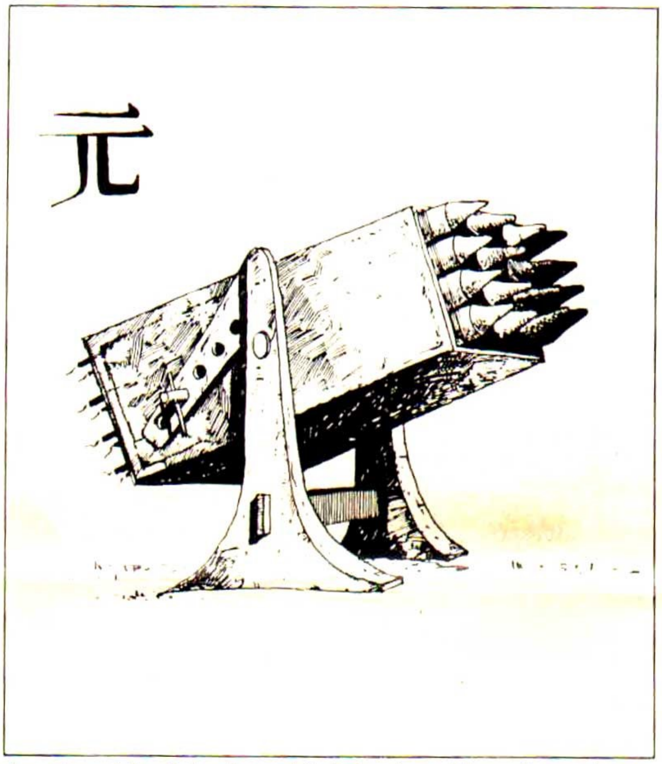
Brian J. Ford Rocket Technology, 1930/1945

THE ROCKET RACE

From the Chinese official Wan Hu, who incinerated himself during the first recorded attempt at manned rocket flight in 1520, to the equally inventive and more successful Werner von Braun, rocketry has played an increasingly important part in man's attempts to propel his weapons, and himself, through the air. It was not until the Second World War, however, that the full potential of rockets became apparent. Every major belligerent power made some advances in this field, but it was the Germans who made the greatest progress



Ancestor of the *Katyusha* and *Nebelwerfer*: a Mongolian rocket battery of the late 13th Century, developed by the Chinese

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A British Z-Battery in action. These rockets were intended to supplement the anti-aircraft barrage

The war was in many ways responsible for a dramatic change in rocket technology. In the 1930s the subject was, if not ignored, certainly widely misunderstood and underestimated by the majority of informed opinion; developments took place in irregular, uncoordinated leaps and the whole subject was more the province of the eccentric inventor than the serious scientific investigator. Today of course the scene is very different indeed. The rocket is part (in some senses a mainstay) of our civilisation, and the technology of rocket development and design has become one of the foremost branches of scientific advance.

It is easy to imagine that progress would have been inevitable even without the stimulus of the wartime effort—but there is evidence to the contrary. In the first place, rockets were first used in war many centuries ago (they were well documented in the 13th Century—and rockets for less warlike purposes date back certainly well over 1,000 years), but without any startling progress in principle being made for literally centuries on end. And secondly it is worth noting that the German A-4 (the V-2 rocket) was still used by the USA as its most successful space vehicle for research as late as 1952—the American scientists had to use one of their former enemy's weapons for their own research!

So we can see the importance to the history of rocketry of the Second World War. Earlier rockets had been no more than simple 'fire-propelled' charges or flimsy, experimental rigs designed to test an idea. It is believed that the first recorded use of rockets in war was in 1232, when the Chinese fired propelled arrows at invading Mongols. Roger Bacon gave a good formula for the propellant gunpowder in the early part of the 13th Century and the Paduans (1379) and the Venetians (1380) used rockets extensively in war. Indeed it was as long ago as 1520 (or thereabouts) that a Chinese government official named Wan Hu built an apparatus made of kites, fitted with a saddle and with a battery of rockets at the rear—truly the first rocket vehicle. Mr Wan, sadly, was blown to fiery pieces in the attempted launch.

In 1802 a British officer, Colonel William Congreve, began to study the use of rockets in war and a few years later the first Rocket

Troop–175 men in all–was formed. By 1815 the Americans had followed suit with the formation of ten rocket batteries; and later William Congreve was knighted for his enterprise. His book on rocketry published in 1814 was the first work of any detail on this subject. Then, following the use of rockets in ship rescue (they were used to secure a line aboard a stranded vessel) the Frenchman Le Prieur produced a rocket that could be fired from an aircraft–the first air-to-ground missile. The Horace Farman F40P biplane was later fitted with racks of five of these rockets on each side of the fuselage.

The father of the rocket, in its theory at least, was the Russian Tsiolkovsky who–in 1903–had designed a hypothetical liquid-fuelled rocket powered by liquid oxygen and liquid hydrogen. He also expounded the principles of the multi-stage rocket. Later, in America, the physicist Robert H. Goddard made several experimental liquid-fuel rockets, many of which flew in the late 1920s to heights of several hundred feet. By the time he died in 1945, Goddard had done sterling work in the field, but he was still largely unrecognised and had (due to unsympathetic treatment by the US government) been unable to take his ideas past the prototype stage. Not until 1959 was he posthumously honoured by Congress.

Though it is not widely realised, the Russians made similar progress at about the same time. In 1929 a petrol-and-air motor was tested by the Russian designer Tsander, and by 1935 a 10-foot rocket (very like the V-2 in appearance) fuelled by paraffin and nitric acid, had been developed and successfully fired. However, it was the Russian *Katyusha* rocket, a solid fuel device, which came to prominence in the war, rather than their larger missiles. The standard model was 5 inches across, 6 feet in length, and weighed just over 90 pounds–half of that was the warhead. The rocket was feared by the Germans, and it was used with devastating effect during the war years.

Japan: time was too short

The Japanese had carried out piecemeal development, like the West, before the war but not on a significant scale. However, on the stimulus of the war conflict, greater efforts were made in the field. Support arms in the form of short-range rockets were hurriedly produced for limited use. The range was between 100 and 150 yards, and the size of the rockets varied greatly, from 10-pound 3-inchers up to 1,500-pound rockets nearer 18 inches in diameter.

