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Can a pile of scrap unmask a new high technology? The A4/V-2 No V89 *Bäckebo-torpeden*

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ABSTRACT

Three months before the first V-2 rocket attack on London a test vehicle crashed in southern Sweden on June 13, 1944. At this time the Allied only had limited knowledge about the rocket (A4/V-2) from agent reports and information from the Polish resistance investigating some remains from a crashed test vehicle in Poland. London was confronted with a new weapon supposedly able to carry an explosive warhead of several tons some 250 km.

The A4/V-2 rocket test vehicle number V89 broke apart shortly before impacting ground. In a short time 2 t of metal parts and electrical equipment was collected and transported to Stockholm for investigations. A first Swedish report was ready by July 21, 1944 and the rocket parts were then transported to England for further investigations. By August 18, 1944 the Royal Aircraft Establishment (RAE) had its preliminary report ready. But how close to reality can a complex vehicle be reconstructed and the performance calculated from a pile of scrap by investigators dealing with a technology not seen before?

In the early 1940s the state of art of liquid propellant rocket technology outside Germany was limited and the size of a liquid rocket engine for the likely performance hardly imaginable. The Swedish and British reports, at that time classified as top secret, have since been released and permit a very detailed analysis of the task to reconstruct the rocket vehicle, the engine itself and its performance. An assessment of the occurrence at Peenemünde and how the rocket became astray and fell in southern Sweden, together with the analyses by Swedish and British military investigators give a unique insight into the true nature of the V89. It shows the real capabilities of early aeronautical accident investigation methods in combination with solid engineering knowledge to unmask a new high technology.

1. Introduction

Information on an emerging German development of a flying bomb and/or a rocket system, including the construction of a new test site at Peenemünde, came to the attention of the British authorities in late 1939 through *The Oslo Report*. Other elements in the report dealt with e.g. German radar and radio navigation developments. The beginning of the Second World War set priorities such that the checking on background and confidence of such information were to be concentrated on the electronic systems development in Germany, and to find countermeasures for the Battle of Britain air war to start in 1940. The information on rocket systems was merely put aside [1,2].

The first air reconnaissance photos of Peenemünde were taken in May 1942, but at this time no flying bombs or rockets were found on the photos. In December 1942 and February 1943 the first agent reports on the

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development of a large rocket with a warhead of some 5–10 t for a range from 110 up to 210 km were received by the British military intelligence. Early June 1943 a detailed report on activities at Peenemünde and a layout of the test site came in from an agent, and the report also describes a rocket vehicle. Photos of Peenemünde from June 12 and 23, 1943 then finally permitted the identification of a rocket (A4/V-2) and allowed the first very crude size estimates. On August 17 and 18, 1943 Peenemünde was bombed by the allied forces [1–3].

On August 22, 1943 a flying bomb test vehicle (a V-1 marked V83) crashed on Bornholm in German occupied Denmark. Photos taken and a sketch of the crashed V-1 done by a Danish naval officer were brought to England for further analyses. Soon after was also the flying bomb (FZG76/V-1) discovered on launch rails at Peenemünde and Zempin on Usedom. In November 1943 two further V-1's (test vehicles, no warhead) crashed in neutral Sweden and could be analysed in detail and all technical details and performance data were revealed and also forwarded to England. A first British report was put together by Reginald Victor Jones at M.I.6, the Secret Intelligence Service, on December 12, 1943 six months before the first operational V-1's were deployed towards London in June 12, 1944. And by then one more V-1's had crashed in Sweden. The Jones-report of December 1943 was fairly exact except for the propulsion system, which was thought to be a rocket propulsion one using decomposed hydrogen peroxide similar to the known Hs 293 missile and not the actual pulse jet engine [1].

The details on the A4/V-2 should however remain unknown for another half a year until May–June 1944 and caused considerable discussions and speculations within the British government and military intelligence. Only when access to real hardware occurred could the true nature of the A4/V-2 rocket be revealed.

2. British investigations of a German rocket until spring 1944

After the British had managed to counteract the German radar and air radio navigation systems and finding an increasing construction activity of supposed launch sites for a rocket or flying bomb in France and Belgium did the counterintelligence concentrate on exposing the true nature of the A4/V-2 system. From late 1942 on reports on a rocket kept coming into the Scientific Section of M.I.6 from agents, interrogation of prisoners-of-war (POW), foreign labourers in Germany and British air recognisance missions. The work of the Scientific Section of M.I.6, headed by R.V. Jones, concentrated on collecting information and facts from aboard and to verify this information by further reports into an overall picture of a threat to Britain and the weapon presumably under development (Project Big Ben). Most reports were describing a rocket of some 10–20 m in length, 1–1.5 m in diameter and with a warhead from 1–5 t [1].

In April 1943 the Chiefs of Staff called for an independent expert to analyse the German development of long-range rockets and flying bombs and Duncan Sandys (later Sir Duncan Sandys) was appointed Scientific and Intelligence Adviser. He mainly relied on scientific and technical experts from outside the military establishment and the basic method used initially was to define a rocket system that could fulfil the performance of transporting a 1–5 t warhead some 250 km. The propulsion technology in Britain during the pre-war and early years of the war was concentrating on solid propellants (cordite) and very limited experiments were carried out on liquid propellant systems. Thus the experts attached to Sandys' group were mainly experts on solid propellant systems and provided the group the concerted opinion that the rocket must be a 2-stage rocket with a launch weight of some 30–40 t (some estimates were even as high as up to 100 t total weight). Such a rocket seemed somewhat unrealistic. The Sandys' group categorically refused the idea of a liquid rocket propulsion system as "not mature" for such a vehicle although experts pointed out that liquid propulsion was far more advanced in the US than in Britain. Some comments went as far as to claim that the observed "objects" on air recognisance photos were too small to be rockets. Due to the low speed at launch it was assumed that a rail or tower would be needed for initial guidance at lunch as other methods were regarded as unfeasible. Thus the evaluation of air recognisance photos was partly mislead and concentrated on finding launch rails or towers and rockets in a horizontal position. Based on the knowledge of the V-1 guidance system it was assumed that the A4/V-2 rocket also use a Siemens manufactured radio navigation system [2,3].

On May 20, 1944 at Sarnaki on the river Bug in east Poland the Polish Underground Army manage to capture and hide a crashed but not exploded A4/V-2 launched from Blizna (Heidelager) and thus for the first time the allied became indirect access to actual A4/V-2 hardware. Reports from Poland in June 1944 confirmed a length of about 12 m and a diameter of 1.8 m. A liquid recovered was identified as concentrated hydrogen peroxide, which would verify that the propulsion system used this as a liquid fuel. Radio equipment recovered pointed to a radio navigation guidance system [1].

3. June 13, 1944 in Sweden

On June 13, 1944 the intelligence work on revealing the details of the A4/V-2 rocket took an unexpected turn. At 15:15 (MET) on that day an explosion took place at some 1500–2000 m above ground in southern Sweden near Bäckebo (Gräsdals gård) and a rain of metal debris and major metal structures came down over an area of some 1 by 4 km (Figs. 1 and 2). Police and military personal called to the site of the impact could at once determine that it was not an airplane crash nor a V-1 flying bomb, but a rocket of unknown origin [1,14,17].

4. Peenemünde June 13, 1944

An A4 test vehicle was prepared for launch at Heersprüfanstalt Peenemünde (HAP) on June 13, 1944. This particular vehicle (V89) was taken out of the regular row of test vehicles for modification of the guidance system. In addition to the two gyros radio guidance equipment was also installed in the equipment bay directly beneath the war head compartment. The purpose of this additional (Fig. 5c) equipment was to test the guidance system of the Wasserfall anti-aircraft missile also under development at Peenemünde. Wasserfall was guided by sight with a joystick (Fig. 3). The A4/V-2 No V89 was for the initial part of the flight to be guided in a zigzag course around the normal 70°E direction, which would take the rocket out over the Baltic and south of the island Bornholm.

