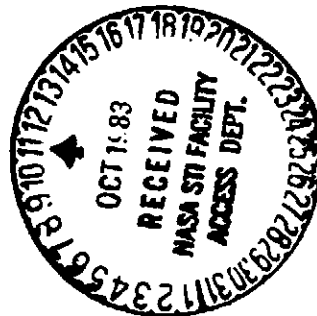


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HISTORICAL DEVELOPMENT OF
WORLDWIDE GUIDED MISSILES



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SUMMARY

The origin of missiles is difficult to pinpoint, but the basic principles on which they are based are about as old as man. This paper attempts to put in perspective the development of missiles from early history to present time. The influence of World War II in accelerating the development of guided missiles, particularly through German scientists, is discussed. The dispersion of German scientists to other countries and the coupling of their work with native talent to develop guided missiles is traced. Particular emphasis is placed on the evolution of the missile in the U.S. and the U.S.S.R. Since the Soviets possess what is probably the world's most complete array of dedicated missile system types, their known inventory is reviewed in some detail. Some philosophical observations of missile design trends and missile purposes are made as related to the interests of various countries.

EARLY HISTORY

The earliest form of a missile was probably a rock which, when hurled through the air, would follow a curved ballistic path from the launching point to a target (fig. 1). The use of such a missile is recorded in The Holy Bible, I Samuel 17:49-50, where the slaying of Goliath by David is described--"And David put his hand in his bag, and took out a stone, and slang it, and struck the Philistine in his forehead, that the stone sunk into his forehead; and he fell upon his face to the earth. So David prevailed over the Philistine with a sling and with a stone, and struck the Philistine, and slew him; but there was no sword in the hand of David." This event represents a form of standoff engagement (as opposed to hand-to-hand combat) using a mobile launcher--David, and his arm and sling; a ballistic missile--the stone; and initial guidance--David's eyes for tracking, his muscle for propulsion, his brain for coordinating, and the power of God. Other similar unpowered, ballistic missile stand-off weapons are the spear, the bow and arrow, the gun and bullet, the hand grenade, and so on.

Some historians believe a form of rocketry or incendiary devices was established as early as 3000 B.C. The Greeks used incendiary missiles such as fire pots and fire arrows as early as the 4th century B.C. (fig. 2). Fire lances were mentioned in the 4th century A.D. During the Arab siege of Constantinople, near the end of the 7th century, the Greek soldiers introduced the "Greek fire" against the dismayed attackers. Byzantine Emperor, Leo III, reported that the Greek fire was ejectable and could be used to destroy naval targets. Greek fire was also used by the Byzantines to repulse Igor the Russian at Constantinople in 941. Following the long use of incendiary materials, it is believed that some form of gunpowder was known at least as far back as the 1st century B.C. It appears that practical application of gunpowder to fireworks and rockets began about the 10th century.

A.D. 1000 - 1900

The literature indicates that around the year 1000 the Chinese had flame-throwing devices. By 1132, they were using long bamboo tubes filled with explosive powder. In 1232, the Chinese defended the city of Kai-fung-fu and repelled the Mongol attackers with the aid of "arrows of flying fire." This may have been the first recorded use of solid-propellant rockets. Details of these rockets reached Europe by 1258 and are mentioned in 13th and 14th century writings. Powder rockets were used in the war between Venice and Genoa in the 14th century where a previously impregnable defense tower was destroyed by a rocket. Pirates often used rockets for attacking the shore from ships during this time period. The use of gunpowder and descriptions of the necessary ingredients are mentioned in several places during this general time period. Recognizing that many sources may be overlooked, some recordings will be cited. In a 13th century manuscript entitled "Liber Ignium ad Comburendos Hostes" (Book of Fire), traditionally attributed to Marcus Graecus, thirty-five Greek pyrotechnic recipes dating from the 8th to the 13th century are compiled. This manuscript refers to the use of the vital ingredient of gunpowder, saltpeter. Others who contributed documentation on the art of creating gunpowder around the 13th century were the German scientist, Albertus Magnus, and the Englishman, Roger Bacon. Another name traditionally tied to the development of gunpowder is Berthold Schwartz, or Bertholdus Niger, or Black Berthold. The use of the word "black" in connection with gunpowder or "blackpowder" is related by some back to Medieval Europe when the making of gunpowder was considered a "black art." During the 15th century, Leonardo da Vinci prepared drawings of rockets; Giovanni da Fontana, a Venetian engineer, described rocket-powered torpedoes that could skip along above, or even go below, the surface on the way to the targets. In the 16th century, Conrad Haas, a German pyrotechnic expert, made sketches of multistage rockets in which the first stage was designed to consume itself so that separation of the stages was not necessary (fig. 3). Haas also developed a swept-back guidance fin, and in another instance, sketched a house-like structure attached to a rocket which might be interpreted as a preconception of future manned rocket-propelled flight. The art of rocketry also found its way into India around the 14th century and played a part in several wars. In 1750, the French army came into contact with Indian rockets. The Indian rocket forces were used in several battles with the British near the end of the 18th century. The Indian rockets were varied--one consisted of a 10-inch long, 2-1/2-inch diameter iron case lashed to a sword blade. Others were sharp-tipped bamboo poles of about 1-1/2 inches in diameter and up to 10-feet long. The weights were from about 6 to 12 pounds. These rockets could be fired along conventional aerial trajectories for about a thousand yards, or could be fired along nearly horizontal paths near the ground. They were effective in killing up to as many as 6 men, but were especially effective in harassing, in startling troops and horses, and in setting off ammunition carts. The Indian rockets were reported to be simple, easily carried, inexpensive to make, uncomplicated to operate, and readily produced--still desired traits today. They were not especially accurate, but could be fired in great numbers.

A British army colonel, William Congreve, became fascinated and quite impressed by the Indian missiles that he had personally encountered, and he began experimenting with rockets in the early 1800's. Congreve's solid propellant rockets contained powder and metallic particles in the nose that exploded on impact. Congreve developed rockets weighing from about 6 pounds up to about 300 pounds--the latter being about 8 inches in diameter and carrying a 50-pound warhead (fig. 4). These rockets soon became standard equipment with the British. With somewhat questionable success, the Congreve rockets were used by the British navy against the French fleet in Boulogne harbor in 1806. With considerable success, the Congreve rockets were used by the

British in the Napoleonic wars and the city of Copenhagen was essentially completely destroyed by incendiary rockets in 1807. The siege continued for almost three days and the estimate of rockets fired ranges from 25,000 to 40,000. Rockets were extensively used by the British in the War of 1812 and, during the siege of Ft. M'Henry in Baltimore, inspired Francis Scott Key to write the "Star-Spangled Banner" and immortalized the words "by the rocket's red glare." Thus, before the 19th century was over, hundreds of thousands of rockets had been manufactured and fired under a variety of circumstances. Other recorded occasions wherein rockets were used include the use by the forces of Joan of Arc in 1428 at Orleans; the Battle of Waterloo in 1815; during the Chilean independence movement; in Peru; the Burmese conflict of 1824-25; during the civil war in Spain that ended in 1840; the Chinese Opium War in the early 1840's; a French-British attack against Argentina in 1846; the Crimean War (1853-56) in which all combatants used rockets; the Indian Mutiny of 1857; the British Abyssinian campaigns of 1867-68; during the Gold Coast action in Africa (1873-74); the British war with Benin (Nigeria); the Sudan conflicts of 1885 and 1896. Rocket warfare had touched all continents and rocket programs, or rocket use, had involved many countries--China, India, Britain, Russia, France, Germany, Austria, Italy, Denmark, Sweden, Africa, Spain, Prussia, Colombia, Mexico, Uruguay, Argentina, and the United States.

During this period, William Congreve had developed the solid-propellant, stick-guided rocket to about its maximum capability. Congreve had recognized and proclaimed some of the fundamental features of rockets such as, "the very essence and spirit of the rocket system is the facility of firing a great number of rounds in a short time, or even instantaneously, with small means;" "the projectile force is exerted without reaction upon the point from which it is discharged"--giving rise to ship-mounted launching platforms and eventually to air-launching and man-portable launching. He also recognized the tremendous psychological effect; tremendous penetrating power; merit of explosive incendiary and shrapnel warheads; and the high degree of mobility.

All Congreve rockets were stick-guided, with the stick lengths depending on the size and weight of the particular weapon. While the sticks were a definite help, a certain amount of inaccuracy in individual rockets was usually present. Of course, the rapidity with which a great number of rockets could be fired; the fact that they were light, mobile, produced no recoil; were not size-limited; were inexpensive; tended to build-up speed on the way to the target; and left a fiery tail behind all were factors that gave rockets certain other advantages over cannonballs and shells. Congreve made some improvements in the stability of his rockets by tailoring the stick length and eventually changed from the side (or laterally) mounted stick position to a center stick position. This change also facilitated tube-launching of the rockets. He also recognized that account must be made for the continual change in weight and the shift in center of gravity for a rocket in flight--factors that still must be considered today.

One solution to improve the accuracy and remove the guidance-stick was known to be through spinning the rocket in the same manner that cannon-launched projectiles spin. An Englishman, William Hale, addressed himself to this problem beginning in about 1839 and developed a stickless, rotary rocket that was given a rotary motion by directing part of the exhaust flame through slanted exits. He received a patent on the rotary rocket in 1844. His spin-stabilized rocket was also patented in the United States and the process was sold to the U.S. Army Ordnance Department in 1846. His ideas were not adopted in his native Britain until the 1860's when the Hale rocket was issued to British artillery men in time to be used in the African campaigns.

Near the end of the 19th century some work that should be noted was being done by Wilhelm Unge, a Swedish military engineer. While he had little official encouragement from his government, and the main stream of events in rocketry revolved around the work of Congreve and Hale, Unge, with the financial aid of Alfred Nobel (the millionaire inventor of dynamite), began in the late 1880's to explore means for improving the performance and accuracy of rockets. Unge tried to increase the range of rockets by using a cannon-launch for initial first-stage velocity. His attempt was not successful because the forces of initial acceleration damaged the rocket ignition system. However, his idea was sound and the cannon-launched guided-projectile was proven in practice almost a century later. Turning his attention then toward improving the propellant powder, an area that had previously been neglected, Unge, drawing on the work of Nobel in double-based, smokeless powder, soon came up with a propellant that had controlled burning; higher exhaust velocity; a stabilizer to increase storage life; a plasticizer to increase workability; and a binder to give greater mechanical strength to the grain. A rocket using such a propellant was flown by Unge in 1896. An additional contribution of Unge's was a spin-stabilized rocket, differing from Hale's in that Unge rotated the launcher to provide the spin rather than angled thrust of the rocket itself. By the turn of the century, Unge's launcher-rotated rockets reached 5-mile ranges with accuracies that competed with the rifled artillery. Unge saw possible applications of rockets for surface-to-air (anti-balloon), ship-to-ship, and ship-to-shore. The Swedish military was not interested, and in 1908, Unge and his patents were bought by Krupp in Germany.

TWENTIETH CENTURY

Pre-World War I Era.- In 1903, a Russian schoolteacher, Konstantin Tsiolkovsky, published a paper on space travel in which he advocated the use of liquid-fueled rockets for propulsion. His work was inspired by reading the 19th century imaginative fiction of Jules Verne who made space travel sound exciting. Tsiolkovsky's mathematical work revealed the principle of mass ratio and told him that the performance capability of a rocket was limited regardless of size. His formula suggested that rocket performance could be maximized by finding the best fuel for increased exhaust velocity and to reduce the empty weight of the rocket as much as possible so that more propellant could be carried. For many years the paper remained unknown outside Russia and, at that time, little attention was given it by Russians.

Otherwise throughout the world, almost no interest was shown in rockets during the opening years of the 20th century. As recorded in the 1898 edition of "Dictionnaire Militaire"--"After having enjoyed, for more than half a century, a vogue that often touched of exaggeration, the war rocket today is almost completely abandoned. It is nevertheless necessary to treat the subject not only for historical reasons but in the hope--not yet abandoned by everyone--that in the future the device will be resurrected because of its simplicity and ease of deployment."