However, the pressure of increased US air attacks was predicted by the Japanese, who then set up a development section at the Naval Technical Research Unit. Solid-fuel rockets were developed for surface-to-air deployment, in the 10- to 55-pound range, and at the same time the first of the *Funryu* missiles was produced, the case being made by the Yokosuka Dockyard, the engines by Mitsubishi. *Funryu* 1 was only experimental. It was designed as a means of attack against warships and had a control guidance system; but the rocket–solid fuelled–was not successful and was abandoned without any flight tests. *Funryu* 2 was more successful. It was produced with modifications learned from the earlier prototype and became a perfectly practical guided missile.

Time was too short, however, with the war nearing its end, for large-scale production to start. However, a liquid-fuelled *Funryu* 3 was produced (again as an unsuccessful prototype), and like the *Funryu* 2 on which it was based it was theoretically capable of reaching an altitude of about 3 miles. *Funryu* 4, the climax of the series, was more successful than the *Funryu* 2. A liquid-fuelled guided missile, it was capable of reaching altitudes of 20 miles although it was never produced on a large scale.

The Japanese also developed air-to-surface missiles which were, in effect, rocket-powered bombs. The framework of these devices was produced by the Kawakasi Aircraft Company and was made of wood, and a Mitsubishi peroxide motor specially designed for the purpose gave them a range of some 3 miles (increased in later modifications to over 5). The maximum thrust developed was in the region of 550 pounds and the rocket motor fired for 75 seconds to accelerate the rocket along its predetermined trajectory. A Mk 3 version of these weapons was also designed, with an audiosensory system intended to 'home' on the shock waves of Allied gun batteries–but the project was cancelled in the early part of 1945.

It was in the same year that the *Ohka* kamikaze rocket plane (also known as the *Madurai*) appeared. This had been conceived in 1943, and was developed during 1944; it was first used in battle in April 1945. The device was a 2,645-pound bomb (which took up more than half of the entire weight) housed in a wooden winged casing equipped with three rocket motors capable of delivering 1,700 pounds of thrust. The overall length was some 20 feet, with fins being just over 16 feet from tip to tip. The device was carried by a mother plane until within 50 miles of the target. Then, with a pilot securely strapped in position, it would be released and allowed to glide at less than 250 mph towards the target–it was, because of its speed, an easy target throughout the glide phase. The pilot then ignited the rockets, which burned for 10 seconds, accelerating the device to over 600 mph, as he tried to keep it aimed at the target vessel; it was capable of causing considerable damage. The pilot, who was of course sacrificed in the attempt, gave rise to the two nicknames of the device used by the Allies: the British often referred to it as 'the suicide plane'; the Americans gave it a Japanese word, *'Baka'*. It means, literally, 'fool'.

Britain: advisers to the USA

Work in Britain during the years immediately before the war was far greater than is generally realised–indeed the USA sent specialists to learn British rocketry techniques as part of the American effort later in the war. British research and development first produced a 2-inch rocket propelled by cordite. Both the inner and outer surfaces of the charge burned during firing, which kept the exposed surface area relatively constant and prevented the risk of premature explosion; the warhead itself was protected from the heat by a special compound of sodium silicate and ground aluminium. Tests were highly encouraging, and by late 1940 a large 3-inch version–which could be fired in volleys of up to 128 from a pad known as a 'projector'–was brought into service. But of course there were many problems to overcome and the organisation of such a rocket battery had to be developed experimentally with virtually no previous tactical experience to go on. Accordingly, on May 20, 1940, in the back room of a public house at Aberporth in Wales, a meeting was convened under the command of the Ordnance Director, and it was decided at that discussion that the rockets should, in principle, be used as a routine measure against aircraft. Within weeks the Greenwich firm of G. A. Harbey had been appointed to the task of mass-producing the 'projectors', and by September over 1,000 had been manufactured.

The following month, Duncan Sandys (then a major) took control of the experimental battery and organised a rocket section to defend Cardiff with the 3-inch rocket, and the first German plane was brought down on April 7, 1941. By the end of 1941 there were three such batteries (known as 'Z' batteries) in existence, one at Aberporth for training (where there is still a missile testing range) and the other two in operation around Cardiff. Later, pioneer radar, radio-command, and order-of-battle prediction apparatus was assembled on the nearby Penarth golf course, and the UP-3, as the rocket became known, was intensively studied and modified, eventually emerging as a 6-foot rocket with a lethal radius of nearly 70 feet. Within a year–by December 1942–there were 91 batteries in existence, despite persistent enemy raids which twice razed the factory producing the rocket fuses.

At about this time, the British produced the first of their air-to-surface missiles, a modification of the 3-inch rocket, nearly 6 feet in length and capable of a speed of 1,000 mph. By 1942 they had been developed to operational stage, and although their use was confined to naval warfare (particularly against submarines) they were a very successful development. In 1943 the army, which had been investigating the potential of a 5-inch rocket, 6 feet in length, decided to turn the idea down as impracticable and in the tactical sense superfluous. However, realising that it could be used to back up assaults from amphibious craft, the navy acquired the interest instead and began production of the six-unit 'Mattress' projectors for use at sea. They were used, with devastating effect–particularly on the morale of the enemy forces–in the landings on Sicily and Italy which followed. Further trials at Sennybridge, also in Wales, encouraged the army to change its mind during the following year, and a 'Land Mattress' went into production which was used by the Canadians when they fought for the Rhine and Scheldt rivers.

