was in October 1942.** *(via AS)*

German Army Weapons Department therefore sought ways to increase firepower for its limited number of troops, but without violating the terms of the Treaty.

Interest in rockets by the army started in 1929, at a time when German civilian enthusiasts were building and flying solid-propellant rockets as a leisure pursuit. The Treaty did not mention rockets specifically, their development thus seen to be within its terms by Germany. Research was commissioned, and this quickly identified that solid-propellant rockets were limited in range and that liquid propellants offered greater scope.

The first test firing of a liquid fuelled propulsion unit took place in 1932, at Kummersdorf firing range near Berlin. After many failures, a unit was perfected and in 1934, the launch of a small liquid fuelled rocket, the A2, was achieved from the island of Borkum into the North Sea. The A2 had been preceded by the A1, which was not flown. Larger designs followed, with the A3 and the A4 – the A4 being the design that was later known as the V2.

The A4 – or Aggregat 4 (series 4) - had its first successful launch in October 1942, and by now a large manufacturing, development and test centre had been established at Peenemünde on the Baltic coast. Bombing by the RAF of Peenemünde in August 1943 led to the dispersion of manufacture, with assembly being transferred to the tunnel complex under the Kohnstein in the Harz Mountains, north of Nordhausen.

Originally a Gypsum mine, the tunnels were taken over in 1936 by the German Government to create a central oil, petrol, and chemical store. By 1943, the site was identified as suitable for conversion to an armaments production facility, and in late August enlargement and extension of the tunnels started, utilising slave labourers who were kept underground 24 hours a day, many of them dying in appalling conditions.

Production of the A4 commenced in late November, in conjunction with equipment installation and fitting-out of the tunnels. A hutted camp was established above ground to house the prisoners and was known as Camp Dora.

The A4 was constructed in the underground industrial complex called Mittelwerk. At the northern end of the tunnels, called Nordwerk, Heinkel 162s were produced. The southern end of the Mittelwerk complex was used for V1 Flying Bomb production.

PREPARING FOR LAUNCH

Over 500 officers and men were required in the sequence of operations leading to a V-2 launch, these split into three specialist troops, each with defined tasks.

The Fuel and Rocket Troop were tasked with the logistics of off-loading the rocket and various fuels and chemicals, using custom built vehicles, from the rail delivery point and to the assembly location for the rocket, and to the launch position for fuels and chemicals.

The Technical Troop mounted the warhead and performed checks ▶

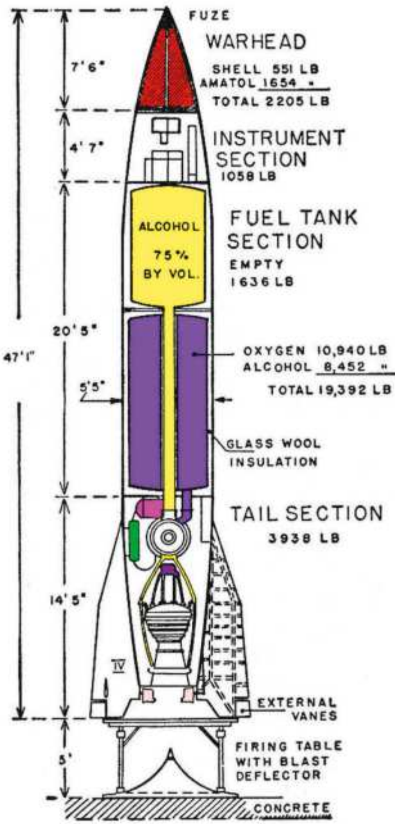
and tests on the systems. They had the technical ability to carry out field repairs to ensure the correct function of the device and moved the rocket to the launch position.

The Launching Troop prepared the launch position, each troop having three platoons - thus supporting three launch positions. They erected the rocket onto the launch table and using optical devices ensured it was vertical. Further tests of systems were performed, and the rocket was fuelled.

The launch table contained a rotating ring which enabled the rocket to be turned so that the number one fin could be precisely aligned with the line of fire to the target. Optical devices were also used for this operation. An igniter, which was an electrically initiated pyrotechnic on the end of a long pole, was placed up into the combustion chamber.

After preparation (which could take five hours), the launch position was cleared of vehicles and troops, the launch controlled from an armoured vehicle connected to the rocket with cables. Launch then commenced.

The fuel, comprising four tons of ethyl alcohol and six tons of liquid



■ A V2 on the launch table showing principal dimensions and components.

