A note about the V1 and V2

Tony Davies, King's College London, written *October 2014 to October 2015*

V1 at the Imperial War Museum London

The German V1 'flying bomb' of World War Two, sometimes incorrectly called a 'rocket', was a small (~ 8 metre long) pilotless jet aircraft which could be characterised in modern terminology as a Cruise Missile, since its role was to fly to a specified location in enemy territory and there deliver its payload - normally a substantial (~ 850kg) explosive warhead of Amatol (a mixture of TNT and ammonium nitrate) to cause extensive damage, but sometimes packages of propaganda leaflets. Since the location of the explosion could not be predicted with accuracy, it was not for use against specific targets, but to cause general destruction (area bombing), and, particularly, intended to create fear in the civilian population (e.g. it could also be classified as a 'terrorist weapon').

The German V2, on the other hand, was a rocket, a surface to surface ballistic missile from which modern ballistic missiles and many of the rockets of the space programme are descendents.

There was no defence against the V2 once it was launched, so that destruction of its launch sites or supply cnains was the only possibility. Less well known is the German V3, a nine foot long dart-shaped shell fired from a long-distance gun with a 416 foot barrel (in the form of a multi-charge cannon, which has additional propellant charges injected along its length to speed up the departing shells), planned to be capable of firing 600 shells per hour. This costly project seems to have had the strong support of Hitler, who believed that by firing from the French coast, it could completely destroy London, and finally enable Germany to win the war. A scientific basis for its proposed performance seems to have been missing and in any case, preliminary attempts to build the gun were destroyed in British bombing raids by Lancaster bombers [7].

Initial ideas for the V1 type of weapon seem to have been in the mid 1930s, and the work was discouraged by the German Air Ministry as unlikely to succeed. They apparently considered that the guidance method was inadequate to result in a hit on a precisely-designated target. If so they were almost certainly correct. However, the designers persisted and persuaded them, final work was done in great secrecy at Pennemünde, initial work having been transferred there because it was a lightly-populated area, so easier to preserve secrecy. Target-accuracy was not important in the actual application to attacking towns, where almost any explosion-location could be expected to achieve extensive destruction and loss of life.

There were many variants of the V1, since it was still being 'developed' when first used against London in June 1944. Many novel ideas were tried out, which often had not been perfected, and many launches failed. During the first night when a few V1s were launched over south east England, most doing little damage, the first V1 to reach London exploded in Grove Road, Mile End at 0425 on the morning of 13th June 1944. It was one of ten launched that day, of which five crashed immediately, and four reached England).

Initial British reaction was that V1 damage would be minimal, but this estimate was soon realised to be false, since a couple of days later, 244 missiles were launched, of which it is estimated that 155 reached the English coastline of which 73 reached London [10]. The scale of the damage that the V1s would cause then became apparent

After the last use against London in March 1945, and when most of the launch sites had been destroyed by RAF and American bombing or reached by the Allies, many V1s (and V2s) were used against Antwerp. The bombing of railways in France had a large effect, by preventing supplies reaching the launch sites. The V1 and V2 bombardment of Antwerp did considerable destruction and yet does not seem nearly so well known as the attacks on London. Altogether 628 V1s are recorded as falling on Antwerp, with a similar number of V2s. Reporting at the time was forbidden, in order to prevent the Germans knowing how successful it was. Antwerp V1 data: Oct.1944: 27; Nov.1944: 64; Dec.1944: 110; Jan.1945: 117; Feb.1945: 224; Mar.1945: 86.

According to Gough [1], Germany launched 10526 V1s against England, 7437 were detected by radar, 5648 crossed the coastline, and 3959 were successfully intercepted. I assume that those for which the launch was unsuccessful are not included in this data, and 'successful' means those destroyed both by aircraft and anti-aircraft guns. Reports say that in London, 6184 people were killed by V1's and 17981 seriously injured.

V1 photographed over Europe (France or Belgium)

The use of 'V' was for *Vergeltungswaffen* (retaliation-, vengeance-, retribution- weapons). For development purposes it was called '*Flakzielgerät*' (flak aiming apparatus, e.g. anti-aircraft-gun target apparatus), with the intention that this codename would hide the real purpose. The code name FZG 76 was often used (to help the secrecy). 'Flak' was an abbreviation of F*lugzeugabwehrkanone* ("aircraft defence cannon") and in British use, came to mean any gunfire aimed from the ground at incoming fighters and bombers.

The V1 was known in Germany as *Kirschkern* (cherry pip), Maikäfer (Maybug) and Krähe (Crow) while the British gave it a number of mostly derogatory names, principally 'doodlebug'. It was a wood and metal structure, the actual identification name being Fieseler Fi103. An objective was to use inexpensive materials, since there would be no recovery after successful use. Once aware of it, British Intelligence gave it the code name 'diver', and Churchill referred to it by the name 'robot'. It is said that the German name of Maikäfer was replaced by V1 from 24th June 1944, [10, p271] in order to create an impression that it was only the first of a sequence of 'wonder weapons', {V2, V3, V4, ...} which would lead to a German victory. The V2 did, of course, follow, and there was a planned V3. The V1 was normally launched from a low-angle ramp pointing in the general direction of the target, and it was these ramps (observed by reconnaissance flights and described in some intelligence reports from agents) which provided the first awareness of the V1 development plans, though it was not understood what the ramps were for. The V1 travelled up the ramp on a sled, which dropped away after the V1 was airborne.

The V1 used a pulse-jet engine, mounted in a tube above the fuselage. When running, it burned petrol (gasoline) stored in the fuselage and the front of the tube had intake shutters which opened and closed rapidly to control the air supply. The air-jet operated in a pulsed mode at about 50Hz, leading to a characteristic easily recognised sound. The engine was started while the V1 was on its ramp, and when running adequately, the V1 was catapulted off the ramp.
Having very small wings, the V1 had a very high stall-speed, so that it could not take off unaided in a short distance. Later, versions were launched from modified Heinkel He-111 bomber aircraft (about 1000 towards England between July 1944 and Jan 1945).

The rudder on the V1 illustrated above has '*Nicht anfassen*' (do not touch) written on it, which seems sensible advice, and alongside is written: '*Stutzkeil hier einsetzen*' (use nozzle-wedge here?), '*bei Transport und bei abgen Abdeckblech*' (during transport load the metal cover?) and '*vor der Start entfernen*' (remove before starting?). The launch catapult process was achieved by using hydrogen peroxide and a potassium permanganate oxidiser (catalyst) which generates steam to propel the V1 along the ramp.