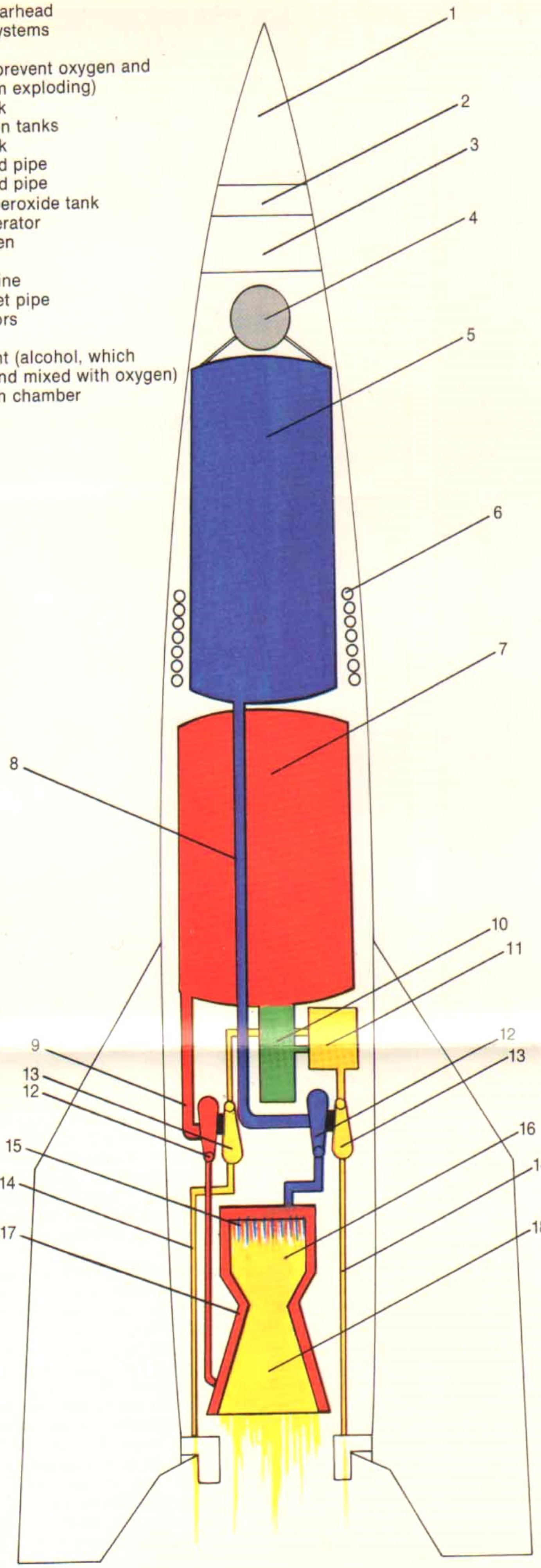
It was towards the close of the war that the most enterprising rocket was developed: the so-called 'Stooge'. This was designed specifically to attack enemy aircraft, particularly (as it happened) the Japanese suicide squads, and was a 740-pound, 10-foot-long, radio-guided missile with a range of some 8 or 9 miles. It had a top speed of 500 mph and carried a 220-pound warhead.

An English scientist, Dr Lubbock, also did some experimental work on liquid-fuel rockets but it came to nothing in practice; however, the British were left with such a fund of knowledge and so wide an experience of solid-fuel devices that after the Pearl Harbor attack the Americans sent specialists to study British techniques. Subsequently a British pilot plant for production of fuel was sent to the USA to help with American developmental research.

America: one step behind Germany

Quite apart from their co-operation with the British later in the war, the Americans had of course carried out much original development in the earlier years and, although they did not make such

1. Explosive warhead
2. Guidance systems
3. Gyros
4. Helium (to prevent oxygen and alcohol from exploding)
5. Oxygen tank
6. Refrigeration tanks
7. Alcohol tank
8. Oxygen feed pipe
9. Alcohol feed pipe
10. Hydrogen peroxide tank
11. Steam generator
12. Pump (driven by turbine)
13. Steam turbine
14. Steam outlet pipe
15. Fuel injectors
16. Igniter
17. Fuel coolant (alcohol, which is heated and mixed with oxygen)
18. Combustion chamber



BOTH ENDS OF THE SCALE

In the notorious German A4 'V-2', shown in cutaway at left, the rocket war reached its technical zenith; but at the other end of the scale were rocket weapons which either saw longer service or which were equally important in the fields for which they were designed. Some of these are shown below

The Russian *Katyusha* missile was invariably used in mass. The full salvo did have an unavoidable 'scatter', and a considerable part of its effect was on the morale of both Soviet and enemy troops; but *Katyusha* salvoes amounted to a vast concentration of firepower

The British developed the 2-inch AA rocket to supplement their anti-aircraft gun barrage, and the rockets were intended for use against low-flying bombers. Like the *Katyushas*, the British 2-inchers were fired from batteries known as 'projectors'

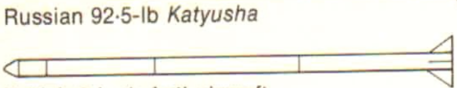
Developed as an air-to-surface weapon, the US 4·5-inch missile was soon pressed into service as a ground-to-ground missile, fired from tanks, trucks, jeeps; and it was also used by the US Navy in pre-landing softening-up bombardments

The British 3-inch followed the 2-inch into service, and by the end of 1940 3-inch batteries were being used alongside the heavy gun defences in the UK. The rockets were fired from batteries of twin-barrelled launchers in salvoes of 128

The US 'Mousetrap' was introduced late in 1942 after the US Navy had asked for an anti-submarine bomb similar to the British 'Hedgehog'. For this sub-chaser role they were grouped in batteries of four, and scored many kills against both Japanese and German submarines

The British 'Stooge' rocket was a winged missile introduced to combat the Kamikaze menace. It had a power plant of four rockets, was guided by radio control, and had a range of 8 miles