World War I Era.- With the outbreak of World War I (1914-1918), some attention was again paid to the rocket. Rockets were used in the development of parachute flares for illuminating battlefields at night. Rockets were also used as a means of transporting messages from one location to another. The Congreve stick-guidance type rocket was resurrected although the Hale rotary rocket technology had been around for about 70 years. This partly serves as an indicator of the extent to which the rocket had retrogressed from disuse. French General Fock ordered a study of the feasibility of using small rockets, air-launched, for combating German observation balloons. The French quickly adapted stick-guided, powered rockets for firing from steel tubes attached to the wing struts of biplanes like the Nieuport fighter (fig. 5). These

rockets, fired in barrages, in accordance to some set procedures, proved to be successful. One quote from the procedures may be of interest to fighter pilots of today--"Extremely Important Remark: The departure of the rockets does not follow immediately the touch of the electrical button, and the delay varies from one rocket to another. Therefore, it is absolutely necessary to continue to hold the sight and the descent until the discharge of the last rocket (about one second). If one redresses or turns too quickly, the last rockets will go in different directions and give a dispersion which is altogether inadmissible."

A completely different path toward guided flying weapons began to appear during World War I. Before 1914, British Professor A. M. Low was at work on a top secret project called a Flying Target, or F.T., which was a small, radio-controlled airplane designed to combat German Zeppelins as a form of a flying bomb. They were also to be flown against ground targets, in which case they were to be controlled from a parent aircraft as a true air-to-surface guided weapon. Several types were built by Low and his assistants, Poole, Brown, and Whitton; by DeHavilland; by Sopwith; and by the Royal Aircraft Factory. The R.A.F. produced six very graceful monoplanes with radio aerals fitted as chord-wise wires on the wings and on the rear of the fuselage. These machines were to be launched from a lorry by means of a compressed air catapult which, in itself, was an idea well ahead of its time. The experiments were successful, but for reasons unknown, no operational use of the weapon was ever made. Low went on to produce radio-controlled rockets in 1917 and these appear to be true ancestors of various similar devices that emerged in World War II and claimed as the invention of others. Flight experiments continued with the radio-controlled monoplanes after the war, and in 1921, a number of them were flown from the aircraft carrier, H.M.S. Argus. These monoplanes took off under their own power from a trolley undercarriage.

Also during World War I, the Kettering Aerial Torpedo (the "Bug") was developed in the U.S. The Bug was invented by Charles F. Kettering of Dayton and built by the Dayton-Wright Airplane Company in 1918 for the U.S. Army Signal Corps. The unmanned Bug was a propeller-driven biplane with a speed of 120 mph and a range of 75 miles. Takeoff was accomplished under power from a dolly running on a track. Guidance to the target was provided by a system of onboard preset vacuum-pneumatic and electrical controls which, after a predetermined time, would shut off the engine, release the wings, and cause the Bug to plunge to the target where its 180 pounds of explosive detonated on impact. Although the initial testing was successful, World War I ended before the Bug could enter combat. Less than 50 Bugs were completed before the end of the war and the Air Service continued additional tests with these. However, a scarcity of funds in the 1920's halted further development, and the progress of guided missiles was destined to wait for several more years.

Scientific work, unrelated to World War I, did continue in the early part of the 20th Century and several independent events were to become interrelated and have a pronounced influence on the development of rockets and missiles. The work of Tsiolkovsky in Russia in 1903 concerning the merits of liquid-fueled rockets has already been mentioned. While this work remained in obscurity, the basis for modern rocketry was being laid independently by Hermann Oberth, a Rumanian-German and Robert H. Goddard, an American. Working separately, both Oberth and Goddard favored the liquid-fuel rocket. Oberth's book "The Rocket Into Interplanetary Space," published in 1923, provided the impetus for experimental rocket work in Germany and also led to the formation of the German Society of Space Travel in July 1927. This society, better known as the German Rocket Society, grew to a worldwide membership of more than a thousand by 1930, including Wernher von Braun, a young engineering student at the Berlin Institute for Technology. Many successful rocket experiments were

conducted by this group, which disbanded in 1933 after training a core of German scientists, who would later produce the world's first large, liquid-propellant rocket, the V-2, of World War II fame.

In the U.S., Robert Goddard had prepared a paper in 1919 entitled "A Method of Reaching Extreme Altitudes," in which he alluded to the possibility of shooting a rocket to the moon. Goddard had experienced problems with the pellet imperfections in solid rockets and, around 1920, began experimentation with liquid fuels. His first liquid-fuel rocket flew on March 16, 1926 for a distance of 184 feet. By 1935, his rockets had reached 75,000 feet and speeds of over 700 mph. By the late 1930's, Goddard was recognized in professional circles as probably the world's foremost rocket scientist. His work was well known to many, including the German Rocket Society, who followed his work very closely. American rocket enthusiasts formed the American Interplanetary Society in 1930, later changing their name to the American Rocket Society. The experiments and meetings of this group stimulated a growing awareness of rocketry in the American public and many members of this group, together with German scientists who were later to come to this country following World War II, would be responsible for the development of missile and space programs in the U.S.

Concurrent with these scientific rocket activities of the early 20th century, some other events were taking place which, in the interest of history, are worth noting at this point. In Russia, Kerenski's Revolution occurred and in November 1917, during the waning years of World War I, Lenin's Communist government came into being and the Five Year Plans were begun with a specific objective to become a world power.

Post World War I Era.- In Germany, recovering from defeat in World War I, thought was already being given in the early 1920's to the rebuilding of power. In the summer of 1922, Captain Eddie Rickenbacker visited Berlin to talk about Germany's future in world aviation with prominent German airmen. One of them, Hermann Goering, told Rickenbacker, "Our whole future is in the air. With air power, we are going to recapture the German Empire. There are but three things we need to do--teach gliding as a sport; build up our commercial aviation, and create a skeleton for a military air force. Then, when the proper time comes, we will mould all three together, and the German Empire will be reborn." That was in 1922. In 1934, Goering, the German Air Minister, was second only to Adolf Hitler, the new Nazi leader of Germany. In 1935, Rickenbacker visited Germany again and talked with the same airmen with whom he visited 13 years before. This time, Rickenbacker was shown through the giant Junkers factory where about 24,000 workers, on a 24-hour basis, were turning out transports and bombers. At the beginning of 1935, Germany had about 600 combat airplanes; by 1936, Germany would have 1600 combat airplanes; plans called for 2600 combat airplanes by 1937. The Junkers plant, if devoted to a single model, could complete 1000 airplanes per month (and Junkers was not the only factory). The significance of such production becomes more apparent when one considers that, at that time, the entire industry of the United States, Great Britain, or France, could produce that number of airplanes only after expanding for about half a year under wartime mobilization conditions. Rickenbacker rushed back to report to the U.S. that the mass production of airplanes was the keynote to strength for the Luftwaffe. The Germans were preparing to meet the demands of any war effort, not a half a year or a year after the fighting starts, but on the day that fighting starts. The warning initially fell on deaf ears. In September 1939, the German power was unleashed over Western Europe and the U.S. began to take notice and to expand production. It should also be pointed out that during the 1920's and 30's, the air forces of Italy, Japan, and Russia were quietly but efficiently growing. A Japanese Army spokesman, while demanding unlimited appropriations in 1936 exclaimed, "The future of our national defense is in the air."

The U.S. was to feel the effects of this growth starting in December 1941 at Pearl Harbor. The German, Italian, and Japanese air forces proved to be exceedingly devastating during World War II, but have been more or less contained since the Allied victory in 1945. Among international powers, the Soviet Union remains today with the largest air force the world has ever known.

German Activities.- Returning now to the early 30's in Germany, many events contributing to the growth of missilery were occurring, all of which cannot be covered in this paper. Oberth successfully fired a liquid-fuel rocket motor in July 1930. Johannes Winkler (who organized the German Rocket Society) went to work at Junkers where he studied the feasibility of solid rockets for rocket-assisted takeoff of heavy airplanes (later to be used for missiles as well). Winkler also worked with liquid-fuel rockets, and in March 1931 was successful in launching the first liquid-fuel rocket in Europe. A team headed by Rudolf Nebel, who had been an assistant to Oberth, was formed in 1930 to continue the work of Oberth, who had returned to his teaching post in Rumania. Among the team members was Wernher von Braun. A water-cooled liquid-fuel rocket motor was developed and flights were made with the rocket motor nose-mounted and pulling parallel fuel tanks up by the fuel lines. Later versions used a tandem-tank arrangement, and about 85 successful flights were made in 1931 to altitudes of 1000 to 1500 feet. These flights attracted much publicity and the Ordinance Department of the German Army (Reichswehr) became interested since it appeared that rocketry offered a legal approach to a long-range weapon unrestricted by the Treaty of Versailles which placed limiting provisions on classical artillery. The Army was interested in supporting the rocket development, but insisted that all publicity and showmanship must stop and that the work be seriously pursued in secrecy at the Army artillery range at Kummersdorf. Nebel and many other independent rocketeers declined the Army offer, preferring to continue with the showmanship and worldwide contacts with other rocket enthusiasts rather than adhering to strict Army classification. However, in the fall of 1932, von Braun graduated from the Berlin Institute of Technology and was approached by Colonel Docter Karl Becker, who was chief of ballistics and ammunition for the Army Ordnance Department and also held a full professorship at the University of Berlin. Colonel Becker offered a research grant funded by the Army to von Braun which would permit von Braun to earn his doctorate based on secret work to be performed at Kummersdorf on the combustion processes in a liquid-propellant rocket motor. In November 1932, von Braun, with one technician, began work on his doctoral thesis on a remote test site of the Kummersdorf Proving Ground. In January 1933, a small water-cooled alcohol-liquid-oxygen motor was tested that developed a thrust of 310 pounds for 60 seconds. Later in the year, a 660-pound motor, regeneratively cooled by its own alcohol flow was successfully tested. The group of scientists increased in number and von Braun, at the age of 20, became chief of the experiment station. The time had come to build a flyable rocket. Six months later the rocket, A-1, was ready but delayed ignition resulted in an explosion when launch was attempted. Later in 1934, von Braun had earned his Ph.D. in physics, and a redesigned rocket, A-2, with a gyroscope stabilizer located near the center of gravity was ready and two were successfully launched.

Hitler, who had come into power in 1933, became interested in rockets as weapons in 1936, and initiated the construction of a vast Army--Luftwaffe rocket research center at Peenemunde on the Baltic Sea. Peenemunde consisted of a Luftwaffe-operated airfield for testing rocket-powered airplanes and an Army-operated research and development center complete with wind tunnels. In April 1937, the Kummersdorf group moved in and von Braun, at the age of 25, was named the technical director of the Army complex.

Following the success of the A-2, the more highly sophisticated A-3 was on the drawing boards. It was 22-foot long and was to be powered by a 3200-pound thrust engine that would operate for 45 seconds. It was to have a three-dimensional gyro control system with jet rudders and actuators. Many new innovations were also included in the rocket motor. In December 1937, three A-3 launch attempts were made and all three failed. Use was made of the wind tunnels to redesign the tail fins; the control system was completely redesigned; the fuselage was redesigned; and a new four-channel telemetry transmitter was installed. The revised A-3 did not have supersonic capability but served as a prototype for the larger A-4 to follow, which would have supersonic capability. The modified A-3 was redesignated the A-5, in order to avoid the stigma of the A-3 failures, and in the summer of 1939, shortly before the beginning of World War II, the first flight of the A-5 with the new guidance system was a complete success. During the next two years, about twenty-five A-5's were launched. The Ordnance Department still wanted a field weapon with a large warhead and a range substantially exceeding that of artillery, however, so the concept of the A-4 (scaled up A-3 or A-5) was resumed. The calculations indicated a rocket about 46-foot long, 5.2 feet in diameter, a launch weight of 26,000 pounds, a warhead of 2200 pounds, a range of 270 miles, and a thrust level of 55,000 pounds. Thus the A-4, later to be known as the V-2, came into being. A large supersonic wind tunnel, and other test facilities, including an elaborate guidance and control simulation laboratory at Peenemunde, were used to answer the many unprecedented questions related to flight at speeds up to five times the speed of sound. In the spring of 1942, the first attempt to launch an A-4 ended with an explosion at launch after a fuel-feed malfunction. Four weeks later, the second A-4 passed successfully through the transonic range but, after forty-five seconds, began to oscillate and broke apart. After some structural reinforcement, the third A-4 was successfully launched October 3, 1942, accelerated for sixty-three seconds, reached a Mach number of about 4.7 (4400 feet per second), an altitude of about 275,000 feet (52 miles), and a range of 116 miles. For the first time, a man-made object had left the atmosphere and reached the fringes of outer space. The first V-2 vengeance weapon was fired against London on September 7, 1944, and over the next year about 3600 V-2's were used against England and Antwerp, Belgium (fig. 6).

There were other developments at Peenemunde worth noting--the Luftwaffe, not to be outdone by the Army, developed a winged, subsonic cruise missile powered by an air-breathing pulse-jet engine. This missile, to become known as vengeance weapon one, V-1, was catapult-launched, controlled in flight by inertial guidance, and employed a predetermined engine shutoff time when the weapon would then dive on its target (fig. 6). The first was launched against London on June 12, 1944, and by March 1945, about 9000 V-1's were launched against England and another 12,000 against Belgium. The subsonic V-1 was more vulnerable than the V-2, but it was also much less expensive.