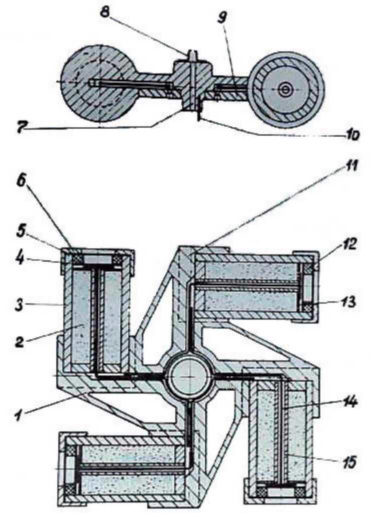


FIGURE 3
SECTION THROUGH IGNITER

KEY:

1. Plastic housing.	**9.** Cover.
2. Pyrotechnic material.	**10.** Coupling pin.
3. Cartridge wall.	**11.** Housing.
4. Washer.	**12.** Throttling disc.
5. Washer.	**13.** Ignition disc.
6. Cover.	**14.** Fuze cord.
7. Arial hole.	**15.** Fuze cord tube.
8. Safety cap.	

■ The igniter in a rather familiar pattern! That this device was in the form of a swastika was probably more by accident than by design.

■ A V2 rocket is prepared for public exhibition in September 1961 at RAF Biggin Hill ahead of its annual Battle of Britain 'At Home' open day. The four carbon directional vanes protruding into the venturi are clearly visible. *(AS)*

■ *Left:* Londoners ruefully examine the debris from a V2 air burst, the parts having been collected up and placed together in a roadway. The black triangular object in the foreground is the remainder of one of the four carbon directional vanes. *(AS)*

Sometimes, the V2 would explode or burst in mid-air prior to impact. In those instances, it was not unusual for the large combustion chamber to fall to earth relatively intact. *(Photo AS. Colour by RJM)*

oxygen, was released under gravity to the combustion chamber by opening electro-pneumatic valves. The 75% alcohol-by-volume fuel took over 25 tons of potatoes to produce and it could be a potent drink. Consequently, various measures were introduced to prevent consumption, such as the addition of purple dye and denaturing. Methanol was introduced later, and if drunk had lethal consequences. But soldiers are ever resourceful and discovered that charcoal filters from gas masks could produce drinkable results.

With activation of the igniter, the fuel commenced burning but the thrust produced was less than the weight of the fuelled rocket. To increase thrust, potassium permanganate and hydrogen peroxide were mixed to initiate a violent chemical reaction producing large volumes of steam. The steam was piped to a turbine powering a pump for alcohol on one side and liquid oxygen on the other. So powerful was the turbo-pump, that it could shift 10 tons of fuel in less than one minute. With fuel under pressure, a thrust of 25 tons could be achieved. This enabled lift-off and connections to the launch control vehicle were disconnected. All aspects of function were now under the autonomous control of the rocket.

Beneath the warhead, and above the alcohol tank, a four-sectioned compartment contained the various devices needed to provide this control. The first four seconds of flight were vertically upwards, a timing circuit then moved the reference table for the main gyroscope, so the pitch of the rocket was at 47° to the vertical. Four graphite vanes in the rocket exhaust, and small air rudders at the end of the fin's trailing edge, provided steering and held the rocket in a straight line.

A device called an integrating accelerometer measured velocity, and when a pre-set velocity was reached, Brennschluss (close of burn) was initiated by moderating the thrust to 8 tons for a few seconds and then closing the fuel valves. In just over 60 seconds, the rocket had accelerated to Mach 5 and was 35 km (22 miles) high. The rocket continued upwards to an altitude of around 88 km (55 miles) before dropping back to earth in a parabolic curve - rather like an artillery shell. Falling back through the increasingly heavier atmosphere created friction and heat, with temperatures on the external steel skin reaching up to 640 °C.

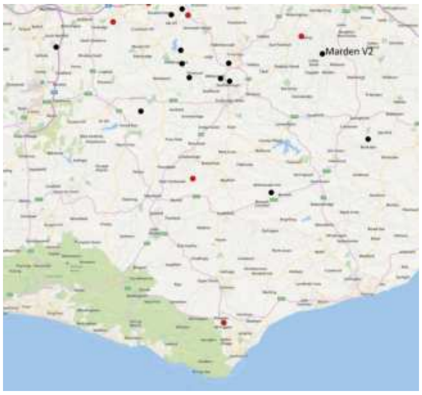
The heat of re-entry could cause fuel tanks to explode and rockets to break up, but a solution was found by packing the space between the fuel tanks and external skin with glass fibre, held in place with one-inch chicken wire. However, break-ups still occasionally occurred. The terminal velocity was between Mach 2.8 and 3, and with its impact fuse the rocket could be three metres into the ground before detonation. A proximity fuse would have been more effective but it was never developed. Although it was considered.

HIDDEN LAUNCH SITES

At 02:13 am (British time) on 9 March 1945, Batterie 1./485 launched the rocket that would fall at Marden six minutes later and 283 km (176 miles) away from Statenkwartier, Den Haag. It was the 973rd such missile recorded as falling on Britain or in its immediate coastal waters.

