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ROCKETS AND MISSILES

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by Bill Gunston

Illustrated by Ron Jobson

Willowisp Press®

The art on page 2 is an artist's impression of flaming fire arrows—rockets—being fired in salvoes by Mongolian forces against the town of Kai-fung-fu in 1232.

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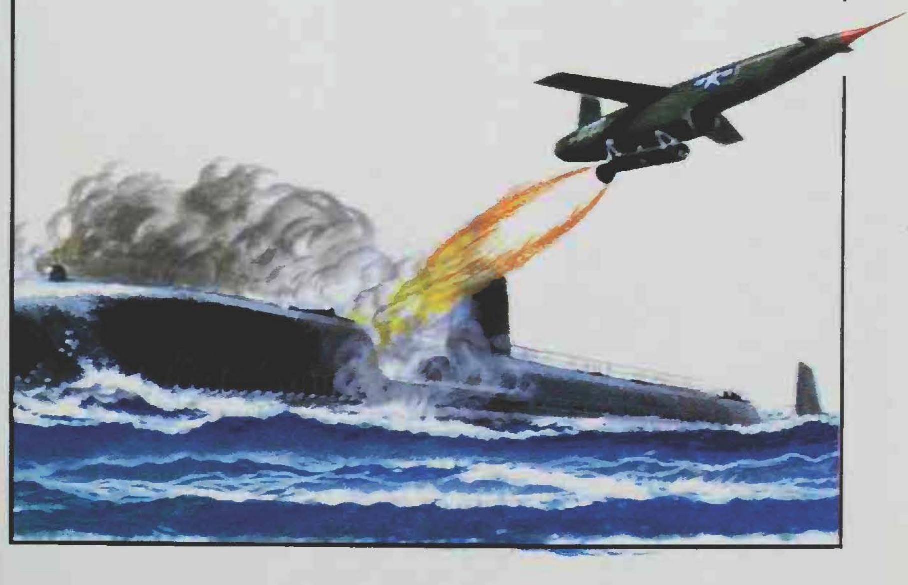
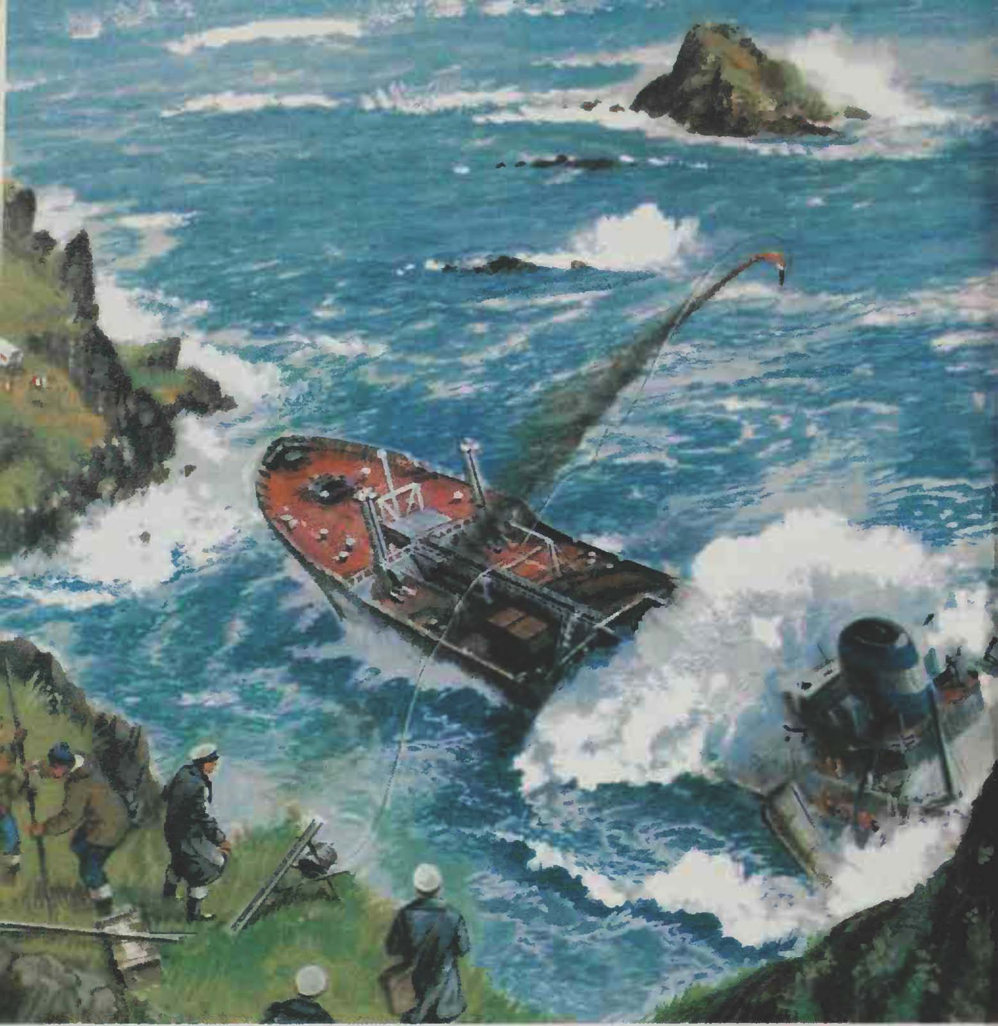



SS-18
(USSR)
Bomarc
AS-6
Titan II
(USA 1962)
Tomahawk
Atlas
(USA no
longer used)
FX-1400
Blue Streak
(UK never
used)
Pershing
(USA for
land battles)
US AIR FORCE
US AIR FORCE

Rockets and Missiles

People think of a missile as something long and pointed, with tailfins and, perhaps, with wings. But all modern intercontinental missiles have neither fins nor wings. They are self-propelled objects (projectiles), accelerated by engines to several times the speed of sound, and then left to follow a ballistic (free fall) trajectory to the target. Some of the newest types carry several warheads that have their own small rocket motors. These rockets can steer themselves to different targets. There is also an important class of missiles, called cruise missiles, that ride like an airplane on wings. Unlike ballistic missiles they cannot rise above the atmosphere. Some cruise missiles are not rocket-propelled but have air-breathing engines. The four missiles in the upper part of the diagram are cruise missiles; the rest are all long-range ballistic missiles.

The smallest of these missiles, FX-1400, was dropped from German bombers in 1943 (they sank large battleships). Tomahawk is a modern U.S. cruise missile fired from submarines, trucks, or aircraft. AS-6 is dropped from Soviet bombers. Bomarc was a big U.S. anti-aircraft weapon. The first long-range missile, V-2, had large fins. Pershing, a U.S. Army weapon, has fins on its first stage and very small ones on its second stage, for steering within the atmosphere. The other missiles are tubes. The Trident and Polaris are submarine-based.



Rockets carry a lifeline to the crew of a stricken merchant ship. The crew will secure the cable and then be pulled along it, one by one, on a pulley device called a breeches-buoy.

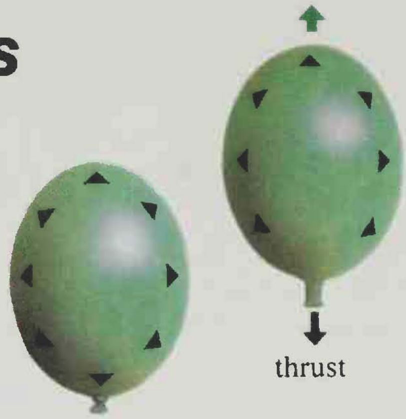
Not all rockets are used to propel missiles. They have many peaceful purposes. One of the most dramatic is to launch astronauts and satellites into space. Perhaps less well-known is the use of rockets to save lives. For more than one hundred years coast guards have used small, portable rockets to carry strong ropes or cables from the shore to survivors trapped on ships a short distance off shore.

Modern combat aircraft have special ejection seats so that the crew can be shot out in an emergency. The basic seat rides up a tube like a gun barrel, driven by a kind of rocket charge. The latest seats have extra multi-charge rockets built in underneath. Fired in quick succession these make the seat rise hundreds of feet and allow the occupant to escape even from an aircraft that is diving into the ground!

Rocket-boosted seats are called zero/zero, meaning they can be safely used at zero height and with the aircraft at zero speed.

How Rockets Work

Rockets are different from other engines because they carry with them everything they need for combustion. They do not need to take oxygen from the air like a jet engine.

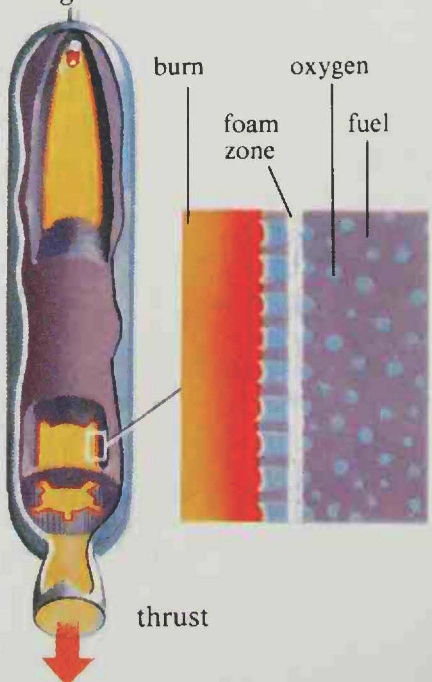


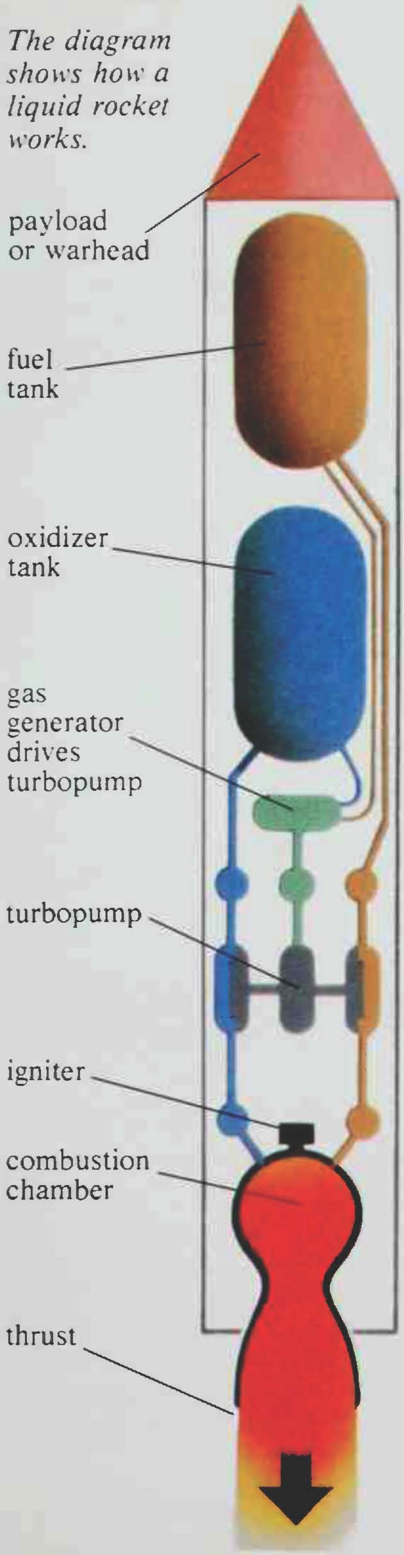
When you let go an untied inflated balloon (above) its balance of pressures is upset; air rushes out. This demonstrates Newton's law of motion.

How They Push

Rockets are proof of one of Newton's laws; that to every action there is an equal and opposite reaction. When a rocket burns its fuel in a chamber, gas rapidly expands. This gas presses on the inside of the rocket and escapes as exhaust out of the rear of the rocket. This causes the rocket to move forward, much as the balloon in the above illustration.

A solid rocket (below), cut away to show the strong case filled with solid or plastic-type propellant. A section of the burning surface has been enlarged.





The diagram shows how a liquid rocket works.

Solid rockets

In a solid rocket, the propellant is made in the form of a solid block, or a powder, and burns where it is. The solid propellant burns faster than most liquid propellants, but the thrust produced is less. Solid rockets are used by the military and for fireworks displays.

