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CONTENTS

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PROCEEDINGS
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GUIDED MISSILES IN WORLD WAR II

by

Dr. Harner Selvidge*

EDITOR'S NOTES

At the conclusion of this paper by Dr. Selvidge, a captured German color movie film was shown to those present at the meeting. This film was taken at a launching site of the V-2 rocket bomb. A number of failures were shown. One particular V-2 started up slowly for a few feet and fell back, toppled over on the ground and exploded in front of the camera. The liquid oxygen created a brilliant color spectacle on the screen. Fire fighters went into action and brought the flames under control. Presumably no war head was present when this test was made; otherwise we would never have seen these excellent and awe inspiring motion pictures.

The relaxation of strict security requirements following the end of the war now makes it possible to discuss, at least in outline form, the use and some of the characteristics of guided missiles of World War II. This information has been gathered from data released by the Army and Navy both on developments in this country and the results of investigations by our technical teams, particularly in Germany, after the end of the war. It should be pointed out in the beginning that in this country a distinction is frequently made between guided missiles and pilotless aircraft; the former usually being defined as a device which depends primarily upon its thrust, or power, for the impetus to sustain it in flight and has only control surfaces, while the latter depends largely on wings or other surfaces to provide lift while in flight. Both types will be covered in this discussion.

In the last war the rocket was in widespread use for the first time, but it has an old history as an ordnance device, while the guided missile which made its first appearance in World War II is, along with the atomic bomb and the proximity fuze, a truly new weapon. While numerous guided missiles made their debut in this war, none of them had a large part in its outcome with the possible exception of the German V-1 and V-2. While the latter were weapons of considerable practical value, their use was not as decisive as it might have been, had they been put into operation several years earlier. It might be argued that these are not true guided missiles, but persons on the receiving end might be hard to convince of this fact. To the individual blown up by them, it is only of academic interest whether they were aimed at him personally or at some area objective which might be a mile or so away.

Thus, while guided missiles made only a small start in World War II, it is generally agreed that they will play a very important, if not a vitally determining part, in wars of the future, particularly if several years elapse in which further development and improvements can be made. In this connection, it should be pointed out that most of the array of guided missiles mentioned in this paper are considered obsolete by present standards, and give only a hint of what is yet to come.

PRACTICAL CONSIDERATIONS

There are two important considerations back of our development of guided missiles. One is our fundamental belief in the value of human life. (Not shared, however, by the Japs.) This makes particularly attractive the idea of remotely controlling an uninhabited aircraft or missile from a safe distance without danger of expenditure of human lives. The other is a less philosophical consideration, which is the physiological limitation of the human body and mind. Even if we grant the human expendability such as in the Japanese Kamakaze, we find such physiological limitations as being unable to see in the dark or through fog, and the inability of the human body to withstand high accelerations present in launching high-speed missiles or in maneuvering them against moving targets. In addition, there is always the chance

*Director, Special Products Development, Bendix Aviation Corporation, Teterboro, New Jersey. Paper presented at the May 9, 1946 meeting of the Radio Club of America, New York City.

that the human pilot might at the last minute be unduly moved by considerations affecting the safety of his own person. Then too, we frequently will wish to guide and control missiles that are too small in size even for a Jap to inhabit. While it is true that radar may be used to pierce fog and darkness, such as in radar bomb sights and radar fire control equipment, it is frequently desired to make last-minute changes in the course of a missile or projectile after launching to compensate for human and mechanical errors existing at the time of launching and original sighting. The goal we are therefore seeking is a completely push-button war in which both offensive and defensive weapons are completely controlled automatically by means of a simple switch which may be located at any safe position. In these days of proximity fuses and atomic bombs, the advantage of such systems are certainly obvious.

TYPES OF MISSILES

Missiles may be classified in accordance with the tactical use to which they will be put. For example; ground-to-air, air-to-air, ground-to-ground, short and long range, etc. They may further be broken down into different categories depending upon the type of power plant, whether rocket or jet propelled, or self-powered such as bombs and gliders.

