Genesis of the surface-to-air missile

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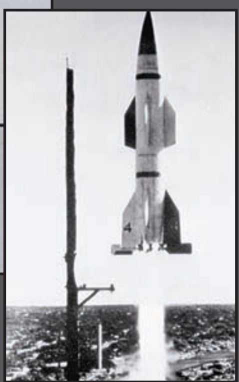
Wasserfall launch trial sequence (RLM)



Post war launch of a US Hermes missile, based on the Wasserfall W-10 series (NASA).

The air war over Western Europe could have had a very different outcome if the Nazi leadership had invested earlier in Surface-to-Air Missiles to defeat Allied bombers, which in 1944/45 devastated large sectors of Germany's wartime industrial base. Towards the end of the war, Germany was mere months away from the capability to launch SAMs in large numbers, with the potential to inflict heavy losses on the Allied Combined Bomber Offensive. How close Allied bombers came to facing the power of the Surface-to-Air Missile is not well known, but the thought provokes disturbing images of Allied aircraft lost on a huge scale.

The impetus for the development of the SAM was indeed the Allied Combined Bomber Offensive over Western Europe, especially Germany, but by then it was too late. Allied bombers initially disrupted and later devastated the industrial base that was critical to the maintenance of the Nazi industrial war machine, effectively ending Hitler's capacity to wage war. Without any credible air defence against the bombing onslaught the German war machine ground to a halt, starved of ammunition, spare parts, replacement equipment and synthetic fuel supplies.

By the end of the war, Germany had no less than five SAM systems in development, none of which achieved operational status, but which could have done so much earlier had the Nazi leadership taken the bomber threat seriously. The Wasserfall (Waterfall), Rheintochter (Daughter of the Rhein), Schmetterling (Butterfly), Feuerlilie (Fire Lily) and Enzian (Mountain Violet) had been developed with varying degrees of success.

The most mature of these was the Wasserfall, which became the design template for development of the post-war US Nike SAMs and the Soviet R-101 series.

Surface to Air Missiles or SAMs are ubiquitous in modern wars, and statistically have accounted for more aircraft losses since the 1960s than any other air defence weapon. While less cost effective individually than fighter aircraft, SAMs by sheer numbers and low demands on operator skills have occupied a permanent niche in air defence.

Little understood is that the SAM as an air defence weapon dates back to the 1940s, when it was devised, developed, and first attempted in use. The first generation of genuine operational SAMs were largely derivatives of wartime developmental SAMs.

The EMW Wasserfall W1, W-5 and W-10 FLA Rakete

Germany's SAM effort was launched in late 1942 when the commander of Flakartillerie ordered the development of 'Flugzeug Abwehr Raketen' or FLA-Raketen as a replacement for FLAK artillery weapons. The first contract on the Wasserfall project was awarded within months to the Flakversuchtsanstalt at the Peenemunde rocketry site, to be led by Dr Thiel and later Wehrner von Braun. Thiel earlier designed the A-4/V-2 ballistic missile engine, and built the Wasserfall around the earlier missile.

Unlike the V-2, which could be launched any time, a SAM had to stand by for days or weeks fuelled and ready to fire until a launch opportunity developed, which precluded use of the liquid oxygen and alcohol fuels used by the V-2. Instead, the Wasserfall's engine used a hypergolic (self igniting) propellant mix, with a Tonka or vinyl isobutyl ether fuel and SV-Stoff (Salbei) oxidiser, comprising 90 per cent nitric acid and 10 per cent sulphuric acid. High-pressure 250 atm nitrogen tanks were used to drive the propellants into the combustor, using an elaborate plumbing system with safety interlocks.

German sources claim that a successful launch of the Wasserfall missile against several USAAF bombers was performed in early 1945 but there appears to be no corroborating evidence of this. Had this indeed occurred, unless the aircraft was observed during the attack and the kills documented, there could be no supporting evidence.

Of all of the German SAM systems, the Wasserfall had by far the greatest potential, and had it entered operational service in early 1944 could have inflicted heavy losses on Allied heavy bomber fleets. Fortunately, the Nazi leadership were obsessed with bombarding Britain with strategically useless A-4/V-2 ballistic missiles, and put their funding into that program, launching over 3000 weapons for negligible military effect. Had the prodigious effort invested into the A-4/V-2 program been put into the Wasserfall, the course of the war could have been very different. The Wasserfall produced most effective in providing a baseline for postwar US and Soviet SAM designs.