Liquid rockets

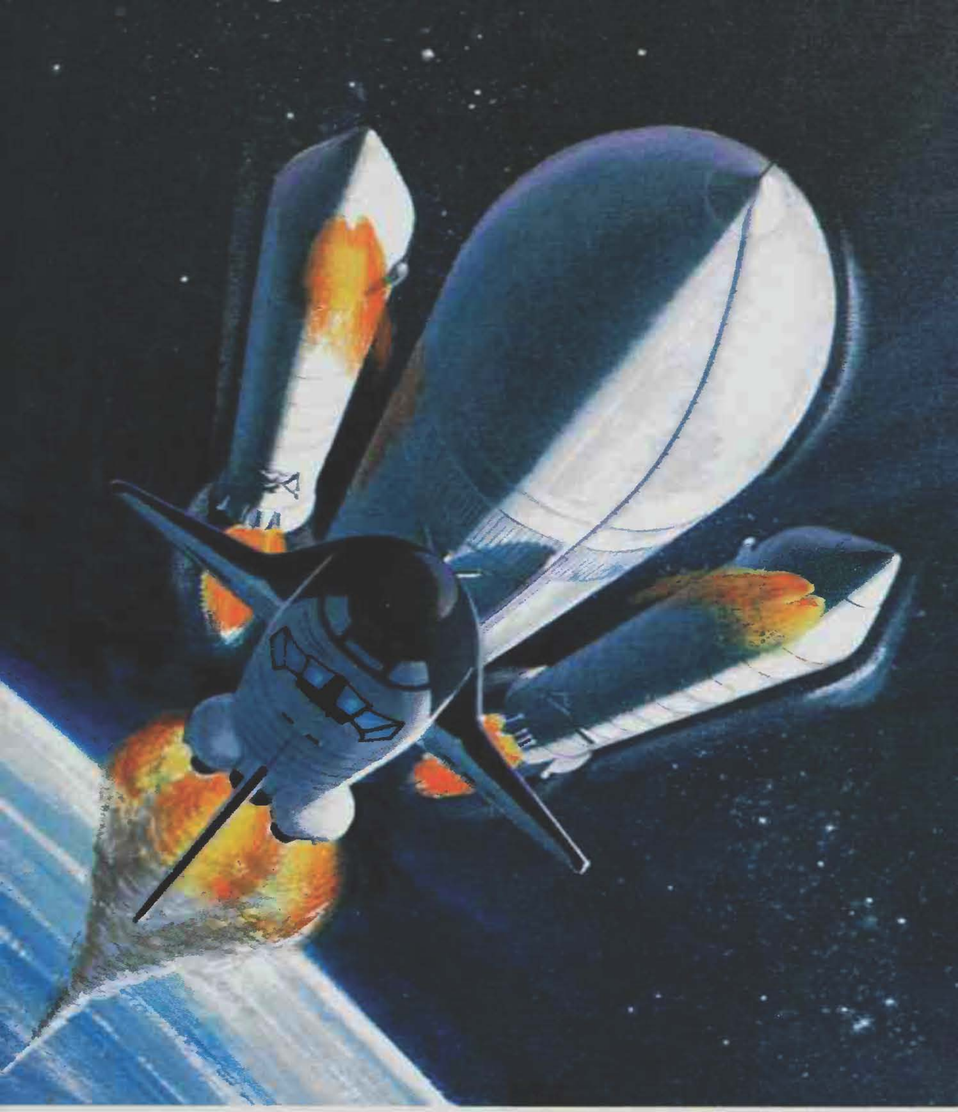
In World War II, the Germans made a giant liquid rocket and bombarded London, England, and Antwerp, Belgium. This rocket, the V-2, was the first big rocket missile. It set the pattern by using its own propellants (liquid oxygen as the oxidizer and alcohol as the fuel) to drive the turbines that pumped the liquids to the combustion chamber. Liquid oxygen is cryogenic (very cold) so the tank has to be insulated.

Solid Rockets

By far the oldest propellant for solid rockets is gunpowder (black powder). This has been made for more than 1,000 years by carefully mixing about 75 percent saltpeter (potassium nitrate), about 15 percent charcoal and 10 percent powdered sulphur. It is still used in firework rockets, but large war rockets by 1900 were mainly filled with cordite. This is a so-called smokeless material used in countless guns in both world wars. It was usually made in cordlike rods. Modern solid fuel propellants are more complex mixtures such as PBAA (polybutadiene acrylic acid), PU (polyurethane), and AP (ammonium perchlorate) with aluminium powder added. They look like rubber.

The earliest war rockets (left) were just tubes filled with black powder rammed in tight with a tapered hole down the center. This was lit by blue touch-paper by a soldier. A stick was added to make the missile fly stably.

In contrast the SRBs (solid rocket boosters) of today's Space Shuttle (opposite) are complex motors. Filled with propellant called a PBAN terpolymer composite, the motors give well over 2,400,000 lb (1,000 metric tons) thrust for two minutes.

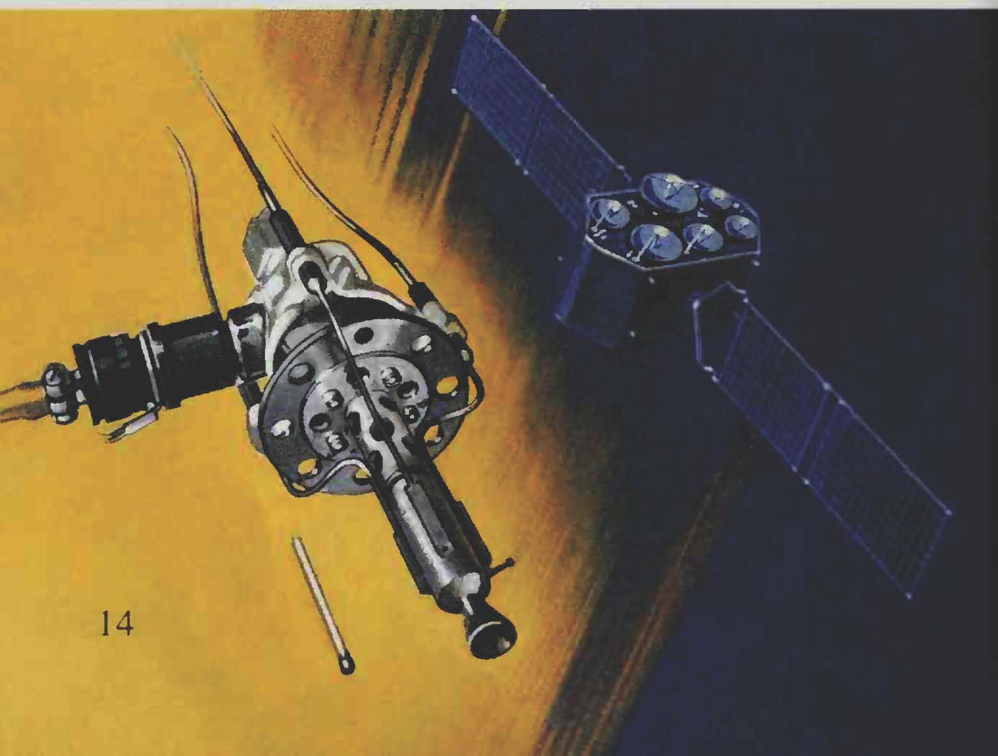


Most rocket designers aim to get more or less constant thrust as long as the rocket is burning. In a solid motor, this means shaping the propellant so that the area of surface actually burning stays roughly constant. Some solid motors are lit at one end and burn steadily to the other. Most have a star-shaped hollow down the middle and burn evenly outward.

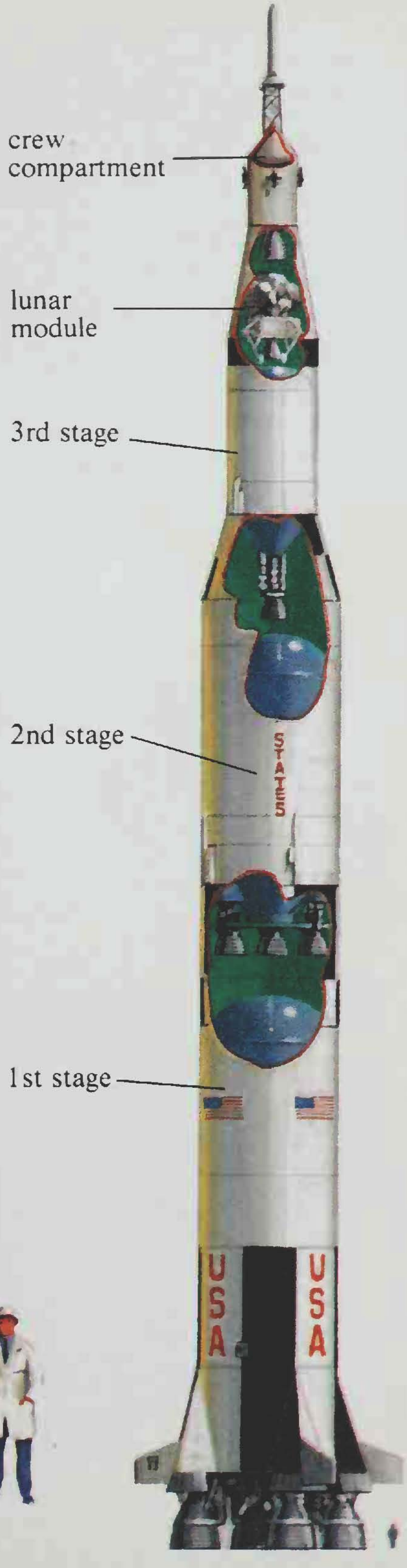
Liquid Rockets

Throughout the period from 1940 to 1970, the liquid rocket was universally used for large vehicles and for space exploration. (Today giant solid rockets are used to boost the takeoff of even the largest space rockets.) Most liquid rockets have a thrust chamber. Fuel and oxidizer are pumped into the thrust chamber at high pressure and then burn with intense heat. The resulting white hot gas accelerates out of a bell-shaped mouth called the *skirt*, reaching a speed of up to 15,000 ft (4.5 km) per second or 10,000 mph. The F-1 engine, five of which powered the first stage of the Saturn 5 (Apollo) moon rocket, gave a thrust of 1,500,000 lbs (680 metric tons) while tiny rockets for controlling satellites give thrusts of a few ounces (grams).

The OTS satellite (right) is accurately maneuvered in space by a tiny hydrazine thruster (left, shown in comparison with a match).



The Apollo missions to the moon were carried by the Saturn 5 vehicle (right) fired in three stages (see page 17). The first stage had five F-1 engines that burned liquid hydrogen and kerosene. Each F-1 (below) stood 220 in. (5.6 m) high and weighed 18,500 lb (8.3 metric tons), developing over 50 million hp. The second stage had five J-2 high energy engines, each much smaller but burning liquid oxygen and liquid hydrogen. This resulted in a faster jet and higher efficiency in space. The third stage had a single J-2 that had to be restarted deep in space on each lunar mission.




A
B
C
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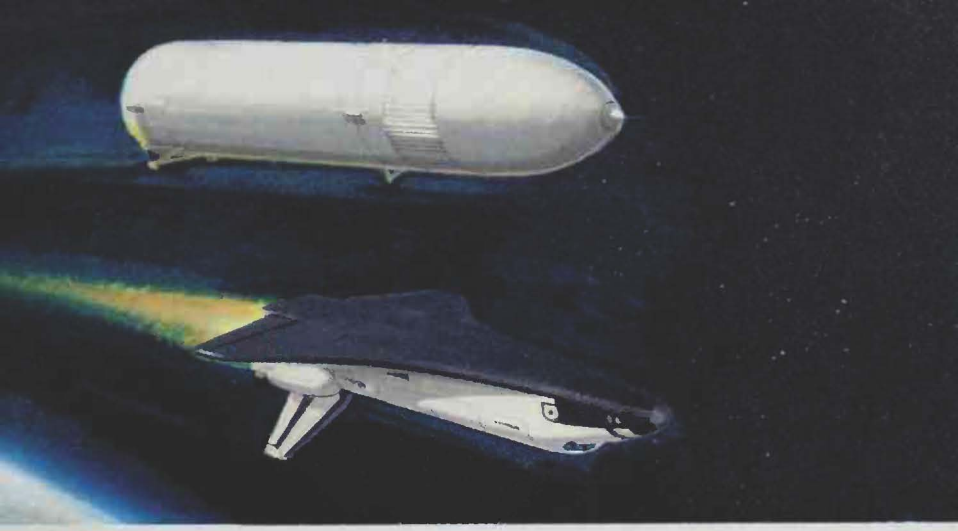
E



Vehicle Stages

The simplest rocket vehicles have just one stage. They are propelled by one or more rockets all fired at the start. Vehicles can travel much faster and farther if they have several stages. When the first-stage rockets have burned all their fuel, the whole stage is separated and falls off. Then the second stage is lit. When it has burned out, it too is discarded. There may be a third or even a fourth stage. The advantage is that the heavy weight of each spent stage is discarded. Each subsequent stage can then accelerate to a higher speed. We have already seen that the giant Saturn 5 moon rocket (pages 14, 15) had three stages. No single-stage vehicle could ever have flown the moon mission.