	
Engine mounted above fuselage	*Rudder and flaps on tail*

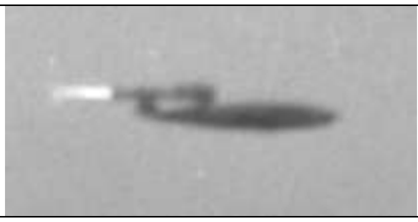
In level flight the V1 had a speed of around 400mph, which was too fast for many fighter aircraft of the time to catch up with it. The Gloster Meteor jet was one exception, being capable of 600mph. Some Spitfires were specially modified by removing armaments, etc. to make them lighter and capable of greater speed.

V1 (replica) on ramp (Imperial War Museum Duxford)

Some success against the V1 was achieved by flying alongside and tipping it from the wingtips, which would make its flight unstable and cause it to crash, and perhaps explode in an unpopulated area. It was not necessary to make contact, simply having the wingtip of the fighter slightly under the wingtip of the V1 could be sufficient to make the V1 unstable. This was actually a safer idea than firing a cannon at the warhead since the explosion could destroy the attacking aircraft as well.

Recorded successes against V1s directed at London are: Tempest 638; Mosquito 623; Spitfire 303; Mustang 232. (source *Wikipedia*). The British development of the radio proximity fuse by Butement and others may have helped to destroy incoming V1s.

The V1 had a range of about 150 miles, so the launch sites needed to be along the French coast in the Calais area in order to reach towns in south-east England, London being the primary destination.



V1 in flight (clip from British Pathé film, probably copyright)

The Pathé news photo shows the flame which came out from the jet engine: that was easily seen and enabled the V1 to be easily identified by Observer Corps personnel, etc.

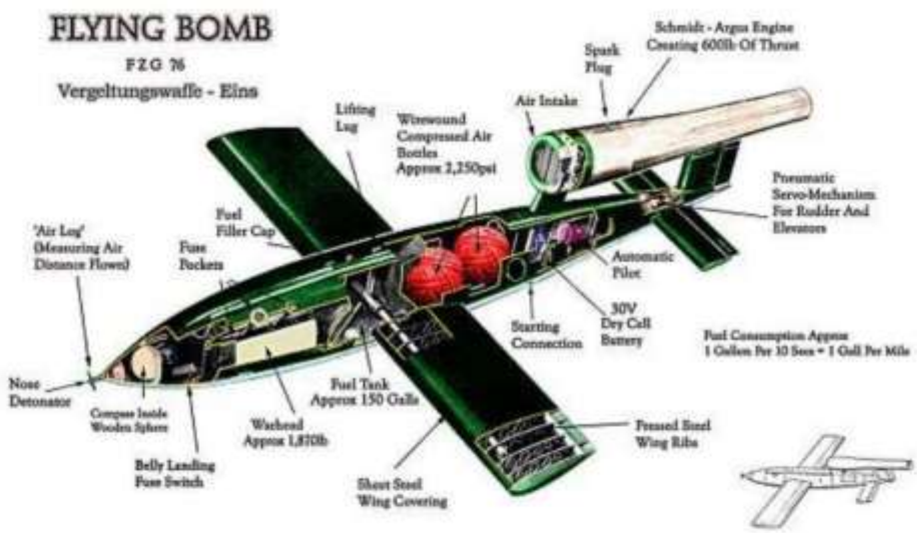
Although later there were plans to have a version with a pilot (who would be ejected before reaching the destination and might survive) or to control the V1 by radio from the ground, the V1s in general use had a simple autopilot and odometer for guidance, which were set for the required target location before launch.

The autopilot used two gyroscopes driven by compressed air, one linked to a magnetic compass for corrections, and controlled the flight by means of the tail rudder and tail flaps (the wings had no control surfaces). A swinging pendulum linked to this gyrocompass controlled the pitch, to maintain level flight and there was no mechanism to roll the V1 when changing direction: the rudder controlled the direction but the V1 was supposed to remain level during changes (e.g. no banking took place). Compressed air was also used to adjust the flaps.


Cut away side of V1 showing parts of Autopilot (Science Museum London)

		
Propeller for counter		*Nose and warhead*

The odometer comprised a mechanical counter, set to an initial value according to the range required, and a small propeller (anemometer) in the nose stepped the counter down to zero. On reaching zero the warhead was armed, and various other actions (including detonation of a small charge to destroy the connections from the autopilot to the control surface) put the V1 into a dive. The design was done by Askania company. The dive angle of the V1 stopped the fuel flow to the engine (which seems to have been an unintended effect). This led to the well-known view of the British public that while the engine continued to run, that was 'good news' because the V1 would keep on flying whereas if the engine stopped, that was time to run for cover. The British Home Secretary informed the public by radio about this useful 'warning signal' of the engine stopping. To broadcast this information may have been unwise, because it is believed to have resulted in modifications to some V1s to enable some to be silenced well before their crash and explosion and others to have their engine running right up to the crash [6].



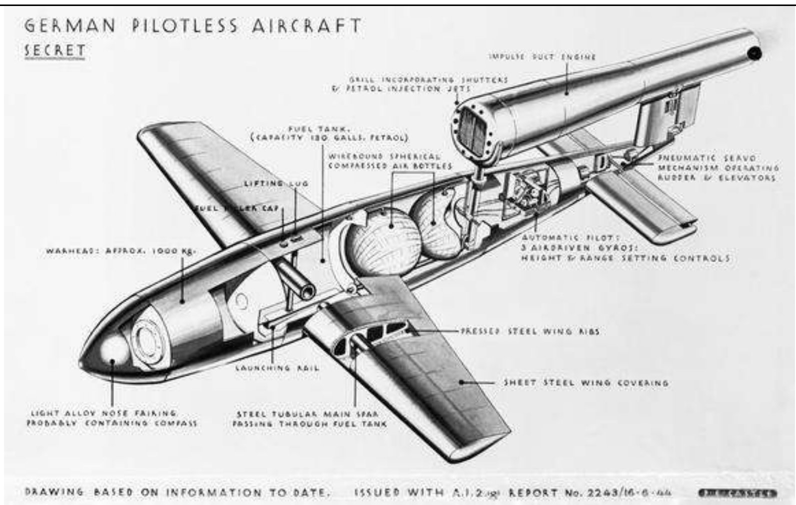
V1 internal parts [2]

The warhead detonated as the V1 nose touched the ground (I have not seen any sign that there was any proximity detection to become aware of the ground approaching). It was designed for very fast detonation, so that the explosion would occur before the V1 was buried by impact in the ground, since an early detonation would generally cause greater blast damage. There was an electrical and a mechanical fuse, and an auxiliary fuse to explode the warhead if the others failed [2]. An essential requirement of the design was for the V1 to be cheap to manufacture, since it would make only one flight with nothing left to re-use.