Another development at Peenemunde was the A-9, which was a winged version of the V-2 (A-4). The purpose of the A-9 was to increase the range of the A-4 by taking advantage of the tremendous kinetic energy available after power cutoff and extend the aerodynamic glide through the use of wings. Two A-9's were flight-tested during the winter of 1944-45--the first being a failure, and the second being successfully launched and reaching a Mach number of about four. Further plans included a manned A-9 with a pressurized cockpit and tricycle landing gear that would have a 400-mile range at twice the speed of sound.

One other development at Peenemunde, that will be discussed in more detail, was the Wasserfall, surface-to-air, guided missile. In the winter of 1942-43, the growing Allied air threat caused the German Antiaircraft Command to ask for the

development of a guided anti-aircraft rocket. The program director, Ludwig Roth, had the former aerodynamic dynamic institute at Karlsruhe assigned to the task, and a summary of the development, compiled by Dr. Herman Kurzweg in a document entitled "The Aerodynamic Development of the Anti-aircraft Rocket Wasserfall," is an interesting account of the problems and solutions that were faced. Optimization studies of the missile size and range (less range requiring more batteries) dictated a body diameter of 40 cm (35.43 in.) and a length of 810 cm (26.6 ft.)--about half the size of an A-4. Performance requirements were simply stated, calling for surface launch at zero velocity; to reach a maximum velocity about three times the speed of sound at an altitude of 20 km (about 65,000 ft); be controlled from the ground to a distance of 50 km (31 mi.) or equipped with a target-seeking device; be able to negotiate turns in order to pursue enemy airplanes and cope with evasive maneuvers. Trajectories and flight conditions are shown in figures 7 and 8.

Liberal use was made of the basic design of the A-4 since that was the only vehicle that had successfully achieved such speeds and altitudes (including traversing the transonic range). Since steering by means of rudders was to be employed, the experience gained from wind-tunnel tests of the guided glide version of the A-4 was also used. The characteristics that were investigated during the development of Wasserfall are fairly remarkable in their revelation of an understanding of the problems involved with maneuverable, guided missiles, and the thoroughness with which the problems were pursued. These characteristics (fig. 9) and some remarks from Dr. Kurzweg's commentary are:

The requirement for turns of small radius at high speeds required the addition of lifting surfaces to produce the necessary lift. Deviating from conventional airplane design, a symmetrical cruciform wing, in addition to the four-tail fins, was selected in order to provide rapid response to maneuvering control signals. This idea also led to the investigation of an annular wing, but this scheme was precluded because of the high drag measured during wind-tunnel tests. A load factor of 12 was selected to provide an excessive maneuver margin of about 2 over manned fighters and about 6 over bombers (obviously the greatest concern was the Allied bomber threat). The characteristics of the body-tail were well known from the A-4 tests. It was calculated that to develop the required lift from the body-tail, very large angles of attack would be necessary, entailing intolerably high drag and unfavorable lateral forces.

Another consideration was the necessity for keeping the center of pressure of the missile constant as much as possible at all speeds in order to obtain low control force requirements. The variation of center of gravity inherent with fuel consumption was also taken into account. The large variation of center of pressure with speed and angle of attack was already well known from the A-4 tests. Considerable tailoring of the wing and tail planform, size, and location was accomplished in the wind tunnel before the final configuration was selected (23 wings were investigated, for example). Some of the configurations investigated are shown in figure 10.

In developing the controls, consideration was given to the fact that steering must be maintained from zero velocity to three times the speed of sound, under power and also during coasting flight. Aerodynamic control was selected because of the coasting

flight maneuver requirement. For the launch phase (near zero velocity), jet rudders made of graphite were mounted to the inboard end of the rudder shafts. The control development also entailed detailed pressure distribution measurements for many shapes to ensure low hinge-moments. The trade between rudder size and rudder deflection was also considered from the standpoint of control effectiveness, control hinge-moment, and trim drag.

Roll control was also a required subject for study since it was recognized that roll would adversely complicate the guidance system and that resonant coupling oscillations might build up. Roll was expected from possible manufacturing inaccuracies and from the oblique flows developed during maneuvering flight. Wing ailerons and differential rudder deflections were investigated with differential rudders being selected since adequate roll control was produced by the rudders and a separate actuator requirement was avoided.

Aerodynamic interference flow fields were also investigated. The disparity between the zero- and 45-degree roll planes was studied and the effects of panel-to-panel flow as well as wing-to-tail flows were investigated. Overall considerations of these effects led to the inline arrangement of the wing and tail as opposed to an interdigitated arrangement.

The effect of the jet stream on the afterbody drag was determined and the effect of the jet plume on the aerodynamic damping was tested, using a model with a compressed air jet. These data were used to optimize the body boattail shape in view of the increased drag at subsonic speeds and the decreased drag at supersonic speeds. The damping tests also revealed that the aerodynamic damping factors at supersonic speeds might be increased by as much as 30 percent due to the jet effect.

One other area of interest in the development of Wasserfall was the use of surface pressure distribution tests and heat transfer tests from work done as early as 1941. This effort was necessary, because of the extreme flight conditions, to insure structural integrity, and to determine the extent of heat effects on the forebody material which housed a warhead, the target tracking equipment, and an optical fuse.

Thus, the Wasserfall (fig. 11) represents the comprehensive manner in which the German scientists at Peenemunde understood the problems and were able to develop a maneuvering, supersonic, surface-to-air, guided missile system over 3 decades ago. The Wasserfall was never placed in operation, 44 experimental flights were made, the majority of which were successful. As the war ended, the vehicle could be maneuvered from the ground with a control stick, and a fully automatic hookup to an analog computer which developed steering signals from a target-tracking and missile-tracking radar was partially completed. An optical proximity fuse had also been developed which was designed to explode the Wasserfall's warhead at the point closest to the target to assure that even a near-miss would be lethal. Although the Wasserfall did not reach service operation, a few less sophisticated German missiles did, and guided missile warfare probably had its beginning in August 1943 with the use of German radio-controlled, rocket-powered, glide bombs against ships.

It was this kind of expertise that existed at Peenemunde when, on August 17, 1943, the installation was bombed by nearly 600 Royal Air Force bombers, and Hitler ordered the whole rocket production underground. Although this caused delays, particularly in the advanced projects, the production of the V-2 resulted in the start of its devastating operation in September 1944. In March 1945, when Russian forces were within 100 miles of Peenemunde, many of the top scientists there, including von Braun, chose to fall into American hands and moved to Bavaria to await capture. Many others who remained at Peenemunde were subsequently captured by the Russians when the Second White Army occupied Peenemunde on May 6, 1945. Under Colonel Holger Toftoy's direction of the U.S. Operation Paperclip, von Braun and 120 other top German scientists were hand-picked through interviews and brought to the U.S. between late 1945 and the summer of 1946 and stationed at Fort Bliss, Texas. There they were to resume flight tests at the White Sands Proving Grounds in New Mexico, using V-2 rockets evacuated by Colonel Toftoy from the underground Harz Mountain production plant before that area was turned over to the Russians under terms of the Yalta agreement. The timing was close. Thus it was that the U.S. began to gain experience with missiles. During a five-year program, 68 German V-2's were fired at White Sands of which only about half were successful. (The Germans achieved about a 75-percent reliability during combat with the V-2.) On February 24, 1949, a two-stage Bumper-Wac (a U.S. corporal second-stage rocket on a first-stage German V-2) was launched to an unprecedented altitude of about 250 miles. The development of U.S. ballistic missiles was beginning to take shape.

U.S. Activities.- A digression at this point is necessary in order to look at other activities in the U.S. during the turn of the decade from the 1940's to the 1950's as the missile involvement spread through the military services and the industry. In addition to Army Ordnance, other branches of the military involved in missile projects were the Air Force, the Navy Bureau of Ordnance, and the Navy Bureau of Air. In October 1945, the U.S. Army Air Force invited selected aircraft companies to submit proposals for participation in a guided missile development program. The contractors were free to propose winged airbreathing cruise missiles, or ballistic missiles, with ranges from 20 miles to 6000 miles. One of the successful bidders was Convair, whose proposal, the MX-774, was purely experimental (no payload), and appeared to be a scaled-down V-2. Some innovations, however, included use of the outer shell as the wall of the fuel tank (thus saving weight), and the use of four separate gimbal-mounted motors to provide thrust and control (thus eliminating tail fins). Three MX-774's were launched at White Sands in July, September, and December 1948. All were successfully launched, but each experienced premature power cutoff due to a vibration-induced valve failure. Nevertheless, important lessons were learned and subsequently Convair was selected by the Air Force in 1951 to begin the development of what was to become the free-world's first ICBM, the Atlas.

Development also began in 1945 for the winged, airbreathing, Northrop SM-62 Snark, which had intercontinental range of 5000-6000 miles at high subsonic speeds and used celestial guidance. Snark had many problems, so much so that the Atlantic Ocean just off Cape Canaveral was often referred to as the "Snark infested waters." Snark finally went into limited production as an unmanned supplement to the SAC B-52 fleet in 1958 but was withdrawn in 1960. A more advanced project, the North American XSM-64 Navaho, was begun by the Air Force in 1947. The Navaho concept was a rocket-boosted, ramjet-sustained missile that was ultimately intended to cruise at a Mach number of three and have a maximum range of 5000 miles. The radio-controlled recoverable test version, X-10, made several successful flights beginning in 1953. The rocket-ramjet version of the SM-64 made 11 flights between 1956-58, successfully demonstrating the rocket-boost, ramjet operation, cruise at Mach 3, a range of 2000 miles, and many technology advances in aerodynamics, propulsion, guidance,

structures, materials, and large liquid rocket motors. With these successes to its credit, the Navaho was abruptly cancelled in 1947, apparently in favor of the coming of the ICBM's. The first tactical surface-to-surface guided missile, the Martin TM-61A Matador, was also begun by the Air Force in 1945. The Matador was subsonic and had a range of about 700 miles. The Matador was deployed in 1954, but phased out in 1959 in favor of the Martin CGM-13 Mace which used a guidance system that permitted low level flight by means of radar terrain map matching. The Mace, in turn, was phased out by 1970.

A fundamental problem with the advent of guided missile technology in the U.S. appeared to be the proliferation of systems within the services and throughout the industry and academic fields with almost everyone having a missile study or contract of some type. There was no national program or plan. By 1948, the Air Force had nine basic guided missile programs with the aircraft industry. By 1952, the U.S. had about 25 active missile projects divided among more than 17 major airframe plants, 5 engine plants, 9 component plants, about 11 laboratories not normally associated with aircraft production, as well as numerous service labs and installations. By contrast, the German organization had been Peenemunde. While backed up by numerous plants and institutes furnishing parts or knowledge as the need arose, the central brain-power with a definable set of national objectives was concentrated at Peenemunde.

The U.S. Army took steps to unify their missile activity in 1950 by moving the German Paperclip group (augmented by about 400 Americans) from Fort Bliss to the Redstone Arsenal in Huntsville, Alabama, which Major General Loftoy perceived as becoming the future home of Army guided missiles. Soon the Army Ordnance Missile Command under Major General John Bruce Medaris would come into being. Headquartered in Huntsville, the Command included the Redstone Arsenal, Army Ballistic Missile Agency (ABMA), Army Rocket and Guided Missile Agency (ARGMA), White Sands Proving Ground, and the Jet Propulsion Laboratory (JPL).

The Air Force began managing missile programs in the early 1950's, through organizations such as the Air Research and Development Command (ARDC) under Lieutenant General Thomas S. Power, that included a deputy for Weapon Systems with an assistant for Guided Missile Systems; a Systems Management Directorate with a deputy for Missile Systems; a Western Development Division for ballistic missile development; Air Force Missile Test Center (Patrick); Air Development Center (Holloman) under which came an Aircraft Missile Test Directorate for air-to-air missiles, missile counter-measures, air defense missiles (SAM's), bombardment missiles (SSM's and ASM's), and drones (RPV's); Air Force Flight Test Center (Edwards) for rocket engine testing; Air Force Armament Center (Eglin) primarily involved, at that time, in guns and ammunition, rockets, bombs, and biological and chemical warfare. The Wright Air Development Center (Wright-Patterson) also became a contributor to missile technology primarily through the Weapons Guidance Laboratory.