The Space Shuttle (top) is not quite a multistage vehicle, though it discards spent rocket parts. First, the two SRBs (solid rocket boosters) are left behind; they drop into the sea and are used again. Then the giant empty propellant tank is jettisoned.

Redstone (A, left) was a single-stage missile; Atlas (B) was a 1½-stage, because though all three main engines were fired on the ground, the two biggest were then dropped off. Titan II (C) has two stages, Trident (D) had three, and the 1944 Rheinbote (E) had four.

First Experiments

The rocket was invented by the Chinese around the 11th century. Only slight advances in design occurred until the 1920's. An American, Dr. Robert H. Goddard, the father of the modern rocket, poured his time and savings into making a rocket burning liquid propellant. On March 16, 1926, he saw the world's first liquid rocket soar aloft. It looked odd. The thrust chamber was at the front (top) of a tall frame, with the tanks for liquid oxygen and gasoline at the bottom. It rose only 184 ft (56 m). At least it did not explode as did most of the liquid propellant rockets of the next decade.

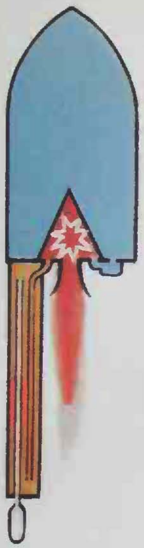
The first liquid rocket (left) led to a larger rocket built by Goddard. This rocket rose to 7,500 ft (2286 m). Gyroscopes kept it upright by controlling vanes in the jet.

S.P. Korolev designed this Type 212 missile with an ORM-65 liquid engine, tested in 1940. He flew a piloted rocket glider in the same year.

The Russians were also active in the development of rockets. Konstantin Tsiolkovsky, a teacher of mathematics, worked out many of the principles on which space flight depends. Other Russian pioneers were concerned with the practical development of liquid rockets. L.S. Dushkin and V.P. Glushko led the main design teams. They made great progress with increasingly complex motors burning either liquid oxygen and ethyl alcohol or concentrated nitric acid and kerosene. The designers included Sergei P. Korolev who designed Soviet rockets after World War II.

Pioneers in Germany

A significant event in rocket history took place in 1927 when a group of German enthusiasts formed a Society for Space Travel, Verein für Raumschiffahrt (VfR). Their experiments caught the attention of German military officers. The officers realized that the liquid rocket fell outside the scope of the Versailles Treaty. This treaty, signed at the end of World War I, banned the development of aircraft in Germany. One member was the young Wernher von Braun. He went on to develop the V-2 rocket bomb. After World War II, he led the American team that designed the Saturn 5 moon rocket.



F. Sander made solid motors for a glider (opposite), flown in 1929 by Fritz von Opel, and a racing car (below). Rockets are not a good way to power such slow vehicles.

One of the first liquid rockets was Mirak I (right) of 1930; the diagram (left) shows how gas (white) forced fuel (orange) and oxidant (blue) into the chamber. The fuel and pressurizing gas were contained in the tail to give stability. Like other large rockets of this period, it had tail fins like a dart.

Aircraft-launched Rockets

Many thousands of rockets were fired from aircraft in World War I, mostly against enemy observation balloons. The most common type was the Le Prieur rocket. This rocket was usually fired in succession in groups of four or more on the interplane struts of fighting scout planes. Pilots became expert at judging the correct distance and elevation angle to score a hit. But all unguided rockets need great skill on the part of the pilot when launched at small targets.

One of the carriers of Le Prieur rockets was the Sopwith Pup (below). The Il-2 (bottom) was in action against Panzers in 1941.

By 1935, the Soviet Union had developed two more sophisticated rocket weapons, RS-82 and RS-132 (the number gave the caliber in millimeters). These were used in vast numbers in World War II, especially by the I1-2 Stormovik armored attack aircraft against German tanks. By 1939, Britain had also begun to work on aircraft rockets. Most of them had 3-in. (76.2-mm) cordite motors. After prolonged effort, these rockets were made to fly straight. They were then fitted with armor-piercing or fat 60-lb (27.2-kg) HE warheads and, from 1942 on, they smashed German targets.

RPs (rocket projectiles) were used from over 21,000 Britain Royal Air Force (RAF) attack aircraft in World War II; here Beaufighters hit enemy shipping.

Rockets on Land and Sea

During the early years of World War II, rockets played a small and largely ineffective role in the war at sea. Merchant ships tried to defend themselves with a parachute and cable (PAC) device shot in the air by a rocket into the path of an attacking bomber. But there is no record of a PAC destroying an enemy aircraft.

On land, rockets were used in far greater numbers and were considerably more effective. Tens of thousands of artillery missiles were used by both sides in World War II. Front-line army units were equipped with batteries of rocket launchers. These had tubes or rails that could rain HE (high explosive) over wide areas. At close range an American rocket, the tube-launched bazooka, was extremely effective against even the heaviest tank. Its projectile had a special hollow head that pierced armor. But the success of the bazooka depended upon the aim of the person firing the missile. Missiles only became deadly when they had guidance. The Germans made all the progress in this vital field, although Great Britain and the United States also made important developments in both missiles and remotely-guided aircraft.

PAC (opposite) was typical of the crude and ineffective weapons that lacked any form of precision guidance. A vertically-fired rocket pulled the cable, which then fell slowly by parachute.

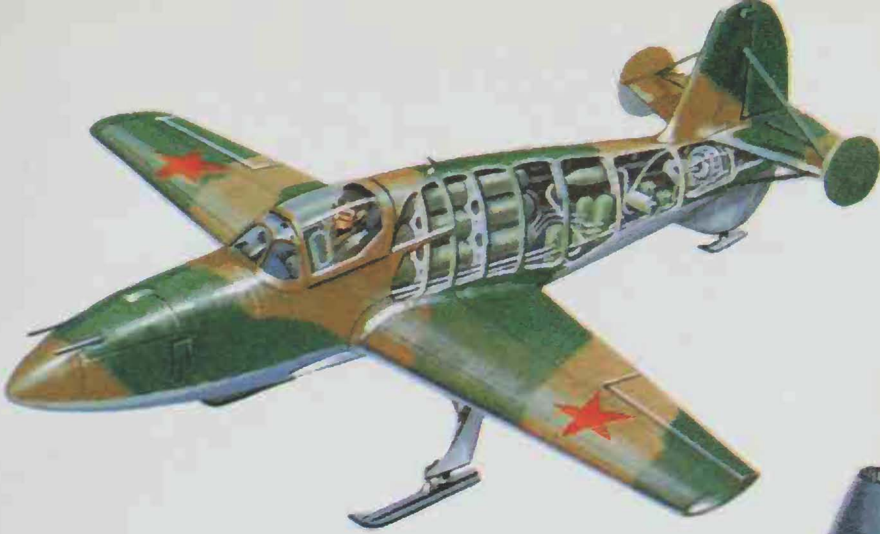
The Bazooka (below) enabled infantry to effectively attack tanks.

The Soviet M-13 (below) fired 16 rockets at a time.

A typical six-barrel towed rocket launcher.

Rocket Aircraft

Rocket propulsion was used for two classes of manned aircraft in World War II: target-defense interceptors to destroy enemy bombers and high-speed suicide missiles to sink enemy warships. In each case rocket propulsion caused a small airplane to move with tremendous speed. The Soviet Union's Berezniak-Isayev BI-1 made its first flight on May 15, 1942. It was powered by a D-1A liquid rocket of 2,425–lb (1100–kg) thrust, was made of wood, and had two cannons. Germany's Me 163 had swept wings but no horizontal tail, and a 3,750–lb (1700–kg) motor. The Ba 349 Natter took off vertically and engaged bombers with a battery of nose-mounted rockets. It never got into combat.



The Soviet Union's BI-1 (above) did some of its test flying on skis. The German Ba 349 (right) could climb vertically. The Me 163 (below) dropped its wheels and had to land on a skid.

In Japan a unique suicide weapon was the MXY-7 Ohka (opposite), which was carried to its target (Allied invasion fleets) under a bomber and then released. The pilot dove on the target and fired three solid rockets in the tail to accelerate to 620 mph (1000 km/h), faster than any other aircraft of its day. In the nose was a large HE warhead. A few of these rocket missiles struck home in spring 1945, causing severe damage. They were too late to have much effect on Japan's final defeat.

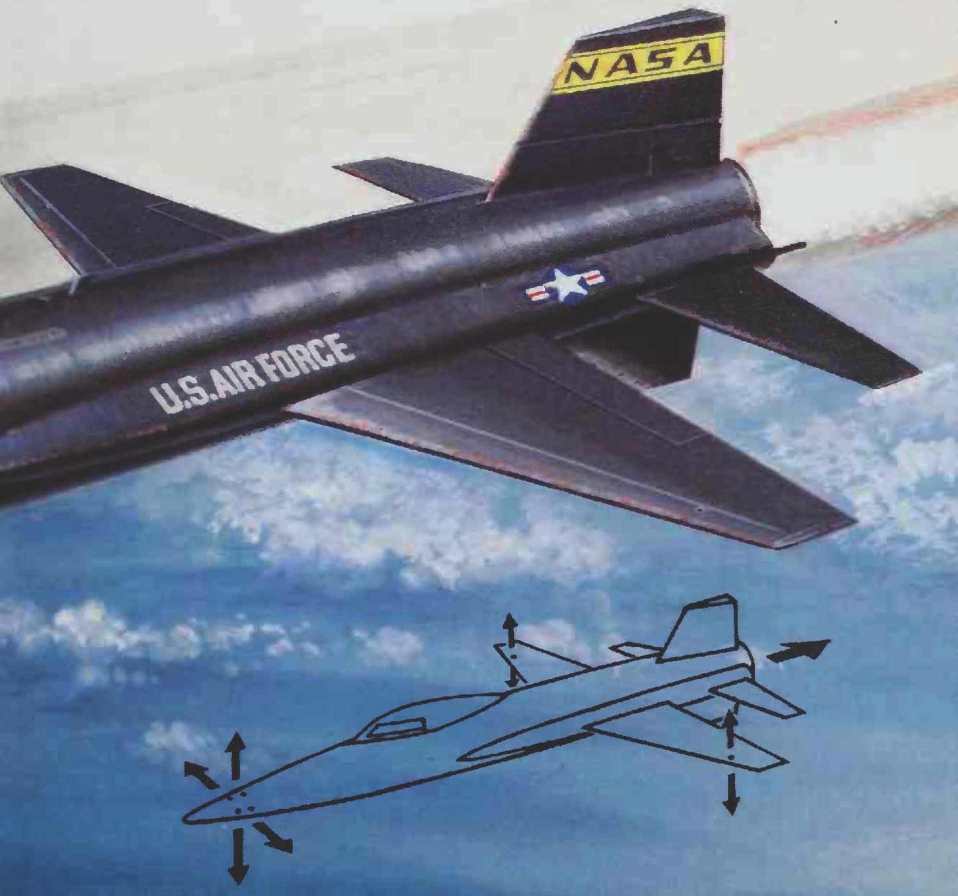
Development of safe and powerful rocket engines opened the way for a fantastic increase in the speeds and heights attainable by aircraft. The Bell X-1, flown by Charles Yeager, a U.S. Air Force captain, was the first supersonic aircraft, reaching just over Mach 1 (the speed of sound) in 1947.

The American series of supersonic research aircraft continued with improved X-1s and the Mach-3 (2,294 mph; 3,670 km/h) Bell X-2 of 1956. By 1959, North America had built the first of three X-15s for the USAF and NASA (National Aeronautics and Space Administration). In 1962, Robert M. White, a U.S. Air Force major, flew the X-15 to heights of more than 50 mi (800 kg). By 1963, the X-15 flew faster (up to 4,534 mph, 7,297 km/h, Mach 6.72) and higher (354,200 ft., 107,960 m) than any other piloted aircraft.

The Bell XS-1 (opposite top), later called X-1, was the first supersonic aircraft.

The Douglas D-558-II Skyrocket (above) flew faster than Mach 2.

The North American X-15 (below) flew higher and faster than any other piloted aircraft. In airless space, the ordinary flight controls were useless, so reaction control jets (inset diagram) were employed. Later versions were colored white rather than black.



Guided Missiles

This SSW missile of 1917 carried torpedos to enemy warships.