V1 Autopilot [3]	Wing profile

V1 Autopilot [3] — *Wing profile*

As an 8 year old child at the time of the V1 flights over England, I never heard or saw a V1 because I had been taken away from the London area to live in the safer countryside, but there was much discussion of them by the adults around me. My understanding was that the reason that the engine stopped was that the fuel had run out [#], and that caused the V1 to dive down and explode. I think that was a generally-held opinion, since the public would have had no understanding of the on-board guidance system. Some V1s were provided with a radio transmitter, so that their position could be determined by direction-finding techniques using radio receivers back in Germany.



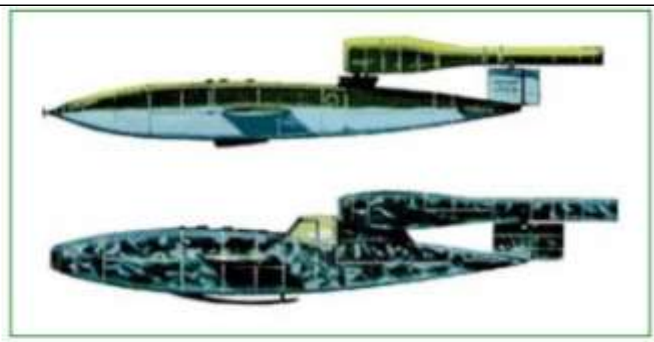
V1 drawing [4] — *V1 image from RAF Museum Cosford*

V1 with human pilot: the Fi103R, called “Reichenberg” version:

Towards the end of WW2, the idea of a V1 version with a human pilot arose. Probably inspired by the Japanese ‘Kamikaze’ planes, the intention was that the pilot would guide the V1 to its destination and bail out at the last moment, just before it dived and exploded. Since it would be flying at 400 miles/hour and there was no technology at the time to enable such an ejection, the probability of the pilot surviving was almost zero, particularly if the pulse-jet engine was still running, but a distinction was drawn with the Japanese suicide pilots who had no possibility to bail out, being generally locked into their cockpits.

Test flights of the modified V1 with a cockpit were carried out by Flugkapitän Hanna Reitsch, who was one of the Luftwaffe’s most senior test pilots, born in 1912, who had extensive experience of flying many experimental planes and was also an expert glider pilot [5]. She successfully landed a modified V1 several times, and reported that this was extremely difficult, because the V1 had not been designed for landing and needed to do so at a very high speed in order not to stall and remain stable. She lived until 1979, and at least until just before her death she remained a loyal supporter of Hitler and the Nazis and everything that they did in the war, being quoted as saying that they made only one mistake, the mistake of not winning the war. Without doubt, she was extremely courageous and skilled, and is notable for having landed in a plane in Berlin as the Russians entered to liberate the city, flying through Soviet anti-aircraft fire, and took off again in another plane after apparently visiting Hitler for two days in his bunker where he died. This led to rumours that she had flown Hitler out of Berlin to a secret location, and that he had therefore survived WW2. This is now regarded by serious historians as a 'conspiracy theory' and not true.

There is a complete, restored, Reichenberg Fi103R-4 in the Lashenden Air Warfare Museum at Headcorn, near Ashford in Kent. The photo shows the cockpit location just in front ot the air intake of the engine.

		
Reichenberg V1 at Lashenden Museum	*Comparison of unmanned and manned V1*	*book cover*

The piloted V1 was somewhat longer than the unmanned version and was never used in actual combat, although the "Leonidas Squadron" was set up and its members trained for this suicidal task.

The USA 'reverse engineered' the V1 with the aid of recovered parts from England, and made an almost identical weapon, the Republic-Ford JB-2 Loon. Many were manufactured with the intention of using them against Japan, but the nuclear bombing of Nagasaki and Hiroshima ended the war before they could be used.

The Tomahawk Subsonic Cruise Missile illustrates how the technology has advanced since the days of the V1; the Tomahawk can be launched from a ship or submarine and uses GPS guidance until approaching its target. It then uses terrain-following with stored data about the target area, and is capable of very precise targeting. It has a range of over 1000 miles and what Raytheon calls 'pinpoint accuracy'. Using a two-way satellite link, it can send a target image back to its controllers, and the target selected may be altered on command during flight. Land-launched versions with a nuclear warhead were developed, but disposed of in accordance with disarmament treaties.

Modern Tomahawk Cruise Missile

The Imperial War Museum London has a substantial collection of photographs of the damage done in London by V1 explosions. At Grove Road, Mile End, E3, there is a commemorative circular ceramic blue plaque on a railway bridge arch to recognise the first V1 to fall on London.

There are a number of books in the German Language which describe technical details of the V1. David Irving has written '*Die Geheimwaffen des Drittes Reiches*' (ISBN 3887410300), Nov. 2000. However, he does not have technical knowledge as far as is known, and his 'so-called historical writings' are full of proven falsifications, so it is unlikely that this book can be relied upon.

Information and advice from several sources is gratefully acknowledged including Emilie Tešinska and Prof. Peter Bussemer in Prague, and Phil Judkins (DEHS).

Commemorative Plaque in Grove Road on Railway Bridge

[1] Jack Gough 'Watching the Skies, the history of ground radar in the air defence of the United Kingdom', HMSO, London, 1993

[2] http://greyfalcon.us/restored/The%20V.htm on 2014 October 18th

[3] http://www.liveauctioneers.com/item/622808 on 2014 October 19th

[4] Image *© IWM London, C-4431*

[5] http://www.ctie.monash.edu.au/hargrave/reitsch.html on 2015 January 31st

[6] Heinrich Temme 'Development and testing of the V1 auto-pilot', AGARD conference, Munich, 1956

[7] http://www.historylearningsite.co.uk/v3.htm on 2015 January 31st

[8] Dieter Hölksen 'V-missiles of the Third Reich, the V1 and V2', Monogram Aviation Publications, 1994, Mass. USA (ISBN 10: 0914 144421 and ISBN 13: 9780914144427). In English, this book contains a huge number of original photographs of the test sites and the people involved, and data about many experimental versions.

[9] Friedrich Georg 'Hitler's miracle weapons', Helion, Solihull, 2003 (includes V1, V2, V3)

[10] Christy Campbell 'Target London under attack from the V-weapons during WWII' Abacus, London, 2013

[11] Steven J Zaloga "V-1 Flying Bomb, 1942-52", Osprey Publications

[12] Donald Nijboer 'Meteor 1 vs. Flying Bomb', Osprey, Oxford 2012

[13] Józef Garlinski "Hitler's Last Weapons, the underground war against the V1 and V2", published by Julian Friedman, London, 1978 (written by a political prisoner in Wittenberg camp)

[14] Norman Longmate "The doodlebugs – the story of the flying bomb", Hutchinson, 1981

[15] http://www.bbc.co.uk/news/magazine-13359064 on 20th April 2015

[16] Göran Jansson, www.zenza.se/vw on 20th April 2015 (many V1 related photos from many sources)

The furthest north in England to be attacked was the Manchester area: Forty five V1s were launched from Henkel bombers flying over the North Sea on Christmas Eve, 1944. Only one landed within the Manchester City area, but altogether these forty five V1s killed forty two people and injured many others. Of all these flying bombs, 14 fell in the sea and a number landed in open countryside. This demonstrates the unreliability of the V1s and the effectiveness of the few which were successful.