In this particular case the operator was seeing an A4 launch for the first time. For what happened at the launch there are two versions available:

– According to von Braun and Dornberger a cloud came into the line of sight after the first commands and the operator gave a left command to avoid that the rocket would drop down over land in Poland. Once the rocket became visible again it was out of range for the radio signals and the rocket continued on its more northern course of 23°E and finally fell near Bäckebo in southern Sweden [4,5].
– Ernst Steinhoff, who was in charge of the guidance system for the A4/V-2 and present at the launch, claimed that the operator had to learn a certain navigation pattern by heart. During this launch he was too excited seeing his first launch of an A4 and thus he mixed left and right and brought the rocket on the more northern course. When this was discovered it was then too late for a correction as the rocket was already out of radio range [6–8].

The two explanations are not directly contradictory and the real fact might even be a combination of both. The fact that an unusual amount of radio navigation equipment was recovered from this particular test vehicle should be of major importance for the following investigations and any countermeasures taken against the operational A4/V-2 missiles.

After the war this test vehicle should be identified as V89 (or serial number 4089) and it was launch number 103 of an A4 from HAP. That it was taken out of the normal line of preparation becomes evident from the fact that when V89 was launched other test vehicles with a much higher number had already been launched for normal A4/V-2 testing [3,8].

5. The Swedish investigation

5.1. Swedish investigation team

Military personal recovered 2010 kg of metal parts, electric and radio equipment, and the rocket engine which was all brought to Stockholm (Fig. 4). The investigation

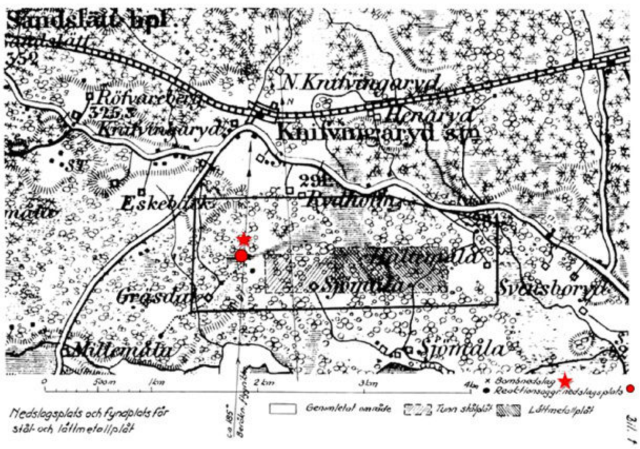


Fig. 1. June 13, 1944. Impact and debris area.
Source: Kjellson, Ref. [9].

Fig. 3. Wasserfall joystick guidance system.

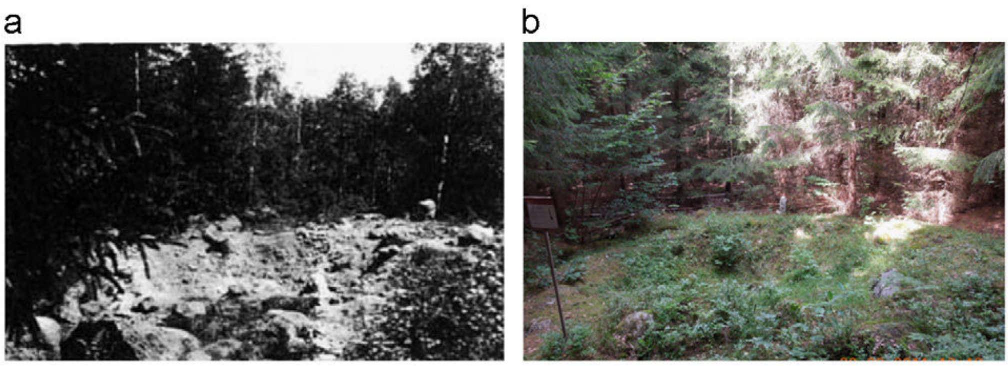


Fig. 2. (a) Impact pit from West, June 1944 and (b) Impact pit from east, August 2012.
Source: Kjellson, Ref. [9] and Skoog.

and reconstruction (Fig. 5) of what was now defined as an "aerial torpedo" (*Lufttorped and thus the final Swedish name "Bäckebo-torpeden"*) started on July 4, 1944 at Flygtekniska Försöksanstalten, FFA (Military Aeronautical Research Institute) in Stockholm. Head of the investigation team was Air Force Colonel (Engineering) Henry Kjellson and he was assisted by Professor Gustav Boestad, Mechanical Design, Royal Institute of Technology, and Sten Luthander, FFA (later Professor, Aeronautical Engineering, Royal Institute of Technology) [9].

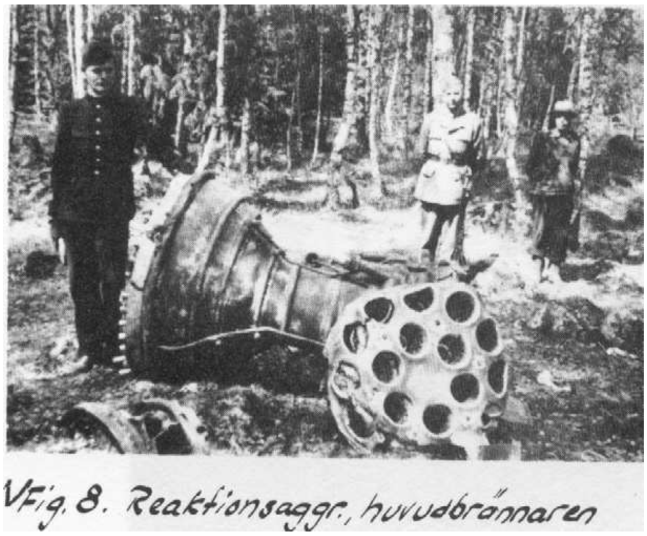


Fig. 4. Rocket engine at the site of impact.
Source: Kjellson, Ref. [9].

Late June two Air Technical Intelligence Officers, Squadron Leaders Burder and Wilkinson, arrived from London with a request to the Swedish General Staff to get the permission to inspect the debris. They returned to England mid July (17th or 18th) when the first Swedish preliminary investigation was almost completed [1].

5.2. Origin

The origin of the rocket was clear right from the beginning. Many parts, in particular pressure vessels, electric boxes and the radio equipment, carried labels with text in German. In the mean time three V-1's had fallen into Sweden, and like the British the Swedish Air Force flew several recognisance missions along the German Baltic coast which had resulted in knowledge of Peenemünde also in Sweden (Fig. 6). The launch site was no doubt Peenemünde and thus the range of the rocket was clear, some 335 km (Fig. 7). In the report Peenemünde is explicitly mentioned by Kjellson as the place of launch [9,11].