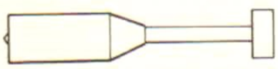
Russian 92·5-lb *Katyusha*



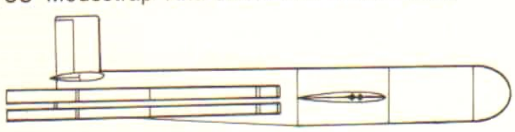
British 2-inch Anti-aircraft

US 4·5-inch Anti-aircraft

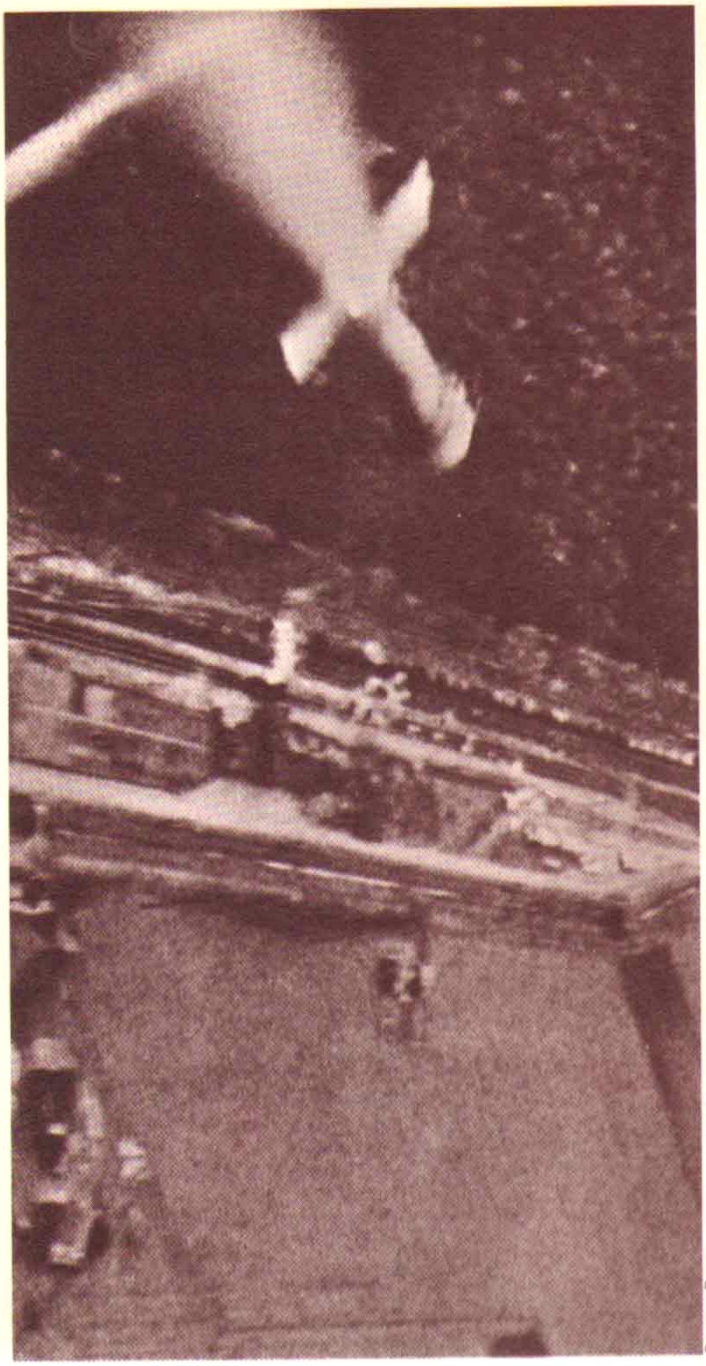
British 3-inch Air-to-Surface



US 'Mousetrap' Anti-submarine rocket bomb



British 'Stooge' 740-lb Anti-Kamikaze



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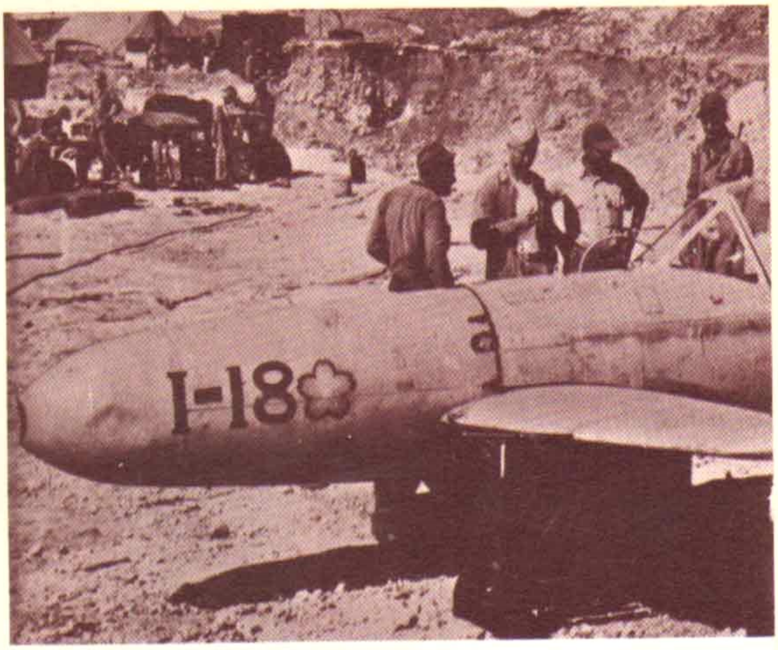


impressive practical strides as the German rocketry teams, they did much work in a greater range of devices than is generally realised. For instance, it is perhaps surprising to realise that by the end of the war the US Navy alone had over 1,200 factories engaged in rocket production in different ways.

Almost certainly the first really successful American missile was one of the smallest: the bazooka. It was in December 1940 that development began, largely to find an answer to the insurmountable problem of recoil when an armour-piercing shell was fired from a portable gun; so fierce was the equal-and-opposite recoil that it seemed impossible to design an anti-tank weapon which could be used by the individual soldier on the battlefield. But of course a rocket-propelled missile would overcome all these problems, since the motive force is generated during flight and is not due to the massive reaction of an exploding cartridge. As a result the 3½-pound, 1-foot, 9-inch rocket was developed and this, fired from a 7-inch tube, was capable of being carried by a soldier and fired from shoulder-height in battle. It is said, incidentally, that the device derived its title from a sardonic description applied by an unimpressed major who witnessed the first demonstrations of the prototype. 'Recoilless gun?' he is reputed to have said. 'It looks more like Bob Burns' Bazooka to me!' – so the name was born and it has stuck ever since.

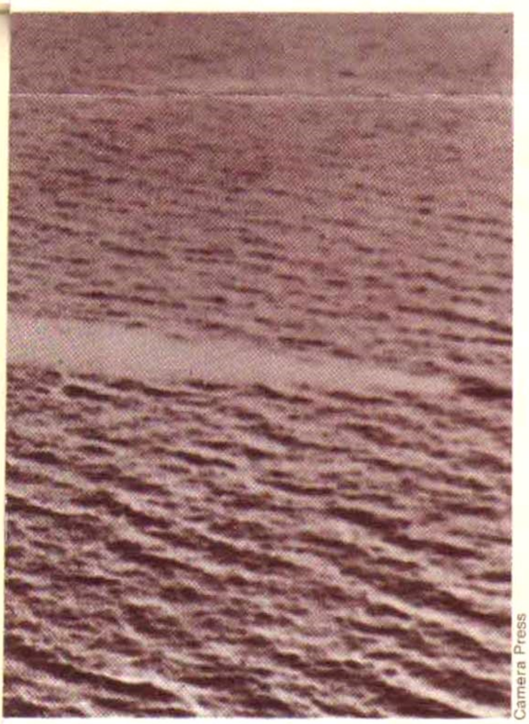
The bazooka in war was a formidable weapon: it could knock out a tank at over 200 yards and was effective against stationary targets (emplacements, etc) at up to 750 yards.