Imperial War Museum London data:

V1/V2: 3531/1024 fell on England, 2419/517 hit London, 6184/2754 people killed in Britain, 17,981/6523 injured in Britain (but more people died making V1 and V2 than were killed by them), 30,000 homes destroyed and 250,000 homes damaged in Britain. 18 June 1944: deadliest V2 strike killed 121, 27 March 1945: last V2 fell on Britain.

Appendix 1: More details of the autopilot (mostly based on Temme's description [6]*)*

The autopilot comprises two position-control servomechanisms, one for heading and roll (which adjusts the rudder) and one to control altitude (which adjusts the elevator/tail-flaps). Each is based on a gyroscope, with a rate-gyro to provide rate-feedback to damp out oscillation-tendencies.

The heading control has an input from a (magnetic) compass and the altitude control has an input from an altimeter. Precision of altitude was not important (±100m was sufficient), but suppression of altitude-oscillations was necessary.

All components of the system are driven by compressed air, from two spherical containers which also supply air to the engine fuel-supply.

After laboratory testing, mostly done by Askania, all flight testing was done at Peenemünde. Since the test missiles normally crashed into the sea, they could not be retrieved for investigation after their flight. In addition to visual observation and radar-tracking, some test missiles were fitted with a long-wave transmitter which enabled a bearing to be measured from receivers on the ground. A few of the test missiles also had a 4MHz transmitter which sent telemetry data to the ground or an accompanying aeroplane. The telemetry data used time-division multiplexing with a frame period of 0.1 seconds. Another method was to have a flare burning at the nose-end during test-flights, to make visual observation easier.

The inevitable magnetisation of the steel airframe caused problems with the compass. Temme describes how wooden hammers were used in an iron-free room to align this initial magnetisation to the direction of the earth's magnetic field. Simple compensating for the initial magnetisation was insufficient, because during flight the engine vibrations caused the airframe magnetisation to decrease, which would have made the initial compensation increasingly inadequate. The engine vibrations during flight also produced large errors in the compass, so the latter was suspended from rubber springs within a wooden sphere, itself suspended by helical springs.

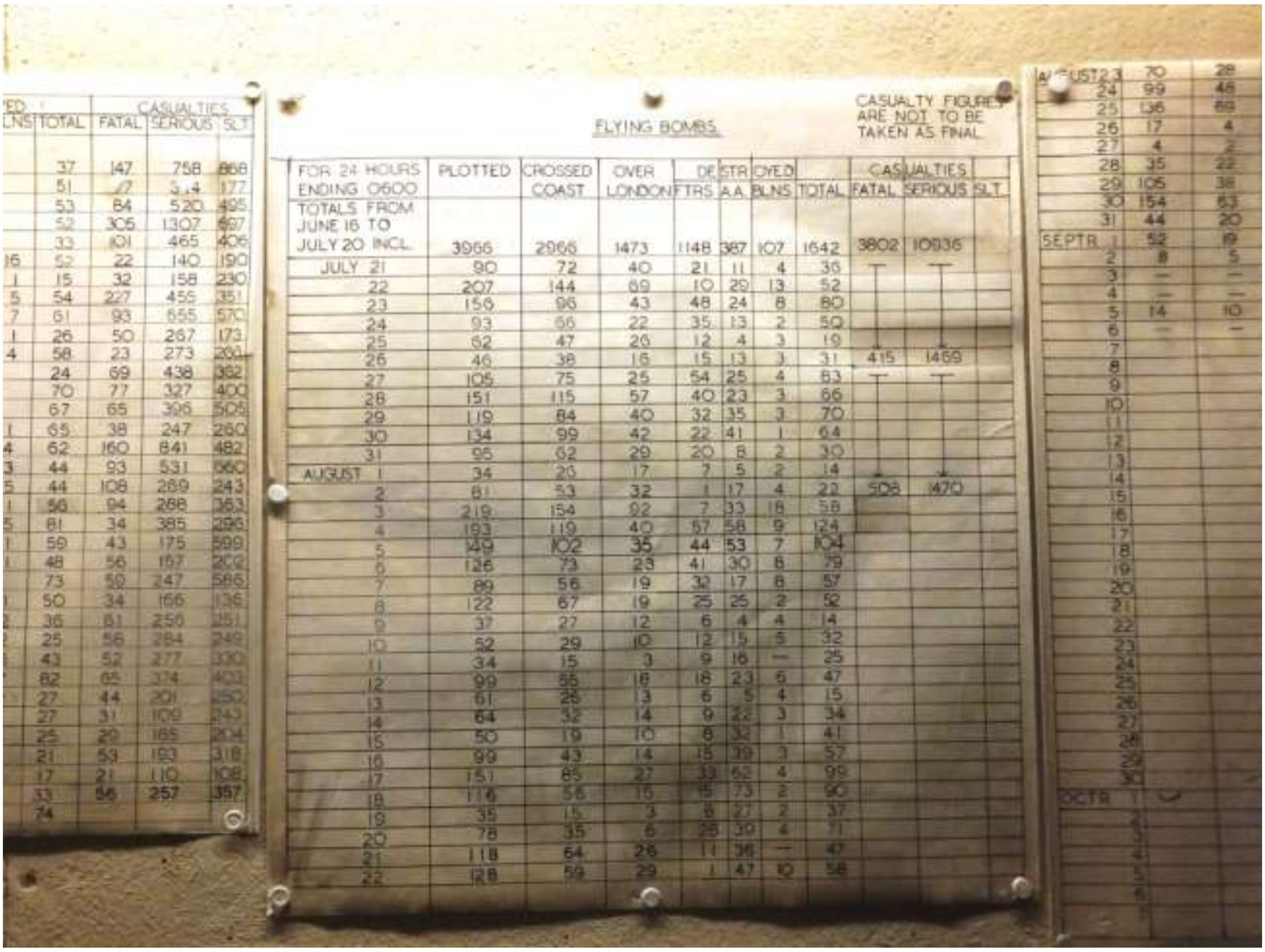
Appendix 2: What is a 'Doodlebug'?