Navy work in missile development began about 1941 when an Office of Scientific Research and Development sponsored group under Dr. Hugh Dryden, began work at the National Bureau of Standards on a series of glide-missiles which included the television-guided Robin and the semiactive-radar-guided Pelican. In 1945, the program culminated in the active-radar-guided Bat which was probably the first automatic homing guided missile to be used in combat by any nation. Following World War II, the NBS group, under Navy sponsorship continued missile development work with the Kingfisher missiles, Puffin and Grebe, and the torpedo-carrying Petrel. In 1951, with two types of surface-to-subsurface and air-to-subsurface missiles in production, and ship-to-shore missiles in advanced development, the Navy began some consolidation of its missile activities. The NBS Missile Development Division and several other

related groups were transferred from Washington to Corona, California in 1951. In 1953, the Corona laboratory was transferred to the Bureau of Ordnance and became the U.S. Naval Ordnance Laboratory--Corona (NOL--White Oak was already in existence), and in 1959 became an activity of the Bureau of Naval Weapons. The NOL--White Oak group was closely associated with the Applied Physics Laboratory, Johns Hopkins University, and was already engaged in many missile related programs. Concurrently, the Navy under USRD was sponsoring aircraft rocket development work at the California Institute of Technology. In 1943, that activity was moved to the Mojave Desert near Inyokern, California (China Lake) and the Naval Ordnance Test Station (NOTS) was established primarily for the purpose of testing aircraft rockets, thousands of which were used in the closing days of the war. In 1945, the China Lake installation was absorbed by the Bureau of Ordnance. In 1967, NOL--Corona was merged with NOTS--China Lake and the organization became known as the Naval Weapons Center, a permanent installation of the Naval Materiel Command. In the early 1970's NWC--Corona was closed and merged at NWC--China Lake.

It is recognized that other organizations were involved and are currently involved in missiles that will not be specifically mentioned. However, it is hoped that the broad coverage of the various service activities will serve to indicate both the intensity and the complexity of birth and growth of missile developments in the U.S. In an attempt to bring order out of chaos, the U.S. created the Office of Guided Missiles under K. T. Keller, Chrysler Motors Board Chairman, in the early 1950's. Almost immediately, Keller's office ordered three missiles into production:

- o Terrier, for Navy air defense. This was an outgrowth of the APL Bumblebee program of BuJrd and went into production at Convair--Pomona and slated for early deployment on the converted guided-missile cruisers Boston and Canberra. Terrier is still in the inventory as the RIM-2. Terrier was followed by Talos and Tartar--the triple T.
- o Sparrow, for air combat. This missile was developed by Sperry Gyroscope Corporation under BuAer sponsorship and went into production at Sperry at Bristol, Tennessee, and at Douglas Aircraft under subcontract. The Sparrow concept has been perturbed many times and is currently in the inventory as the AIM-7.
- o Nike, for anti-air defense. Sponsored by Army Ordnance, this missile was a joint development program by Bell Telephone (Western Electric) and Douglas Aircraft. The Nike was the progenitor of a family consisting of Ajax, Hercules, and Zeus--none are currently in the U.S. inventory.

After these first announcements from Keller's office, a number of further contracts were reported by 1953. These included:

- o Regulus (I, subsonic airbreather, and later the Regulus II, supersonic airbreather) Navy BuAer, Chance Vought long-range cruise missile for surface-to-surface bombardment, never operational.
- o Corporal, Army Ordnance surface-to-surface missile, based on the German V-2 technology, to be built by Firestone Tire and Rubber Company, now phased out.
- o Redstone, Army Ordnance surface-to-surface missile developed by the German Paperclip group at Redstone Arsenal, to be produced by Chrysler, phased out.

- o Rascal, USAF Bell B-63, based on the X-1 design, classified as a bombardment weapon, intended to be air-launched against surface targets (ASM) with a 100-mile range using mid-course and terminal guidance by radar from the launch aircraft. Never became operational.
- o Hermes, Army Ordnance project with General Electric Company, research missile based on German Wasserfall with prospective outcome to be medium-range guided surface-to-surface missile. Sometimes referred to as first "American-made" guided missile--the basic design having been done a decade before by the Germans at Peenemunde. Never operational.
- o Loki, Army Ordnance anti-air defense, barrage-type unguided fin-body rocket based on German flak rocket Taifun, produced by Bendix, phased out.
- o Lark, BuAer/Fairchild, anti-air defense (SAM) with a semiactive guidance system that was considered by many to be ahead of its time. The Lark was subsonic and was relegated to training purposes.
- o USAF pilotless bombers Matador and Snark, previously mentioned, were already in production during the Keller regime.
- o Bomarc, USAF pilotless interceptor by Boeing, originally designated F-99, later the IM-99, and then CIM-10 Bomarc was a boosted, ramjet sustained cruise interceptor missile with a range of about 260 miles at nearly three times the speed of sound. Phased out in 1972.
- o Falcon, USAF/Hughes project originally designated F-98 developed to be the pilotless armament system integral to the Convair F-102 interceptor. The Falcon was iterated through the GAR series and eventually became the current AIM-4.
- o Sidewinder, NWC/Philco heat-seeker air-to-air missile (AAM), perturbed many times, currently in the inventory as AIM-9.
- o Oriole, Navy BuAer/Martin, a 1500-pound, ramjet AAM with a 20-mile range at Mach 3 intended for long-range intercept of large aircraft but the project was cancelled.
- o Meteor, Navy BuOrd/MIT/Federal Telecommunications Lab/Bell, a 500 pound AAM using a phase-comparison fixed antenna, homing seeker guidance system. Many technology advances were accomplished but the project was cancelled.
- o Petrel, Navy BuOrd/Fairchild air-to-under-surface homing torpedo, airborne with turbojet engine to impact with water when appendages sheared off and torpedo homed on target. Relegated to training role.
- o Honest John, Army Ordnance/Douglas surface-to-surface battlefield rocket.
- o Lacrosse, Army Ordnance/Cornell/Martin surface-to-surface close-support, guided tactical missile. Lacrosse and Honest John subsequently to be replaced by Vought Lance.
- o Rigel, Navy BuAer/Grumman surface-to-surface, long-range missile with integral ramjet propulsion. Project relatively short-lived and was cancelled.

- o Firebird/Ryan, a missile that never went into production but one that should be mentioned since the first postwar work on air-to-air missiles for air armament was typified by the 10-foot long, 6-inch diameter Firebird that was a forerunner of missiles to come.

Needless to say, countless other missile systems have been pursued, many of which were outgrowths of the preceding list of missile programs, and others have been continual attempts to fill apparent gaps in the missile inventory. Examples of such systems are Hawk and Redeye to provide field army air defense, Hound Dog to provide an air-launched, long-range, stand-off ASM capability as an extension to strategic bomber capability, and Skybolt to provide an air-launched ballistic missile system.

U.S.S.R. Activities.- For the historical record, it is necessary to return to Peenemunde at the time of the arrival of the Red Army in 1945. The Russians were not without experience in rocketry, having the background knowledge of men like Tsiolokvsky working with liquid-propellant rocket principles beginning in 1903. Others contributing to rocketry applications included Tsander and Kondratyuk. The Leningrad Dynamic Laboratory was formed in 1928 and built a series of monopropellant and bipropellant liquid rockets in the early thirties--more than 118 motors being tested between 1937 and 1944. Some of these motors were used by the Group for the Study of Reaction Propulsion, Moscow, which became known for developing airframes and missiles. The Russians also developed a family of solid-propellant, short-range, tactical weapons and made massive use of them in World War II. Among the more renowned for their devastating effect was the Katyusha (Stalin's organ pipes) and the KgAT antitank missile. Thus when the Russian Second White Army occupied Peenemunde on May 6, 1945, the Soviets were quick to recognize, and take advantage of, the German scientific expertise and began their own version of the Paperclip operation. Along with the rocket center and production plants, the Soviets acquired hardware and other technical information on many vehicles--the V-1, V-2, Rheinbote (solid-fuel, long-range, SSM), R-4/M (an air-to-air missile), Rheintochter, Wasserfall, and others. Although von Braun and the team of 120 top German scientists were in American hands, the Soviets acquired large numbers of lower level technicians and scientists. They did get Helmut Groettrup, an electronics expert, who was undoubtedly a valuable asset. More than 6000 Germans were moved to the Soviet Union and put to work on various missile projects. The Soviets also took several hundred V-2's for further evaluation and many were launched for training purposes, for upper atmosphere research, and propulsion and guidance studies. A reengineered V-2 known as the M-101, equipped with a Russian rocket motor, had a range of about 400 miles (double that of the V-2) and was placed in production. This work was soon to lead the Soviets to a position of world leadership in large ICBM's (first launched in August 1957) and to the development of a powerful booster that succeeded in placing the world's first satellite, Sputnik, in orbit in October 1957. The German scientists were used by the Soviets to assist Russian teams in many varied projects. Typically, as these projects neared fruition, they would be cancelled and the Germans transferred to other work areas. The projects would then be completed by the Russian team and the Germans would have little knowledge of the capability or purpose of the final product. The Germans were essentially isolated from the Russians as far as the practical aspects of the projects were concerned and when their talent had been exploited they were allowed to return home--most of them being returned by 1953.

With the preponderance of German guidance experts in Russia, the Soviets were apparently quick to put them to work on the development of surface-to-surface missiles from the tactical battlefield type to intercontinental strategic types. In addition to the rapid development of ballistic missiles fostered by the aid of the Germans, several other missile development trends occurred in the Soviet Union.

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For air defense, the change from antiaircraft artillery (AAA) began with the development of unguided rockets by several countries. The British produced over 5 million such weapons before the end of World War II for defense against the Germans. When the tide of the air war began to change, the Germans began a concerted effort to improve air defense systems by developing the solid-fuel June Bug and later the liquid-fuel Taifun missile which was used in World War II. Then came the Schmetterling, Rheintochter, Wasserfall, Enzian, Hecht, and Fuerlilie. Some of this knowledge almost certainly was fed into the early development of Soviet SAM's. The Soviet obsession with homeland defense and the relatively early date of deployment of the SA-1 and later the SA-2 would tend to indicate that German technology was quickly applied. The Soviets first demonstrated the value of guided air defense missiles when a single SA-2 was used to down the U.S. U-2 in 1960. From these early beginnings, the Soviets have now developed a very impressive array of SAM's (fig. 12). These systems provide for air defense over a very broad spectrum ranging from the man-portable close-in SA-7 to the high-altitude, high-speed (M = 6) SA-5. Some systems are mobile while others are emplaced. Propulsion includes solid and liquid propellant; pure rocket; airbreathers; ramjets; dual-cycle rocket ramjets. Various types of aerodynamic configuration and control systems are used depending upon the mission and environment. Old systems are retained and modified while new systems are periodically introduced.

Air-to-air combat missiles also began with several countries developing unguided rockets such as the U.S. Mighty Mouse and Zuni. The Germans were developing guided AAM's by the end of World War II and again it is reasonable to assume that much of this technology was picked up by the Soviets and resulted in the deployment of the AA-1 in the early 1950's. The AA-1 has all-weather capability, was first deployed on the MIG-17, is still in service on several airplane types in several countries. Soviet AAM's are shown in figure 13 and again present an impressive array. It is evident that the AA-2 is a development based on the U.S. Sidewinder. The rest of the AAM family displays a wide variety of configuration types and weapon sizes and are obviously intended to cover a broad spectrum of missions. Almost all of the Soviet AAM's are produced with a radar-guided version and a heat-seeker version to provide all-weather capability and versatility of operation. The only missile not retained in this inventory was the AA-4 wing-control missile that was shown in 1961 on the Flipper airplane. Neither the Flipper nor the AA-4 entered the inventory.