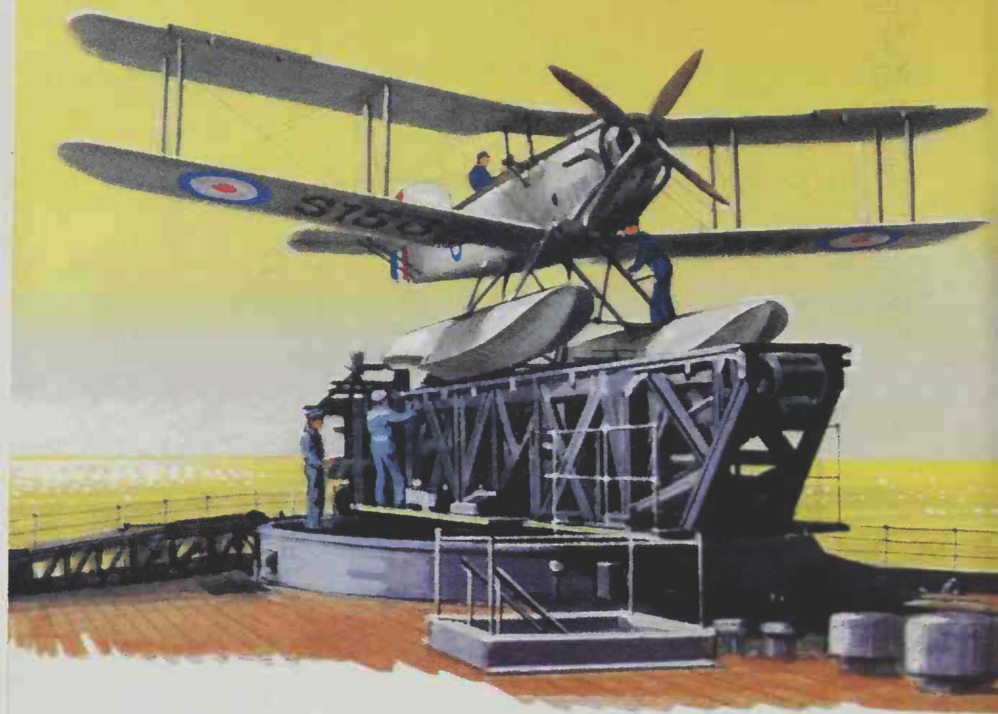
Most people think guided missiles are very new and date from World War II or later. In fact hundreds were made in World War I, but they were not used in combat. Some were designed in the form of small pilotless aircraft. These were intended to take off in the normal way and navigate by themselves to a fixed target such as a barracks, ammunition dump, or fortress. Others, notably the SSW (Siemens-Schuckert Werke) series in Germany, were carried under zeppelins (blimps) or giant bombers and released near the target. They were then steered to the target by an operator in the carrier aircraft, as is still often done today.

Capt Geoffrey de Havilland designed this 1917 British missile.

The Kettering Bug was a very cheap biplane missile made by the hundred in the USA in 1918. The war ended a few weeks before they got into action.

The SSW missile shown opposite was a biplane. It was first steered to its target, a large enemy warship. Then the missile was given a special command that caused the left and right halves to fall apart and drop the central part, a torpedo, into the sea. The two other World War I missiles shown here were pilotless bombers, ancestors of today's cruise missiles. They were kept on course by gyroscopes arranged like a simple version of today's automatic pilot. Some of the Larynx cruise missiles of the Britain RAF of the 1920's were tested by being catapulted from a warship. Most of these were flown on a desert range in Iraq.

The British RAF's Larynx of 1926 carried a 250-lb (112-kg) bomb.



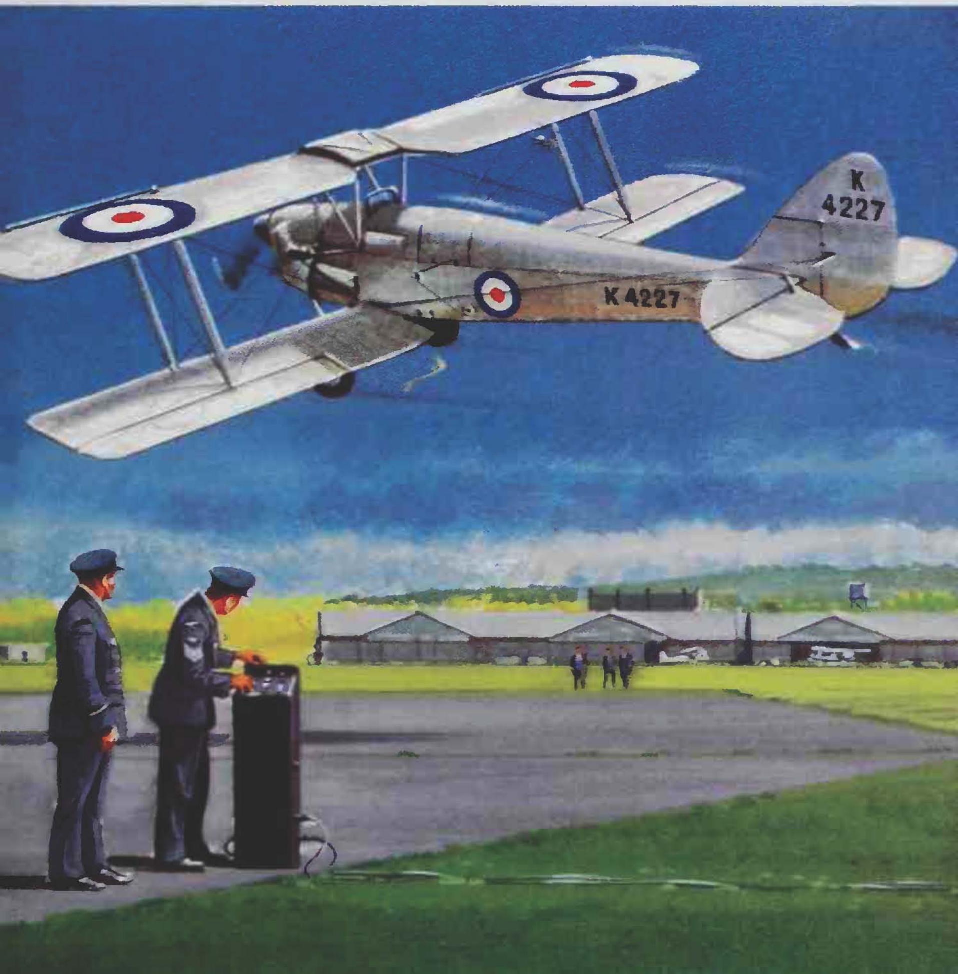
Radio-Controlled Aircraft

Most of the early RPVs (remotely-piloted vehicles) were not cruise or reconnaissance (spying) aircraft, as they are today. Instead, they were just ordinary airplanes flown by remote control and used as targets for anti-aircraft gun practice. The British were leaders in developing such pilotless aircraft. One of the first was the Fairie Queen. The one made in the largest numbers and put into regular use, was the de Havilland Queen Bee designed (on the basis of the famed Tiger Moth) in 1934. The British Royal Air Force had 380 of these, some of them seaplanes. The other pioneer of radio–controlled aircraft was the U.S. Navy. They tested a radio-controlled Vought VE-7 seaplane in December 1924 but it sank on landing. In November 1937 another Navy machine, a Curtiss N2C-2 trainer, was tested under radio control with no pilot.

The radio-controlled Curtiss N2C-2 (above) was one of the first aircraft with nosewheel-type landing gear.

The RAF's Fairie Queen (opposite) was shot off a catapult like those fitted to warships of the Royal Navy.

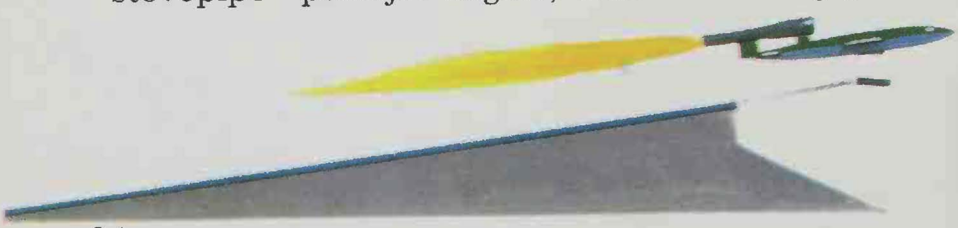
The de Havilland Queen Bee (below) was guided by a pilot on the airfield, or on a ship, working a radio link from a console.

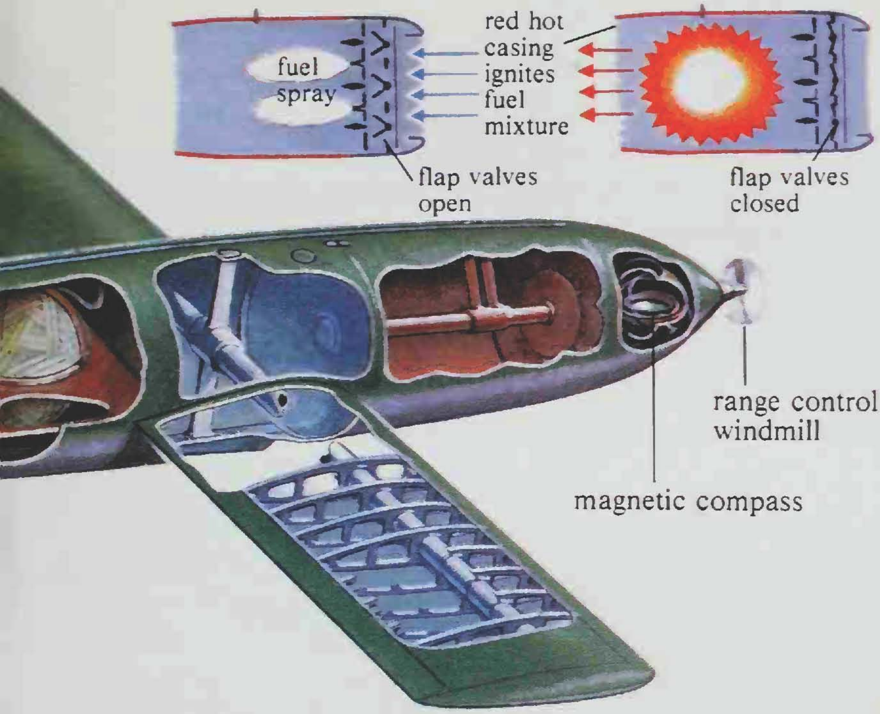


The Flying Bomb

The V-1 (Vergeltungswaffe 1, literally Vengeance Weapon 1) was a very effective and cheap cruise missile. It was the first weapon of its type in history to go into mass production. It was about 25 ft (7.6 m) long. It lacked precision guidance and was merely launched from a sloping ramp pointing in the right direction. It cruised for a set time and distance of about 150 miles (240 km), at a steady height of about 1,500 ft (450 m) and then dived on to the ground. Fired from northern France against a target as big as London, it was very destructive and caused immense devastation.

One of the keys to its simplicity was its "stovepipe" pulsejet engine, with no moving parts





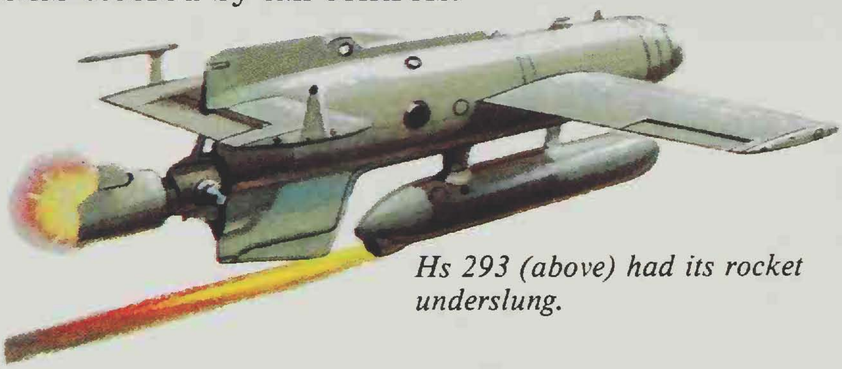
except a grid of springlike flap-valves. These flap-valves alternately let air in and were then blown shut by an explosion of fuel in the duct.

The throbbing bombs flew faster than most fighters, but the British RAF and USAF did have a few fighters able to shoot down V-1s. One of them was the first jet fighter, the Meteor, in July 1944. By 1945 the launch bases had been captured by the British Army, and the last V-1s were launched from converted He 111 bombers. Over 30,000 V-1 flying bombs were made.

Most V-1s were shot off launching ramps in France (opposite) under the push of a piston running in a tube under gas pressure. The piston then fell clear. A few were dropped from Heinkel He 111 bombers (right).