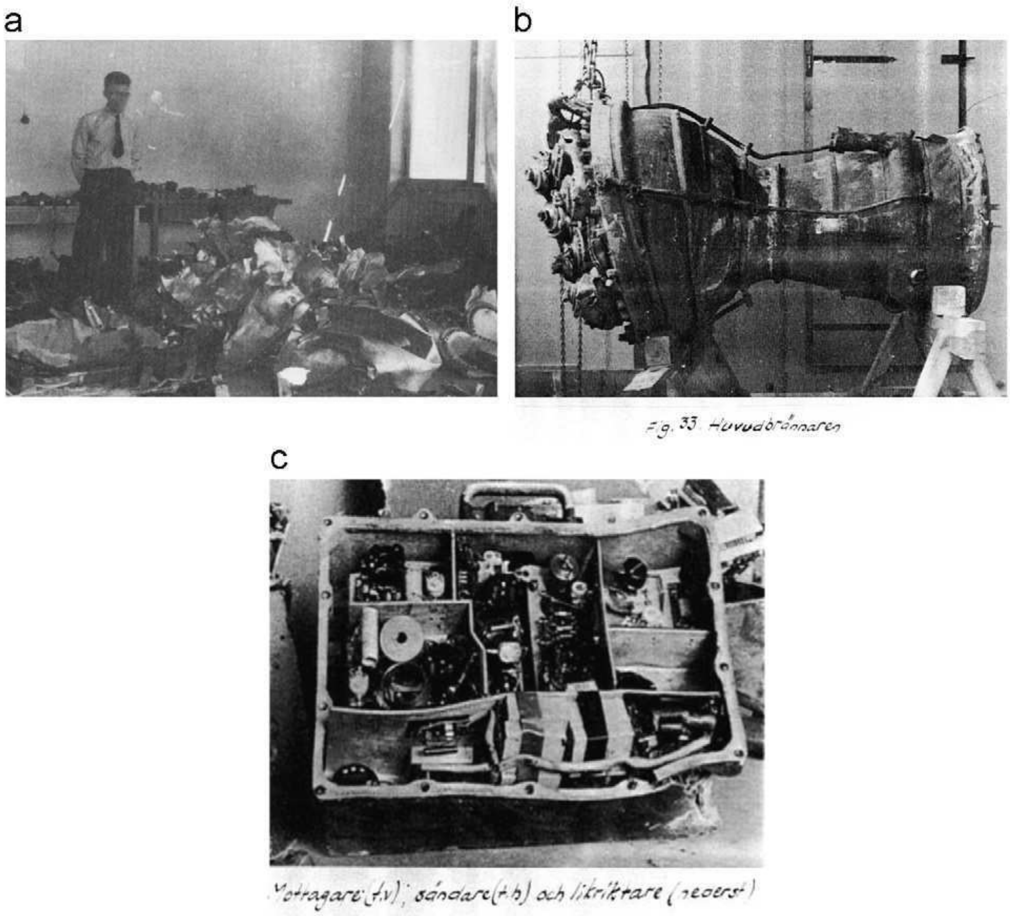


Fig. 5. (a) Reconstruction at FFA, (b) Rocket engine reconstruction at FFA and (c) Reconstruction at FFA. Receiver and transmitter.
Source: Kjellson, Ref. [9].

5.3. Rocket trajectory and impact

The estimated trajectory was out of ~185° from the location of the impact. This was based on the line of impacts of the so called "explosion pit" ("krevadgropen") and the rocket engine (Fig. 1). This base is short (~50 m) for a very exact determination of the trajectory, but sufficient for a general confirmation of the origin of the rocket. The exact direction from Peenemünde was 23°E. At the time of the explosion the wind direction was from W—WSW (out of ~260°) and 7 m/s. All debris of sheet metal fell in an area east of the line of impact (Fig. 1).

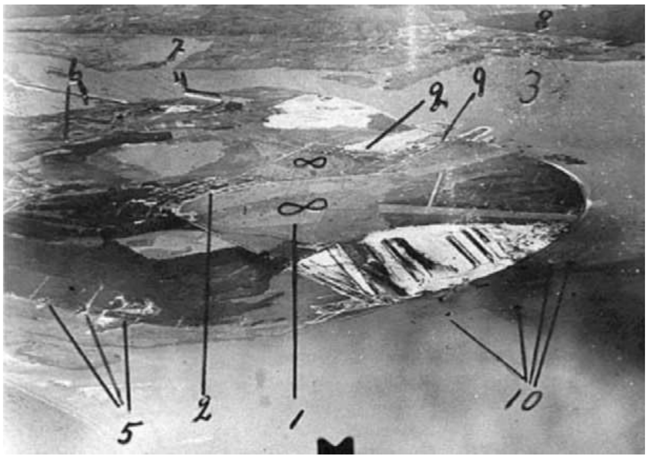


Fig. 6. Swedish aerial photo of Peenemünde Summer 1943. *Source*: Royal Swedish Air Force.

At the time of the impact several witnesses close to the impact point heard just one very strong explosion or bang from a high altitude, other recalls at least two explosions or "bangs" with very short interval. Based on the distinct difference in spread of steel metal and alloy sheets (Fig. 1) to the east of the line of impact, the height of the rocket at the explosion could be determined. First drop tests of similar steel and alloy sheets from a high bridge in Stockholm (a unique test method) helped determine the speed of fall and the drag. Taking the wind speed and direction at the time of explosion into consideration the altitude of the explosion was set to about 1500 m and about 800 m south of the "explosion pit" [9].

The circumstance that some persons close to the impact location heard just one bang and others two is explained by the fact that major rocket parts fell on a very stony ground and this must have caused a load bang at impact in addition to the explosion in the air. Those persons very close to the impact were according to own statements "almost deaf" from the first explosion and could probably not hear the second bang. This confirms that the rocket broke apart at re-entry before hitting ground, which happened to some 30%–40% of the A4/V-2 rockets at this time [5].

5.4. General configuration

The rocket configuration was defined into five main parts: the war head, radio equipment compartment, fuel tanks, turbine and pump section and the rocket engine. Each part was estimated at 1.5 m giving an overall length

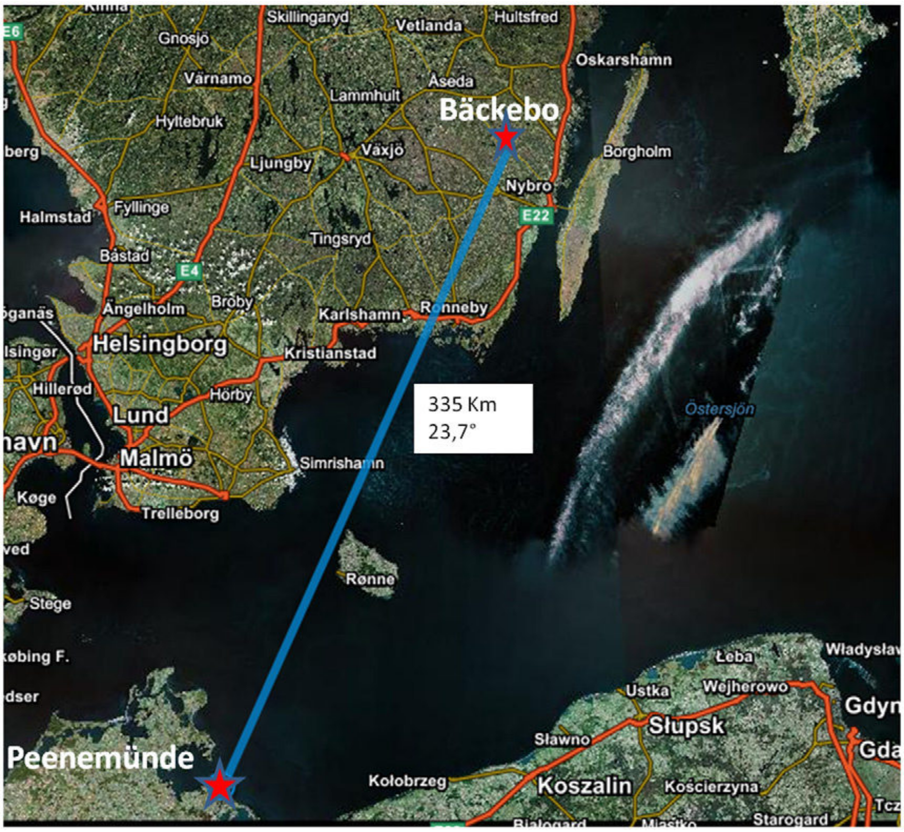


Fig. 7. Trajectory Peenemünde—Bäckebo, 23°E and 335 km (Map Google).

of at least 7.5 m. The reconstruction with ribs and stringers showed a circular form of 1.5 m (or larger) diameter. Many parts were welded together or put into what was assumed to be the original position of the rocket.

A total of 2010 kg of debris was recovered, but it was estimated that at least some 200 kg were "missing" (not found due to swamp area and smaller water ponds, or taken as souvenirs by locals). A later search with metal detectors in 1945 resulted in an additional 200 kg of debris [10].

The analysis of the liquid propulsion system estimates the overall propellant mass to 4800 kg for a rocket engine with a thrust regulation for a most efficient propellant consumption giving a total rocket mass of 8 t. The general mass figures of the rocket in the main part of the report are:

Empty mass	2,200 kg
Fuel	4,800
War head	1,000
Total Launch Mass	8,000 kg

In the appendix on the propulsion system by Prof. Boestad the values for a constant thrust propulsion system are given (11 t of propellant and an overall mass of 15 t) and this would enable the rocket to reach the true range of 350 km (see also comments by Professor Boestad, below).