A further classification can be made on the basis of the type of control and guidance system used. For example; many of the World War II weapons operated by what is known as the Command System in which data on the position of the missile was transmitted and presented to an operator who then controlled and corrected the path. Information on the position of the missile may be obtained visually or by use of radar, radio direction finding or by television equipment mounted on the projectile. On the other hand, a completely automatic system may be used in which a path is set up in space which the missile automatically follows. A third type of control system which may be used in combination with the two previously mentioned is the homing control, sometimes referred to as a "seeker". In this arrangement, apparatus on board the missile may seek out particular targets by means of radar, infra-red, television or light characteristics which are peculiar to the target being attacked. Thus the weapon may be automatically guided and corrected during the last stages of flight when such corrections are most desirable.

AMERICAN GUIDED MISSILES

During World War II, work on guided missiles in the United States was performed by many universities, industrial laboratories, manufacturers, and research laboratories under direct contracts with Army Air Forces, Navy Bureau of Aeronautics, and Navy Bureau of Ordnance, as well as large-scale work for the Armed Forces sponsored by the Office of Scientific Research and Development and the National Defense Research Council. Information has now been released on the following types.

Pilotless Aircraft

Even before our entrance into World War II, both the Navy and the Army had obtained considerable experience with the so-called "drone", which is a conventional type of aircraft flown completely by remote radio control. These were, and are, used on a very large scale for target practice and similar tests. It was only natural therefore that they be heavily loaded with explosives and sent against enemy targets. This simplest form of guided missile was used in World War II, one project being known as "Weary Willie". The Weary Willie's were usually war-weary B-17's which were loaded with 20,000 pounds of explosives and sent against the enemy by means of remote radio control. According to Wright Field, these charges were the heaviest ever sent against the enemy from the air. In order to simplify the control system and insure its proper operation during take-off from friendly territory, it was customary to use human pilots to take the plane into the air and set the course, after which they bailed out. No information has been released upon the results achieved in these missions. However, the Navy has announced that one PB4Y loaded with 20,000 pounds of block TNT successfully executed a mission against the German island of Heligoland. Final control of this aircraft was by means of television with a television camera located in the nose. Bad weather, coupled with difficulties with the television and radio communications caused the aircraft to strike the island some distance from the assigned objective, however. This was in the fall of 1944. The Navy also has developed what was called an "assault drone", which was originally tested against the Japanese at Rabaul in late 1943. The results of this use were not announced, and no other instances of the participation of drones in actual battle have been reported.

Glombs

This name was applied to a series of glide bombs which in some cases have been merely standard bombs with wings and tail surfaces added, while in other cases have been large-sized gliders loaded heavily with explosives. Several dozen varieties of this weapon have been designed. One is the GB-1 which is a pre-set glide bomb. In February, 1943, fifty-eight B-17 bombers flew to Cologne, each towing two GB-1 bombs. They were released more than twenty miles from the target which was well out of range of anti-aircraft fire, and all aircraft were able to escape. Army Air Forces stated, "A large percentage of these missiles hit their target". The size of the bomb load carried by the GB-1 was not given, but some glide bombs have carried as much as 4,000 pounds of explosives. GB-4 was a similar glide bomb with television in the nose.

In the LBT glomb made for the Navy, an interesting device was used to control the flight of the glomb while being towed by the mother airplane. A metal rod several feet long sticks out in the front of the glomb with a ring on the end. Through it is passed the tow cable which is attached to the nose of the glomb fuselage. If the glomb tends to fly up or down, or in any way out of line with tow cable, it moves this metal stick by means of pressure on the ring through which the tow cable passes, and this pressure is transmitted through switches to the control surfaces of the glider in such a way as always to keep it aligned with the tow cable. After this glider is cut loose, it is directed by means of television to its target, the television receiver being located on the mother plane. Figure 1 shows the GB-8 glide bomb, radio controlled in range and azimuth by visual reference to the flares which are shown in their cylindrical cases. A modification of GB-8 to use heat or infra-red homing is shown in Figure 2.