The hidden launch sites at this location were along the hard standing for tramlines that were surrounded with trees, or in small woodland areas of parkland. Branches and leaves offered some camouflage to preparations for launch, but in winter this was not the case.

Because of the lack of natural camouflage, launches were increasingly undertaken in darkness to protect against roving Allied fighters armed with cannon and bombs. Just a few days earlier, an RAF bombing raid on the Haagse Bos rocket assembly and storage area of the Hague highlighted the danger. Then, the bombs fell on the Bezuidenhout residential area, causing many civilian



Plot showing V2 impacts in SE England, red for day and black for night.

and refugee deaths.

But could the launches carried out under the cover of darkness provide a clue as to why the Marden rocket was so far off-course?

As part of launch preparations, a survey team used optical devices to determine the rocket was vertical and aligned to the target, the use of torches being recommended to facilitate this at night. In reviewing the procedure, it is clear that the distance at which the reference points had to be read, and the accuracy required, would be difficult to achieve in darkness and with weather conditions sometimes affecting visibility.

Analysis of the times of fall of V2s across Kent shows the majority of these to have been night launches, and off-course.

DISTORTED BY HEAT AND IMPACT

A comprehensive archive record of the V2 rocket impact at Chainhurst, Marden, exists, including a clear contemporary aerial photograph and a site visit was made in April 2017. With permission from the landowner, a non-invasive field walk survey was carried out and it was discovered that a drainage ditch running along the southern edge of the field (then under crop) had recently been cleaned out. Among removed debris, the unmistakable evidence of a V2 rocket impact emerged: a piece of heavy-

Valentine's Day Encounter

Raymond Baxter became a household name in Britain in the post-war years as a broadcaster and TV personality. During the Second World War, however, he was a Spitfire pilot with 602 Squadron who had a uniquely 'close Encounter' with a V2 rocket. This event is the subject of our stunning cover artwork by Keith Burns.(inset below)

Raymond Baxter later recalled:

"Together with the similarly-equipped Nos 229, 453 and 603 Squadrons, we were given the task of maintaining vigorous patrol activity over the area from which the rockets were coming, mainly around The Hague – we dubbed our quarry 'Big Ben' sites. If V2 activity was spotted, we were given the clearance to sort it out immediately, but the Germans were masters at camouflaging these extremely mobile sites.

"In attempts to keep the pressure on the enemy, we were given a wide-ranging brief, and as we knew the Germans were short on fuel, any vehicle caught on the road in Holland was invariably assisting the war effort. We therefore 'shot at anything that moved' but went to great pains not to endanger Dutch lives.

"We also carried out pre-planned strikes on rocket storage areas and launch sites, based on information fed to us by the Dutch Resistance. We often had to rely on their accurate assessments of these targets, as from the air little more than wheel tracks at most could be seen.

"Our usual force on a typical anti-V2 mission consisted of four to six Spitfires loaded with a single 500 and two 250lb bombs, or just the latter with a centreline fuel tank. Once we departed RAF Coltishall, or its satellites at Matlaske, Ludham or Swannington (from where we operated for much of the campaign), we headed over the North Sea, climbing to 8,000 ft. As a formation leader, one had one's hands full navigating a bloody long way over an expanse of water that had already claimed our previous CO ['ace' Squadron Leader 'Chris' Le Roux] just weeks before. Our navigational aids consisted exclusively of a map and a compass, and visual aids in the North Sea are few and far between! We quickly got to know the shape of the sand banks off the Norfolk coast, however, which gave us the means to check our drift since setting course after take-off and forming up.

"As we crossed the enemy coastline, we were traditionally greeted by flak thrown up by 88 mm anti-aircraft batteries, although these were easily evaded in a Spitfire as long as one continually altered direction and altitude in long gently climbing or diving turns. The V2 sites themselves were guarded by light flak, and we would vary our attack profiles to suit the weather and target layout. Occasionally, we would attack straight away. On other sorties, we dodged in and out of cloud until in the most favourable attack position. Our last strike method was to overfly the target as if we hadn't seen it, then reverse course a little way away and come in out of the sun.

"One mission I remember vividly. On 14 February 1945, Valentine's Day, we caught the V2 crew well into their launch countdown. We had already dropped our bombs, and my 'No 4'* turned back into the target to perform a strafing attack when the V2 came climbing out of the clump of trees immediately in front of us, belching flame.

"He re-sighted his guns and fired a long burst at the rocket, but fortunately his attempts at becoming the first person to shoot down a ballistic missile in flight met with failure, for the resulting explosion might well have taken all six Spitfires down with it!"

*Appropriately, for the date of this event, the 'No 4' pilot was Flight Sergeant T L 'Cupid' Love of 602 Squadron.

Our thanks to Tony Holmes for the information included in this panel.

gauge distorted aluminium fuel tank, annealed by heat and impact.