Empty mass	3,000 kg
Fuel	11,000
War head	1,000
Total Launch Mass	15,000 kg

The fuel mass was calculated from the determined performance of the rocket engine (see below). The size of the war head was based on the configuration of the collected armoured steel sheets and the fact that a stronger explosive than conventional explosives could have been used. This would justify such a vehicle (estimated value more than 250,000 Swedish crowns) with only 1 t of explosives and not 2–3 t as more likely for conventional explosives. It was assumed that this particular rocket might have had a limited amount of conventional explosives due to the size of the "explosion pit" (∅ 5 m and 1.5–2 m deep) and that it was most likely a test vehicle ("*The air torpedo seems to have been a test vehicle, which got out of hand.*") [9].

The rocket was fitted with aerodynamic rudders at the end of the four fins and four additional graphite rudders in the rocket engine exhaust stream, which showed that the rocket was designed for very high altitudes.

5.5. Propulsion system

The propulsion system was defined into two engines for liquid propellants each with its own tank system, a smaller one for driving the turbine/pump unit (in the report called "turbine burner") and a huge rocket chamber for the propulsion (called "main burner").

The gas generator for driving the turbine/pump unit was estimated to operate for some 60 s with a fuel consumption of 1.9 kg/s. The turbine of Curtiss-type operated at 4000 rpm and provided a power of 450 hp to drive the two centrifugal pumps for the liquid propellant components, one with an impeller diameter of 270 mm (Fig. 8) and the other one with 350 mm (only fragments found). Based on traces of a bluish colour in one of the smaller tanks and some pipes it was assumed that the propellant fuel for the turbine burner was potassium permanganate. The oxidiser was identified as high concentrated hydrogen peroxide due to the fact that the ground around this tank at the point of impact was "burned" (Fig. 9).

The rocket engine was of "*huge*" dimensions with a mass of 450 kg and with the exhaust nozzle opening of 735 mm and a length of 1.7 m (Figs. 4 and 5b). The engine was equipped with 18 injectors for the oxidiser and the fuel, and some fuel was fed into the lower end of the nozzle for regenerative cooling. The estimated chamber pressure was 16–20 atm and the thrust 28 t. With a constant thrust the propellant consumption would be about 11 t for a total launch mass of 15 t. According to Prof. Boestad this would result in a max altitude of 120 km and a max speed of 1400 m/s and is also in accordance with the actual range of some 350 km. However with a regulated thrust for better propellant efficiency the consumption would be only 4.8 t for an overall mass of 8 t, but the altitude and range would not correspond to the actual values for an engine operating time of some 60 s.

As a major part of the upper fuel-tank was destroyed at the air explosion no clear evidence of the actual propellant composition could be found but a combination of hydrogen peroxide and gasoline was considered. It is also noted in the report that the higher numbers could only be verified when the actual size of the destroyed tanks could be more exactly determined [9].

5.6. Electrical and radio equipment

The radio equipment recovered was "*very elaborate*" and "*shows that the rocket was radio guided*". The report contains only a list of all equipment including two receivers for 23.3 MHz and ~50 MHz, two transmitters one of

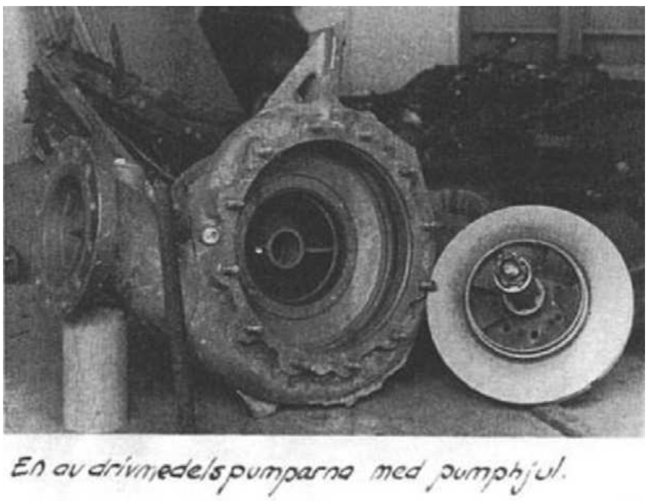


Fig. 8. One of the propellant pumps, ∅ 270 mm.
Source: Kjellson, Ref. [9]).

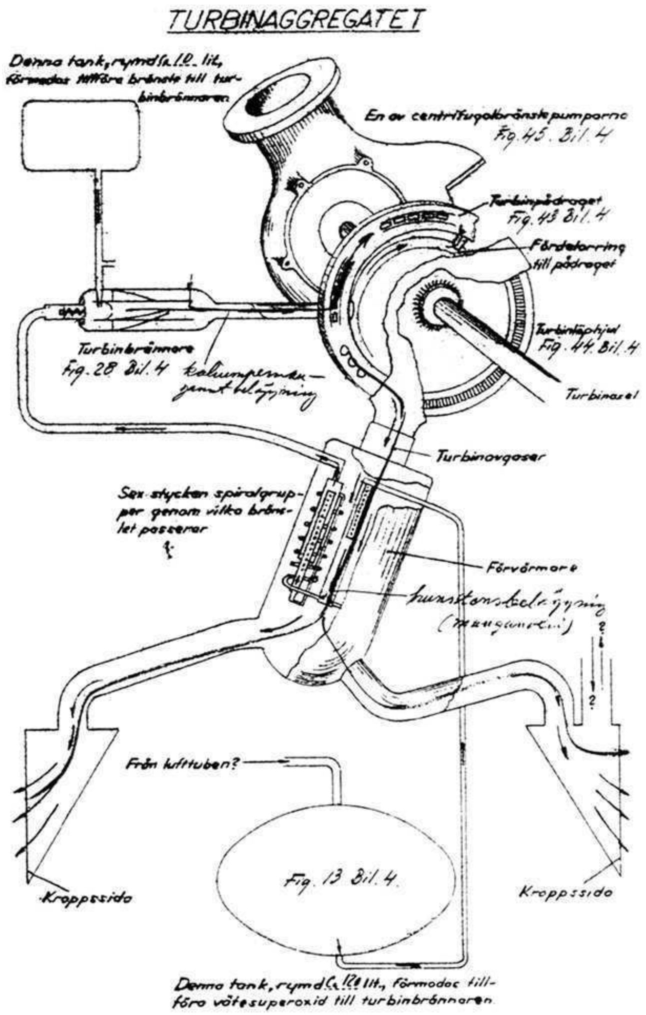


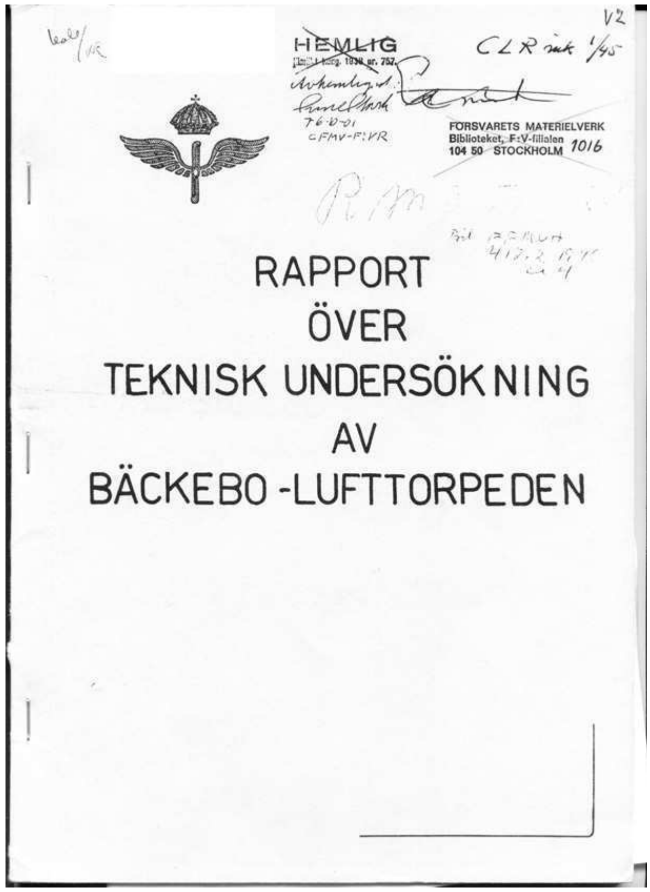
Fig. 9. Turbine/pump section.
Source: Boestad, Ref. [9].

which for 42 MHz, one amplifier, two generators and four rudder motors (Fig. 5c). No external antennas were found. It is noted that the investigation of the electrical equipment is ongoing when the first report is completed. (See also below concerning transport to Britain.)