An interesting development in the U.S.S.R. was related to the air-to-surface guided missiles. The Soviets were intrigued with the V-1 project and produced several hundred (known as J-1) after World War II. This was followed by a J-2 which had a turbojet engine probably developed from the British RD-45F which powered the MIG-15 (about 5000-pounds thrust). A J-3 was postulated which was thought to be a submarine-based missile. The Soviets also acquired the Henschel HS-293 and 294 experimental ASM's from Peenemunde together with the guidance experts who developed them. It seems likely that this intense interest was a clear indication of the desire to develop cruise missiles--both surface-launched and air-launched--and a recognition on the part of the Soviets of the value of stand-off cruise missiles. Having acquired the German technology by 1946, and having repatriated most of the Germans by 1953, it appears that the Soviets had their active cruise missile programs well underway by the early 1950's. This evidence is further supported by the 1961 Tushino airshow when the AS-1 Kennel, AS-2 Kipper, AS-3 Kangaroo, and AS-4 Kitchen were all shown. These ASM's are airplane size and vary from subsonic, jet powered, to supersonic, rocket powered with a range spectrum that varies from about 60 miles to about 400 miles. These large ASM's have been followed by the AS-5 Kelt and AS-6 Kingfish. More recently, the Soviets have turned their attention to smaller ASM's for fighter strike-type mission with systems such as AS-7 Kerry (on Fitter airplanes) and other types believed to include antiradiation missiles (ARM), and electro-optical

guided ASM's. In the surface-launched cruise missile family, the Soviets produced early versions of the AS-1 for tactical use, the SSC-2a Salish, and for coastal defense, the SSC-2b Samlet. The AS-1 and its derivative, the SSC-2, can almost certainly be traced to the German Peenemunde group in Russia. For ship-launched cruise missiles, the Soviets produced the SS-N-1 Scrubber for destroyers about 1960, and later the SS-N-2 Styx for patrol boats, and the SS-N-3 Shaddock for cruisers and submarines. The SS-N-3 was derived from the SSC-1 Shaddock that appeared in the early 1960's both as an Army tactical missile and a coastal defense missile. The frequent use of a basic missile design for serving different service roles is a common Soviet practice. When a specialized point-design system is required, then it will be provided. Wherever multiple roles can be achieved without compromise, then a basic common system will be used. The philosophy is sound with regard to providing broad coverage of both offensive and defensive missile systems and economical in the sense that different systems are not built to perform identical missions.

The Soviet missile inventory also includes a series of anti-tank missiles (AT-1, 2, 3, and 6), short-range tactical army missiles (Frog 1 to 7), medium-range tactical army missiles (Scud A, B, C, and Scaleboard), and strategic missiles (SLBM, IRBM, ICBM) numbering about 14 in service and at least another half-dozen in development.

The Soviet inventory of missiles is indeed impressive from the standpoint of the variety of operational types available. The inventory is also impressive from the standpoint of quantity of missiles, notwithstanding the qualitative value. When considered with the sum total of all-Soviet military power, it should cause one to recall the military status of Germany in the mid-1930's when it was observed by Rickenbacker and others that German air power was geared to the point of being able to sustain the demands of any war effort beginning the day that war was declared.

CONCLUDING OBSERVATIONS

The development of rockets and missiles has played a key part in the history of mankind. From the days of David, to the ventures of war, and travel to outer space, it might be said that the "impact" of the missile has been felt on society, on history, on economics, on politics, and on the lives of people. There is reason to believe that missilery will continue to play a part in the history of mankind for some time to come.

Some world missile systems are listed in the following summation. Some omissions and uncertainties are quite likely due to incomplete sources of information. However, some reasonably accurate statistical observations can be made. Currently, there are approximately 180 missile systems worldwide. Of this number, about 30 percent each can be attributed to the U.S. and the U.S.S.R., about 12 percent each to France and the U.K., and the remaining 16 percent being distributed primarily between W. German, Sweden, Italy, Japan, Israel, China, and Norway. Of these identifiable systems, about 35 percent are surface-to-surface (ballistic and cruise), and about 20 percent each are air-to-surface and surface-to-air, about 13 percent are air-to-air, and about 13 percent are anti-tank. Thus, the bulk of the systems are to be found in the U.S. and U.S.S.R., and the predominant mission is surface-to-surface.

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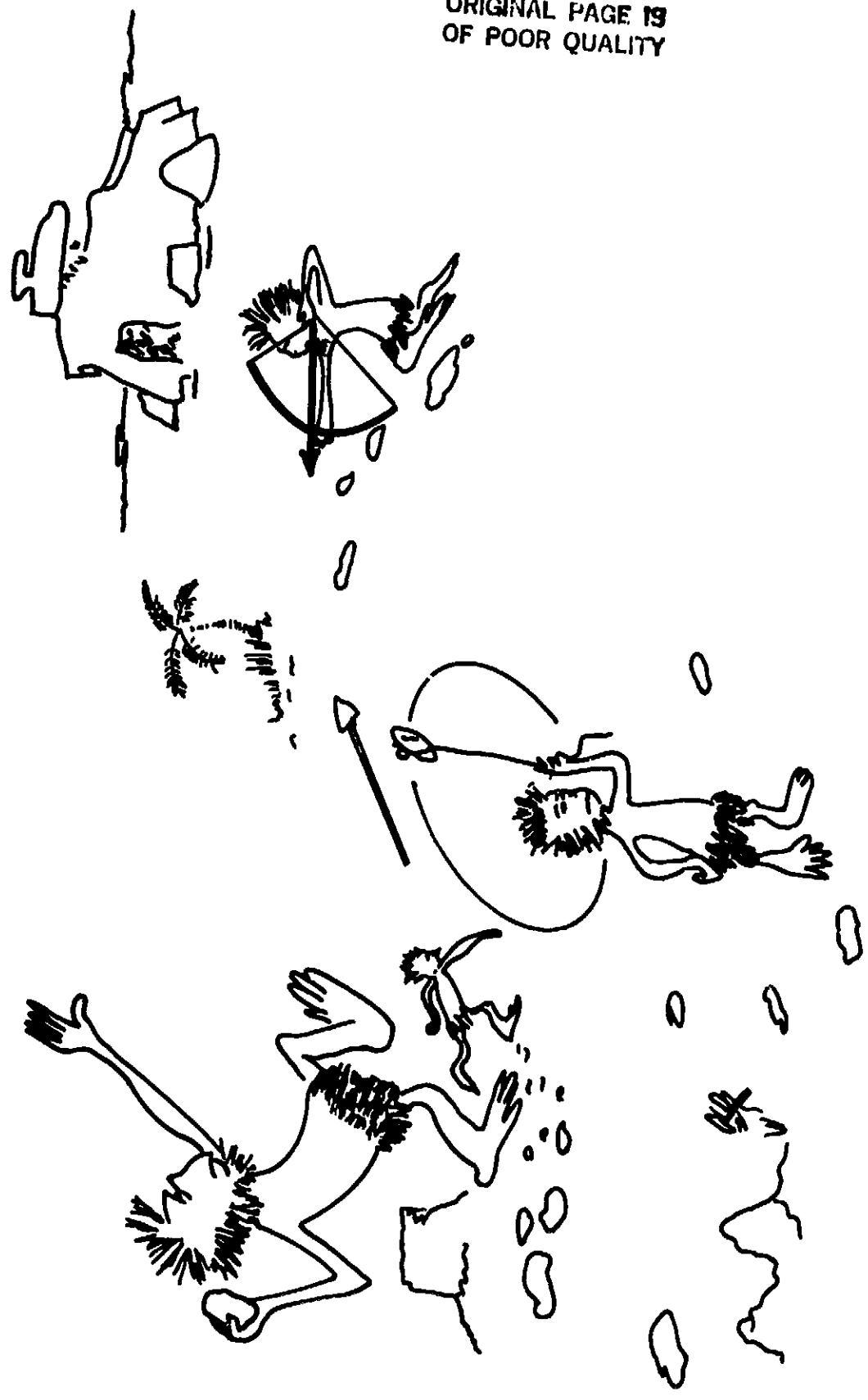


Figure 1.- Early ballistic missiles.

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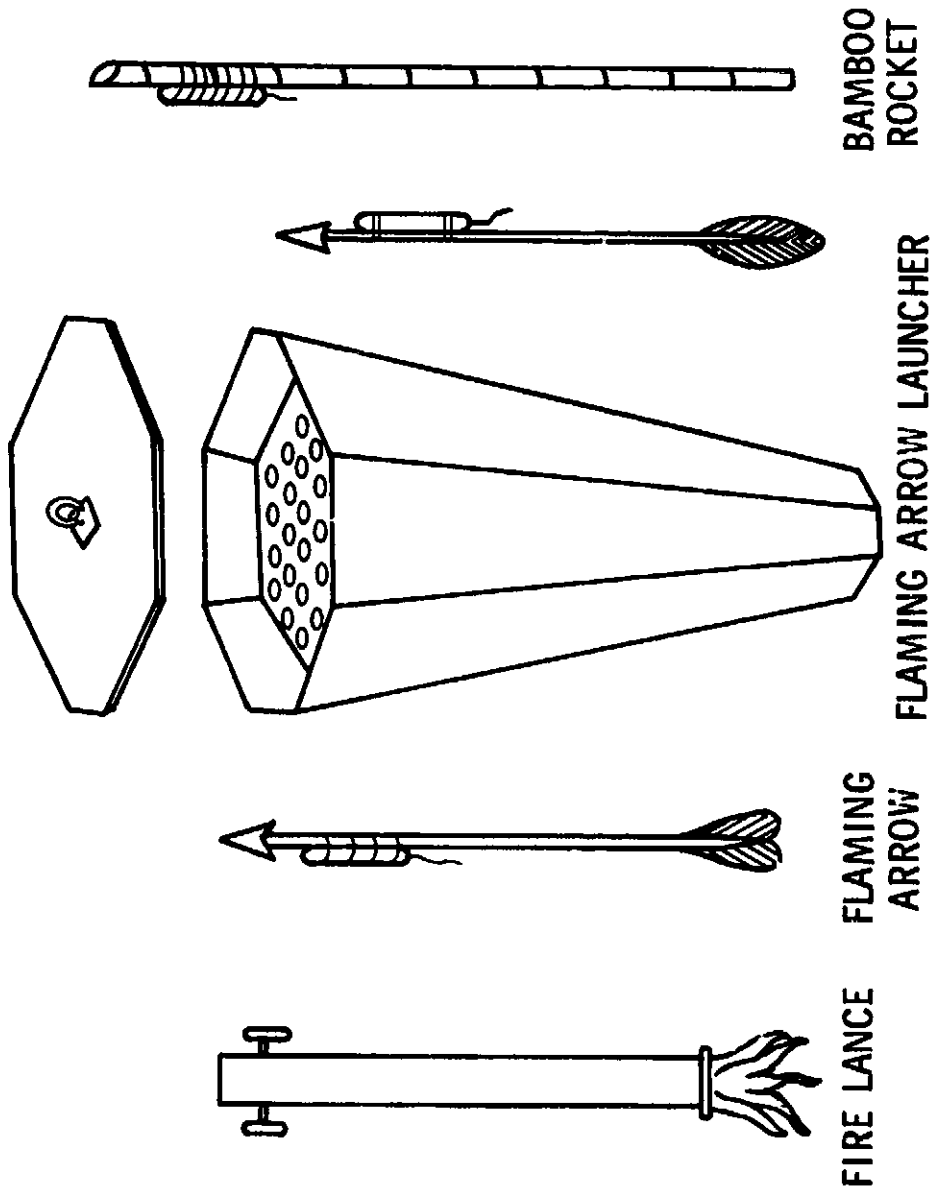


Figure 2.- Early rockets.

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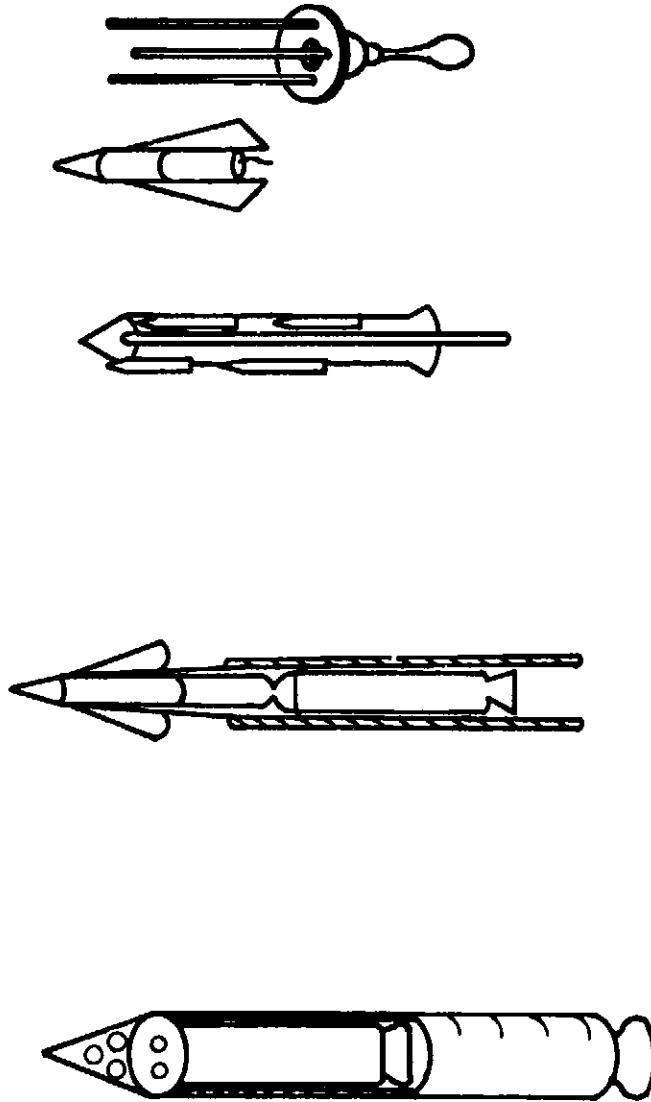


Figure 3.- Multistage rockets.