The airframe of the earliest Wasserfall W-1 was a scaled down derivative of the A-4/V-2 design, with an ogival taper, cylindrical fuselage, and additional cruciform centre fuselage wings to increase the missile's achievable turn rate and glide performance. Like the A-4/V-2, the Wasserfall was launched vertically from a mobile pad, emplaced from a transloader truck or trailer.

The first launch attempt in January 1944 failed, with a pad explosion, but by the end of the war between 25 and 40 successful firings were performed, some with prototype guidance systems installed. Over this period, the airframe design evolved to the W-5 configuration, with shorter span and wider chord wings and larger tail, and the final scaled down W-10 configuration, with a smaller diameter and shorter fuselage and spans. The Wasserfall W-10 weighed 3500kg, had a diameter of 0.72m, a wingspan of 1.584m and length of 6.128m.

Achieved performance varies with sources, with the W-5 usually credited with a top speed of 2736km/h, ceiling of 60,000ft and range of around 14 nautical miles. This is similar performance to the much later Soviet SA-3/S-125 Pechora/Goa SAM, but using a heavier single stage airframe.

Initial warhead was designed to use 100kg of conventional explosive, later replaced with 300kg or liquid explosive, using proximity or command link fusing. German sources put the unit production cost of the Wasserfall at 7,000 -10,000 Reichmarks, using 1/8th of the manhours to produce the strategically ineffective A-4/V-2 missile.

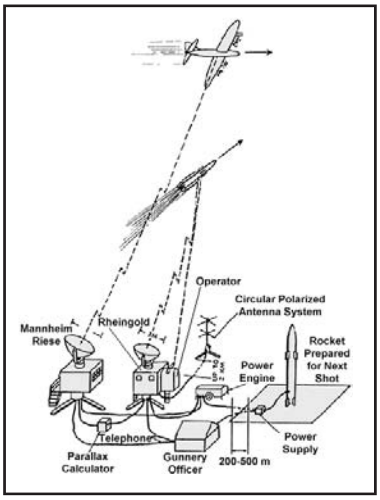
The guidance and control scheme is of particular interest. The missile used a gyro autopilot for pitch/roll/yaw control, with pitch, roll and yaw control forces generated by mechanically coupled tail surfaces and graphite thrust vectoring vanes in the exhaust, an arrangement found today in many missiles with TVC capability.

Three guidance schemes were in development. The baseline system used a radio command link, with an operator using a joystick to steer the missile to impact, a formidable task even against a 150 KTAS cruising piston engine heavy bomber.

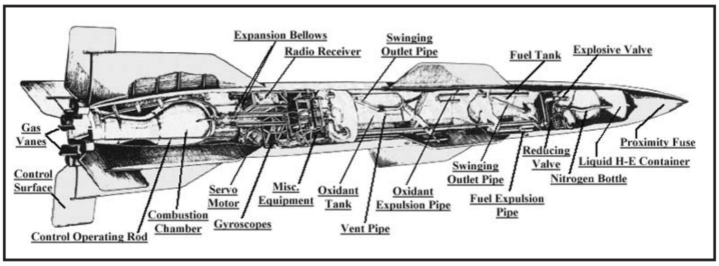
Two more advanced radar guidance schemes were in development. The first was the Rheinland, which was a manual command to line of sight system, using a transponder beacon in the missile and a tracking radar for both missile and target, allowing night attacks on RAF bombers or daylight attacks through an overcast. The second system has to have been a beamriding automatic guidance system, using two orthogonal fan shaped beams, which rotated as the beam tracked the target. In the latter system, the missile would automatically ride the beam to impact.

It is interesting that the rotating reticle infrared seeker, developed by von Braun for the A-4/V-2 and used to this very day, never found its way into the Wasserfall program.

The Wasserfall program was suspended in February 1945, as Soviet forces overran East Prussia. The Luftwaffe had ambitious plans for the Wasserfall, envisaging 200 batteries installed in three SAM belts across Germany, requiring monthly production of 5,000 Wasserfall reload rounds. The never implemented plan would have seen the first operational battery in November 1945, with twenty sites operational by March 1946.

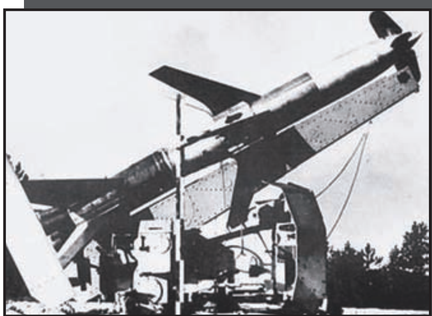


Wasserfall W-10 CONOPS (EMW)



Wasserfall W-10 Cutaway (EMW)

Rheinmetall-Borsig Rheintochter R I and R III FLA Raketen


Rheintochter R I on launcher.