German Guided Missiles

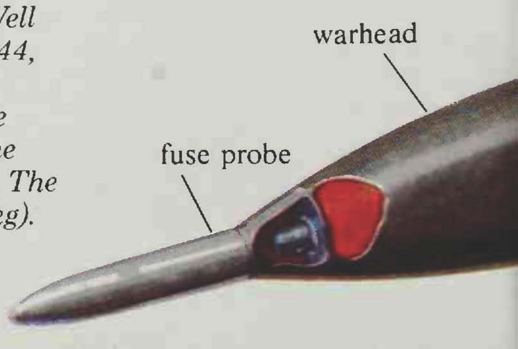
Germany was a major leader in the development of guided missiles for hitting surface targets from the air. In 1943, two types were put into service. The Hs 293 rocket missile was shaped like a miniature airplane. It was steered by an operator in the launching bomber. An Hs 293 sank HMS *Egret* in August 1943. Much larger, the Fritz X, was a huge bomb steered by tail controls.

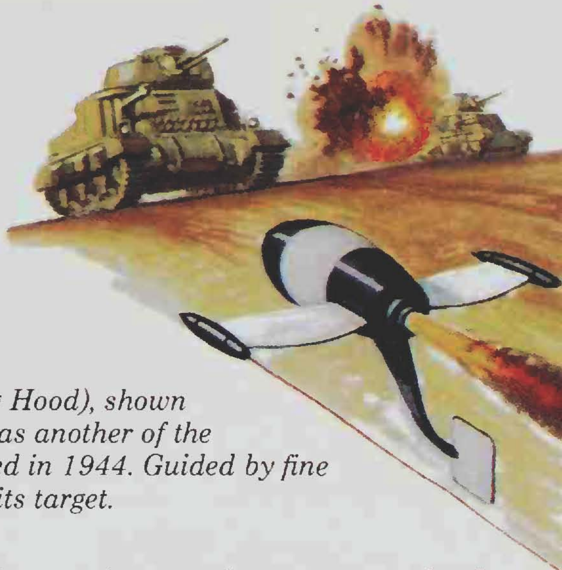


Hs 293 (above) had its rocket underslung.

Fritz X had radio control but no propulsion.

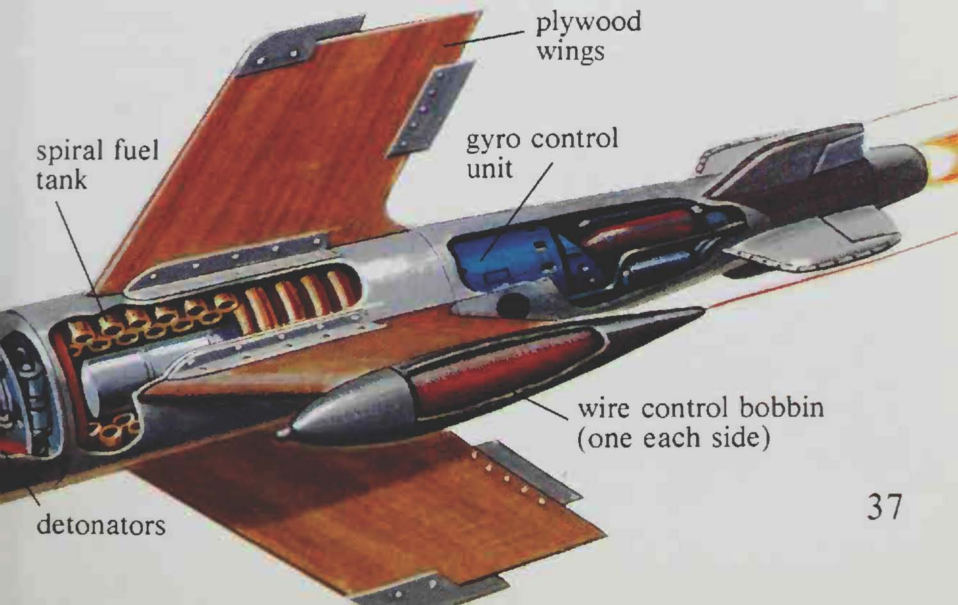
The X-4 (right) was the first guided AAM in the world. Well over 1,000 were made in 1944, but it never got into proper service. Guidance wires were unwound from bobbins at the tips of two of the four wings. The missile weighed 132 lb (64 kg).



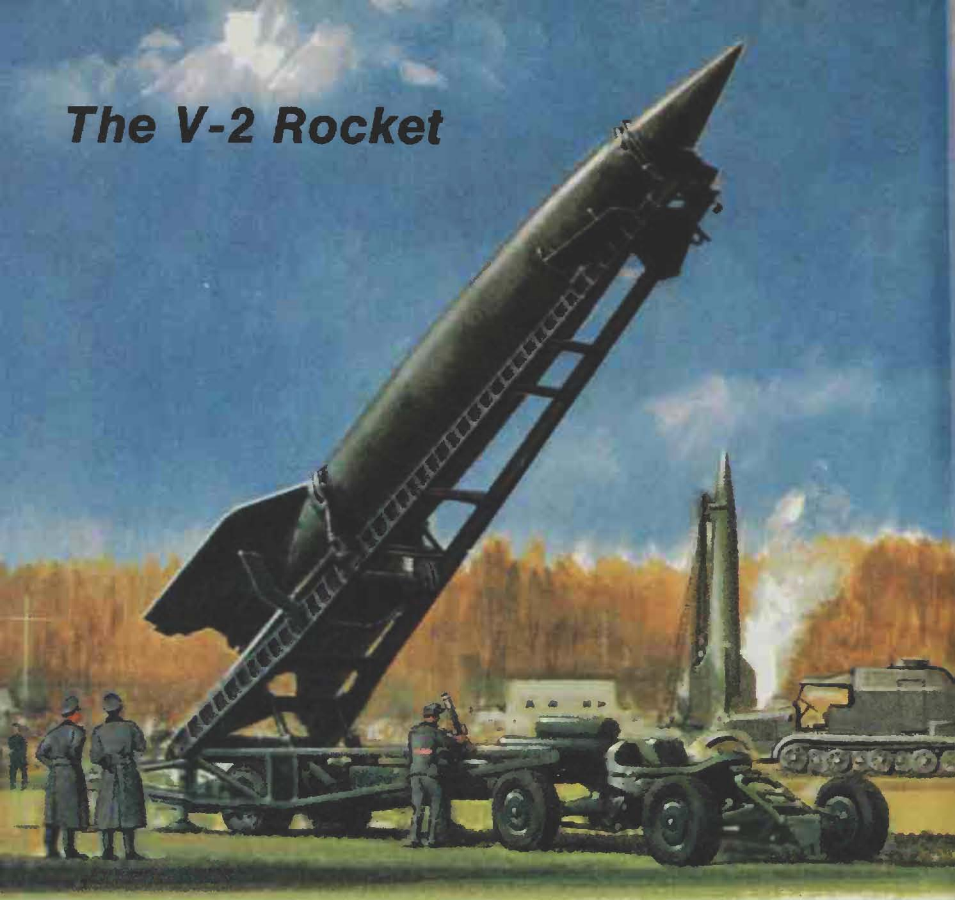


Rotkäppchen (Red Riding Hood), shown attacking tanks (right), was another of the German missiles developed in 1944. Guided by fine wires, it was steered into its target.

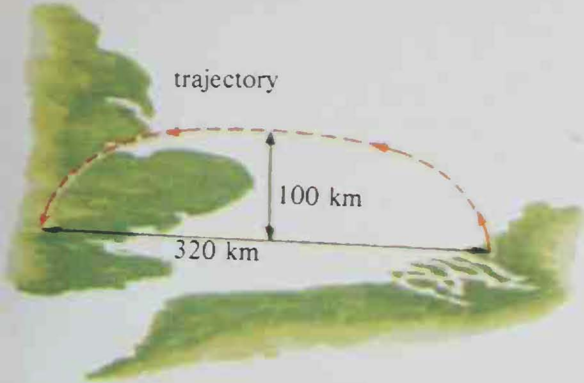
Though it sounds crude, guiding a missile by sending electric signals along fine wires trailed behind it is very effective. One advantage is that the enemy cannot interfere with it, unlike radio methods. The Germans made several such wire-guided missiles in World War II. One was the X-4 air-to-air missile (AAM), launched by fighters against enemy bombers. Driven by a liquid rocket, it was steered into its target from a safe range of just over 2 miles (3.5 km).



The V-2 Rocket



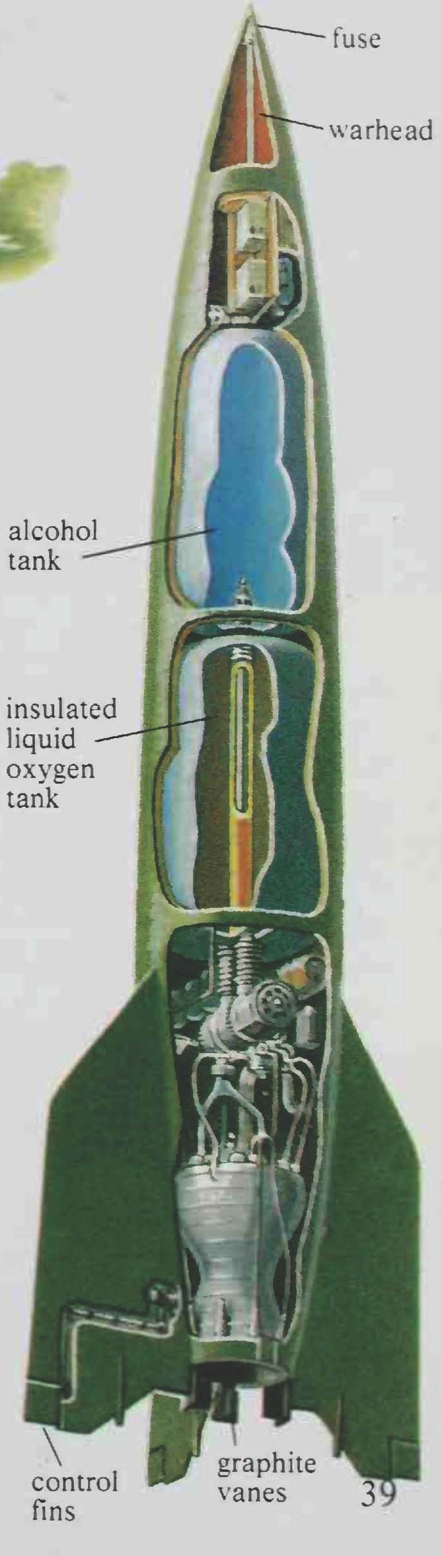
Though it was not made in quite such quantity as the V-1, the V-2 rocket was a fantastic technical achievement, far ahead of any other weapon of its day. It was the world's first large rocket and the first rocket to hit one country after being fired from another. British scientists did not believe such a weapon possible, despite photos taken by their air force. When London began to suffer unexplained explosions in September 1944, they were said to be faulty gas mains. The V-2 was fired by German army mobile units. About 10,000 were made and 4,320 were fired (mainly against London, England, and Antwerp, Belgium). Its warhead was filled with 975 kg (2,145 lb) of HE and was even more powerful than that of V-1.



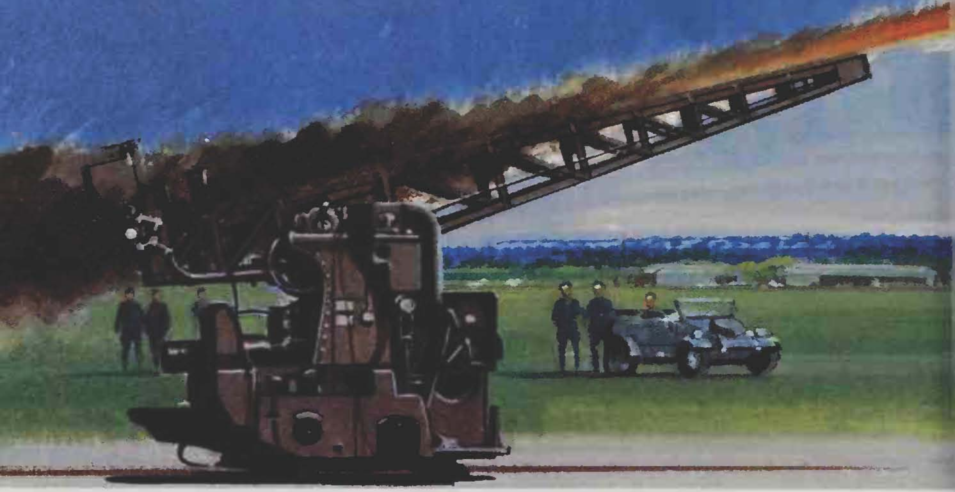
Fired from Holland (above) each V-2 rose 62 miles (100 km) above the earth, flying at five times the speed of sound or over a mile a second. Its turbopump-fed engine was many times larger than any previously built.