'Doodlebug' is a name for the larva of the Ant-lion insect. The name appears to be of American origin and to arise from the wavy lines in sand which the larva leaves behind. The term does not seem to be used in UK for this larva, and so it is unclear why the British chose this name for the V1 flying bomb. The name ant-lion appears in some form in many languages right across Europe, although its origin is somewhat uncertain – it really applies only to the larva, which in many cases does eat ants. In German, it is *Ameisenlöwe*, and is *formicaleo* in (medieval) Latin.

Photo is copyright 2008, Purdue University, Indiana, USA

Appendix 3: Data about V1s launched over Britain

Production of V1s was planned to increase to 5000 per month, though the maximum achieved was 3000, many constructed with the aid of slave-labour. Comprehensive data, as compiled at the time, showing the fate of all known V1s launched over Britain, is displayed in the Cabinet War Rooms in London, where it can now be seen by visitors. An extract from this data is shown below. It illustrates the very detailed statistical data which was collected to support decision-making throughout WW2. (*photos: ACDavies, 24th Feb 2015*).



FLYING BOMBS

CASUALTY FIGURES ARE NOT TO BE TAKEN AS FINAL

FOR 24 HOURS ENDING 0600	PLOTTED	CROSSED COAST	OVER LONDON	DESTROYED				CASUALTIES		
				FTRS	A.A.	BLNS	TOTAL	FATAL	SERIOUS	SLT
TOTALS FROM JUNE 16 TO JULY 20 INCL.	3966	2966	1473	1148	387	107	1642	3802	10936	
JULY 21	90	72	40	21	11	4	36			
22	207	144	69	10	29	13	52			
23	156	96	43	48	24	8	80			
24	93	66	22	35	13	2	50			
25	62	47	26	12	4	3	19			
26	46	38	16	15	13	3	31	415	1469	
27	105	75	25	54	25	4	83			
28	151	115	57	40	23	3	66			
29	119	84	40	32	35	3	70			
30	134	99	42	22	41	1	64			
31	95	62	29	20	8	2	30			
AUGUST 1	34	26	17	7	5	2	14			
2	81	53	32	1	17	4	22	508	1470	
3	219	154	92	7	33	18	58			
4	193	119	40	57	58	9	124			
5	149	102	35	44	53	7	104			
6	126	73	23	41	30	8	79			
7	89	56	19	32	17	8	57			
8	122	67	19	25	25	2	52			
9	37	27	12	6	4	4	14			
10	52	29	10	12	15	5	32			
11	34	15	3	9	16	—	25			
12	99	55	16	18	23	6	47			
13	61	25	13	6	5	4	15			
14	64	32	14	9	22	3	34			
15	50	19	10	8	32	1	41			
16	99	43	14	15	39	3	57			
17	151	85	27	33	62	4	99			
18	116	56	15	15	73	2	90			
19	35	15	3	8	27	2	37			
20	78	35	6	28	39	4	71			
21	118	64	26	11	36	—	47			
22	128	59	29	1	47	10	58			

FLYING BOMBS

24 HRS ENDED 0600	PLOTT'D	OVER COAST	OVER LONDON	DESTROYED				CASUALTIES		
				FTRS	AA	BLNS	TOTAL	FATAL	SERIOUS	SL'T
TOTALS FR'M 16-6-44 TO 22.8.44 INCL'SVE	7369	5074	2359	1850	1291	259	3400	4918 (To 9-8-44.)	14625	......
TOTALS TO DATE	8107	5402	2470	1927	1654	269	3870	5791	17034	

Appendix 4: Supplementary information

Many of the V1s (as well as V2s) were manufactured underground in the Kohnstein mountain (known as the Dora concentration camp, later called *Mittelbau KZ*). The factory was called *Mittelwerk*. The mountain contains gypsum, and had been used for mining for many years. The gypsum material made the building of extensive tunnels, etc. quite easy. Some of the workers were low-paid Germans but the majority were Russian, Polish and French concentration-camp prisoners (*Häftlinge*) living and working in appalling conditions.

Hölksen [8] suggests that the concept of the flying bomb can be linked to French pre-WW1 ideas: René Lorin planned an engine based on jet propulsion and during WW1 he proposed pilotless jet aircraft which could be used to attack large-area targets (e.g. cities), dropping bombs and then returning. These ideas were then forgotten. In Germany, Fritz Gosslau (with a Dr.Ing from TU Berlin) worked on the development of remotely-controlled aircraft, initially as targets to train gunners, but then by 1939 had the idea to carry explosives. The Fieseler company submitted a proposal in April 1942 similar in appearance to what became the V1. By June 1942, the deterioration of the German war position led to the project to develop the Fieseler Fi103 (e.g. the V1) with high priority [8]. For speed, development proceeded in parallel with production, which led to many problems, and the programme was hampered by conflicts and jealousies between SS personnel, Luftwaffe officers and the indecisiveness of Hitler. Sabotage by the *Mittelwerk* workforce, despite severe punishments, hampered V1/V2 production. All this was, of course, very fortunate for the British.

It seems that Hitler did not propose 'terror bombing' against Russia, because of his belief that the Slavic people were a sub-human species which would not succumb to terror tactics, whereas he believed that the 'superior' British would do so! There was therefore no plan to use the V1 or V2 against Russia.

Imperial War Museum (IWM) London photo collection:

	
V1 on ramp at Duxford	*V1 delivery process*

German Torpedo G7eT3, IWM London (MUN 3847)

note similarity of small propeller at nose to that in nose of V1

The small Torpedo front propeller is a safety-device used to arm the torpedo. It measures the distance travelled and after about 250 metres, it arms the torpedo. Prior to that there is no risk of the warhead exploding.

Appendix 5: What did the British know about the V1 [10] *?*

Unmanned drone aircraft were not unknown, the British had pioneered this with the Queen Bee, used from 1935, which was a pilotless radio-controlled plane based on the Tiger Moth, capable of taking off, use as a gunnery target, and returning to land for re-use. 380 of them were made for RAF use over the 1935 to 1947 period. Their speed was low, so using a pilotless plane as a guided weapon probably did not occur to many people. Of course, the V1 with its jet engine could go much faster than a Queen Bee, so the reality was very different.

Many reports from agents, spies, etc. indicated that some kind of novel and very secret weapon was being developed. However, such agents, not being experts on such things, often mixed up rumours and observations which related to the V1, V2 and V3. So reports of an unmanned aircraft (e.g. the V1) were confused with reports of a rocket-development (the V2), which were then mis-interpreted by the British experts who tried to make sense of them variously as incorrect or inaccurate or 'invented'. They disbelieved reports about the rocket plans because they supposed that solid-fuel would be used, at that time unable to provide the performance needed. In fact, liquid fuel was used for the V2, which the British scientists did not think of at that time.

Opportunities to find out started in September 1939, with a broadcast statement by Hitler that there was a weapon in development which no others would have and against which there would be no defence possible. However, this was in effect ignored, and no serious notice taken of it.