The land was subject to a countryside stewardship scheme which specifically forbade metal detecting or digging at this location. Thus, any thoughts of excavation were placed aside. In 2018, we were approached by a TV production company who wanted to make a documentary about the V2 rocket for National Geographic, their intention being to include our archaeological analysis. This resulted in the review of many sites studied, including a re-evaluation of the one at Marden. Whilst Marden was not chosen for this filming, a site visit with the production team and landowner allowed a non-invasive magnetometer survey which gave strong readings. This survey was carried out in the winter, on the bare field and while the ground was very wet.

An application was kindly made by the landowners to Natural England for permission to fully excavate the site, and this was ultimately granted - in time for a separate request (from the BBC) to feature our work in a documentary.

The excavation was scheduled for July 2019, on the unplanted field. Work began with a full metal detector GPS survey to determine the shape and extent of the impact blast field.

■ *Left:* A 1945 aerial image of Marden, clearly showing the V2 impact crater.

■ *Below:* The first evidence of the V2 found near the impact point: a piece of its fuel tank.

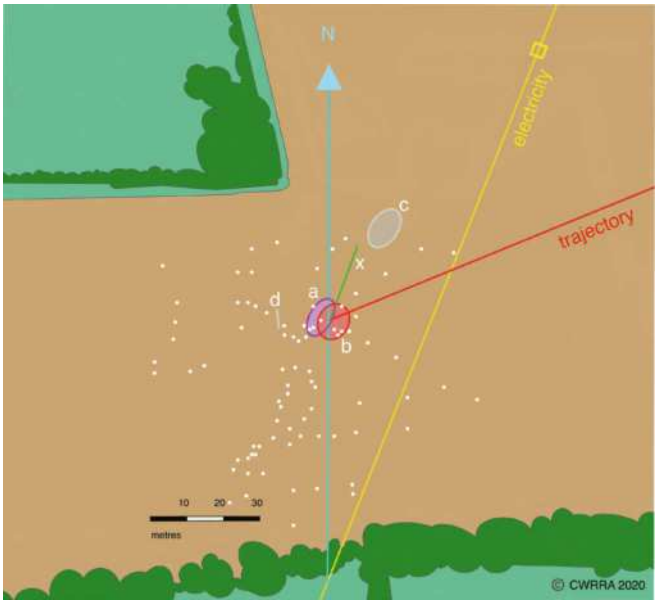
This achieved a clear picture, with fragmentary evidence of the V2's impact and detonation surrounding the presumed location but manifesting to the south and west of the site.

A fresh magnetometer survey gave a slightly different result than in 2018, either due to the now dry condition of the soil, or a shifting of the GPS machine's relationship with overhead satellites at the time. This also identified two further unrelated anomalies. To the west, a line of metal irrigation pipes, and to the north-east a reasonably strong response of the correct dimensions. However, non-related surface finds and a lack of V2 blast debris surrounding it led to the conclusion that it was probably an area of deposited refuse.

To achieve a clear idea of the incoming trajectory of the V2 as an excavation planning tool, and also for visitors to the excavation, which included two secondary schools and daily live broadcasts to Marden Primary School (who took a very keen interest in the project), an accurate analogue compass was used to deduce the 67.8°T bearing. This was physically marked out on the field.

With new equipment added to the team's array of analytical tools, each item has proved its worth. For this excavation, it was the turn of a drone and it was only later, when we reviewed our drone footage, that we realised there was something very

■ The original detonation crater at Marden, clearly revealed after scraping back the topsoil.



■ ***Left:*** **The Marden V2 site plan showing the blast field survey (white dots), (a) winter (wet) magnetometer survey, (b) summer (dry) magnetometer survey, (c) unrelated area of refuse, (d) irrigation pipe, and (x) the false compass trajectory reading.**

■ ***Right:*** **The blast damaged remains of a fruit tree recovered from the impact crater.**

strange about the compass reading. The first scrape over the chosen magnetometer target (b), using a mechanical excavator had produced a very convincing and well-delineated crater shape.

However, the axis of the crater appeared to be different to the compass reading. After much deliberation, it appears that high-tension electricity lines running close to the site had deflected the compass needle by 48°, so the trajectory reading ran parallel to the power lines, when in fact the true reading ran underneath the cables.

EVIDENCE OF THE BLAST

Having established the crater outline, the excavator was positioned on the north-eastern corner of the crater to begin working downwards in levels. Among the first relevant finds to emerge (at 0.8 metres) were the stumps of fruit trees present in the orchard at the time of the rocket's impact. Several showed evidence of the blast.

Below this, it became clear that any idea of hand trowelling would

■ **The conserved burner cups from the Marden V2.**

■ **The conserved oxygen feed to the combustion chamber-head from the Marden V2.**

■ **A contemporary image of a recovered combustion chamber showing the burner cups around the central oxygen inlet.**

■ **The conserved turbo-pump shaft and remains of rotor disc from the Marden V2.**

■ **A contemporary image of a recovered turbine rotor and shaft.**

be completely impossible since the sub-soil was an extremely dense yellow and progressively blue-grey clay. While possible to record some finds in situ, the only option became to remove quantities of clay to the surface by excavator for later analysis.