Subsequently (and after a period of Air Corps opposition which was only overcome by witnessing the results of British experience in the field) similar but slightly enlarged rockets were developed for use in aircraft. One of the most popular was a series of devices 4½ inches in diameter, some of them with a range of several miles, and a slightly smaller rocket (3¼ inches in diameter) was also developed as a test vehicle for proximity-fuse experiments. Later a larger version – 7⅕ inches in diameter – was used for heavy bombardment on land. Then 20-tube 'Whizz-Bang' launchers, and 24-tube 'Grand Slam' launchers were fitted to tanks, and later a 120-tube launcher – the 'Woofus' – was fitted to landing craft. These missiles had a range of only a few hundred yards and a speed less than 125 mph but they did prove effective for their specialised purposes.

Two other Air Corps developments in 1943 were less successful. The first of these was a 'hydrobomb', a kind of rocket torpedo which would propel itself through the air and then through water to its target by means of conventional rockets – but this idea was soon abandoned as impracticable. Another plan was for a rocket-assisted bomb which – because of the boost in speed it received in flight – would penetrate heavy armour. This idea, too, was dropped; however, the experience gained in its development was used in a navy project. At the time too many enemy submarines were escaping because the pilot overshot his target: by the time the attacking aircraft had sighted the submarine and released its bombs, they were usually too late to land, and so overshot the submarine harmlessly. The navy therefore decided to develop a retrorocket which would slow a bomb and allow it to fall straight down on to the target – this was, in many ways, the same principle the Air Corps had already developed, and after modifications the idea became

Far left: A British 3-inch rocket streaks away from a Hawker Typhoon. Around the target – a goods train – other rocket bursts can be seen. These rockets were far from accurate but those which found their way to the target inflicted spectacular damage
Top left: It was the Japanese who developed the biggest operational anti-shipping missile of the war: the Kamikaze Ohka, carried within range of the target by a mother plane and then released to become a piloted stand-off bomb; it was powered by three rocket engines
Top right: America's 'Tiny Tim' – 10 feet long and 11·75 inches in diameter – packed the punch of a 12-inch naval shell. It was primarily created for use against pill-boxes and bunkers in the invasion of the Japanese home islands.
Bottom right: The US 'Bat' was a radar-guided air-to-surface missile, 12 feet long with a 1,000-lb payload. In April 1945 a Bat sank a Japanese destroyer 20 miles from its launch point – its maximum range

Imperial War Museum



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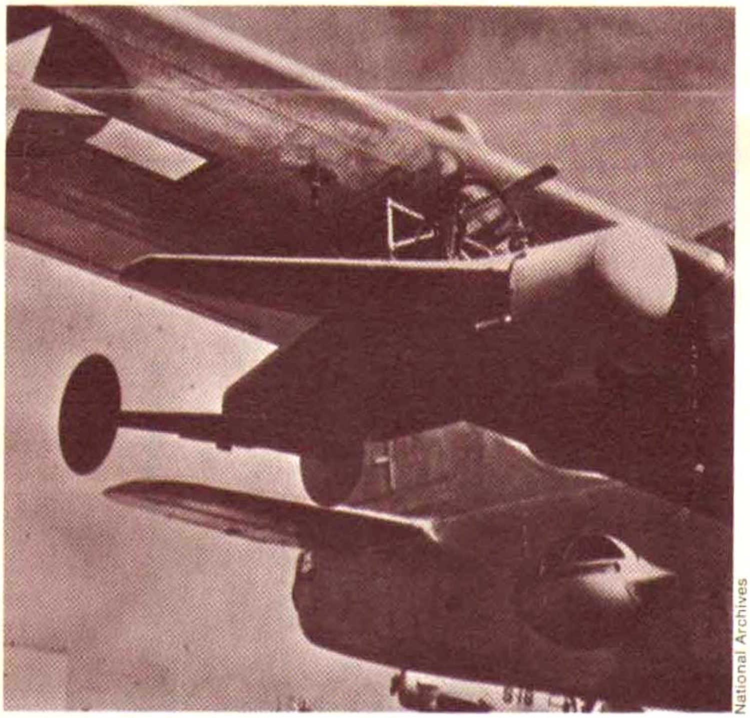

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reality. The last submarine to be sunk in the war, on April 30, 1945, in the Bay of Biscay, was destroyed by one of these weapons.

The USA also developed, during the later years of the war, what proved to be the largest airborne rocket (fired from an aircraft in flight) used in battle. This weapon – as is often the case – was incongruously dubbed 'Tiny Tim' and was a 10-foot missile carrying 150 pounds of TNT, and designed for attacks on bunkers. It was fired by a length of cord which triggered the ignition sequence when the rocket had fallen a few yards below the aircraft that released it. It was a crude method of firing: too crude in some ways, as the first test – in 1944 – resulted in the rocket demolishing the mother-plane entirely. The crew was killed.

Air-to-surface missiles also made an appearance in the American war effort; one, the 'Gargoyle', was developed from a glide-bomb and was fitted with liquid-fuel motors when it went into production in 1944; but it missed the war, and ended up as a postwar test vehicle. The 'Bat' was a long-range radar-guided weapon nearly 12 feet in length and capable of speeds of 3,000 mph. It had a range of 20 miles, but also arrived too late to make any significant impact on the progress of the war.

It is not generally known that the French, during the period of occupation, also made some small progress in rocketry by the development of liquid-fuel prototype rockets at a secret base in Lyons. This was given the title of *Service Central des Marchés et de Surveillance des Approvisionnements* (literally: Central Service for Markets and the Control of Supplies) and developed a perfectly workable LOX (liquid-oxygen) petrol-ether motor which was fired experimentally in 1941. During the tests one of the rockets disappeared and was never found; it apparently flew some 20 miles from Le Renardiere and landed – but the occupying troops do not seem to have made any record of finding it. It was probably just as well.

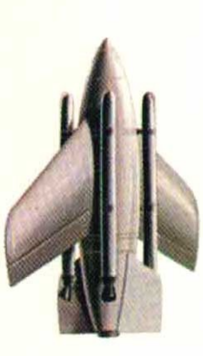
Germany: supreme in the field

There can be no doubt, however, that the major advances in rocketry were made in Germany. The German scientists and technicians were supreme in their field, and set the pattern that postwar missile development – including the modern drama of space exploration – has followed. And yet much of the German effort in the field was prewar; it was anticipatory – unlike the other developments we have considered – and was designed to fit the nation for its envisaged rôle: as a leading world power, with force to back its arguments.