In November 1939, a parcel was left on a window at the British Embassy in Oslo, containing a detailed technical manual describing the development of remote-controlled missiles with built in gyroscopes at an army test site at Peenemünde. After investigation, the Navy decided that this was just a hoax and all copies were burned. It has been claimed [10] that R.V. Jones had a copy which he filed away and did not use, but he may really have used it and he contributed substantially to the interpretation of reports and photo-reconnaissance.

Development of the V1 and V2 continued in the early years of WW2, and one can understand the basis of some of the confusion by noticing that early experimental rockets which would lead to the V2 were named A-4 with versions A-4/V3 and A-4/V4, etc. In December 1942, Himmler went to Peenemünde to see the launch of A-4/V9. It failed, but Himmler nevertheless confirmed that the development of the rocket would receive priority.

Even when photo-reconnaissance showed without doubt that some special testing was happening on a huge scale at Peenemünde, there was no adequate understanding of what it was, and the bombing raids on Peenemünde were carried out before it was known exactly what was being developed there, starting with a major raid by British bombers in August 1943. There were suggestions that the observed A4 (e.g. V2) rockets were some kind of torpedo.

The photo-interpreters at RAF Medmenham used 3D imaging (e.g. using two photos taken from separated cameras) and this substantially improved the understanding of the scenery. Many unexplained structures were observed by such photo-reconnaissance, and were linked with the German claims about novel secret weapons which would enable Germany to win the war. However, there was no agreement among the various British groups who were trying to identify what had been seen and to interpret reports from a variety of agents. For example, many launching ramps for the V1 were photographed in various places, but mistakenly linked to the reports of rocket weapons, and therefore for some time were not understood.

"Operation Crossbow" was a mission started in late 1943 to destroy the locations where all these structures were seen. It was already seen from 1942 that unusual activities on a large scale were going on at

Peenemünde and the consequent bombing of Peenemünde in 1943 led to some of the work being transferred further away, to Poland (Blizna) and southern Germany. A BBC TV programme with the name Operation Crossbow was transmitted in May 2011, and some extracts may currently be available. There is a description by Jon Kelly in the BBC News Magazine [15].

When basic features of the V1 had been discovered, it was assumed that propulsion would be by some chemicals which included an oxidiser (as was the case with rocket fuels) and estimated that this would leave space for only a small payload – leading to ideas that the V1 might be intended to carry poison gas or harmful bacteria rather than an explosive warhead. It was thus not realised for a long time that the pulse-jet engine would use incoming air as its source of oxygen and so leave space for a much higher explosive payload than the earlier estimates.

Lord Cherwell (prof. Lindemann) consistently dismissed the 'secret weapon' reports as much exaggerated, and so tended to minimise their possible impact.

An aerial photo of a V1 on one of the launching ramps was seen by the photo-interpreters at RAF Medmenham. Flight Officer Constance Babington-Smith is credited with this discovery in November 1943, having been asked to look for signs of a pilotless plane. The difficulty of spotting this can be imagined taking into account that huge areas of Europe were photographed, and in this mass of photographic data, the interpreters had to identify objects of military significance. This photo provided an explanation of the many launching ramps which had previously been photographed, but not understood.

In May 1944, a reasonably-complete V1 fired for test purposes crashed in Sweden without being completely destroyed, and although Sweden was a neutral country, the British were allowed access to it, and from this time onwards, therefore, had a reasonably good idea what they were looking for in the photo-reconnaissance images before the V1 attacks started.

Despite having fairly accurate information about the V1 by mid 1944, the British were not well prepared when the actual V1 bombardments started in June 1944. The first V1 to cross the coastline (at Dymchurch, Kent) was observed and reported, but the observer did not know what it was.

My childhood belief that the V1 flew until it ran out of fuel must have been widespread, and is, astonishingly, repeated in educational resources for schools in the National Archives website:

http://www.nationalarchives.gov.uk/education/resources/british-response-v1-and-v2/ as viewed 4th April 2015

The 'lesson plan' introduction includes the statement *"The V1 missile, once launched, flew without a pilot until it ran out of fuel and came crashing down, blowing up"*. Presumably nothing of the elaborate guidance system is to be revealed to schoolchildren. The document contains other questionable material.

Although the use of poison gas in warfare had been made illegal by the 1925 "Geneva Protocol" as a result of its use by both sides in WW1, the allies were fully prepared to use it (including more modern types) at the first sign that Germany was going to use it, and would probably also have used gas and biological weapons in the case that Germany successfully used significantly-novel weapons with no available defence (as Hitler's 'secret weapons' threatened to do). The British have secretly experimented with gas and biological weapons at Porton Down since the location there was established in 1916.

Supplement: attacks on Manchester

Extracted from www.aircrashsites.co.uk on 26th April 2015

Luftwaffe V1 attack on Manchester, Christmas Eve 1944

…… on Christmas Eve 1944, 45 Doodlebugs were launched off the Yorkshire coast from beneath Heinkel He111 bombers flying over the North Sea. The bombers released the V1s aimed at Manchester, then turned back to base. Many of the missiles landed harmlessly; the worst was at Abbey Hills Road in Oldham where 27 people were killed.

45 V1s were launched in total.
31 crossed the Yorkshire coast, while 14 fell in the North Sea.

Only 7 fell within the built up area of what is now Greater Manchester, and only 1 missile (out of 45) fell within the Civil Defence Area for Manchester (that one was at Didsbury).

It was the furthest north V1s were ever used.

42 people were killed in the attack.

109 were injured, of which 51 people were seriously injured.

The V1s were launched between 0500 and 0600 on the morning of Christmas Eve 1944. It took about 30 minutes from launch to the missiles falling to earth.

Typically buildings were damaged up to a mile away. The missiles could not be guided with accuracy, hence they came down in fields, on the moors as well as in towns. Sometimes they would turn round or spiral down. A few of the Doodlebugs were well off target, one landing near Chester, one as far north as County Durham while another came down at Woodford in Northamptonshire.

One of the attacking Heinkel 111s was shot down over the North Sea by Mosquito TA 389 while another was damaged by Mosquito HK 247 and crash landed at Leck in Germany, killing one of the crew.

More remarks about the V2

The second of the 'vengeance weapons', the V2, was very different from the V1. It was a ballistic missile, which travelled at far greater speed, and after its upward launch, followed an approximately parabola-trajectory which went into the edge of 'space', the first man-made object to do so. It was developed from a series of experimental rockets (A2 in 1934, A3 in 1937), and also had the designation A4. There was also a much smaller A5 experimental rocket.

The photo above shows a V2 in the Royal Engineers museum, Gillingham, Kent with a map of the 517 locations in Greater London where V2 rockets fell during WW2. Unlike the V1, there was no defence against the V2. Over 3000 V2s were launched by Germany.