Down to 2.0 metres depth, only modest finds (compared to other sites) that came from above the V2's combustion chamber emerged. These were fragments of fuel tank, turbo pump and associated pipework.

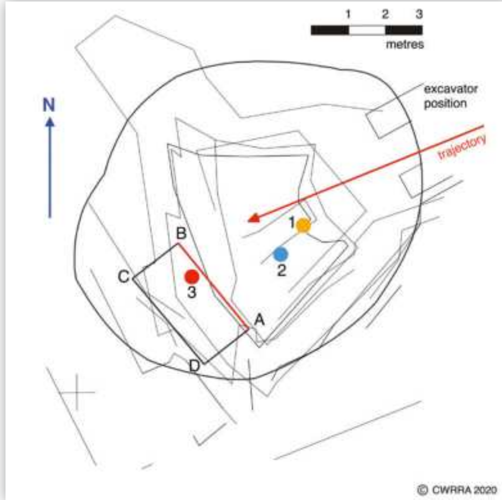
From this level to 3.0 metres, representing the crater contour bottom surface, and deeper than recorded by Air Ministry inspectors at the time, more components relating to the combustion chamber were discovered. In previous V2 excavations, the burner cups which processed liquid oxygen and alcohol into the combustion chamber (fitted in a rose-pattern of 18 on its top) have been found in concentrated areas. However, in this case, they were dispersed across the bottom of the crater floor, some completely fragmented.

At 3.6 metres depth, the central spline shaft, still attached to the turbine rotor disc from the turbo pump, was discovered. Parts of the turbo pump had previously

■ **The carbonised layer discovered during site archaeology, shown in section.**

■ *Left:* The largest find, the conserved remains of the lower combustion chamber.

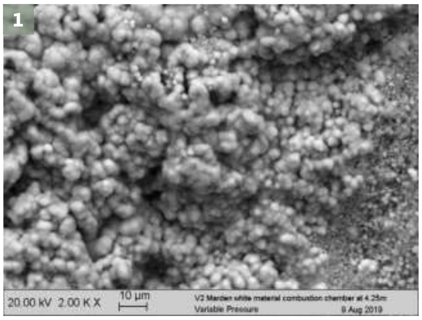
■ *Right:* The Marden V2 excavation plan showing the crater outline, digging phases and the detonation residual layer (A, B, C, D). Major items recorded in situ were a burner cup (1) at 3.2 m (orange dot), turbo pump central spline shaft and disc (2) at 3.6 m (blue dot), and lower combustion chamber section (3) at 3.6 m (red dot).

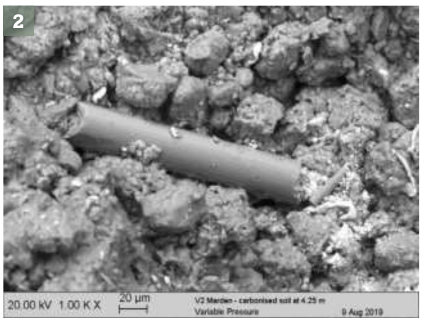


represented the deepest finds in V2 excavations.

At the end of the second day of the excavation, the vertical section in the south eastern quadrant produced a clearly delineated dark 15 cm thick line of carbonisation across the section, from left to right, and progressively lower to the north of the crater.

This feature was carefully studied on day three, revealing a most extraordinary detonation residual layer. The area measured 3.05 m x 1.6 m, and while it represented an excavated rectangle, no part of it was level in any dimension. All four corners reached different heights and depths. Resting on this burnt layer was a sizeable section of the lower combustion chamber, the largest find of the excavation.

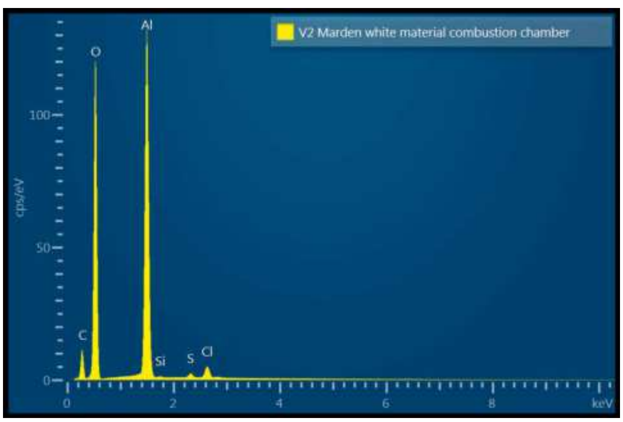




INCOMING TRAJECTORY

Soil and material samples from the top surface of the burnt layer, and the area around the lower combustion chamber at the detonation residual layer, were submitted for scanning electron microscopy and dispersive energy x-ray elemental microanalysis. The intention was to assess environmental residues. This study produced remarkable images.