Two electrically driven gyros were recovered but are not mentioned in the report except covered by one photo. It is also mentioned that major parts of the radio equipment seem to be missing and had probably fallen into the hands of "souvenir hunters" [9].

5.7. First Swedish report

The first official Swedish report was ready by July 21, 1944 (Fig. 10) after only two and a half weeks of investigations. The report consists of an 8 pages main part, 4 appendixes and an attachment with 45 photos of the debris at the place of impact and from the investigation at FFA in Stockholm. The appendixes cover e.g. the analysis of the propulsion system, an estimate of the max rocket altitude and the altitude of the rocket at the explosion. The major characteristics from the Swedish analysis are summarised in Table 1. Interesting is the title on the first page of the report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RAPPORT
ÖVER
TEKNISK UNDERSÖKNING
AV
BÄCKEBO -LUFTTORPEDEN

Fig. 10. First report on the A4/V-2 crash in Sweden. Bäckebo-Lufttorpeden, July 21, 1944.
Source: Ref. [9].

"*Report 21.07.1944 concerning the Bäckebo-bomb*" (*Rapport 21/7 1944 angående Bäckebobomben*) [9].

It should be pointed out that there is no evidence of an attempt to reassemble the whole rocket to an original configuration similar to praxis by aircraft accident investigations during the work in Sweden. This was probably due to the limited time available for the investigation after the British request to have the rocket parts transported to England. The report is also without any references to the later known official designation A4/V-2. It is worth noticing that some given data in the detailed investigations (appendices) are rather exact, but the overall report still gives ranges for certain values.

After the war, on January 7, 1946, a very extensive addendum to the original report was issued containing a large input from British sources. This was probably in return for the transport of the rocket debris to England during the war (see below). This report uses the names A4 and V-2. Both reports were classified as top secret and only declassified on October 1, 1976, 30 years after the war [9,10].

6. Transport to England

The two British intelligence officers attached to the investigation team also had the order to try and get the Swedish authorities to agree to handover the debris of the rocket to the British Intelligence Team. A first shipment of

Table 1
Performance data results of investigations.

		Kjellson, July 1944, Ref. [9]	RAF/Sandys, July 1944, Ref. [1,8]	RAE, August 1944, Ref. [13]	OKH/Wa, Feburary 1945, Ref. [16]	Notes
Mass (kg)	Total	8000/15,000 a	31,000–37,000	13,500	12,700–12,900	a = regul. vs. const. thrust
	War head	1000	6000–8000	868	1000	
	Radio/Nav. section			421	480	
	Upper tank section			857		
	Lower tank section			147	742 b	b = upper + lower tank
	Pump/turbine section			210		
	Engine section	450		590	931 c	c = pump + engine
	Fins			563	855	
	Propellant, fuel	4800/11,000 d	20,000–22,000 d	9612 d	3800	d = fuel + oxidiser
	Oxidiser				4900	
	Turbine propellant			178	188	
	Rocket empty	2200/3000	5000–7000	2803	3000	Without war head
Length (m)	Total	> 7.5		13.97	14.036	
	War head			1.70	2.10	
	Radio/Nav. section	1.2		1.41	1.41	
	Upper tank section			3.03		
	Lower tank section			3.03	6.215 de	e = upper + lower tank
	Pump/turbine section			2.18		
	Engine section			1.52	4.401 f	f = pump + engine + fins
Diameter (m)	War head lower end			0.97		
	Tank section	1.5	1.6–1.9	1.68	1.651	
	Fins (span width)			3.56	3.564	
Thrust (ton)		28		27	25.7	
Burning time (s)		60		75–80	60–63	
Propellant	Fuel	(Gasoline?)		Alcohol	Alcohol	
	Oxidiser	(Hydrogen peroxide?)		LOX	LOX	
	Turbine fuel	Potassium permanganate		Permanganate	Hydrazine + methanol	
	Turbine oxidiser	Hydrogen peroxide		Hydrogen superoxide	Hydrogen superoxide	
Rocket engine	Length (m)	1.7		1.53 g	1.78	g = Inject. head not incl.
	Diameter outlet (mm)	735				
	Diam. smallest sec. (mm)	400			440	
Gas turbine	Power (hp)	300–500		680	460	Boestad: 450 hp
	Revolution (rpm)	4000		5000	3800	
Range (km)		350	(250)	(350)	300	
Max altitude (km)		120			80 h	h = for used trajectory
Operating time (s)					320	
Guidance		Radio		Radio (+Gyro)	Gyro	

112 kg of electrical and radio equipment was received at the Royal Aircraft Establishment (RAE) in Farnborough on July 19, 1944 still while the investigations are ongoing in Sweden. This is presumably due to the fact that Squadron Leaders Burder and Wilkinson "hand carried" this equipment on their return to England on July 17 or 18, 1944. Nothing is mentioned of this delivery in any of the Swedish documents [1,3,12].

The main part of the V89 rocket debris (2 t) was flown to England at the end of July. On July 30, 1944 12 wooden cradles, earlier packed by S. Luthander at FFA, were picked up by Lieutenant Colonel Keith N. Allen on Bromma airport. Allen, flying for American Air Transport Service, a civil detachment of the US Army Air Force Transport Command, took off with his C-47 Dakota (NC 18639, *The Bug*) at 22:13 and the debris were flown via Leuchars in Scotland to RAE in Farnborough where they arrived on July 31, 1944 [1,4,13,14].

7. Technical investigation at RAE, Farnborough

7.1. Electrical and radio equipment

The electrical equipment was first in place at RAE and the investigation report was ready already on August 7, 1944 (Fig. 11). [12] One of the major findings was the identification of an E230 receiver, which was known from the HS 293 and Fritz X anti-ship missiles.

The report contains a number of detailed circuit diagrams of the equipment. The E 230 receiver operated in the frequency band 47–50 MHz, a TD5 transceiver operating in the transmission range 49–52 MHz and the receiving range 18.8–27 MHz and a third receiver operating at 51 MHz.

There is no mentioning of any gyros in the listing of the content of the shipment. This might be due to the fact that the amount of radio equipment found was so overwhelming that the first logical conclusion was that the A4/V-2 was using a radio guidance system and thus the gyros were of less importance and might have come with the shipment of the overall debris [13].

FEB 1356 MUSTERED

RADIO/S.4640/CPE/34 MAY 1955

RADIO DEPARTMENT,
ROYAL AIRCRAFT ESTABLISHMENT.

SECRET

RADIO EQUIPMENT OF BIG BEN

FIRST REPORT ON ITEMS RECEIVED FOR EXAMINATION ON 19TH JULY, 1944.

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The large quantity of boxes, components and miscellaneous fragments was found to be divisible into a number of groups as listed below, leaving a comparatively small number of items not associated with any group. The interconnections between the main units cannot be traced, however, and in some cases the functions of the equipment groups are at present unknown.

The total weight, with allowance for cabling is 250 lbs. ± 10%.

MAIN ITEMS

1. Rooeiver E.230, as used for radio control of HS293 and FX guided missiles.
2. Cast aluminium box containing a transmitter-receiver and power unit and arranged for retransmission of amplitude or frequency modulated signals, probably for accurate range measurement. Stencilled letters on the lid of the box are TO5 or possibly TD5. Manufacturer's code cae.
3. Cast aluminium box containing a receiver, set to 51 Mc/s., a 3-phase rectifier power unit and two other plug-in units in very badly damaged condition. Labelling Trg.1a/1b., and a numeral in large characters, probably 05630.
4. Cast aluminium box which is almost certainly the container for a second transmitter, a modulation amplifier and other units. The lid has the code SH26 painted in large characters.
5. Cast aluminium box labelled SN72 containing a rectifier power unit and five plug-in A.F. oscillators associated with so-called modulators. Five additional sockets are mounted in the base-plate, but the plug-in units for these positions are missing. All cast aluminium boxes have rubber gaskets beneath the lid and compound or fused-glass seals for outgoing connections.
6. A heavy cast alloy mounting plate measuring 10 x 13 ins. and arranged to take five plug-in "gerätegruppen" numbered 2, 3, 4, 5 and 6. Parts of one only of these units were found, i.e. No.5, and at a later date a complete specimen of this same unit has arrived from a Polish source. The mounting plate is labelled TD5.
7. Two long laminated iron-cored solenoids in hairpin formation, carrying a multi-layer coil on the bridge of the hairpin.
8. Miscellaneous items including motor alternators, D.C. to 3 phase 36 volt 500 c/s, lead-acid accumulator, tangled masses of wire associated with a main distribution frame, and a set of four rectifier units labelled TD5 apparently associated with the servo-motors which carry the same marking.