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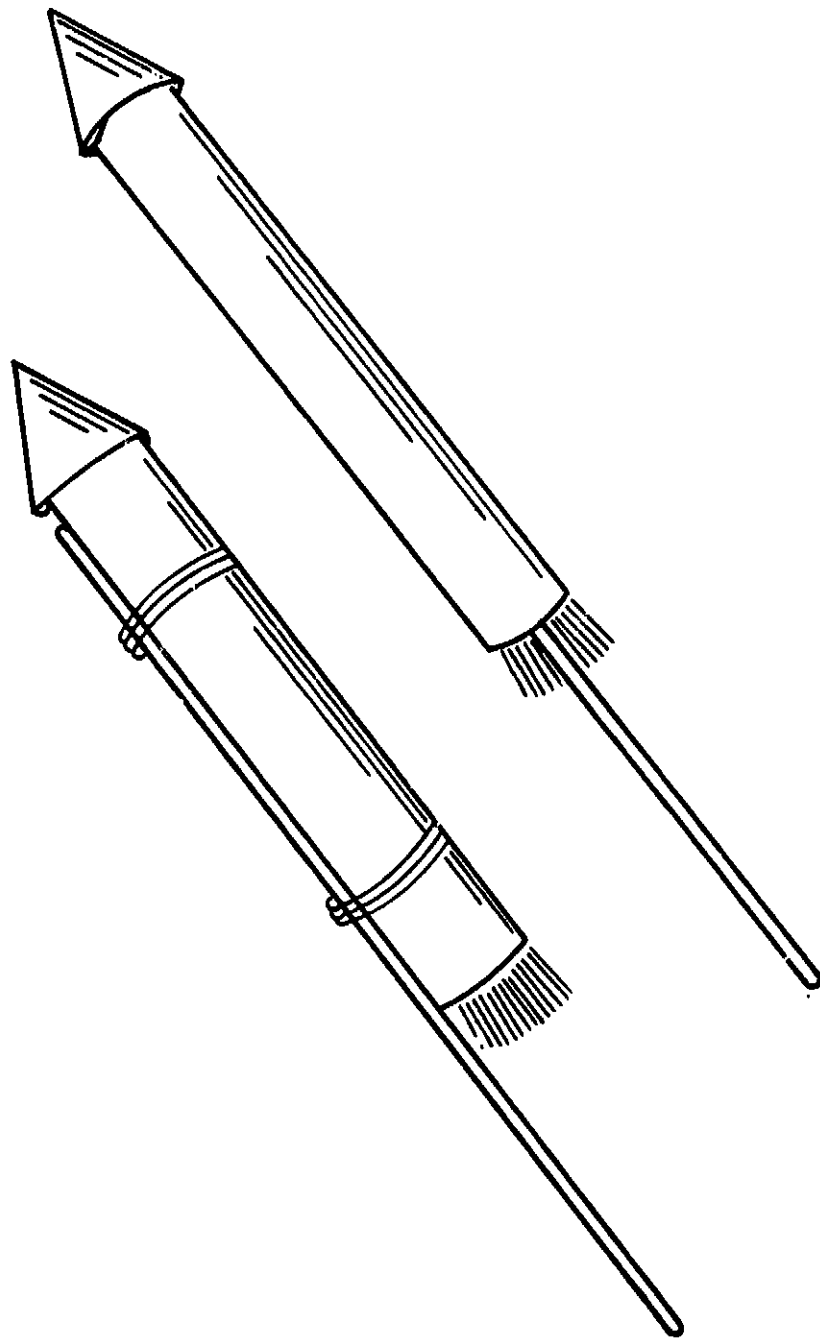


Figure 4.- Congreve stick rocket.

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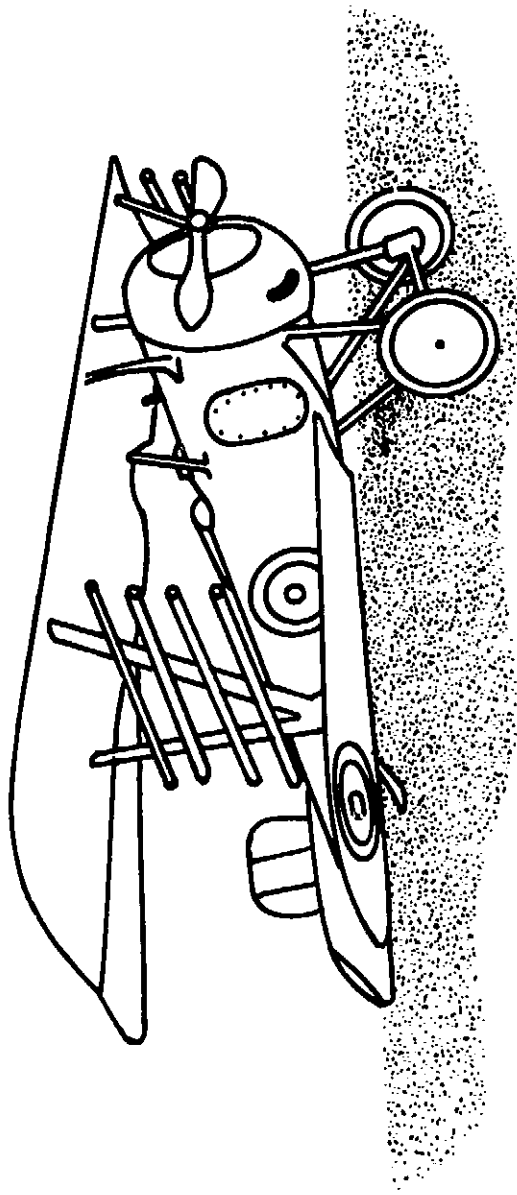


Figure 5.- Nieuport fighter with rocket tubes.

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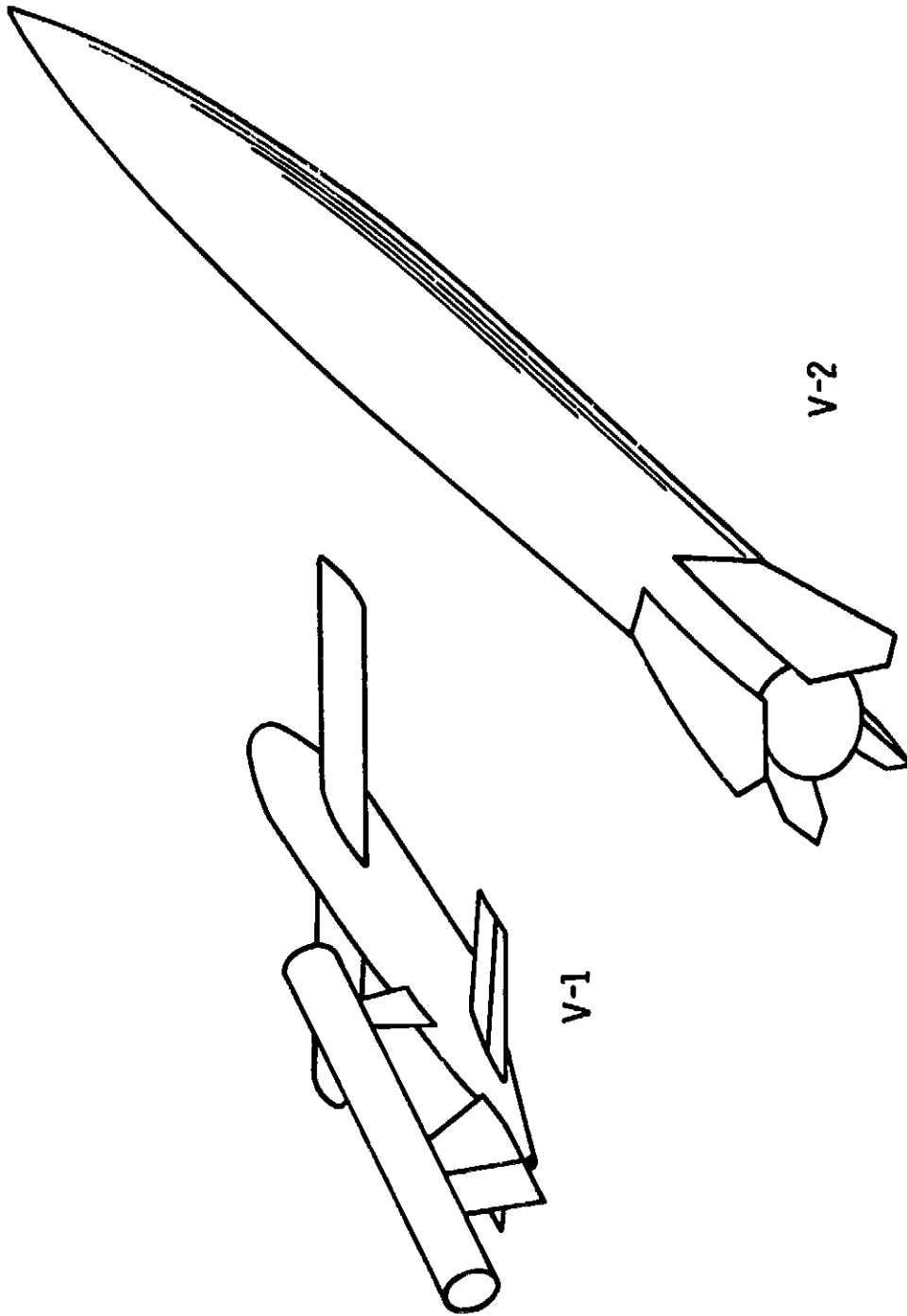


Figure 6.- Vengeance weapons.