The excavation followed the general pattern of finds and depths that appear in the range of crater sizes examined elsewhere. It is noticeable that although there may be variation as to where the major finds are in relation to the incoming trajectory (left or right), in all cases, the heaviest finds appear in an area perpendicular to the further surface of the original crater edge.

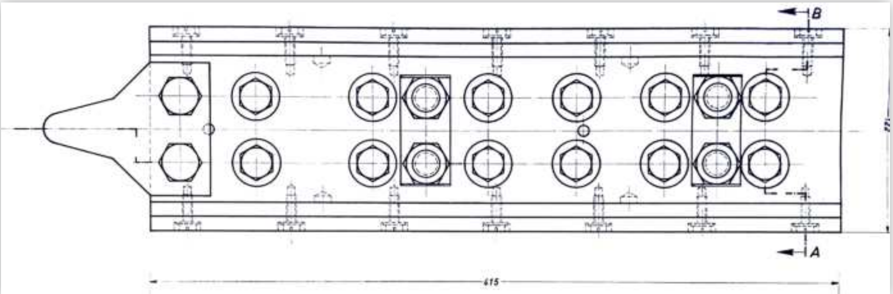


■ **1:** **At 2,000x magnification, this sample, which appeared white in situ, has a very consistent 'oolitic' (egg like) nature and appears to have been precipitated. The spectrum analysis (below) shows that in composition the material is either aluminium oxide or hydroxide.**

■ **2:** **In situ, this sample appeared to be carbonised soil. The magnification is 1,000x, and shows sub-angular material (boulder shapes) with a fine bright powdery material with some spots of iron present. The white 'fingers' are probably fungus. The general material is a shattered clay or silicate, ground up with pores in it, different to the usual appearance of clay which has been created by wind or water. There is also evidence of carbon amongst the glassy or fused structure. The most obvious feature is the long cylindrical object in the centre. This is a piece of 'ceramic' or 'glass' fibre from the insulation material used in the V2.**

■ ***Left:*** **Spectrum analysis reveals oxidised aluminium.**

■ **Locating key and shoe from graphite vane.**



■ **Locating key and shoe from graphite vane.**

The conservation of the 709 kg of material from the excavation was a lengthy and sensitive process, with the object of removing excess oxidisation but retaining surface patina and any critical evidence.

The immediate observation concerning the finds is of the heavy duty, solid construction of parts, with welds used rather than rivets or nuts and bolts. The second observation is the immense energy released at impact and detonation which tears and shreds large assemblies into small pieces.

Although this is hardly surprising. The robust construction of mechanical units, designed to withstand 25 tons of thrust and supersonic speeds, contrasts with delicate electrical components connected with wiring no thicker than internal telephone wire.

Thick clay at the impact site minimised surface oxidisation by the exclusion of air and moisture, and this revealed detail on the finds not seen so clearly from other sites. Machining marks, Waffenamt codes (WaA: the German military inspection proof mark) and armament supplier codes are very clear.

Following conservation, the finds were photographed and catalogued with MDA coding applied.

SECRET ARMAMENT CODES

Of particular interest were armament supplier codes which have given an insight into the vast web of manufacturers feeding the assembly of the rocket.

The use of codes originally began around 1925, during covert re-armament, from non-permitted companies and outside the terms of the 1919 Peace Treaty. A new system of three lower-case letters was implemented in 1940, the benefit being that the origin of equipment or ordnance examined by an enemy would have untraceable origins and thus be concealed from attack.

An American document "ETO ORDNANCE TECHNICAL INTELLIGENCE REPORT NO. 270, 8 MAY 1945. V-2 Assembly Plant at NORDHAUSEN, Germany" states that:

"Although in the beginning many sub-assemblies such as tail sections etc. were made elsewhere in Germany and sent to Mittelwerk for final assembly, the plant could and did manufacture every part and component for the V-2, with the exception of small electrical and radio parts and control gyroscopes. The plant was in every sense tooled for mass production."

The Nordhausen complex, comprising 20 km of tunnels, was discovered by the Americans on 11 April 1945, its significance quickly realised. However, it lay in the zone allocated to Russia in the Yalta Conference and where Germany, post conflict, was divided into four zones of occupation. The Americans had only a short time to learn what they could from the tunnels before handing over to the Russians. Analysing manufacturing capabilities in the time available would have been challenging indeed.

It has since become clear that major ▶

■ **A wider view of the Marden excavation in 2019.**

internal components of the rocket - such as warhead, gyroscopes, fuel tanks, turbo pump and combustion chamber - were manufactured elsewhere. Mittelwerk had facilities to re-machine units that failed the exacting inspection of delivered parts, and it is this which probably gave the Americans the impression of it being a prime manufacturing site.