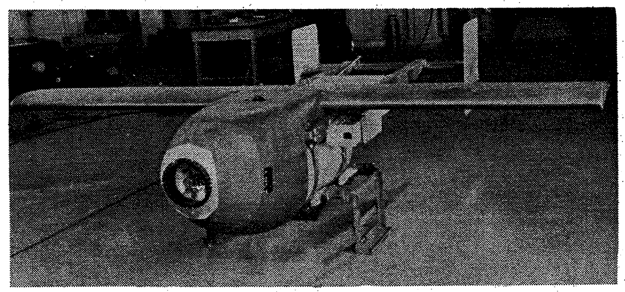

Figure 2
GB-8 Glide Bomb (Heat Homing Type)

Azon

Even a casual examination of photographs of targets which were bombed during the war indicated that a very large percentage of the bombs which were dropped fell wide of the mark. The Azon bomb, Figure 3, was designed to permit corrections to be made, after the bomb was dropped, for any azimuth errors which might have occurred in the original bomb sighting operation. The missile consisted of a standard 1,000 pound bomb with a special tail containing a radio receiver, control surfaces, and a flare. The bomb was dropped from the aircraft by use of the standard bomb sight, and shortly after release the flare on the tail was ignited, and the bombardier then visually steered the bomb in azimuth by means of remote radio control. Since only right and left corrections could be made, it was particularly valuable against targets which were long and narrow so that an error in range would not be serious. Such targets would be roads, bridges and the like. These bombs were success-

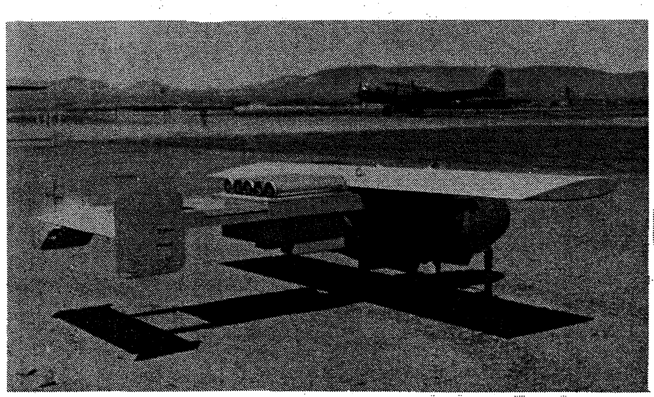

Figure 1
GB-8 Glide Bomb

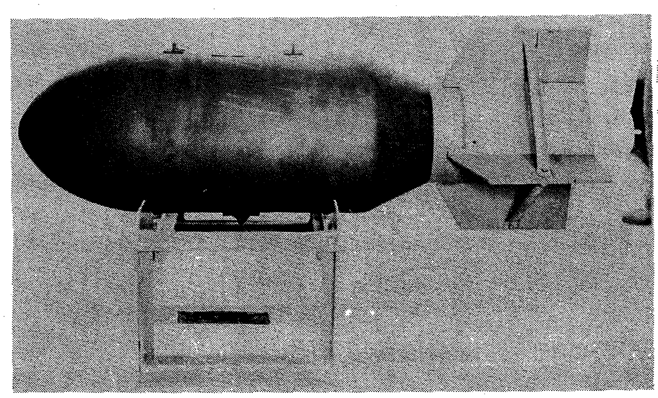

Figure 3
Azon Bomb

Illustrations in this article were made available through the courtesy of the Air Materiel Command, Wright Field, Navy Bureau of Aeronautics and Navy Office of Public Information.

Figure 4
Application of Azon Bomb in Burma

fully used in Italy and Burma in 1945, largely against bridges.

Figure 4 shows one of the most spectacular operational uses of this bomb. The target was an important bridge on the Japanese supply line in Burma, and the photograph was taken at the instant that six bombs struck. These were dropped in pairs from three aircraft; one Azon and one standard bomb from each ship. All were sighted with the standard bomb sight. Three arrows show where the three unguided bombs struck, while the three guided missiles are shown striking squarely at each end and in the middle of the bridge. Examination of the original of this photograph also shows approximately 650 craters in the surrounding countryside indicating the futile prior attempts to hit this bridge with conventional bombs.