V-2 was 46 ft (14 km) tall and weighed about 28,373 lb (12,780 kg) at liftoff (opposite). While under power, its flight was steered by a guidance system, containing gyroscopes and precision accelerometers. These activated small rudders on the large stabilizing fins and small graphite vanes in the jet from the rocket thrust chamber.

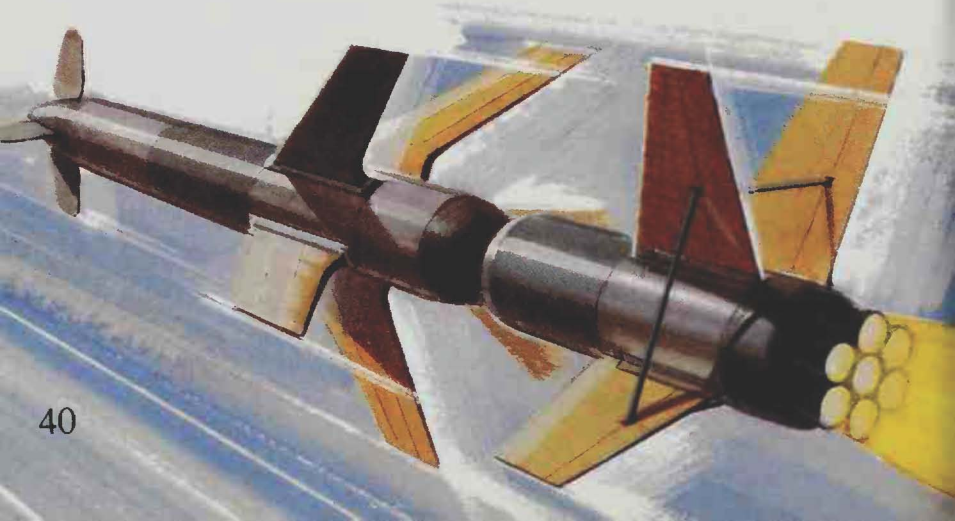
Once the engine had shut down, the missile was in freefall. A few of these rockets exploded prematurely. This was often because the nose became red-hot during its fall through ever denser air. Because the V-2 flew faster than sound, there was no warning of a V-2s approach. People near the target heard the explosion of the warhead first, followed by the rumbling of its passage.



The First SAMs

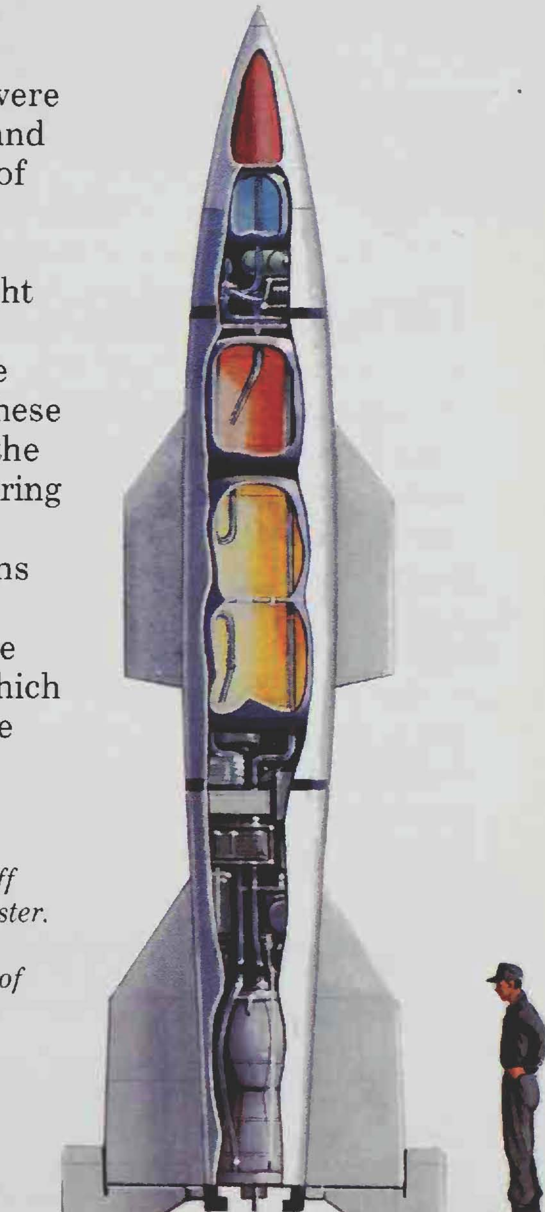


In World War II, anti-aircraft guns could get literally red-hot firing nonstop at enemy bombers without bringing any down. The shells needed to be steered toward their target to be more effective. Germany, hit hardest by bombers, did the most to develop SAMS (surface to air missiles). The army Rheintochter had two stages, but Wasserfall was a one-stage SAM, much like a miniature V-2.

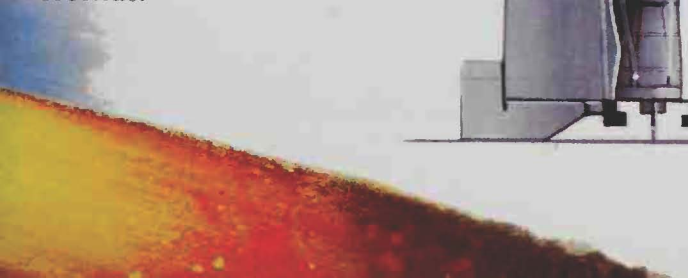


Few people knew that Britain was developing a guided SAM in World War II. Brakemine (opposite) was fired from converted gun mounts. It had a very advanced form of guidance in which the missile flew up a radar beam.

Most of the early anti-aircraft missiles were propelled by rockets and guided by some form of radio control. The massive (1¾-ton) Rheintochter had bright flares on its wings. A skilled operator on the ground tried to keep these exactly lined up with the enemy aircraft by steering via a radio link, which worked four control fins on the missile's nose. Wasserfall used a more advanced system in which the aircraft and missile were both kept in the beams of radars.



Rheintochter (left) blasted off with a first-stage rocket booster. Wasserfall (right), like V-2, rose vertically on the thrust of its single liquid-propellant rocket that burned for 40 seconds.



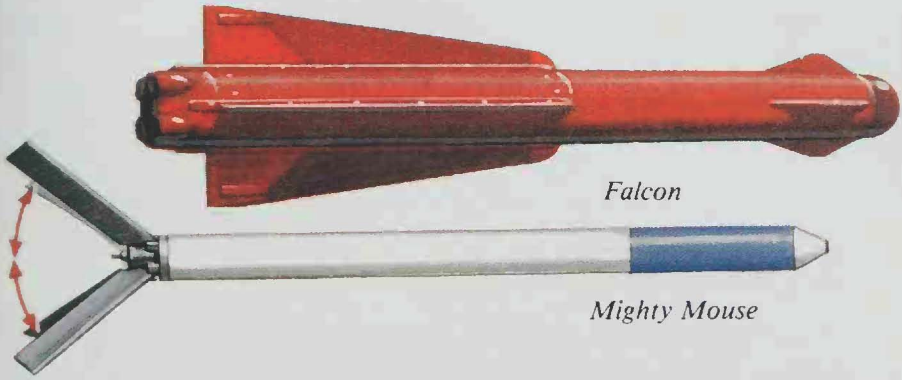
Fifties' Firepower

The air-to-air missile (AAM) story began with the X-4 (page 37). It continued after World War II, dominated mainly by American progress. An unguided rocket called Mighty Mouse was for a time favored. It fired in barrages under exact radar control. But soon, the AAM with guidance became supreme. The first in wide use was Falcon. The Falcon was a small 6-ft (2-m) rocket weapon with fantastic acceleration and speed but a short range of some 6 miles (10 km). Falcons developed a prolific family with radar or IR (infra-red, homing on the heat of target engines) guidance. One version has a nuclear warhead.

One of the few guided AAMs to have twist and steer configuration like an airplane was this Matra R.510. Developed in France, it had unusual optical guidance that in effect "saw" the enemy aircraft.

The big 144-in. (3.66-m) Sparrow forms the main air-to-air armament of the famed Phantom fighter, as well as of other types.

Today one of the most important families of AAM is Sparrow, with radar guidance over ranges around 25 miles (40 km). Britain has produced a much more effective version of Sparrow called Sky Flash. Most AAMs have four wings and four control fins. This allows them to maneuver without first having to roll. A few old AAMs had airplane-type wings and tail, and thus had to roll first and then make the desired turn.



Falcon

Mighty Mouse

One of the first interceptors to be armed with Falcons was a version of Northrop F-89 Scorpion (below) that also carried salvoes of simple folding-fin Mighty Mouse rockets.

Cruise Missiles

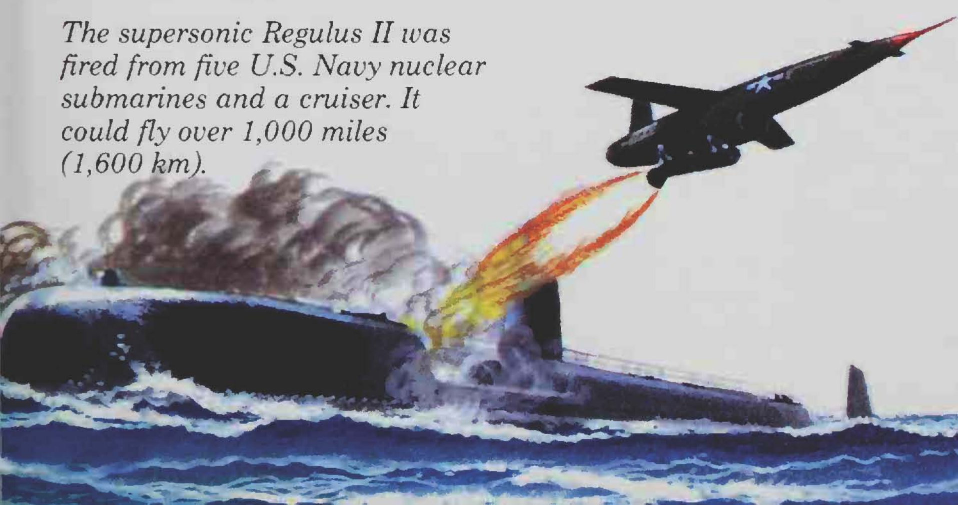
Until the 1950's nobody knew with certainty that an intercontinental ballistic missile (ICBM) could be created, so they continued making cruise missiles. The largest was Northrop's SM-62 Snark, used for a short time (1957-61) by USAF Strategic Air Command. Launched by two large rockets, it cruised 5,500 miles (8,850 km) on an air-breathing turbojet (the same engine as in Boeing 707 and DC-8 jetliners) before diving on its target with a thermonuclear warhead.

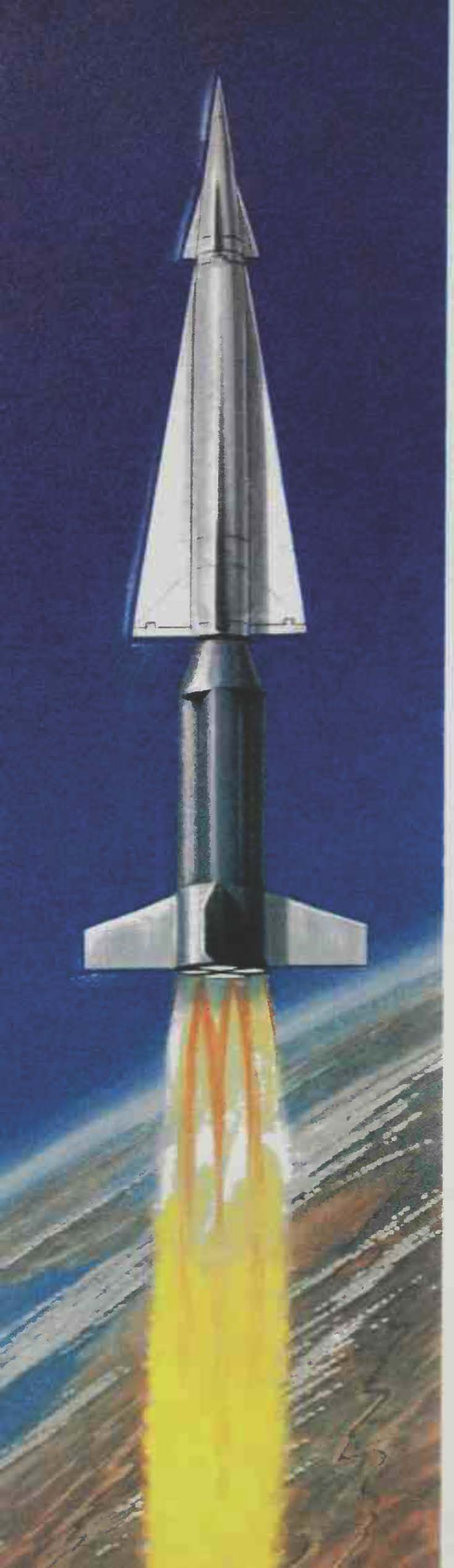
Snark (opposite) was as big as many bombers. It was unusual in that it had no horizontal tail. Weight at launch was 60,000 lb (27,216 kg) and the large warhead had a yield of from 5 to 15 megatons. Snarks were withdrawn in 1961.