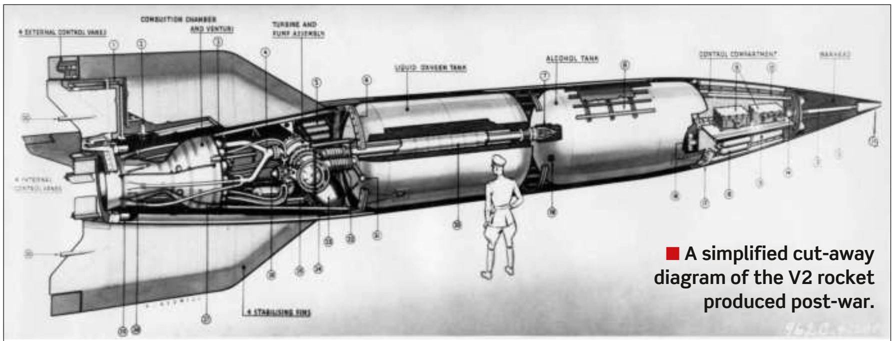
What was surprising was that small components and sub-assemblies were manufactured right across the invaded and annexed lands of the Third Reich. A good example is provided by examination of supplier codes found on the remains of the Marden V2's combustion chamber.

The steel burner cups have a series of markings, many not visible on final assembly of the combustion chamber/thrust unit. The internal surface of each cup held 44 phosphor-bronze injector nozzles in addition to 24 drilled holes for alcohol delivery and a large brass central rose for oxygen.

Three separate supplier codes were found on the alcohol injectors: *bgq, bmz and csl*. These all decode to suppliers that were in what is now the Czech Republic: respectively, Batá Maschinenfabrik AG, Zlin; Minerva Nähmaschinenfabrik AG, Werk Boskowitz and Prager AG, Werk Kolin.

It is interesting to note that codes were applied with individual letter punches, one cup showing that the final "u" has been applied upside down and appears as "n".

Finally, the combustion chamber wall has the marking *Be* which appears to follow the pre 1940 coding principles. If so, this would be the Berndorfer Metalwarenfabrik Arthur Krupp AG, Berndorf, Austria. But, as combustion chambers were manufactured by Linke-Hoffman-Busch-Werke AG, Breslau, Poland, this seems unlikely. Manufacturer's codes on other parts, where space was available, always have Waffenamt stamps alongside them, and because there is no WaA code with the *Be* stamp it could simply be an internal works inspection marking.



■ A simplified cut-away diagram of the V2 rocket produced post-war.

KEY:

1. Chain drive to external control valve.
2. Electric motor.
3. Burner cups.
4. Alchol supply from pump.
5. Air bottles.
6. Rear joint ring and strong point for transport.
7. Servo-operated alcohol cutlet valve.
8. Rocket shell.
9. Radio equipment.
10. Pipe leading from alcohol tank to warhead.
11. Nose probably fitted with nose switch, or other device for operating warhead fuze.
12. Conduit carrying wires to nose of warhead.
13. Central exploder tube.
14. Electric fuze for warhead.
15. Plywood frame.
16. Nitrogen bottles.
17. Front joint ring and strong point for transport.
18. Pitch and azimuth gyros.
19. Alochol filling point.
20. Double walled alcohol delivery pipe to pump.
21. Oxygen filling point.
22. Concertina connections.
23. Hydrogen peroxide tank.
24. Tubular frame holding turbine and pump assembly.
25. Permanganate tank (gas generator unit behind this tank).
26. Oxygen distributor from pump.
27. Alcohol pipes fro subsidiary cooling.
28. Alcohol inlet to double wall.
29. Electro-hydraulic servo motors.
30. Aerial leads.

V-2 'A-4' ROCKET SPECIFICATIONS

■ **Mass:**	12,500 kg (27,600 lb)
■ **Length:**	14 m (45 ft 11 in)
■ **Diameter:**	1.65 m (5 ft 5 in)
■ **Warhead:**	1,000 kg (2,200 lb); Amatol (explosive weight: 910 kg)
■ **Detonation mechanism:**	Impact
■ **Span:**	3.56 m (11 ft 8 in)
■ **Propellant:**	3,810 kg (8,400 lb) 75% ethanol. 25% water. 4,910 kg (10,820 lb) liquid oxygen.
■ **Operational range:**	320 km (200 miles)
■ **Flight altitude:**	88 km (55 miles) maximum altitude on long-range trajectory. 206 km (128 miles) maximum altitude if launched vertically.
■ **Maximum speed:**	Maximum: 5,760 km/h (3,580 mph) At impact: 2,880 km/h (1,790 mph)
■ **Guidance system:**	Gyroscopes to determine direction. Müller-type pendulous gyroscopic accelerometer for engine cut-off on most production rockets.
■ **Launch platform:**	Mobile - Meillerwagen.