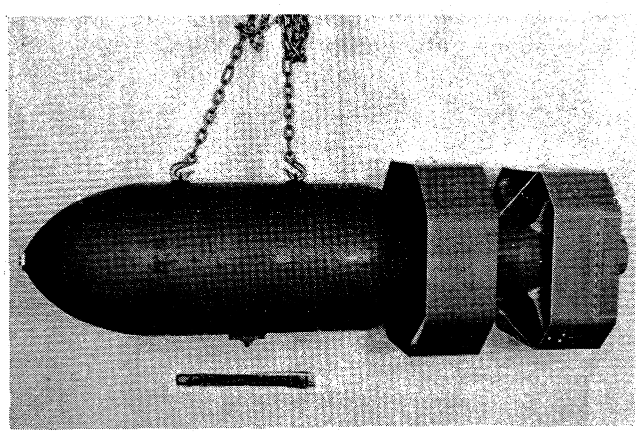

Figure 5
Razon Bomb

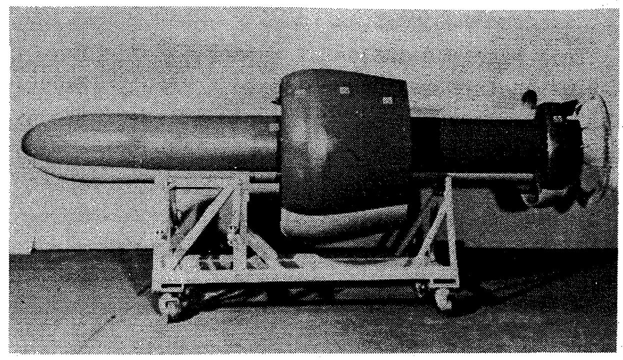

Figure 6
Roc Bomb (Television Equipped)

Razon

This was a further modification of the Azon bomb which provided control in range as well as azimuth. Complete field tests were made on Razon, and it was ready for operational use at the time of the Japanese surrender. It is shown in Figure 5.

Roc

This was a 1,000 pound bomb guided remotely by radio with the operator controlling by means of information furnished from a television transmitter located in the nose of the bomb. It was thus not necessary for the launching airplane to continue to fly a straight course in sight of the bomb as in the case of Azon and Razon. Roc was particularly notable because of its unusual aerodynamic control surface which was a shroud-ring type of wing as shown in Figure 6. It is the equivalent of a standard wing wrapped in the form of a doughnut around the bomb. It was almost ready for oper-

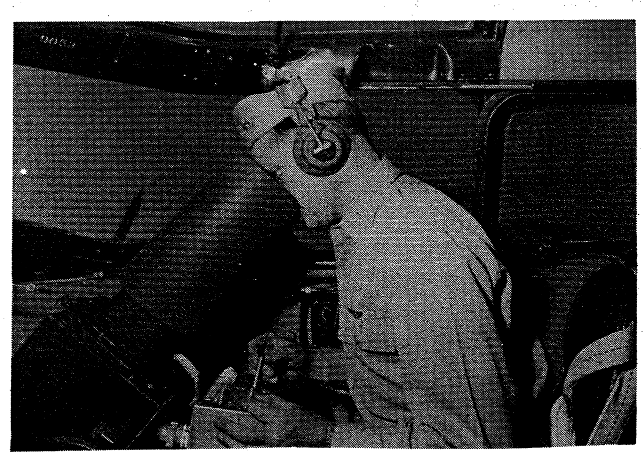

Figure 7
Guiding a Television Equipped Missile

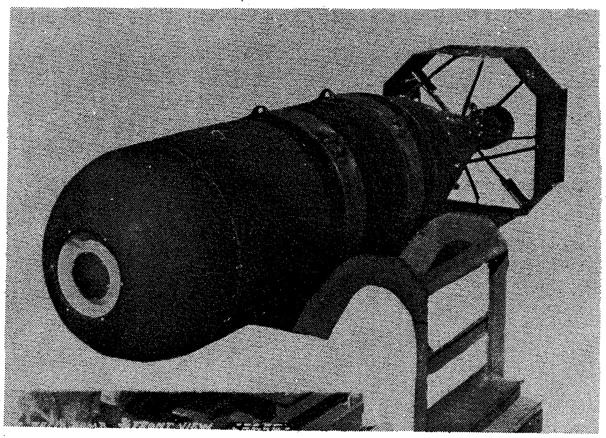

Figure 8
Felix Bomb

tional use at the end of the war. Figure 7 shows a bombardier controlling a television guided missile while watching the television picture relayed from the nose of the bomb.

Felix

This is a bomb the existence of which has been announced by the Army Air Forces. It is automatically guided by means of an infra-red homing device located in the nose of the bomb. No further details on Felix have been released, except the photograph shown in Figure 8.