We must not interpret this widely-held view too literally, however. The gist of it is accurate, certainly, but Germany did have a heritage of rocket development in the early 1930s which was carried out for its own sake by earnest and well-intentioned pioneers, and it is arguable that this in itself engendered the right climate of opinion which in turn gave impetus to the later development of rockets as machines of aggression. Early in 1931 the first of the modern era of liquid-fuel rockets was launched from a base near Dessau. It had been made by an enthusiast, Herr J. Winkler, with financial support from Herr H. Huckel; and the so-called Huckel-Winkler 1 flew, on March 14, 1931, to an altitude of perhaps 1,000 feet.

In May of the same year the first Repulsor rockets were fired to heights of several thousand feet, and simpler solid-fuel rockets

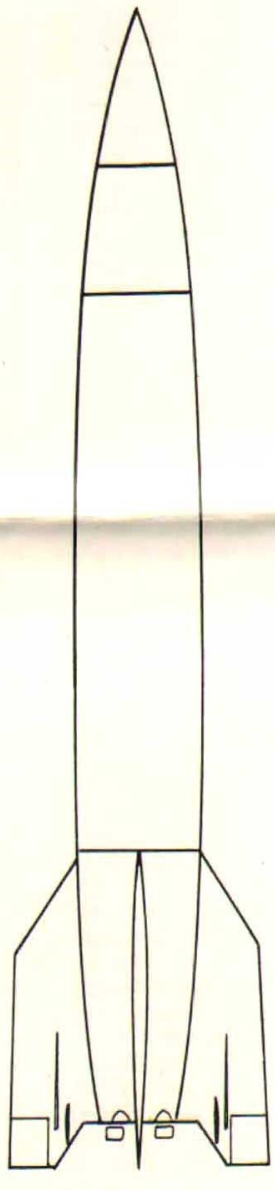
Konrad *Enzian*
Designed in 1944 by Dr Konrad of Messerschmitts, the *Enzian* was basically an unmanned development of the Me-163 *Komet* rocket fighter, intended for an AA rôle. Some 60 *Enzians* were completed, of which 38 were flight-tested. Although series production began in late 1944, none of these highly powerful missiles ever saw service.
Warhead: 660 lbs (with proximity fuse)

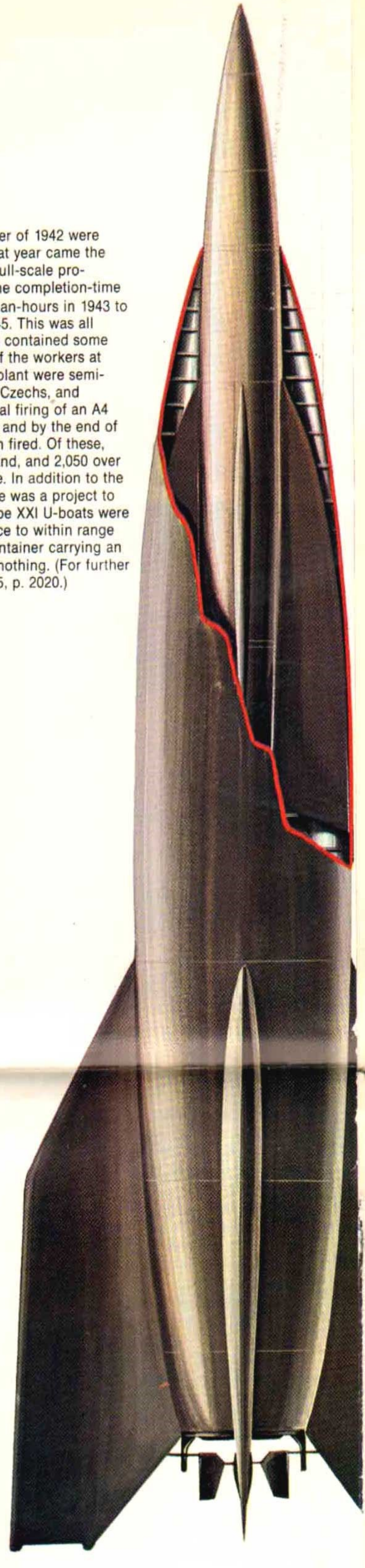


Henschel Hs 117 *Schmetterling* ('Butterfly')
Developed from the Hs 293 glider bomb, the *Schmetterling* was a subsonic AA missile with swept-back wings and a cruciform tail. When first submitted in 1941, the design was rejected, only to be resurrected in 1943 too late to attain full-scale service. It was the most advanced German missile of the war, radio-controlled, with the altitude range to combat high-flying bomber formations.
Range: 3,300 feet.
Warhead: 50 lbs

***Rheinmetall Rheinbote* ('Rhine Messenger')**
A four-stage ground-to-ground missile, based on experience gained with the two-stage *Rheintochter*. The first and second stages separated from the missile 6 miles after launch, while the third and fourth stages remained attached to the warhead. Tests were so successful that at least 220 *Rheinbote* missiles were fired against Antwerp in November 1944; but the missile's chief weakness was its very light warhead.
Range: 136 miles.
Warhead: 88 lbs

A4 ('V-2')
First test flights in the summer of 1942 were failures, but in October of that year came the first successful flight. Once full-scale production had been ordered, the completion-time was cut down from 19,000 man-hours in 1943 to 4,000 man-hours in early 1945. This was all the more notable as each A4 contained some 30,000 parts—and the bulk of the workers at the Nordhausen production plant were semi-skilled slave workers: Poles, Czechs, and Russians. The first operational firing of an A4 came on September 8, 1944, and by the end of the war some 5,000 had been fired. Of these, 1,115 came down over England, and 2,050 over Brussels, Antwerp, and Liége. In addition to the normal land-based rôle, there was a project to use A4s against America. Type XXI U-boats were to tow three containers apiece to within range of the US seaboard, each container carrying an A4; but the project came to nothing. (For further details see p. 2839, and Vol 5, p. 2020.)