THE V2 AS A WEAPON OF WAR

The V1, carrying a similar sized warhead to the V2, glided down and detonated causing a blast that spread over a large area because it did not penetrate the earth. The V2, as already observed, penetrated to depth before exploding, creating a large crater, channelling the blast upwards. A direct hit by a V2 was devastating, causing immense destruction. However, it was not accurate and the mean point of impact against London was 10 km to the north-east of the City of London. Nor did it have the precision required to consistently hit London and its surrounding conurbation, the spread of the fall of shot being in the order of three times greater than this area. As a result, many rockets fell on farmland, in woods or water.

The V2 also consumed resources and skilled manpower that could have

■ Fragment of wood from a fruit tree, dragged down to 3.5 metres inside a piece of wreckage.

■ *Right:* Manufacturer's codes on injectors. The steel burner cups were marked *bpu*, for Hofherr-Schrantz-Clayten-Shuttleworth, Landwirtschaftliche Maschinenfabrik AG, Vienna XXI, Austria.

■ Markings on burner cups.

■ The Final "u" on the burner cup manufactuer's code has been accidentally applied upside-down.

■ The "*Be*" marking on the combustion chamber wall.

■ The Waffenamt stamp alongside the manufacturers' code.

been used for the manufacture of conventional armaments. Comparison between the cost of the V1 and V2 have been made that put the V2 at a factor of 100 times the cost of the V1 – thus, the drain on resources was 100 x greater than the V1 for the delivery of the same amount of explosive. So why did Germany continue with the V2 above all else?

The spectacle of the launch, the secret weapon that would win the war, and which, once launched, was unstoppable, must have bolstered German morale when the war was all but lost. The regime understood that the mood of the people was vital in fuelling determination for the continuance of the war. But in pursuing the V2, and allocating resources away from defence projects, that *perhaps* helped bring about an end to the conflict sooner. The technicians working on an anti-aircraft liquid fuelled rocket, Wasserfall, were laregely re-allocated to the V2. It could be argued that the development of weapons to counter the vast armadas of Allied aircraft in round-the-clock bombardments might have been a better use of resources.

The archaeological study of the remains of the V2 which fell at Marden, and the examination of its impact crater, tells us much about the weapon itself and the effects of its detonation. In the instance studied, no deaths or injuries resulted directly from the explosion.

However, the casualty figures exacted by the V2 campaign in Europe, and the death toll among those who built them, or who were affected by Allied attempts to disrupt rocket construction, was a truly terrible one.

V2 - The Human Cost

On 26 October 1944, 53 people were injured when a V2 fell in front of a train at Palmers Green station. The crater left by the blast was reported to be 60ft wide and 30ft deep, although trains were running again after two days. *(AS)*

17/18 August 1943: RAF bombing of Peenemünde. 735 killed including 557 foreign workers, mostly Polish.
1943/1945: Construction of Mittelwerk and the assembly of V2s' estimated to have cost the lives of 20,000 slave labourers, although the movement of many prisoners from concentration camps in 1945 to the area has added to the figures.
3 March 1945: RAF bombing of Bezuidenhout, Netherlands. 511 killed, 344 injured, 20,000 made homeless. Target was V2 assembly and storage, but a residential area was hit.
3/4 April 1945: RAF Bombing of Nordhausen killed 1,500 sick prisoners from Camp Dora who had been left to die at the Boelcke Kaserne barracks. (Over 7,000 people were killed in Nordhausen town).
V2 campaign against London: In total, 2,754 people were killed and 6,523 seriously injured. The first V2 struck London on 8 September 1944, the last on 27 March 1945.
V weapon campaign (V1 and V2 combined) against mainland Europe targets: 3,736 killed and 8,166 wounded. The largest loss of life in a single V2 impact being in the packed Rex Cinema, Antwerp, 16 December 1944, 576 killed, including 296 Allied servicemen.

On 27 November 1944, a V2 struck Antwerp killing 126 people including 26 British soldiers in a military convoy. This was the grim aftermath. *(AS)*

The awesome power of the V2 blast is demonstrated by this railway line which has been blasted into a tree some distance away after the Palmers Green impact. *(AS)*

FOOTNOTE

I have known Colin and Sean ever since they demonstrated both their passion and skills at recording a crashed Second World War airframe, a project licensed under the Protection of Military Remains Act 1986.

Their commitment to best practice and a passion for their subject is noteworthy, and the skills they display in tenacious background research is something I would commend in all archaeologists. Their project examining the V-weapons is a fascinating one and provides incredibly valuable new information on a subject that will interest many. Long may their work continue.

Richard Osgood ***(Senior Archaeologist, Defence Infrastructure Organisation, Ministry of Defence.)***