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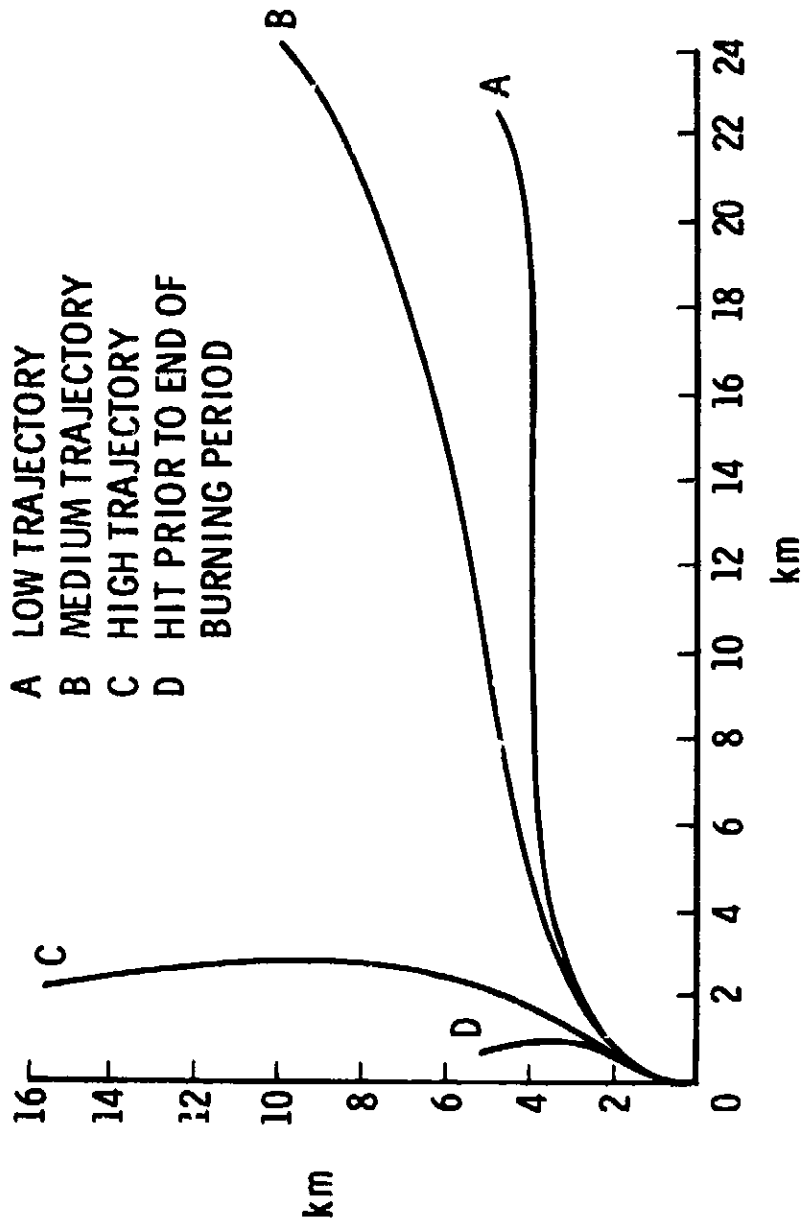
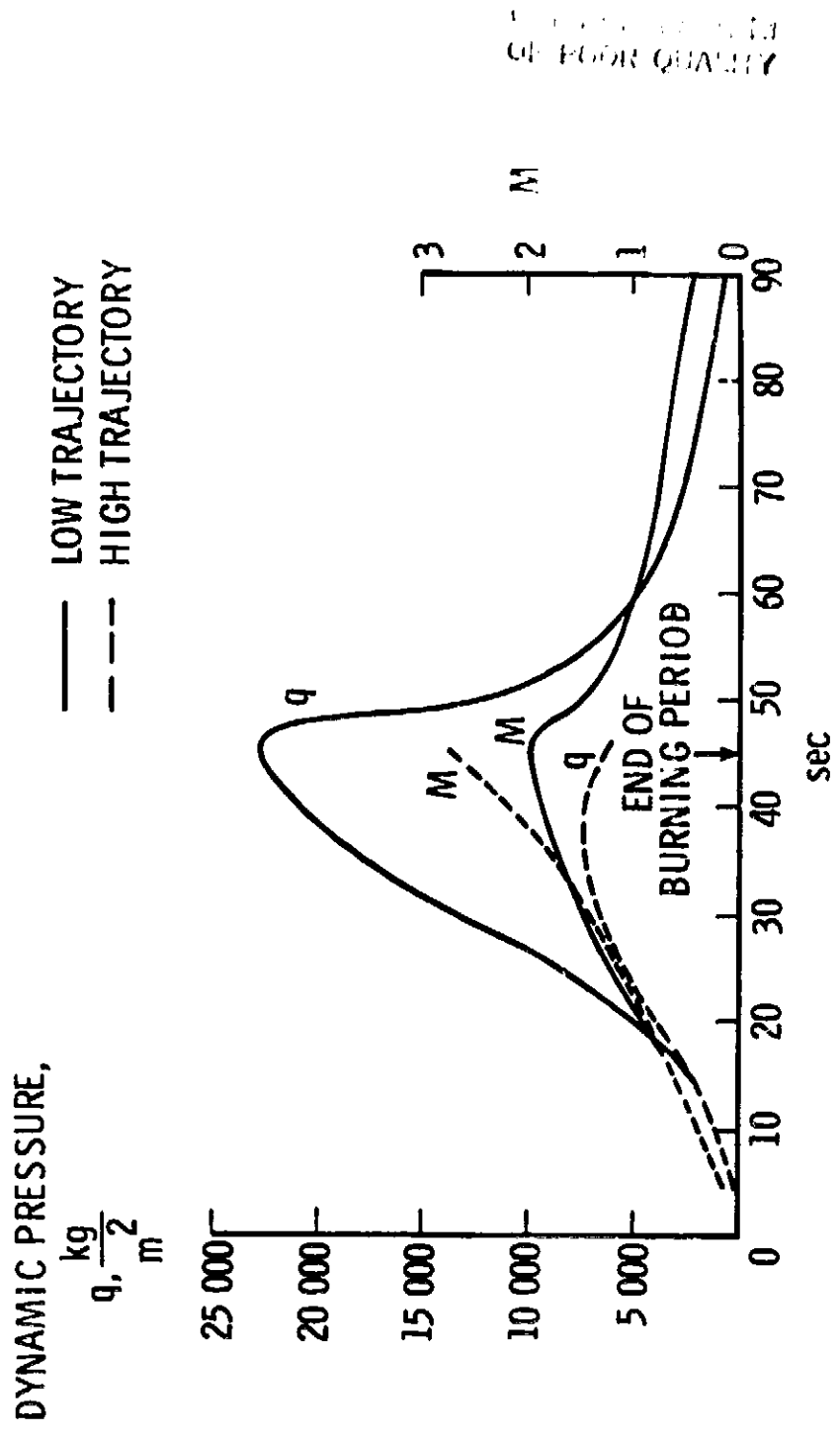


Figure 7.- Trajectories for air defense missile.



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Figure 8.- Flight conditions for air defense missile.

- MANEUVERABILITY TO EXCEED TARGET BY FACTOR OF 2 TO 6
- LOW INDUCED DRAG
- CONSTANT CENTER OF PRESSURE LOCATION
- RAPID RESPONSE
- LOW HINGE-MOMENTS
- POSITIVE STABILITY
- FREEDOM FROM ROLL
- STRUCTURAL LOADS
- SKIN TEMPERATURE
- JET PLUME EFFECTS
- PROXIMITY FUSE

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Figure 9.- Characteristics considered for air defense missile.

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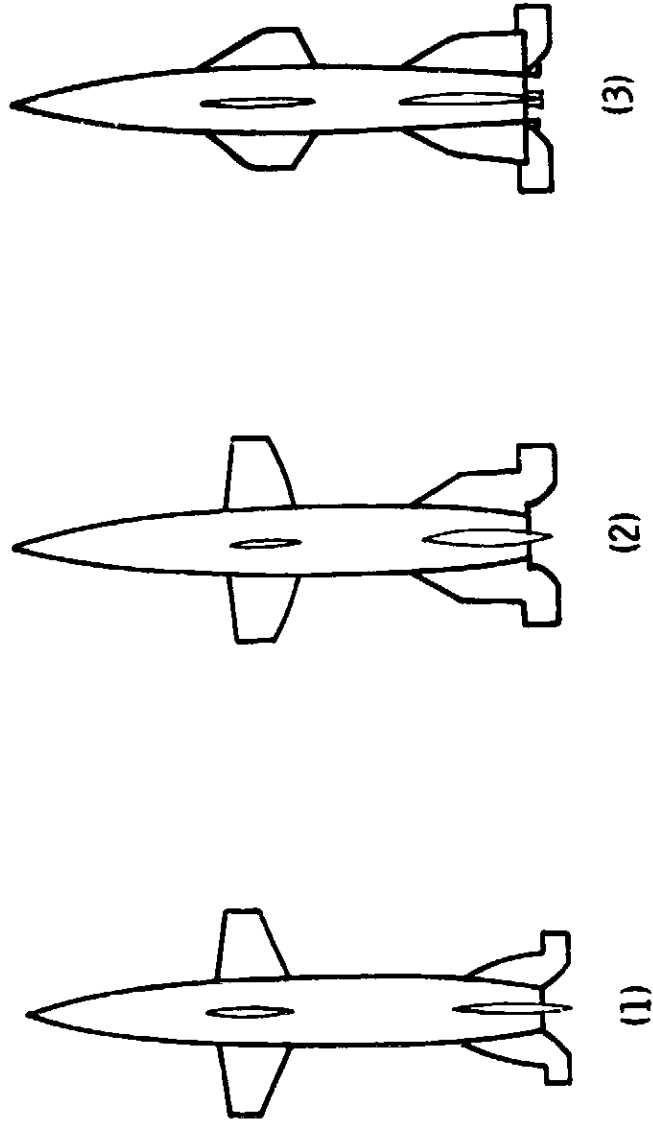


Figure 10.- Wasserfall configuration variations.

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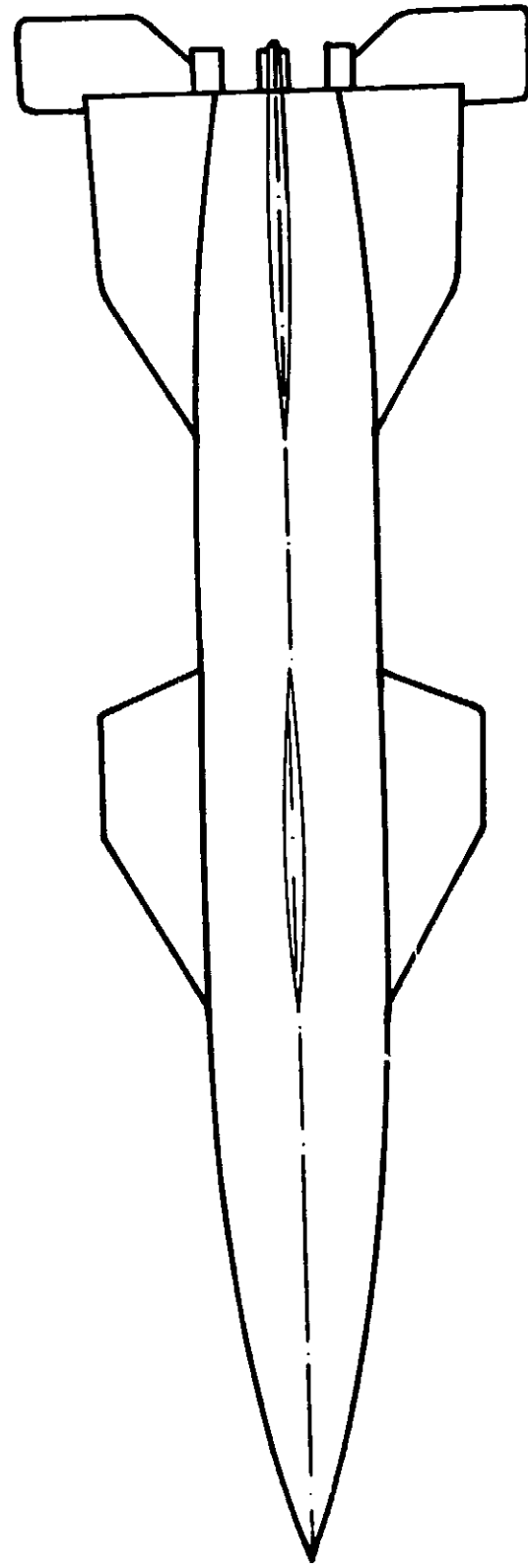


Figure 11.- Wasserfall configuration.

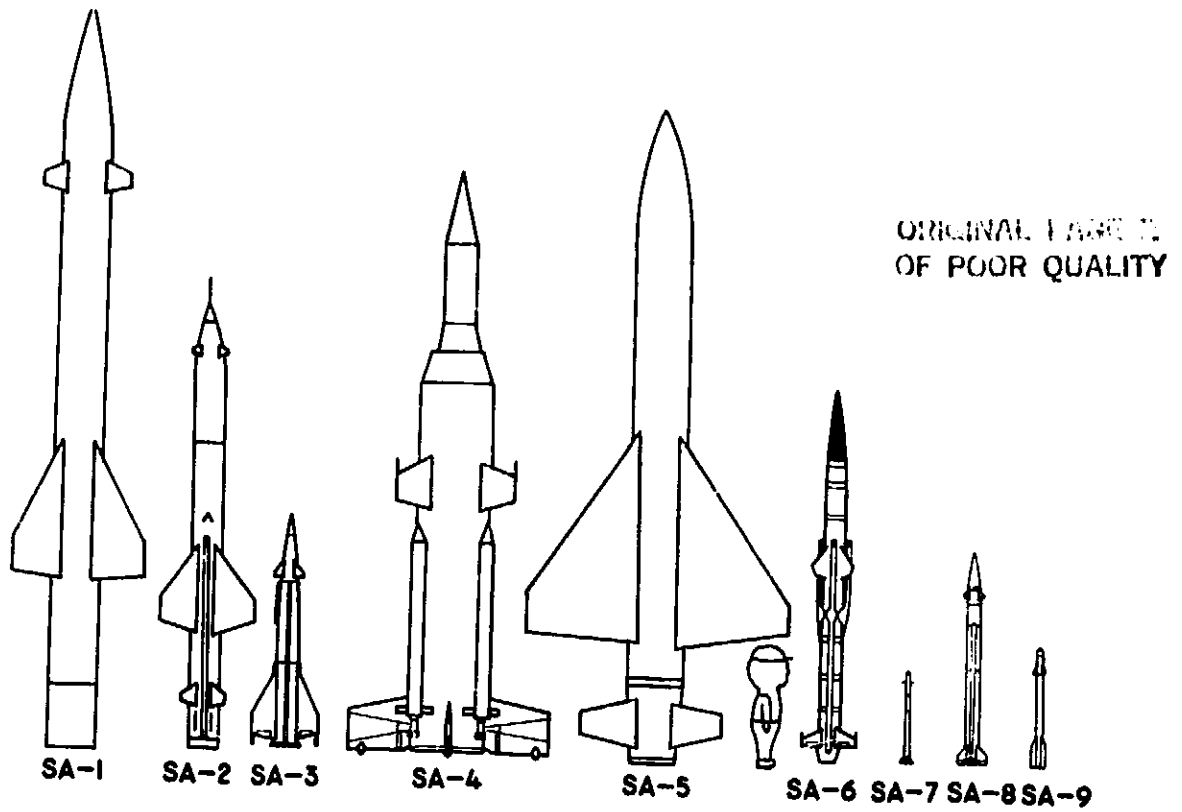


Figure 12.- Soviet surface-to-air missiles.