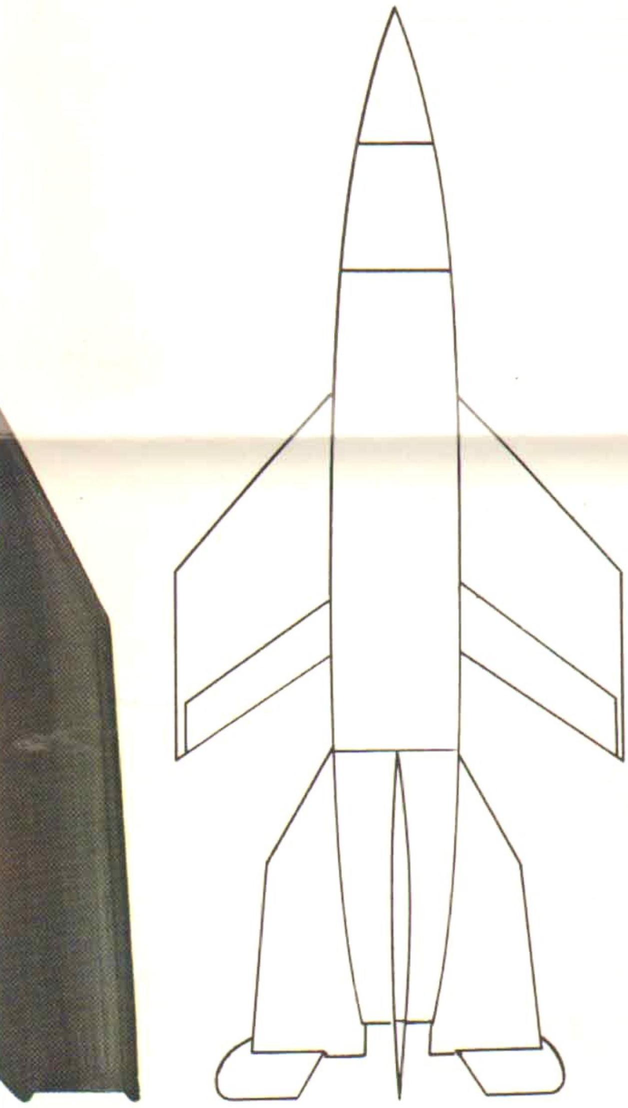




From the Reich's rocket armoury

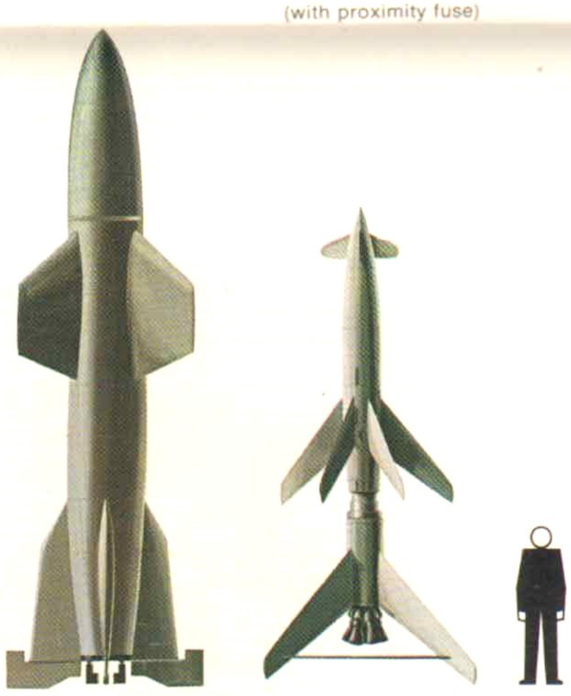
A9/A10 (Left)
As a result of the A4-B tests, the two-stage A9/A10—a projected rocket to bombard the USA from Germany—was rushed ahead: too late to reach prototype stage. The A10 booster was to separate at 110 miles; it was to be recoverable, and special parachutes had to be designed to cope with the thin air of the stratosphere. The A9 second stage, a streamlined winged version of the A4, would then continue under its own power to an altitude of some 217 miles. It would then descend to 28 miles, where the air would be dense enough for the wing controls to guide it on the final glide-path to the target. Range was estimated at about 3,000 miles; the warhead was the standard A4 weight of 2,145 lbs

A4-B (Below)
It was practically impossible to enlarge the A4, or to use more powerful fuels to extend its range; and so the Peenemünde team decided to perfect a winged A4, which would use the speed of the missile after power cut-off for a prolonged glide. The result was the A4-B, which had reached test-flight stage by January 1945



C-2 *Wasserfall* ('Waterfall')
Very similar in basic design to the A4 (V-2) rocket, *Wasserfall* was shorter, with four stub wings. Like *Schmetterling*, it was intended as an AA missile to break up the high-flying US day bomber formations; but only 45 firings had been made by the end of the war, of which only 12 were successful. *Range:* 31 miles. *Warhead:* 220 lbs

***Rheintochter* R1 ('Rhine Daughter')**
A two-stage flak rocket launched from an inclined ramp, *Rheintochter* was designed for use with the *Rheinland* system: two radar plots, one following the target and the other guiding the missile, both of them correlated by a ground controller. The booster unit separated from the main missile just over 1 mile from the launch point. *Altitude:* 20,000 feet. *Warhead:* 250 lbs (with proximity fuse)



were carrying mail on an experimental basis in the same year. Indeed in 1933 a largely unsuccessful rocket was built in Magdeburg as an experimental forerunner of a manned projectile! But in Germany, as in other parts of the world, the slump of the following years put a brake on progress in the field.

However, by the beginning of the war there had been several new developments – and these were directly orientated towards weaponry. The first of the 'A' series (which culminated in the V-2 rocket) was developed about 1933; the A-2 flew to 6,500 feet at the end of 1934, and by 1937 the A-3, a large rocket of 1,650 pounds and standing 21 feet tall, had been flown. Its LOX/ethanol motor was virtually the experimental prototype for the A-4 – the V-2 rocket as it came to be called.

Subsequently an A-5 was built, a smaller version of the A-3 and with a much improved guidance system, and by 1939 it had been successfully flown in test flights over the Baltic. Many of the rockets were recovered by parachute and flown again. Most of this work was carried out at Peenemünde, under the direction of Germany's two leading rocket scientists, a Captain Dornberger and Wernher von Braun (who now commands America's side of the 'space race'). There were, however, other workers in the field: Hellmut Walter had set up his own *Kommanditgesellschaft*, a firm to produce rockets for assisted take-offs in aircraft, and the Bavarian *Bayrische Motoren Werke* was engaged in rocket development work in Munich.

As we can see, then, Germany had something of a national heritage of rocket expertise before the declaration of war in 1939, and further developments were clearly possible. One of the first devices to materialise was the V-1, a winged missile propelled by a petrol-fuel pulse-jet developed in the late 1930s by *Argus Motoren Gesellschaft* from an idea by the Munich engineer Paul Schmidt. It was a principle of almost captivating simplicity. The motor was, in essence, a tube several feet long, closed at its front end by a series of hinged flaps which could only open inwards. In the middle of the tube was a series of perforated fuel-delivery tubes.