The fuel was a 3 to 1 ethanol-water mixture with liquid oxygen as the oxidiser. It was distributed by steam-operated pumps, steam being produced by hydrogen peroxide with a sodium permanganate catalyst. The V2 was powered for about the first minute of its flight, during which its stability and direction was adjusted, initially vertical and then tilted to 45° if maximum range was required, and thereafter it continued on a ballistic path [A,E]. All fuel was burnt in about 60 seconds, by which time it had reached at least Mach 2.

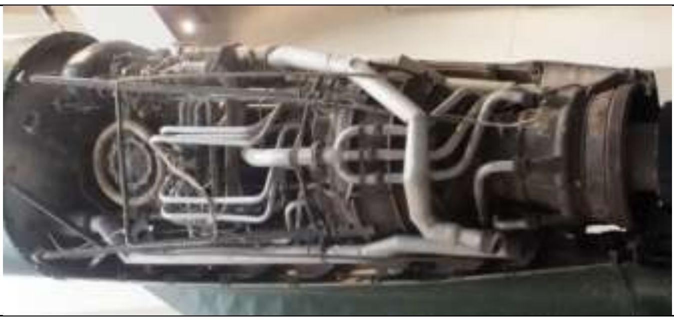
V2 on display at the Imperial War Museum in London

The enlarged view shows the complexity of the 'pipework' etc. for the required rocket engine supplies.

The vertical take-off of the V2 (and subsequent rockets derived from it) is slow, and therefore aerodynamic controls using fins are not effective for initial stability and direction control, it is necessary to adjust the direction of thrust from the rocket motor [B]. To provide stability, the direction of thrust at take off of the V2 is controlled by four graphite vanes in the exit of the rocket motor. Graphite was used because the heat of the rocket fuel would have melted metal vanes. Later in the launch, as speed increases, additional control is by four rudders in the tail fins.

The control is achieved by hydraulic servo motors. The control signals are derived from two gyroscopes, one for pitch and one for yaw and roll (from [C].

This black and white colour scheme of the V2 displayed at Cosford was used for ease in tracking during experimental firings, especially to detect roll (axial rotation).



Parts of V2 on display at IWM, London

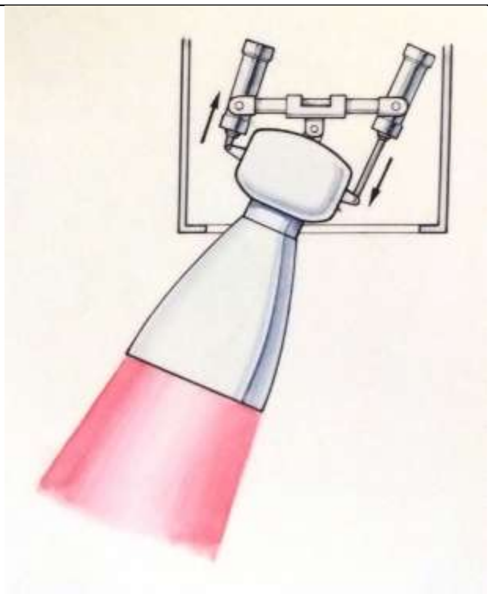
V2 on display at RAF Museum, Cosford

V2 rudder in tail fin and V2 graphite vanes in motor exit (RAF Museum Cosford)

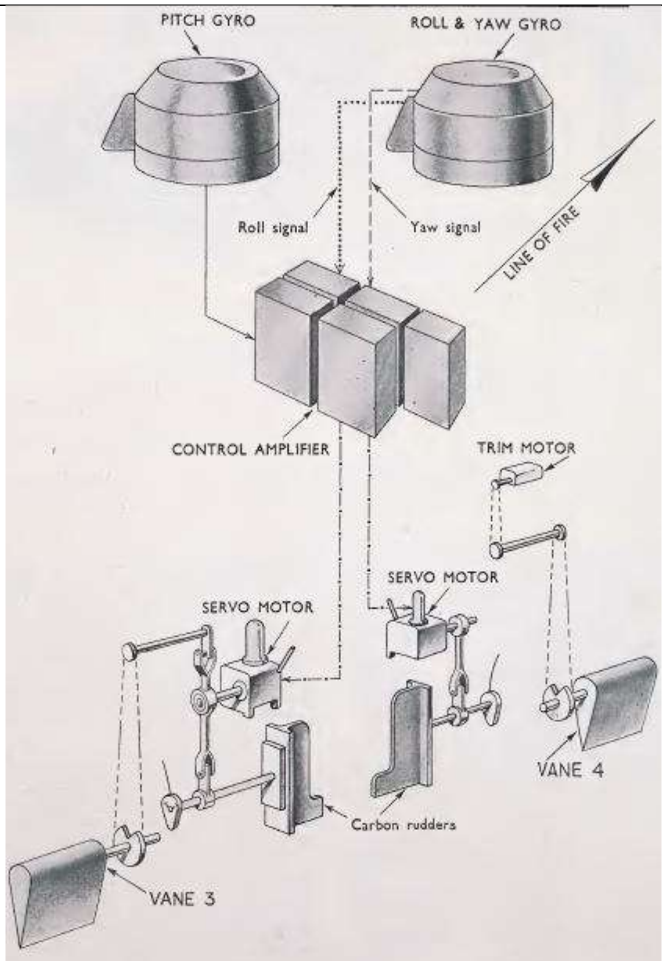
The experiments with these rocket launchings (the 'A' series leading to the A4 which was, in effect, the V2) involved many failures, and this was necessarily associated with many technical advances which have been of importance for post-war space and military rocket developments. In early test firings, the rocket often exploded on re-entry to the earth's atmosphere, which was found to be a problem of the empty fuel container. By filling this with glass wool this particular difficulty was overcome.

Some subsequent vertically-launched missiles controlled the thrust direction by mounting the whole rocket motor on gimbals: this enables the initial launch speed to be very low, while aerodynamic forces on fins cannot be used. The diagram (from RAF Museum Cosford) shows how the thrust chamber of early USA ballistic missiles was mounted on pivots so as to be tilted in any direction

The V2 travels vertically for 5 seconds after lift-off and reaches Mach 1 in 25 seconds. The trajectory goes up to 90km, the maximum horizontal range is 320km, and the maximum speed is over 3000 miles/hour.
The fuel is burned at a rate of 1300kg per second.
Because of the vertical launching, all that was needed was a flat concrete surface which was easy to prepare and to camouflage, and a V2 could be brought out of hiding and prepared for launching quite quickly. This was not understood by the Allies until very late and so much effort was wasted in unsuccessful bombing raids rather than blocking supply lines.