Martin's TM-76 Mace (below), a later 1955 version of TM-61 Matador, was used by the USAF in many areas until 1966. In this view a Mace is being shot from its launch ramp by a large solid-propellant rocket.

Matador and Mace were smaller tactical missiles that could be fired from mobile trailers or hardened land shelters. They were guided by various systems. Among the first were Tercom (terrain-comparison) methods. These are being introduced again today. The U.S. Navy developed a succession of turbojet-powered Regulus missiles. The later versions were supersonic. The main carriers of Regulus were large nuclear submarines, forming a formidable combination.

The supersonic Regulus II was fired from five U.S. Navy nuclear submarines and a cruiser. It could fly over 1,000 miles (1,600 km).

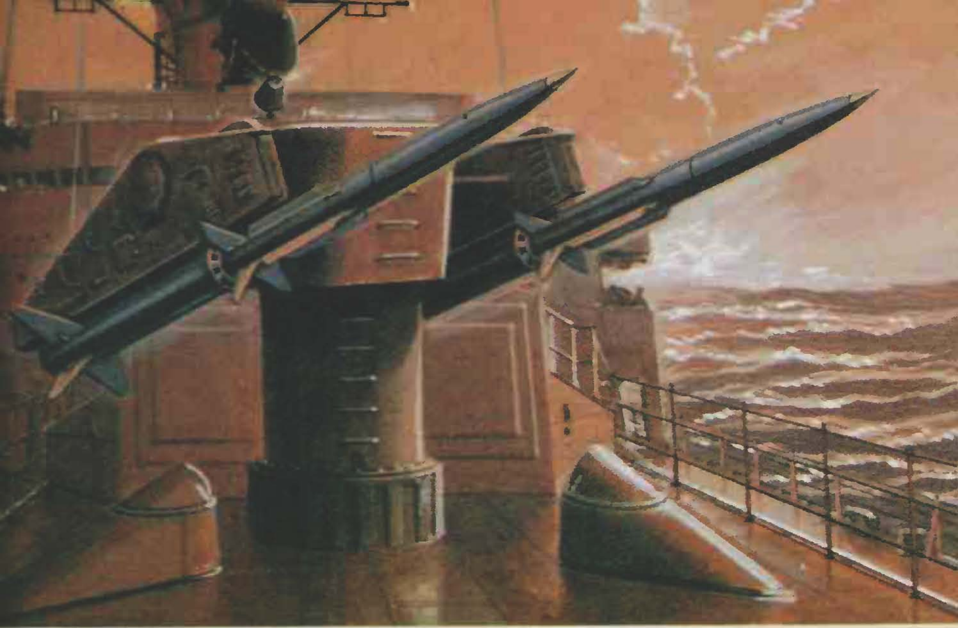




SAMs of the Fifties

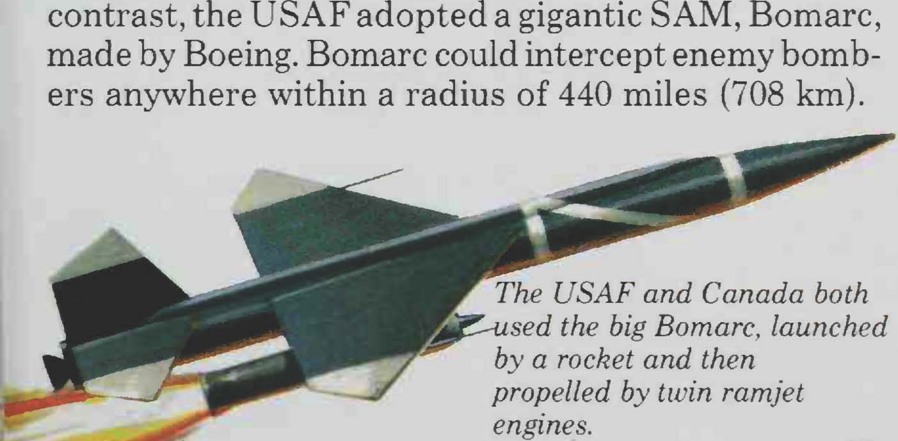
The biggest family in the history of surface-to-air missiles (SAMs), the Nike (pronouned Nikey, the name of a Greek goddess) series was developed from 1948 by the U.S. Army. Nike Ajax was in service in 1956. It was replaced by Nike Hercules (left), which could reach out 87 miles (140 km) and destroy aircraft flying at heights of up to 150,000 ft (46 km), about three times as high as the limit for any normal aircraft.

In the 1960's, the Nike Zeus was developed. This led to the great Safeguard antiballistic missile (ABM) system intended to protect the United States against hostile missile attack. Americans put up a fight against the ABM, and the whole network had to be deactivated.



Most large cruisers of the U.S. Navy are protected by twin launchers for Advanced Terrier (above) or standard missiles.

The U.S. Navy pioneered guided SAMs fired to defend surface warships against air attack. Little Joe and Little Lark were programs urgently begun in 1944 to combat terrifying kamikaze suicide attacks by Japanese aircraft on U.S. ships. Lark made the first-ever guided interception from a ship on January 13, 1950. Later came the giant program that resulted in the Terrier, Tartar, Talos, and Standard missiles. In contrast, the USAF adopted a gigantic SAM, Bomarc, made by Boeing. Bomarc could intercept enemy bombers anywhere within a radius of 440 miles (708 km).



The USAF and Canada both used the big Bomarc, launched by a rocket and then propelled by twin ramjet engines.

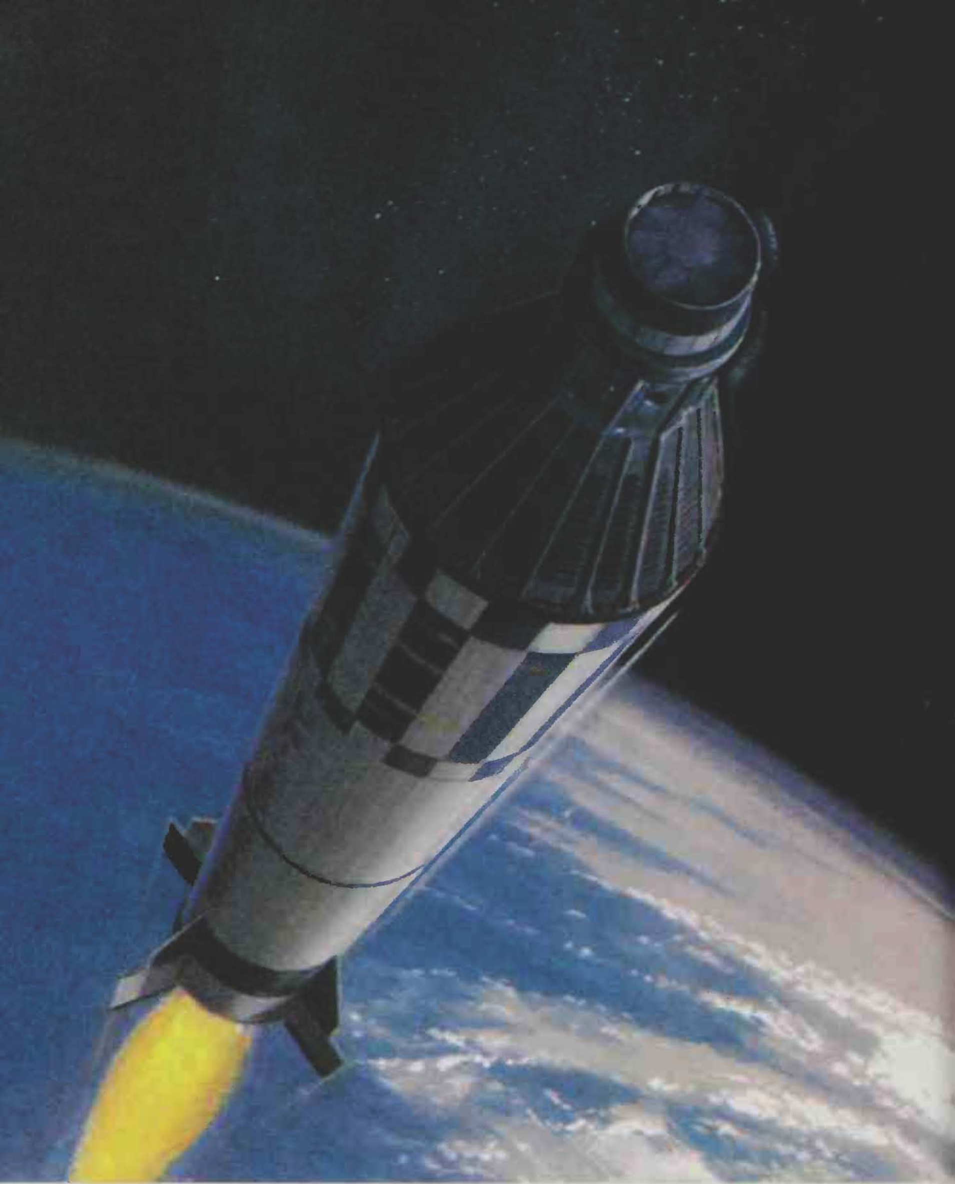
Ballistic Rockets

After World War II, many rocket designers returned to their original goal—the exploration of space. One early space rocket (1952) was the Rockoon. The Rockoon was a rocket launched after it had already been lifted to a high altitude by a balloon. Many Rockoons were launched from heights around 18.6 miles (30 km) and zoomed on to 62 miles (100 km).

A typical Rockoon (left) carried a payload of about 20 lbs (9 kg) of scientific instruments. Today we can fire such payloads much higher without first using a balloon to lift the rocket.

After World War II, the Allies had numerous V-2 rockets, and a few were put to good use. One of the most forward-looking ideas was suggested by U.S. Army Col H.N. Toftoy, who pointed out that it would be possible to achieve record heights by fitting a smaller rocket on the nose of a V-2. A U.S. rocket called the WAC-Corporal, weighing some 650 lb (300 kg), was fitted in the nose of a V-2, which was launched from White Sands range in New Mexico. The combination was called Bumper, and Bumper No. 5 achieved the record height of 244 miles (393 km) on February 14, 1949.

In Project Bumper (right) a small rocket was fired from the nose of a V-2.



Redstone, an old U.S. Army missile, was used to lob the first American in space in a Mercury capsule on May 5, 1961. Navy Commander Alan B. Shepard made a quick up/down flight to a peak height of 116 miles (186 km) lasting just 15 minutes 22 seconds.

Ballistic vehicles have no wings, and today they usually don't have tailfins either. Launched vertically, they are steered by guiding the direction of the jet from the rocket engine(s). Long-range rockets can climb above the atmosphere and reach tremendous speed (in some cases enough to reach the planets). All early space exploration was done with ballistic rocket vehicles. Many thousands are also used as heavy artillery and are able to hit any target within a range of thousands of miles (kilometers).