JB-1

This was a flying wing type of guided missile which was launched from the ground with pre-set controls. It carried two 2,000 pound bombs and was powered by two turbo-jet engines. It had a range of 200 miles and was launched from a 400 foot ramp with five large rockets. Only one JB-1 was built and tested. It is shown in Figure 9.

JB-2

This was the designation of the American copy

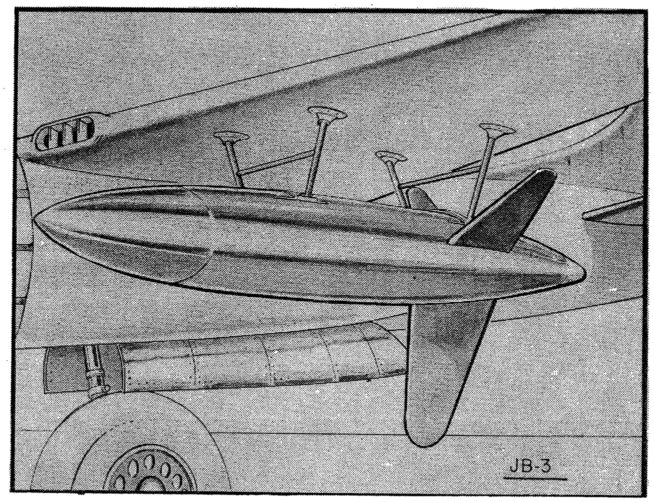

Figure 10
JB-3

of the German V-1 Buzz-Bomb. In outward appearance it was identical to the German version but was remotely controlled by radio and radar throughout its 150 mile flight. It was planned to use these missiles in a large scale bombardment of Japan had not the war ended when it did. The American JB-2 was launched by means of auxiliary rockets up to a speed at which the jet engine operated efficiently enough to continue the flight.

JB-3

This was a small guided missile launched from a conventional airplane as shown in Figure 10. No specifications have been released except that it used a proximity fuse and was originally designed to attack the German V-1. It did not see operational use, however.

JB-10

This missile shown in Figure 11 replaced JB-1 and carried 3,400 pounds of explosives. It was built around an American copy of a German V-1 jet engine and had a top speed of approximately 400

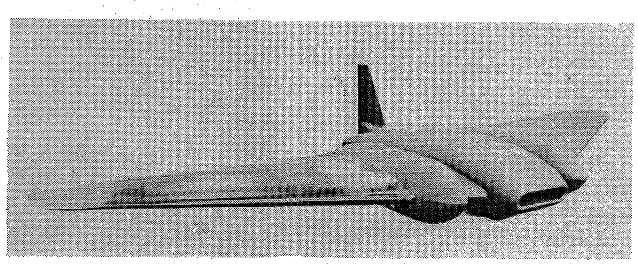

Figure 9
JB-1 Jet Powered Missile

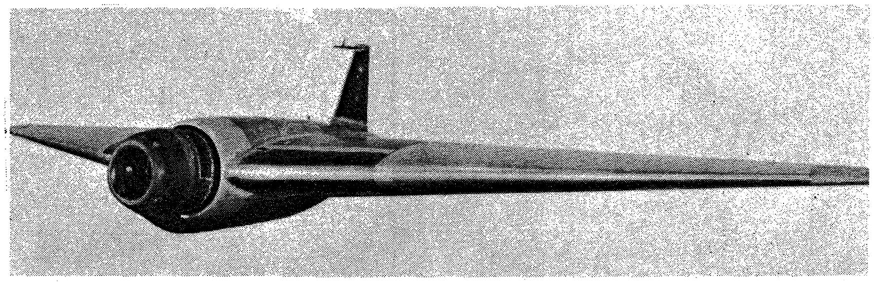

Figure 11
JB-10

miles per hour. It did not see operational use during the war.

Gargoyle

This missile carried a 1,000 pound bomb and is also equipped with a jet engine to give it additional speed. It might be described as a jet propelled dive bomber. It is said to be equipped with a homing device, the nature of which has not been revealed. It is an air-to-ship missile and is shown in Figure 12. In flight it attains a speed of approximately 600 miles per hour.

Gorgon

This name is applied to a series of airborne missiles developed by the Bureau of Aeronautics of the Navy Department. None of these missiles saw operational use during the war.