Fig. 11. RAE report EA 228/3 on the investigation of the electrical and radio equipment.
Source: Ref. [12].

7.2. General design

The overall configuration of the rocket and its weight and performance was documented in the RAE report EA 228/6 dated August 18, 1944 (Fig. 12). It is noted that "*It was found possible to establish most of the details by examination of the parts received from Sweden, but the overall length and the length of the main fuel compartment have been fixed more by information derived from Normandy sources than by direct measurement of the parts received from Sweden. In no case, however, does the information from the two sources conflict*..." [13].

The debris were investigated and assembled in a classic fashion known from reconstruction methods after an aircraft accident (Fig. 13). This final reconstruction at RAE revealed the missing major elements of the upper (alcohol) fuel tank which would explain the shorter length and lower mass in the Swedish report.

F.A.228/6

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Report on the German Rocket that landed in Sweden

Summary

From an examination of the parts of the German long range rocket, received from Sweden, it has been concluded that the leading particulars of the rocket are:-

Length	- 45 ft. 10 in. (14 metres)
Maximum body diameter	- 66 ins.
Weight about	- 13.5 tons
Weight of warhead probably	- 1900 - 2000 lb.
Weight of fuel about	- 9.6 tons
Thrust about	- 27 tons at ground level

The main fuels are probably oxygen and alcohol. These fuels may be mixed with other substances, with some variation in performance. The auxiliary fuel for providing power for the turbine-driven fuel pumps is hydrogen peroxide and permanganate, the fuel system being similar to that on the HS.293 rocket propelled glider bomb.

The rocket contains radio and gyro equipment for control and the control is by means of two sets of controllers. One set is located within the main jet and the other is carried externally on stabilizing fins.

Fig. 12. Final RAE report EA 228/6, dated August 18, 1944.
Source: Ref. [13].

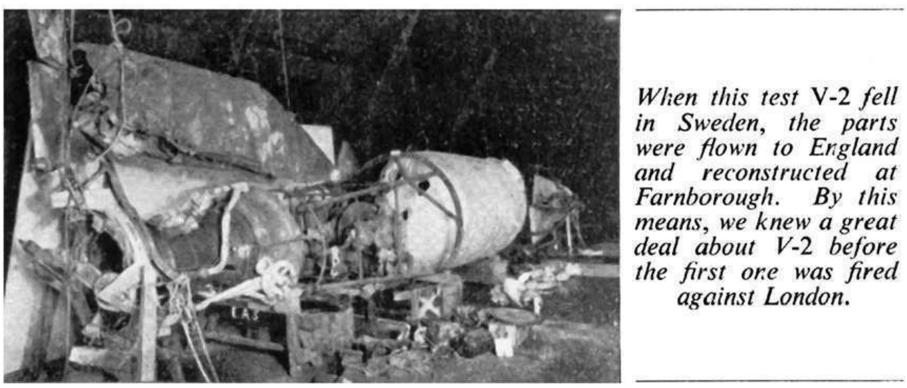

Fig. 13. Reconstruction of the A4/V-2 No V89 from Sweden at Farnborough.
Source: Ref. [15].

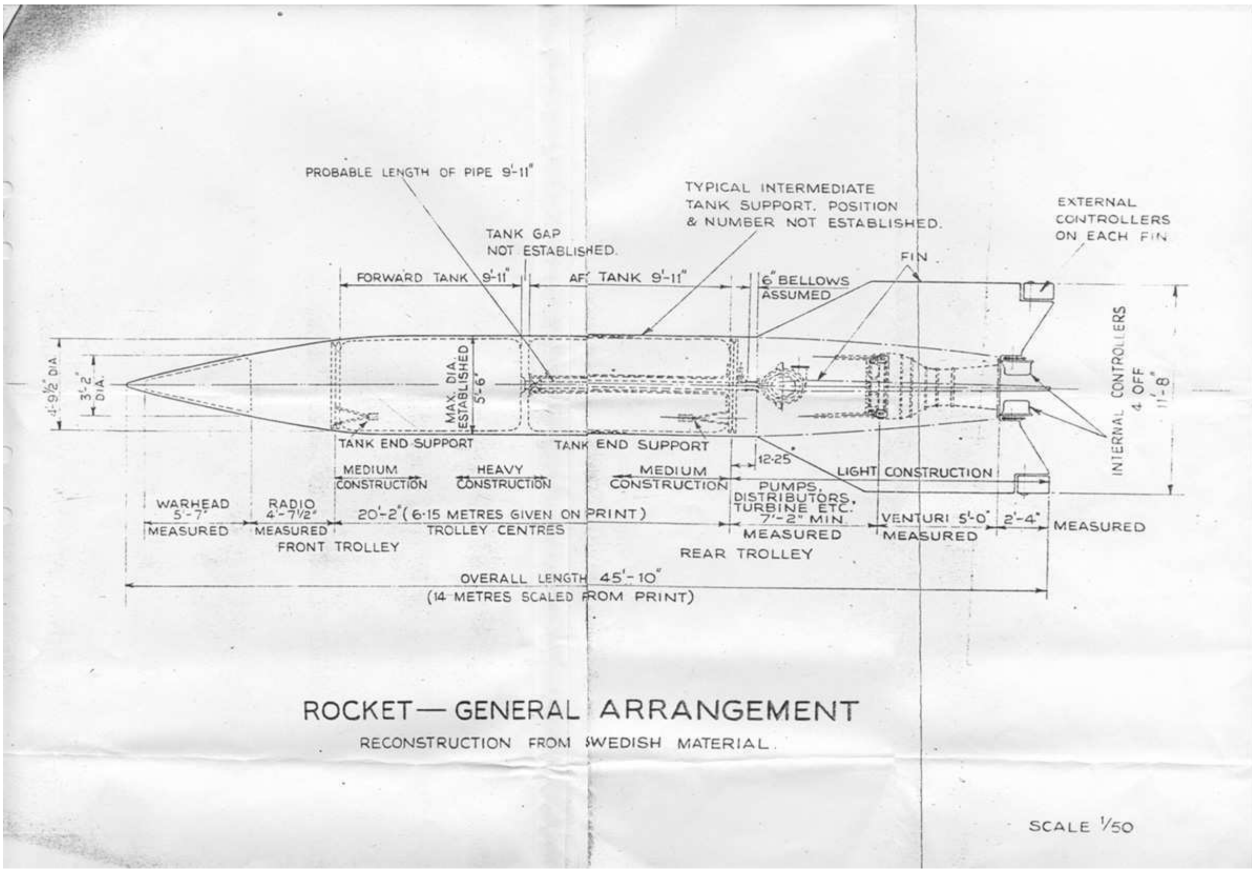

Fig. 14. Drawing in RAE report EA 228/6, dated August 18, 1944.
Source: Ref. [13].