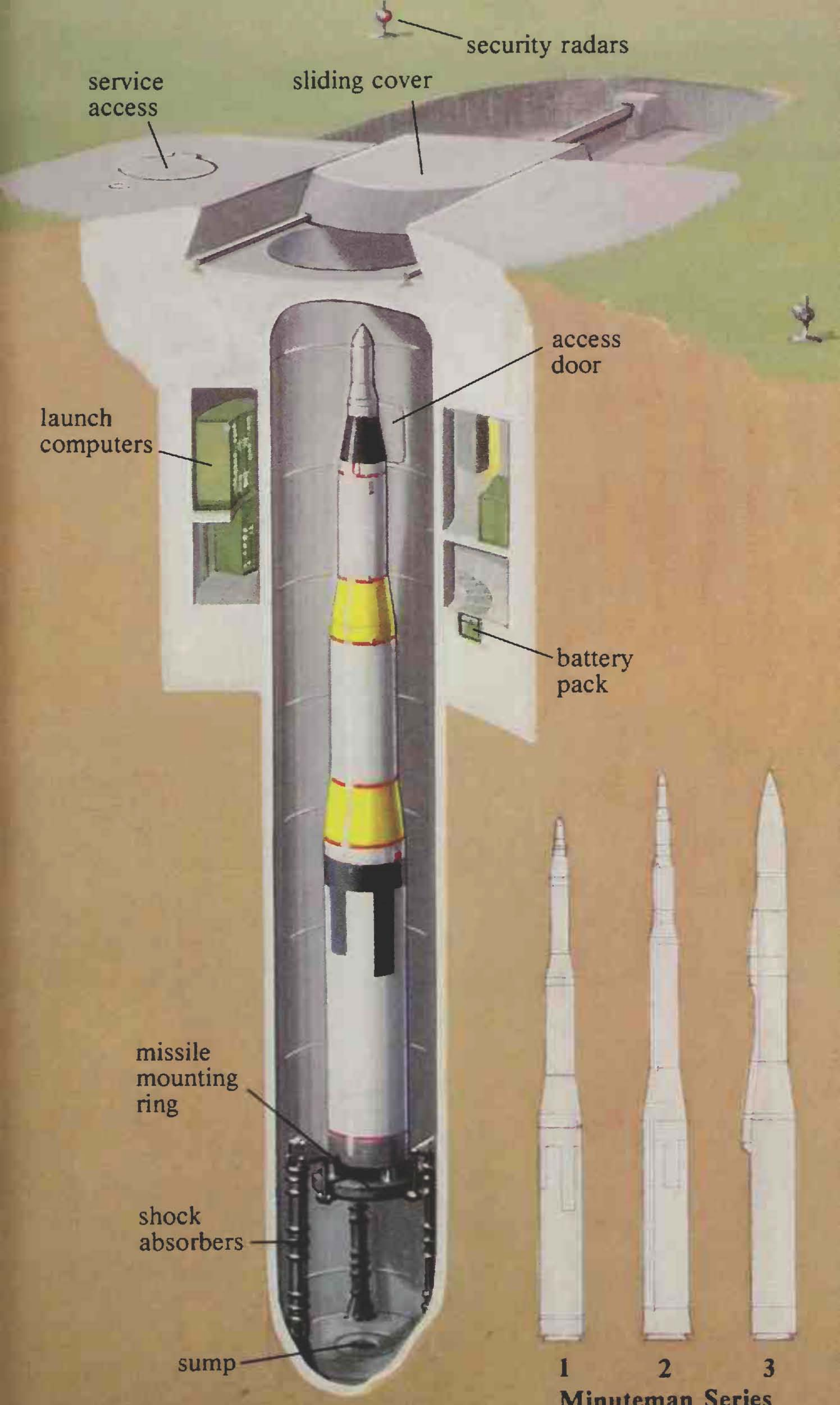
A modern battlefield ballistic missile is the precision radar-guided Pershing (above).

This impressive missile is actually quite old. The Soviet Union put SS-4 (called Sandal in the West) into use in 1959 and had over 500 on active status by 1963. With a range of 1,118 miles (1800 km), it is among the smallest Soviet ballistic weapons.

The ICBM exerts a vast influence on the modern world. Today thousands of ICBMs in the United States and the Soviet Union rest silently in their underground silos.

The first ICBM in the West, the Atlas (left), was much smaller than the giant 32-engined SS-6 of the Soviet Union, which was developed in the same timescale. All its engines were ignited before lift-off. The two large boosters were then jettisoned. Its thin stainless-steel airframe was kept in shape by internal pressurization.

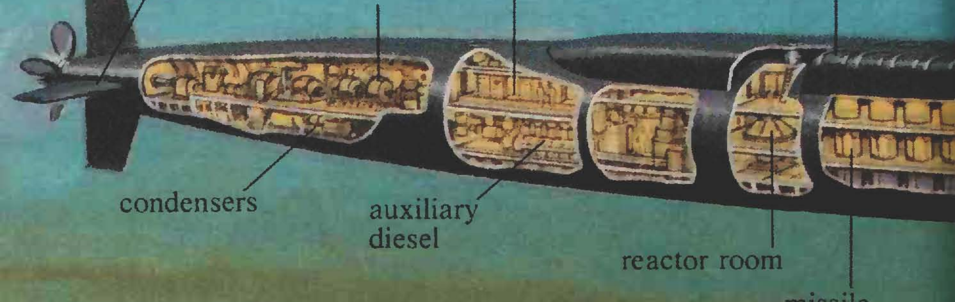
In the early 1960's Atlas was withdrawn and replaced by Minuteman (right). Made by Boeing, this slim ICBM has three stages. It was the first large missile with solid rocket propulsion. It was designed to be carried aboard special trains. It was put in deep concrete silos, but today these no longer offer adequate protection.



Minuteman Series

Global Deterrence

Today ICBMs and SLBMs (submarine-launched ballistic missiles) are the chief weapons deployed by the United States and the Soviet Union to effect global deterrence. The concept of global deterrence claims that aggression can be deterred if each side has the ability to hit any place on earth with devastating force. Some deterrence is directed against cities, but even these intercontinental missiles have become so accurate that increasingly they are being targeted against the land-based ICBMs of potential enemies. ICBMs have been stored in nuclear-hardened silos (as is the case with Minuteman, page 53). Now they have to be mobile. Such terrifying ICBMs as the Soviet SS-18, with eight thermonuclear warheads, each with its own precision guidance have forced the USAF to try to develop MX. A new ICBM for the 1990's, the MX or "Peacekeeper," will move around a system of rail tracks mostly buried below ground in the midwestern area of the United States.



Even mobile ICBMs on land, such as MX (B), may not be able to withstand the warheads of such monster ICBMs as SS-18 (C). But the SLBM can hide in such a large volume of ocean that it may remain useful. Moreover, modern nuclear-propelled submarines (even the 1962 USS Lafayette, *below) can carry the missile closer to its target. The Trident SLBM (A), like Soviet SLBMs , has a much longer range. This greatly increases the sea area where missile submarines may lurk while still covering their targets.*

Modern Winged Missiles

We know nothing of the latest Soviet cruise weapons, but all about the U.S. types. The ALCM (air-launched cruise missile) carried by some B-52 bombers is the AGM-86B, made by Boeing. Their

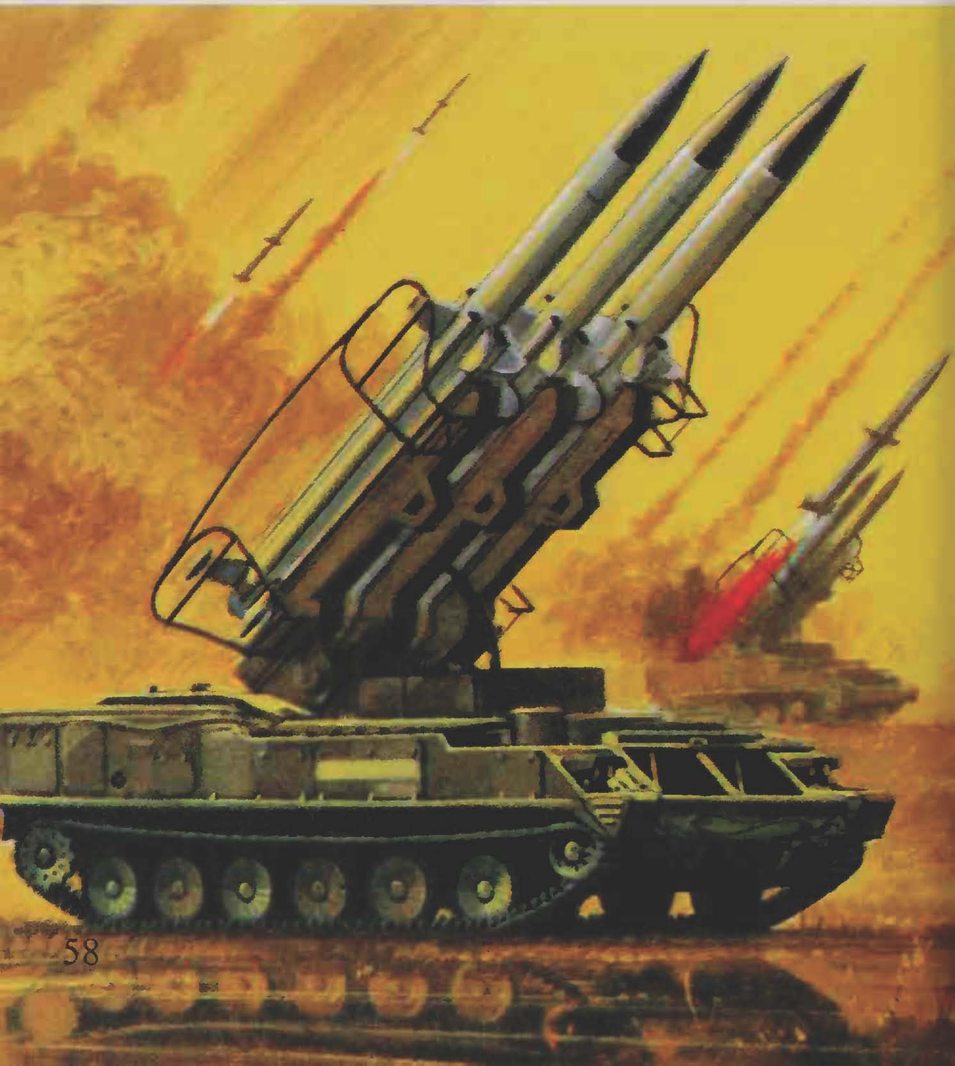
Three Western cruise missiles: the AGM-86B ALCM (opposite); the Tomahawk BGM-109 (top); the Sea Eagle anti-ship missile (below).

range is 1,550 miles (2500 km) with a thermonuclear warhead.

The Tomahawk is even more versatile than ALCM. It has been developed in versions that can be fired like torpedoes from surface warships and submarines, dropped from aircraft, and launched from mobile land vehicles. Today, smaller cruise missiles are almost universally used for hitting enemy surface warships. Cruise missiles can readily be made to fly just above the tops of the waves. In this position, they can home in on the target vessel while being very difficult to shoot down themselves. Sea Eagle is one of the longest-ranged anti-ship missiles. Unlike some of its contemporaries it has a turbojet engine.

Modern SAMs

Modern surface-to-air missles have to have almost instant readiness, because they are unlikely to receive much warning of an attack. They also need reliable guidance that cannot be jammed or misled by the enemy attack. Army SAMs have to be driven at high speed by tracked vehicles. SAMs fired from ships have to be able to hit not only aircraft by also supersonic sea-skimming missiles, or small missiles plunging down from above.



The British Rapier (above) is certainly the most cost-effective SAM for a modern army. It comes in many versions with different kinds of visual or blind guidance. In the model shown here, the Rapier is mounted in batteries of eight on a fast amphibious tracked vehicle. Rapier can be small, because its guidance is so accurate it explodes inside the hostile aircraft, a concept proven in hundreds of test shots.

Missiles that explode near a target have to be much larger. The Soviet SA-6 (opposite) influenced heavy casualties on Israeli aircraft in 1973 because, at that time, its continuous-wave radar guidance could not be jammed. SA-6 is fired by rocket but cruises on an internal ramjet engine.

Britain's Seawolf (below) is the only naval SAM in use that can intercept not only aircraft but also shells.

Modern Tactical Missiles

Strategic weapons are long-range weapons directed against enemy countries. Tactical weapons are local weapons used in land or sea battles. In recent years almost all tactical missiles have become precision-guided, often homing automatically on to laser light scattered away from the target. Laser guidance is now even being used to achieve pinpoint guidance with artillery shells.

Today's tank commander has no defense against high-speed anti-armor missiles (this is Italy's Sparviero) except to keep its hull down and remain unseen.

Typical of modern antitank missiles, TOW (initials of tube-launched optically-tracked wireguided) has been made in enormous numbers exceeding 200,000.

One of the widely used air-launched missiles is the USAF's AGM-65 Maverick (below, being fired from USAF A-10A attack aircraft). It can use any of several different forms of guidance. While TOW weighs 46 lb (21 kg), Maverick scales a hefty 462 lb (210 kg), of which 130 lb (59 kg) is warhead.

Index

Rockets and Missiles is an exciting, easy-to-read book that contains the latest expert information on all kinds of rockets and missiles. It is full of fascinating facts, diagrams, full-color illustrations, and has a comprehensive index.

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- What different purposes do rockets have?
- What are solid rockets?
- How are rockets used in space?
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- What is a cruise missile?
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