Gorgon II-A was a rocket powered missile with a top speed of 550 m.p.h. It carried a 100 pound special shaped charge, and after launching was guided to the target by means of radio or a homing device. It was approximately sixteen feet long and had a wing spread of eleven feet and is illustrated in Figure 13.

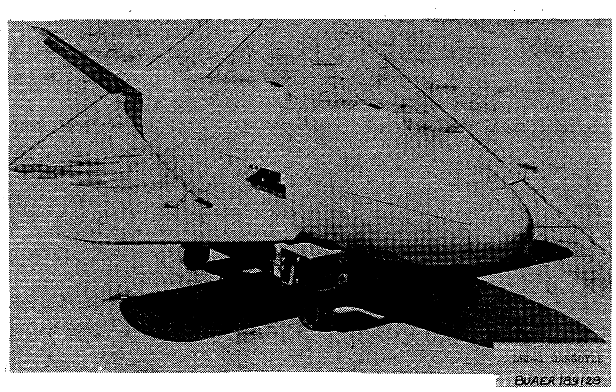

Figure 12
Gargoyle

Gorgon III-B is a missile of similar size but is powered by means of a conventional turbo-jet engine. It is shown in Figure 14.

Gorgon II-C carries 1,000 pounds of general-purpose explosives at approximately 400 m.p.h. and is shown in Figure 15. It is powered by reso-jet type of engine.

Bat

From a controls and guidance standpoint, this missile development by the Bureau of Ordnance of the Navy is one of the most advanced and interesting in the whole series of American missiles, particularly since it saw operational use during the war. It is built around a 1,000 pound bomb and has a 10 foot wing spread and is approximately 12 feet long. One can be carried under each wing of a PB4Y-2 airplane. It is a glide bomb equipped with radar homing. An early model called Pelican is shown in Figure 16 with the final Bat illustrated in Figure 17. The radar equipment includes a transmitter and receiver whose total weight including power supply is less than 200 pounds. This