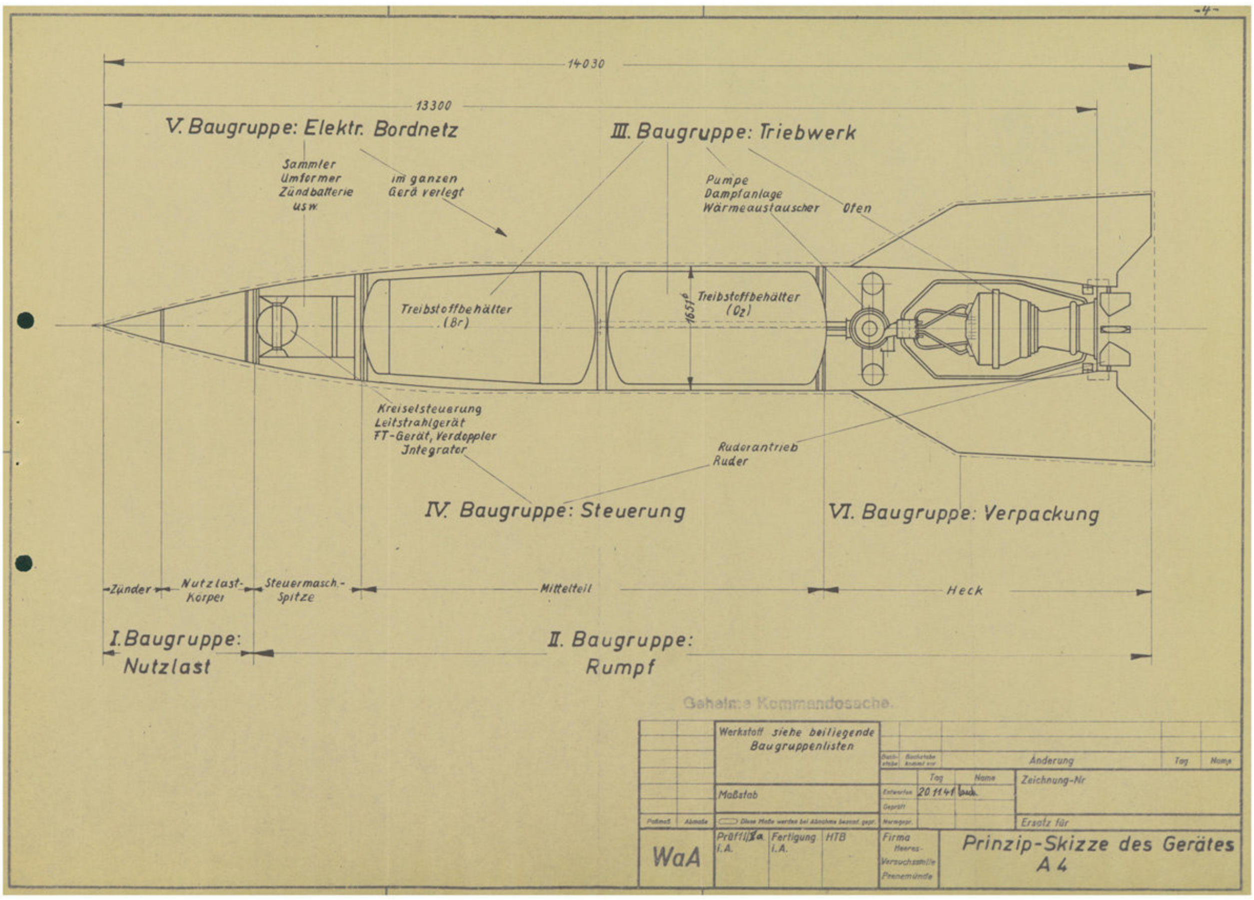

Fig. 15. Official German Drawing of the A4 from 1941.
Source: BArch RH 8–1350, Germany.

In discussions with the two Intelligence Officers visiting Sweden upon their return to England some unusual details came to light. The smaller propellant pump showed no traces of grease and it seemed the pump was lubricated by the pumped liquid itself. This would point at liquid air or oxygen as the oxidiser and the fuel was assumed to be alcohol.

The final report mentions the existence of gyros and concludes: *"The rocket contains radio and gyro equipment for control and the control is by means of two sets of controllers. One set is located within the main jet and the other is carried externally on stabilizing fins"* [13]. The continued investigations for adequate means of counter measurements of the expected upcoming war fare with the A4/V-2 should however be fully concentrating on a sole radio guidance option. The British government was by October 1944 permitted (against rules of neutrality) to put up two radio intercept stations in southern Sweden in order to follow the assumed radio guidance traffic of the A4/V-2 at Peenemünde.

The final report contains, in addition to detailed characteristics, a complete drawing of the A4/V-2 (Fig. 14), a diagram of the propellant system and details of the reconstructed war head. And here ends the long discussion on the actual mass of the war head: ~900 kg. The total mass of the rocket was calculated at 13.5 t with a propellant mass of 9.6 t. The overall length was 13.97 m with a max diameter of 1.68 m. The accuracy of the drawing in the final report, made after about two weeks of reconstruction work is remarkable when compared with an official German drawing (Fig. 15). There is no mentioning of the German designation A4/V-2 in this report either. The detailed characteristics are included in Table 1.

8. Analysis of Swedish and British findings

The investigation of the remains of the A4/V-2 no. V89 was to be performed in a similar way both in Sweden and England. The investigation teams consisted of a combination of experts in analysing and reconstruction of crashed aircraft and specialists for propulsion and guidance systems technologies. The method of reconstruction of the vehicle from the separate parts was used by both teams but at different levels of depth.

From the beginning there was no doubt about the origin of the rocket and thus the trajectory and the range (~350 km) was clear, except for the exact max altitude.

The overall dimensions were estimated differently due to the fact that debris from one major section, the upper tank one, was missing. In Sweden the length was assumed to be more than 7.5 m, were as the British colleagues came to the final length of 13.97 m, very close to the actual 14.036 m, a difference of only 7 cm. The low Swedish figure is mainly due to the missing elements of the fuel tank. The diameter was actually 1.65 m and in Sweden determined to at least 1.5 m and in England 1.68 m. The British experts had in the reconstruction work access to intelligence reports from France, Germany and Poland helping out with the overall size and thus the size of the missing fuel tank. The later Swedish search of about 90,000 m^2 did only result in some 200 kg of additional debris and would hardly have influenced the Swedish results had these additional parts been available already in early July 1944, as more than 800 kg were still missing.

Why was there a problem with the size of the fuel tank? First the actual fuel was not known and thus theoretical calculations for the assumed performance of the rocket turned out somewhat complicated. But fact is that the rocket broke apart and/or exploded at lower altitude before impacting ground. Normally and in this particular case, the V89 without an explosive war head, the whole rocket should have impacted ground without an explosion. The A4/V-2 rockets had for a very long time problems with the re-entry into the lower atmosphere. In the lower atmosphere the rocket reached a speed of at least 1.000 m/s and this cause an aerodynamic heating of the outer skin of the front part to some 680 °C. In particular the radio compartment, covered by wooden elements, was not designed for this heat. Furthermore the section around the radio compartment and the fuel tank was subject to sever vibrations. This all lead to a disintegration of the rocket before impact, and with residual fuel in the upper tank an explosion followed, which totally fragmented the fuel tank section [5].

The mass distribution was fairly well estimated by both teams, 15 t from the Swedish analysis to 13.5 for the British against the actual 13 t, this despite the fact that a rocket engine and a propellant pump system of this size had not been seen before. The Swedish team did not know at the time of the first report what exact propellant combination was used but assumed hydrogen peroxide and gasoline and thus the mass was slightly higher than with the use of the very efficient oxidiser LOX. The British managed to figure this out from the debris out of Sweden, but still overestimated the size of the gas turbine/pump unit (680 hp at 5000 rpm). Professor Boestad, a Swedish expert on gas turbines, concluded a thrust of 450 hp at 4000 rpm, close to the actual 450 hp at 3800 rpm. The reconstruction of the shell of the war head finally settled the mass to ~1000 kg, exactly the actual mass, and this was to end the long and partly irreconcilable discussions in England. And the altitude calculated for the disintegration, 1500–2000 m, was in accordance with German observations [9].

Concerning the propulsion system solid engineering knowledge gave the answer to this most critical question of propellant for a rocket engine of this size, LOX and alcohol. The engine in itself was of a size not known before, used a regenerative cooling principle and was some 30–50 times larger than any engines known outside of Germany at that time. The actual thrust of the rocket propulsion system 25.7 t was just slightly below what was calculated, 28 and 27 t. The drawings of the propulsion system and the rocket engine itself were rather accurate.

When it comes to the guidance system both teams could only arrive at the erroneous conclusion that the A4/V-2 was guided by radio signals, due to the equipment found and partly known from other missiles. The fact that the V89 was a test vehicle for the Wasserfall missile guidance system in addition to a regular test of the overall A4 vehicle could only have been arrived at by intelligence information from Germany, and thus very unlikely. It should take the British intelligence team another 6 months and many V-2 crashed in Britain to make the final conclusion on the actual guidance of the A4/V-2 as a ballistic missile.