As the motor moved at high speed through the air the power was produced in a series of pulses: the shutters at the front end, forced open by the slipstream, admitted a column of air to the combustion chamber, drawing with it a spray of fuel. The mixture was ignited by an electrically heated filament and it burned rapidly, the back-pressure forcing the shutters closed and so propelling the machine forward by the jet of exhaust gases leaving the rear of the motor. Then, because of lack of air, the burning gases were temporarily extinguished and the slipstream was once again sufficient to open the one-way shutters and so another blast of air was admitted to continue the cycle.

This motor is extremely simple to manufacture, almost foolproof to run, and cheap to produce on a large scale – indeed it has only one practical disadvantage, and that is of course that the device needs to be rapidly moving forward before the motor will start at all. A spontaneous takeoff is therefore impossible, and the Germans had to launch the machine at speed from specially designed ramps or from aircraft. The ramps that were built were visible to aerial reconnaissance, however, and many were destroyed by Allied bombing.

As we have seen, the V-1 had much to commend it. But it also had many disadvantages, and these prevented it from becoming the serious threat to the Allies which Hitler had envisaged. For one thing, it was too slow and could be shot down by anti-aircraft gun emplacements or ignominiously tipped over in flight by a judicious nudge from a fighter aircraft and sent to a premature end in the English Channel. The guidance system, too, was unreliable, and of the 5,000-odd V-1s fired at Antwerp only 211 ever detonated on the target. Moreover, less than one-fifth of the V-1s fired at the British Isles are believed to have actually exploded anywhere in the target area.

A little known four-stage rocket was developed in 1944 and tested in Poland. This was the *Rheinbote*, of which little was ever heard in the West; it was a solid-fuel unguided missile, merely aimed at the target. It was not a success: some 60 *Rheinbote* missiles were fired at Antwerp in January 1945, but virtually no damage of any kind resulted.

The only rocket offensive

The A4 rocket – or the V-2, as we shall call it – was first given a completely successful test flight on October 3, 1942, and after several delays production of the missile went ahead near Peenemünde. After heavy Allied bombing in August 1943, the assembly line was moved to Nordhausen in the Harz Mountains and towards the end of the war 900 missiles per month were being produced. The V-2 offensive started on September 6, 1944, when two were fired towards Paris. They both failed in flight. Two days later the assault against southern England started but here too there were many problems: the payload was too small, the development time had not been sufficient to eliminate all the teething troubles of the rocket's many mechanisms, the control system sometimes failed suddenly or – because of design weaknesses – the missile would occasionally explode violently on the pad or during its descent. Roughly 4,000 were fired against England in the seven-month offensive, but less than 1,500 reached England at all. Even so they caused much damage and claimed 2,500 lives – although the great speed of the rocket at impact (it landed at over 3,500 mph five minutes after the launch) meant that it dug itself in before detonation and it expended most of its energy on producing no more than a deep hole.

Though the V-1 and – more particularly – the V-2 were giant examples of ground-to-ground missiles, there were also smaller versions in existence. A smoke-rocket, designed to produce cover for advancing assault troops in 1941, proved so accurate that it was modified for bombardment a little later, and the Germans also developed a copy of the American bazooka after its effectiveness had been demonstrated in battle. Later a two-stage anti-tank rocket 2½ feet long was developed; it was guided by impulses sent along wires which unspooled from the wingtips as the missile flew. Underwater missiles were launched with complete success in the latter part of 1943, but (because of fears about the impairment of submarine manoeuvrability that might result) this enterprising idea never became a production-line reality.

A range of surface-to-air and air-to-surface missiles was also developed in Germany during the war years. The *Feuerlilie* F-25, which first flew in 1943, and the F-55, which followed a year later, were both surface-to-air missiles using sophisticated gyro-control and servomechanisms for direction and stability. The latter missile flew faster than the speed of sound, and both were about 16 feet long. The unsuccessful *Enzian*, developed at about the same time, was a solid-fuel plastic wood device but it was cancelled when only 25 of the rockets had been produced. The aircraft-like *Hecht*, a peroxide-powered rocket only 8 feet long, was only developed to the prototype stage, and 80 *Rheintochters* – of which only 18 were successful – were produced experimentally too. These were 3,500-pound rockets over 16 feet in length and capable of near-sonic speeds. The *Schmetterling* Hs-117 was 12 feet long and took the form of a midwing monoplane. It was fired from a pad with some success, and began to be known as the V-3, but it never entered large-scale production. The 6-foot *Taifun* barrage rocket which could reach over 2,000 mph was still in trial stage at the end of the war, although both liquid- and solid-fuel motors for it were in production by 1945. Last in this category was the *Wasserfall* missile, virtually a smaller model of the V-2, which was intended to have an infra-red homing device for the final 'kill'. Over a dozen of them were successfully fired.

Rockets designed for firing from aircraft were just as varied. The BV series were unsuccessful attempts to make an anti-ship missile that would drop to within 10 feet above the sea and then level off and fly to the target. But the task was too difficult in practice and the idea was abandoned. Several Hs rockets were also designed: winged missiles between 12 and 20 feet long with a range varying between 4 and 10 miles. They were liquid-fuelled, but not a success in practice and many modifications throughout the series were carried out. The X-4 was a 6⅔-foot-long rocket guided by signals sent along a wire unspooled from the wing-tips (rather like the X-7 discussed earlier, which was intended for land use) and said to be in an advanced state of production at the war's end; these were descended from the so-called X-1, the SD-1400, a 15-foot rocket with four wings and a tail unit containing automatic guidance apparatus.

However, despite the variety and the undoubted technical skill embodied in all these devices, the war was already moving to its inexorable end. Early in 1945 contradictory directives from different authorities were arriving at Peenemünde and the aura of the chaos inevitable in defeat led to the halting of research and development. Within weeks Braun and his colleagues had moved south, to the Harz Mountains, in an effort to make contact with the advancing American troops. This they succeeded in doing, early in May 1945, when in the town of Reutte they finally surrendered to a counter-Intelligence officer, Charles L. Stewart. It is interesting, with the benefit of hindsight, to recall the difficulty that Stewart had in convincing the authorities that these rocket technicians were of any importance at all, and indeed Dornberger, who was turned over to the British, spent two years in a POW camp in England before being released and joining the others in the USA. In fact, as we can now see, these scientists have probably done more than any other wartime team to alter the face of modern civilisation.

[*For Brian J. Ford's biography, see Vol 3, p. 1117.*]