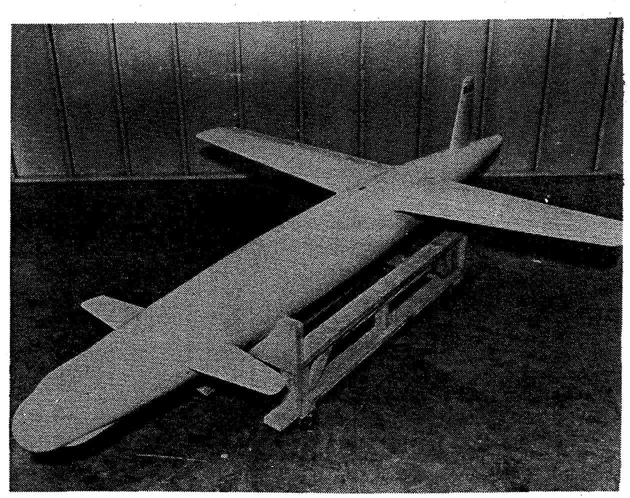

Figure 13
Gorgon II-A

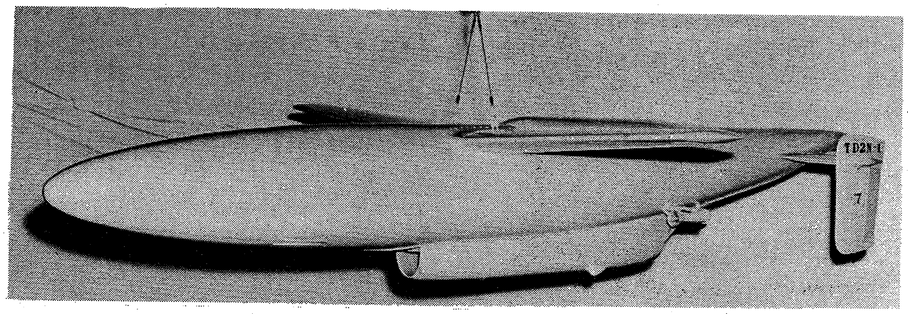

Figure 14
Gorgon III-B

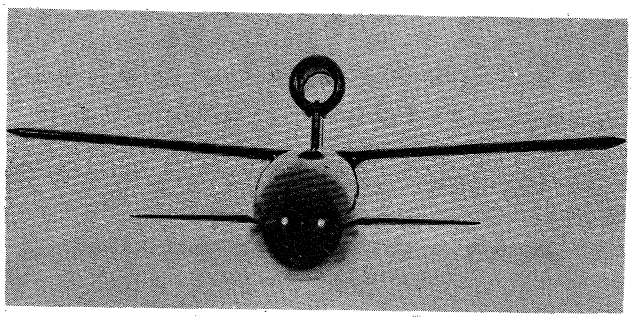

Figure 15
Gorgon II-C

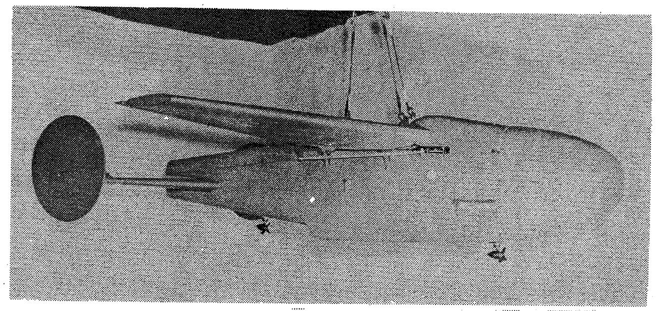

Figure 16
Pelican

radar equipment scans in a forward direction, the signals being monitored by an operator on the mother aircraft. As soon as a target is seen by this equipment and identified as an enemy, the Bat is cut loose and automatically homes on this previously selected target no matter what evasive action it may take. Figure 18 shows the AAf missile GB-14 which used the Bat homing radar. In this view the radome housing has been removed.

The additional gliding range obtained by means of the wings enables the Bat to be launched outside of the range of ordinary anti-aircraft fire. The launching plane can then immediately leave the vicinity as soon as the missile is launched. Work on this missile was started in April of 1942, and it saw operational use in the Philippine area in May, 1945. The Navy has released information that one of these missiles sank a Jap destroyer and in other actions accounted for "many tons of Japanese shipping". This was probably the first fully automatically guided missile to have been used in combat by either side.

Little Joe

Development of this weapon was started by the Navy late in the war with the objective of producing a missile specifically to meet the Jap Kamakaze attacks. It carries a 100-pound explosive charge which is actuated by means of a proximity fuse and is shown in Figure 19. It may be launched either