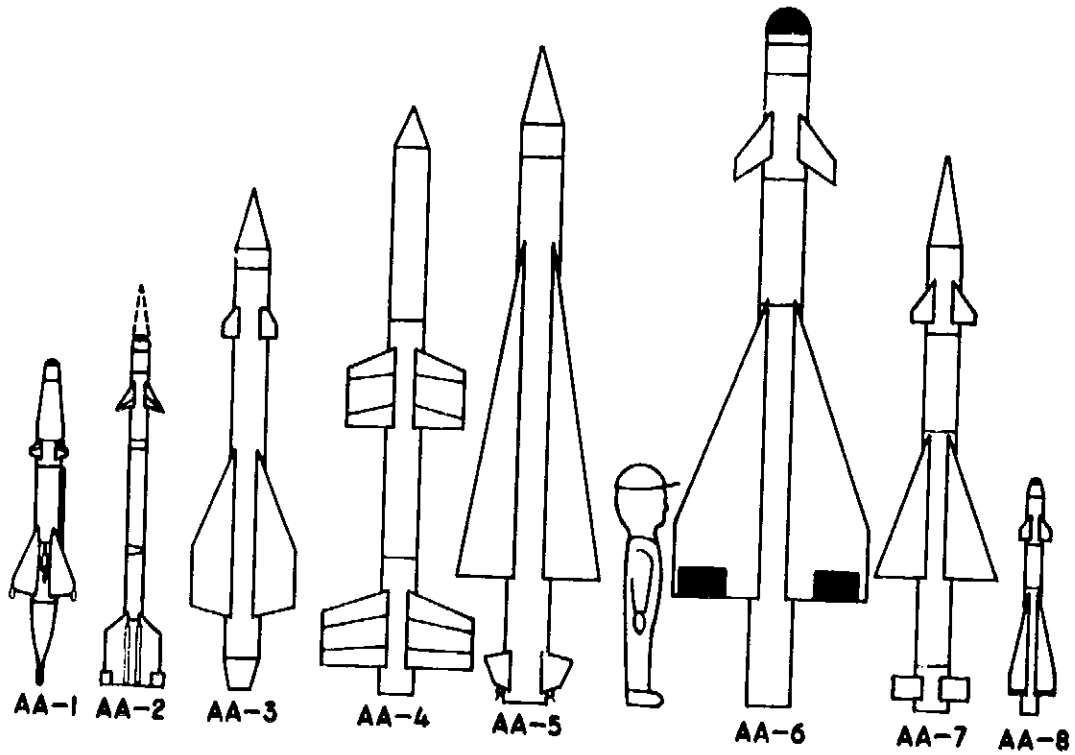


Figure 13.- Soviet air-to-air missiles.

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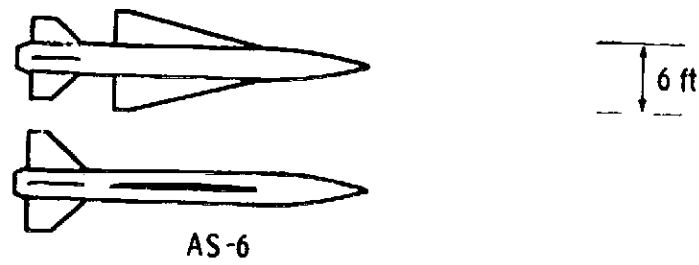
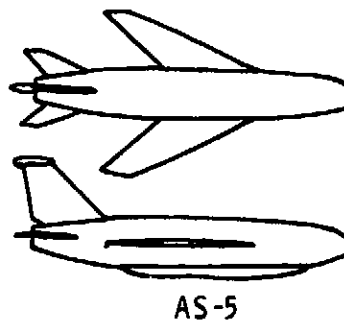
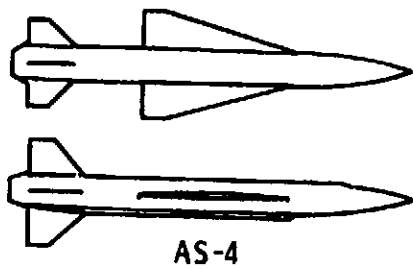
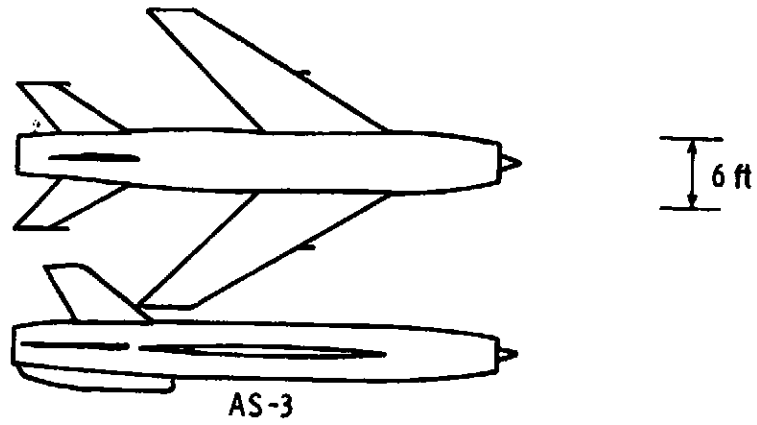
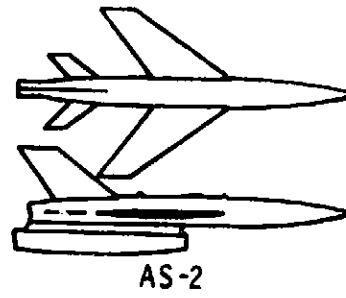
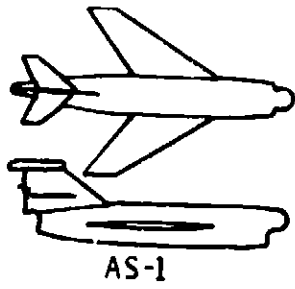


Figure 14.- Soviet air-to-surface missiles.

SUMMATION OF SOME WORLD MISSILE SYSTEMS

MISSILE	COUNTRY										MISSION					
	FRANCE	W. GERMANY	ISRAEL	ITALY	JAPAN	NORWAY	SWEDEN	UK	USA	USSR	AAM	AJM	SAM	SSM	SSM/Anti-Tank	ASM/Anti-Tank
ACRID ALCM AMRAAM ANAB APEX									X	X	X	X				
APHID AS. 11/SS. 11 AS. 12/SS. 12 AS. 15/AS. 15TT AS. 30/AS. 30AL	X X X X									X	X			X		
ASALM ASH ASM-1/XSSM ASPIDE ASROC				X	X				X	X	X	X		X		
ATOLL BANTAM BLOODHOUND BLOWPIPE BRAZO							X			X	X			X	X	X
BULLPUP CHAPARRAL/IMP. CHAPARRAL COBRA CROTALE CROTALE-NAVAL	X X	X							X	X		X		X		
DRAGON EXOCET (AIR) EXOCET (SHIP) FALCON FROG-3	X X								X			X			X	
FROG-4 FROG-5 FROG-7 GABRIEL GAINFUL										X X X				X X X		
GALOSH GAMMON GANEF GECKO										X X X X				X X X X		

Summation (Continued).

MISSILE	COUNTRY										MISSION					
	FRANCE	W. GERMANY	ISRAEL	ITALY	JAPAN	NORWAY	SWEDEN	UK	USA	USSR	AAM	A3M	SAM	SSM	SSM/ Anti-Tank	ASM/ Anti-Tank
GLCM GOA GRAIL GUIDELINE HARM									X	X X X		X	X X X	X		
HARPOON HARPOON HAWK, IMP. HELLFIRE HOT	X								X X X		X	X	X	X		X X
HOUND DOG IKARA INDIGO/MEI KAM-3D KAM-9				X	X X			X	X		X	X	X		X X	X
KANGAROO KELT KENNEL KINGFISH KIPPER									X X X X X		X X X X X					
KITCHEN KORMORAN LANCE MAGIC MALAFON	X X	X						X		X	X X		X X			
MAMBA MARTEL AJ168 MARTEL AS37 MASURCA MAVERICK 65A/B	X X X	X						X X			X X	X			X	
MAVERICK 65C/D MAVERICK 65E/F MILAN MINUTEMAN II MINUTEMAN III	X	X						X X			X X				X	
MOSQUITO MSBS MX	X		X						X				X X		X	

Summation (Continued).

MISSILE	COUNTRY										MISSION					
	FRANCE	W. GERMANY	ISRAEL	ITALY	JAPAN	NORWAY	SWEDEN	UK	USA	USSR	AAM	AAM	SAM	SSM	SSM Anti-Tank	ASM/Anti-Tank
NIKE HERCULES OTOMAT PATRIOT PENGUIN ASM PENGUIN SSM				X					X			X	X	X		
PERSHING IA PERSHING II PHOENIX PICKET PLUTON/HADES	X		X						X X X		X		X X X		X	
POLARIS A3 POSEIDON C3 R530 RAM RAPIER	X								X X		X		X X			
RBS15 RBS70 REDEYE REDTOP ROLAND	X	X					X X		X			X	X X	X		
SAAB 04E/T SAAB 05A SAAB 08A SABRE SAGGER							X X X	X			X X		X		X	X X
SANDAL SARK SASIN SAVAGE SAWFLY MOD. 1/2									X X X X				X X X X			
SAWFLY MOD. 3 SCALEBOARD SCAPEGOAT/SCAMP SCARP SCUD A									X X X X X				X X X X			
SCUD B/C SEACAT/TIGERCAT SEA DART/LAND DART							X X		X			X X	X			

Summation (Continued).

MISSILE	COUNTRY										MISSION					
	FRANCE	W. GERMANY	ISRAEL	ITALY	JAPAN	NORWAY	SWEDEN	UK	USA	USSR	AAM	AJM	SAM	SSM	SSM/Anti-Tank	ASM/Anti-Tank
SEA EAGLE SEA KILLER SEA SKUA SEASLUG SEA SPARROW								X X X X	X			X X X	X X			
SEAWOLF SEGO SERB SHADDOCK SHAFRIR			X					X			X X X		X	X X X		
SHILLELAGH SHRIKE SIDEWINDER B/C/D/E SIDEWINDER G/H/J SIDEWINDER L/M								X X X X X			X X X	X			X	
SIDEWINDER N/P SKEAN SKY FLASH SNAPPER SPANDREL/SPIGOT								X	X	X X	X X		X		X X	
SPARROW -7E SPARROW -7F SPARROW -7M SRAM SS-16								X X X X		X X X		X		X		
SS-17 SS-18 SS-19 SS-20 SSBS	X									X X X X				X X X X		
STANDARD ARM STANDARD ER STANDARD MR STINGER STYX								X X X X			X	X X X	X			
SUBROC SUPER 530 SWATTER SWING IRI	X							X	X	X	X		X		X X	

ORIGINAL DOCUMENTS
OF POOR QUALITY

Summation (Concluded).

MISSILE	COUNTRY										MISSION					
	FRANCE	W. GERMANY	ISRAEL	ITALY	JAPAN	NORWAY	SWEDEN	UK	USA	USSR	AAM	ACM	SAM	SSM	SSM/ Anti-Tank	ASM/ Anti-Tank
TALOS									X				X			
TAN-SAM					X				X				X			
TARTAR									X				X			
TERRIER									X				X			
THUNDERBIRD 2								X					X			
TITAN II									X				X			
TOMAHAWK MRASM									X				X			
TOMAHAWK SLCM									X				X			
TOW									X				X			
TRIDENT I/II								X					X			
VIGILANT								X					X			
ADVANCED MISSILE PROGRAMS-INTERNATIONAL	X	X	X	X	X	X	X	X								
ADVANCED MISSILE PROGRAMS-USA									X							
ADVANCED MISSILE PROGRAMS-USSR										X						