Rheintochter R I at NASM, via Wikipedia.

Rheinmetall-Borsig, best known for designing guns, were heavily involved in developing SAMs. The two stage Rheintochter R I entered development in 1942 and first flew in August 1943, being later cancelled in January 1945. Unlike the larger Wasserfall, the Rheintochter R I used solid propellant rockets for both stages and carried a 150kg explosive warhead. Guidance was via a radio command link, with the operator optically tracking flares on the tail of the weapon. The Kranich acoustic fuse, designed for Ruhrstahl's X-4 air-to-air missile, was used to detonate the warhead. This design sensed changes in the Doppler shift of the target's propeller sound to trigger the warhead.

By the time the Rheintochter R I was cancelled, 82 rounds had been fired, with claims that only four failed. The R I missile was limited to a ceiling of 20,000ft, and the RLM demanded a ceiling of 27,000ft, which led to the development of the R III variant. The R III retained much of the R I upper stage but introduced a simpler cruciform wing and a pair of external strap-on boosters replacing the first stage of the R I. The aerodynamic and control configuration of the Rheintochter SAMs was used repeatedly by Soviet designers during the 1950s, reflected in the S-75/SA-2 Dvina and S-125/SA-3 Pechora SAMs.

Rheinmetall-Borsig F25 and F55 Feuerlilie FLA Raketen

Rheinmetall-Borsig's other foray into SAM development was the Feuerlilie series. The F25 was a subsonic test vehicle, designed to gather aerodynamic and control data. It used a Rheinmetall 109-505 solid diglycol fuelled rocket, which produced a six second burn at 4900 kN thrust.

The F25 variant was designed for air and surface launch and was trialled during 1943. The intended production weapon was the F55, designed to be supersonic and powered by a liquid fuel engine, rated at 62,000 kN, using R-Stoff or Tonka 250 fuel, comprising 57 per cent crude oxide monoxylidene, 43 per cent tri-ethylamine and SV- or S-Stoff oxidiser.

Initial trials were flown using the Rheinmetall 109-505 solid rocket achieving supersonic speeds, but the subsequent trials using the liquid propellant engine failed, with the last shot at Peenemunde cancelled.


F55 prototype during trials (RB)

Henschel Hs-117 Schmetterling FLA Rakete

Henschel, best known as an airframe and later glide bomb manufacturer developed the Hs-117 Schmetterling series of weapons, intended to be used as a SAM and heavy AAM. The initial proposal to the RLM in 1941 by Dr Wagner of Henschel was rejected as unnecessary given Goering's assurances that Reich airspace was immune to Allied attacks.

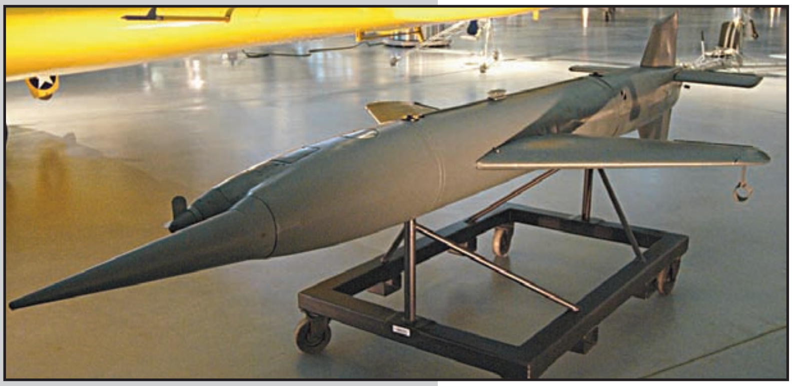
Development of the Hs-117 was approved in 1943 resulting in a prototype in early 1944. The four metre long Hs-117 used a conventional, swept wing aircraft configuration, with strap-on dorsal and ventral Schmidding solid rocket boosters for rail launch as a SAM.

The primary engine was the 3.7 kN thrust Walter HWK 107-729 using hypergolic liquid R-Stoff and SV- or S-Stoff propellants. A radio command link was used for guidance and a Fuchs proximity fuse was used to initiate the 250kg warhead.

Twenty-one launches were performed between May and November of 1944, with the missile reaching a ceiling of 36,000ft. German sources claim some operational trials but there is no supporting evidence for these.