Pivoted thrust chamber concept



V2 stabilisation by rudders and vanes

Following WW2, there was an operation by the British named 'Backfire' to experiment with and practice V2 launching, and to evaluate the results. Many German technicians who had worked on the V2 (A4) rocket development were used, and later offered employment in UK and USA. Three V2s were launched from Cuxhaven on the North German coast during this operation. The report on Operation Backfire [C} is available from the Smithsonian Museum.

The explosive used in the warhead was Amatol (mixed TNT and ammonium nitrate).

As is well known, the leading designers were taken and employed in USA to assist in their missile and space programmes. Werner von Braun became a leader of the USA space programme launches. The V2 was fully evaluated initially at the White Sands Proving Ground in USA, with the first launch in April 1946. Apparently, the British would have preferred von Braun to be tried as a war criminal, since he never showed any remorse about the use of slavery and extreme cruelty, etc. in the underground V2 manufacturing places, which it is known that he visited and so was fully aware of what was being done [10]. Indeed with the success of the USA space programme, von Braun became a national hero and his murky past was virtually forgotten. A popular biographical movie was made about him in 1960 with the title '*I aim for the stars*' to which a satirical comedian was to suggest the title be changed to '*I aim for the stars but sometimes I hit London*'.

The Russians tried to obtain these experts too, apparently using deceptions and attempted kidnapping from the American Zone, but were unsuccessful. However, Peenemünde was in the Russian Zone, which enabled them to obtain all the manufacturing facilities, and it is said that the British had supplied the Russians with captured rocket components (at that time, of course, Russia was an ally in the war against Nazi Germany).

The ICBMs and IRBMs which were then developed can be regarded as direct descendents of the V2. The first surface to air missiles installed to protect cities such as Moscow (the S-25 Berkut "Golden Eagle") used liquid propellants, with the associated complications of pumping in the fuels at low temperature, etc.

The particular V2 shown in the photo at the Royal Engineers museum was used for bomb-disposal training from the 1960s. This included the handling of chemical agents in the warhead, and dealing with liquid rocket fuels.

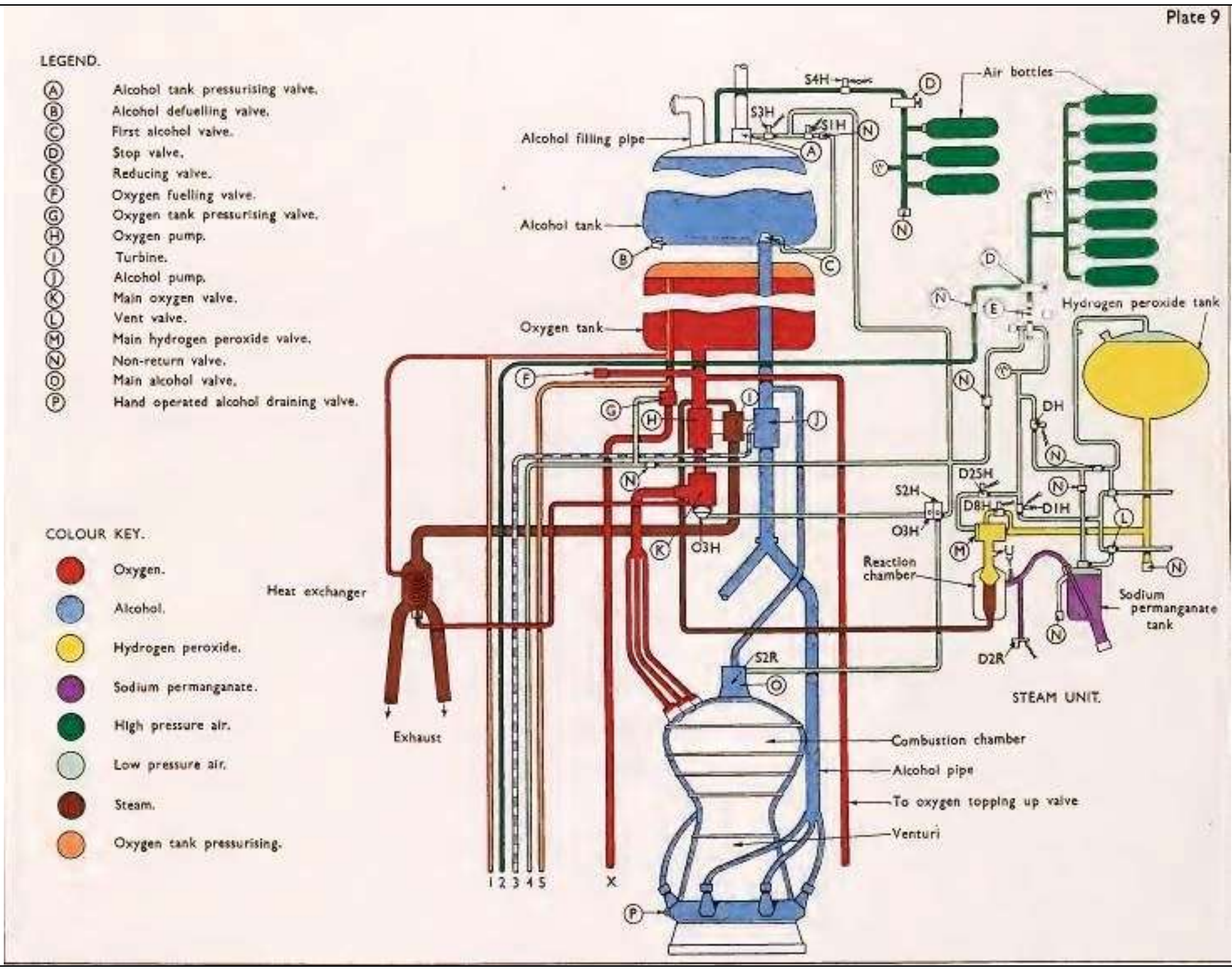


Diagram from Vol 5 of Report on Operation Backfire [C]

[A] http://www.v2rocket.com/start/chapters/backfire.html accessed on 23 August 2015

[B] P. Garnell and D.J. East, Guided Weapon Control Systems', Pergamon Press, 1977

[C] Major General A.M. Cameron, Commander, Special Projectile Operations Group, Report on 'Operation Backfire' (five volumes) , The War Office, London, January 1946.

[D] Dept. of the Air Force, 'Guided Missiles, Operation, Design and Theory', McGraw Hill, NY, 1955

[E] W. Dornberger "V2" Hurst & Blackwell, London, 1954 (translation by J. Cleugh and G. Halliday): original in German "V2: Der Schuss ins Weltall", 1952

[F] 'Hitlers Secret Weapons 1933 1945', Amber Books, London 2010 (text at archive.org/stream/HitlersSecretWeapons…)