With the knowledge of the propulsion system and the rocket guidance by means of fin rudders and rudders in the exhaust jet the explanation for the very simple launch platform for a vertical takeoff became evident and settles why no A4/V-2 launch rail was ever found on aerial photos of Peenemünde. The use of graphite rudders in the exhaust jet (thrust vector control) was again an example of a new rocket high technology put into operational use.

9. Was this entirely top secret?

The reports made by Swedish [9,10] and British [12,13] investigation teams were all to be classified as top secret. But despite this, information and some pictures of the rocket (rocket engine) were published in the local and national Swedish press in the day's right after the incident. Only one article, on June 15, 1944, contained photos (3) from the crash site (Fig. 16) [17].

That the press were not yet familiar with rockets is evident from the text of the lower two photos in Fig. 16. The left one, the rocket engine, is titled the "*Rocket Structure*" and the right one, the rocket engine fuel injector head, "*Rocket Body End Nozzle*". These photos


Experter från Stockholm till Bäckebo

Raketbombens rester skall undersökas

Flera blindgångare anträffade

Raketbombnedslaget i Bäckebo på tisdagseftermiddagen var givetvis allmänna samtalsämnet i orten hela gårdagen och mycket folk samlades i närheten av platsen, där "något inträffat" men då området var starkt bevakat av militär fick man i går nöja sig med att på avstånd betrakta resterna av raketbomben.

Enligt vad man meddelat Kalmartidningen finns det också mycket starka skäl till att hålla området avspärrat; man är nämligen inte fullt på det klara med ännu, om det inte finnes föremål i grannskapet som kunna explodera. På en enskild väg mellan Sjömåla och Gräsdal har exempelvis ett bombliknande föremål härrörande från raketbomben borrat sig ned i marken, så att endast överdelen är synlig och då man inte vet om föremålet rymmer explosiva ämnen, har man ordnat med särskilt noggrann bevakning av denna plats.

Ytterligare tre "blindgångare" anträffades på tisdagskvällen och äro givetvis föremål för behövlig övervakning. De föremål som här nämnts äro omkring 60 cm. långa och cirka 15 cm. i diameter.

Beträffande övriga rester av raketbomben ligga de också inom spärrat område och komma icke att röras förrän experter, som väntas till platsen från Stockholm i dag, undersökt desamma.

Hemvärnsmännen fortsatte sina efterforskningar även under gårdagen, men några nya fynd gjordes därunder icke. Det är också nu med säkerhet konstaterat att inga djur ute på bete kommit till skada, vilket man ej var fullt övertygad om på tisdagskvällen. Sedan besiktning av fynden i dag företagits komma desamma att insamlas och omhändertagas av de militära myndigheterna, för vilka raketkanonens rester böra utgöra ett välkommet studiematerial.

Den flera meter vida och halvannan meter djupa bombkratern. På hålets kant skönjes delar av bombens hölje av pansarplåt.

Till vänster del av radioraketens stomme och till höger raketkroppens slutmunstycke.

Fig. 16. Kalmar Läns Tidning June 15, 1944.
Source: Ref. [17] via Royal Library, Sweden.

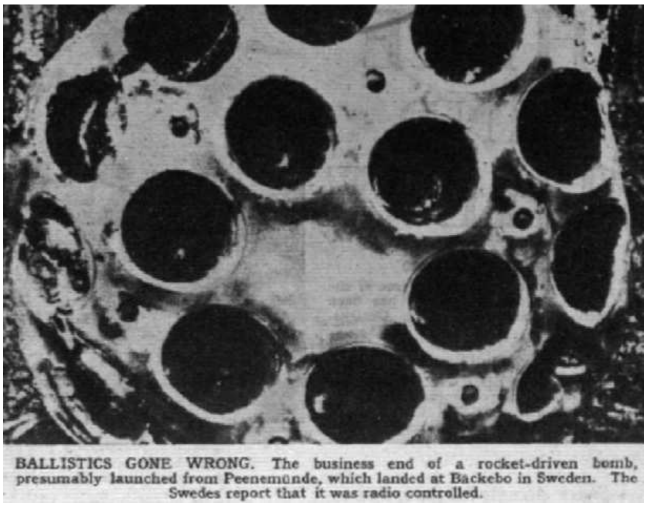
BALLISTICS GONE WRONG. The business end of a rocket-driven bomb, presumably launched from Peenemünde, which landed at Bäckebo in Sweden. The Swedes report that it was radio controlled.

Fig. 17. Flight International September 7, 1944.
Source: Ref. [18].

are not included in the official report and thus most likely press photos.

The situation was also known to the Germans the very day after the crash by reports from the German Embassy in Stockholm confirming the crash.

Obviously the Swedish general staff classified the incident and all material as secret and after June 17, 1944 nothing more was published in Sweden. This situation should remain until 1963 when the first post war articles were published.

In England a photo of the rocket engine taken at Bäckebo and with a clear statement of the location was published in Flight International on September 7, 1944 (Fig. 17) the day *before* the first V-2 attack on London. This photo is identical with the one published on June 15, 1944 by Kalmar Läns Tidning. Later, on December 21, 1944 Flight International was to publish a 4 pages article with technical details of the A4/V-2, but merely photos of rockets fallen in England were included [17,19].

In the very next years following the war a lot of information was to be published on the details and design of the A4/V-2 rocket. Despite this the technical investigation reports were to remain classified for a long time. The Swedish reports [9,10] were not declassified until October 1, 1976 and the British ones [12,13] were to remain classified at least until February 1956 according to markings on the documents available.

10. Conclusions

"*CAN A PILE OF SCRAP UNMASK A NEW HIGH TECHNOLOGY*?" The answer must be YES, assuming the right methodology is being used and provided experts with solid basic knowledge of physics and engineering are at hand. In only two months after the impact in southern Sweden the secrets of the A4/V-2 No V89 had been unmasked (except for the method of guidance) by two independent teams. And this for a vehicle of size and advanced technology not seen before outside Germany.

It is not known how much of the details from the Swedish investigation were available to the British team in early August 1944. The Swedish reports are all in Swedish and no English translations are known.

The two teams made an excellent job in reconstructing the rocket from the 2 t of debris and scrap. It is remarkable how close to actual data and performance the results by both teams were considering the fact that they were confronted with a totally new high technology. The analysis of the propulsion system and the rocket engine is astonishing, as this system was so far out of what the experts had seen or heard about at the time of the investigations. The problem with the guidance system is also a clear example of the fact that you can only analyse available hardware and reach conclusions from that. The fact that a Wasserfall guidance system was included in this test flight was just a pure coincidence for the following investigations of V89.

The Swedish report is containing very special information just added as the thoughts of a member in the investigation team. Colonel Kjellson reflected on an overall cost for a rocket of this size to be about 250,000 Swedish Crowns as very high to just transport 1 t of explosive. Similar thoughts were also coming into play in England in the year before the details of the A4/V-2 were known. It is to be noted that according to official rates of exchange during the war this would amount to some 150,000 Reichsmark in 1944 and should be compared with official German cost figures for the early series of A4/V-2 of 100,000 Reichsmark [3].

It is surprising how long the Swedish and British intelligence reports on the A4/V-2 No V89 were to be remained classified, although most information was in the public domain not too long after the war. This might also have contributed to some extent to the myths around this unusual incident and this particular rocket.

The debris of the A4/V-2 No V89 was after the war to be buried together with other German equipment like Würzburg radar under a runway extension at RAE in Farnborough. At this point in time a large number of A4/V-2 rockets were available to the allied and no need to store scrap anymore.

Acknowledgement

The author is in great debts to Dr. Ernst Steinhoff (deceased) for his elaborate and very personal accounts of the activities at Peenemünde during the war. Special thanks to Stephen Ransom, the RAE in Farnborough and the Arboga Robotmuseum in Sweden for making the British and Swedish investigation reports available. Last but not least special thanks to John Becklake for providing the information on the “final destiny” of the V89 debris and that of much other German equipment investigated at RAE.

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