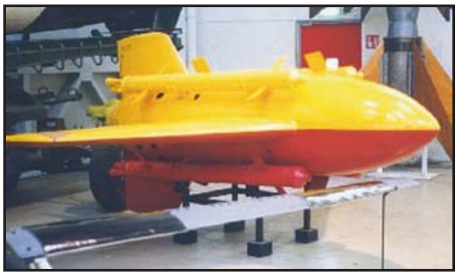
The Hs-117 is also of interest as it became the basis of the first heavyweight AAM to be developed, the Hs-117H. This missile used the Hs-117 airframe, less the external boosters, with a BMW 109-558 main engine. It was to be launched by heavy interceptors such as the Ju-88 and Do-217 used as night fighters.

Like the Wasserfall, the Schmetterling had the potential to become an effective weapon, which thankfully never materialised.

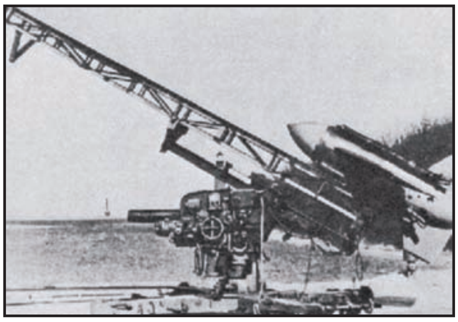


Hs-117 at HASM. (Wikipedia)

right: Hs-117 on Flak 88 launcher (Henschel/RLM)



Enzian at Cosford in the UK.



Enzian on Flak 88 launcher.

Messerschmitt FR-1 through FR-5 Enzian FLA Raketen

The last of the German SAM designs was Messerschmitt's Enzian series, which exploited experience from the Me-163 rocket fighter program. Like the Me-163, the Enzian was a compact short tailless delta wing design but much smaller as it was a missile, with a span of 4.05 m, length of 3.75 m and launch weight of 1,800 kg.

The airframe was built from 'non-strategic' materials including glued plywood and sheetmetal. Walther HWK 109-502 dual propellant engines were used for most trials. The final engine configuration was by VfK-Triebwerk Zg.613 A 01 designed by Konrad for the Rheintochter, burning Visol and SV- or S-Stoff propellants. This engine was fuelled by 550lb of propellant and delivered 20 kN down to 10 kN over a 24 second burn. Takeoff boost was provided by four strap-on Rheinmetall-Borsig boosters, rated at 60 kN.

The Enzian was launched from a modified Flak 88 trailer, in which a launch rail replaced the 88 mm gun. Once the boosters burned out and were jettisoned, the Enzian would climb under rocket power guided by radio link to a position ahead and above a bomber formation. Gliding at motor burnout, the original aim was to fly the Enzian into the formation and detonate its massive 500 kg warhead by radio link. Repeated experiments proved this impractical, so terminal guidance was then introduced. The Enzian would glide under terminal seeker control into the bomber formation.

The Enzian warhead is especially interesting since its large size was intended to produce fatal damage effects to multiple bombers at once. Three warhead variants were planned. The first involved a payload of 25mm steel pellets filled with incendiary material and cast into explosive using a thin sheetmetal casing. The second warhead was a container, which fired 550 small rockets into a conical volume in front of the missile, lethal to 500 metres. The third warhead was designed for pure blast effect, lethal to a radius of 45 metres.

Guidance and control involved elevons with electrical actuators and a gyro autopilot. The prototypes flew with the Strassburg Kehl III VHF radio command link, to be supplanted in production with the Telefunken Kogge operating at L-band.

At least two terminal seekers were planned: the Austrian Kepka 'Madrid', a scanning infrared homing seeker; and the Elsass (Alsatian), an active radar homing seeker. Proximity fusing was to be via a Marabu or Fuchs radio proximity fuse, or the Paplitz infrared fuse.

Flight trials of the Enzian prototypes continued through 1944 but the project was also halted in January 1945.

In perspective, Germany's SAM programs were 'too little too late' to have achieved significant effect. Had programs such as the Wasserfall and Schmetterling been funded earlier and more generously, then the course of the air war would have changed decisively. While the Allies could have used jamming and defence suppression aircraft to attack guidance radar sites, there is no doubt that an operational Wasserfall would have caused significant losses, as the S-75/S-125 did in Vietnam during the 1960s. A respite from Allied bombing would in turn have delayed Germany's collapse, as it would have allowed more resources to be invested in the land campaigns. The Nazi leadership was thus in more than one way culpable for Germany's defeat.