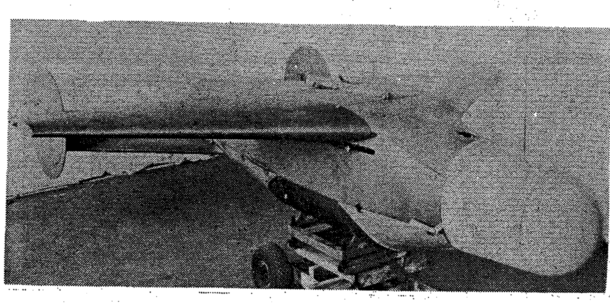

Figure 17
Bat

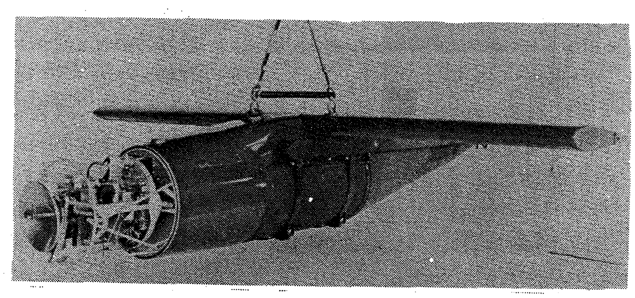

Figure 18
GB-14

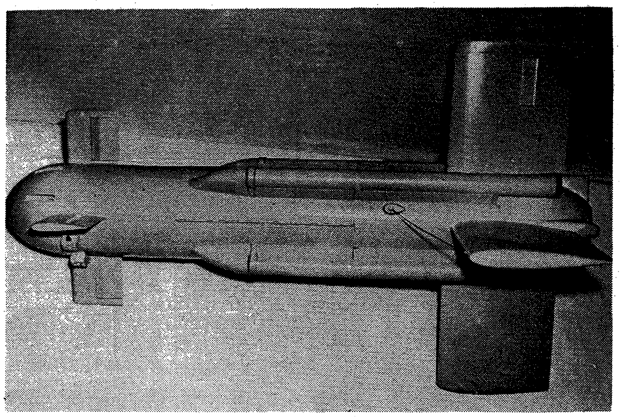

Figure 19
Little Joe

from a ship or from the air. Launching is accomplished by four high thrust rockets which get the missile up to speed with principal power then being furnished by a large jet-assisted-take-off unit contained within the fuselage. A flare is mounted on one wing tip to enable the operator controlling the missile to follow its flight under all light conditions. Signals are transmitted to it by radio from the launching position.

GERMAN GUIDED MISSILES

In quantity and number of types, the German guided missile program was roughly the equivalent of ours. However, the long background of rocket development and experiments in supersonic aerodynamics had given the Germans a considerable advantage in the application of these techniques to guided missiles. In the fields of radio, radar and controls they held no advantage, however.

V-1

As is well known, the V-1 Buzz-Bomb was steered after launching on a pre-set course determined by a magnetic compass located in the nose of the craft. Apparently at no time was there any effort made to use radio control or radio steering on these missiles. However, some few did carry radio transmitting equipment so that the path could be followed by radio direction finders and suitable corrections added to the settings of the controls of the subsequent missiles. This type of guiding was quite satisfactory for the type of area targets attacked.

V-2

Like the V-1, the German V-2 was not, strictly speaking, a controlled or guided missile, since it followed a pre-set course. However, like the V-1 it offers excellent possibilities as a guided missile and is of considerable interest since it is the most advanced vehicle of its type yet made. A V-2 missile with an atomic warhead, a proximity fuse and remote radio guidance is probably nearer the weapon of the future than any other we can now imagine. The German designation of this weapon was A-4. They had also experimented with an A-9 which is a V-2 equipped with wings which would enable it to glide a considerably greater distance than would the A-4. It is estimated that it would have increased the range from 180 miles to approximately 300 miles. The A-9 is shown in Figure 20. If the so-called step rocket principle were used, the A-9 could be boosted by an A-10 and thus be converted into a trans-Atlantic rocket. It is estimated that such an A-10 would have weighed on take-off eighty-five tons. No rocket of this size was made, and it is not known what plans the Germans had for guidance and control of this combination.

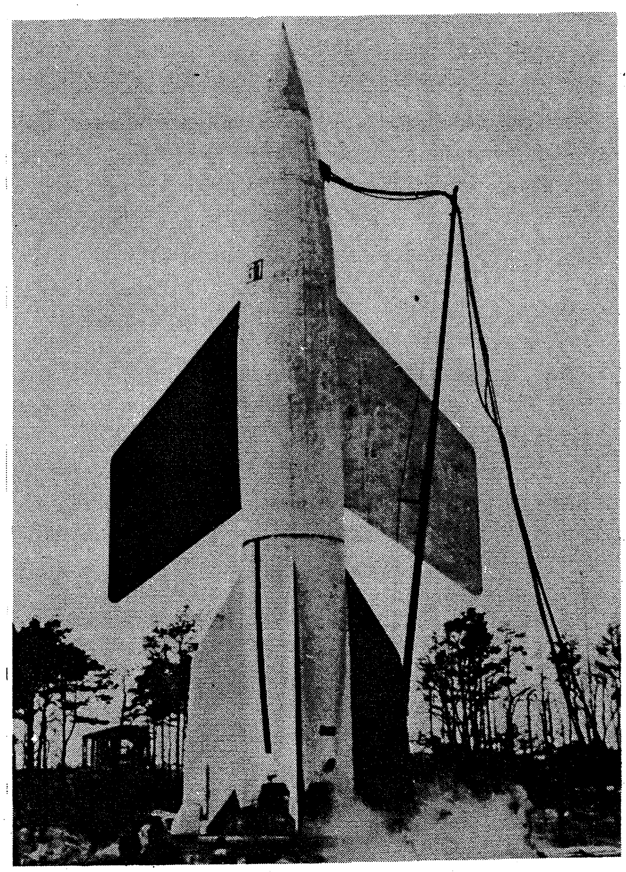

Figure 20
German A-9

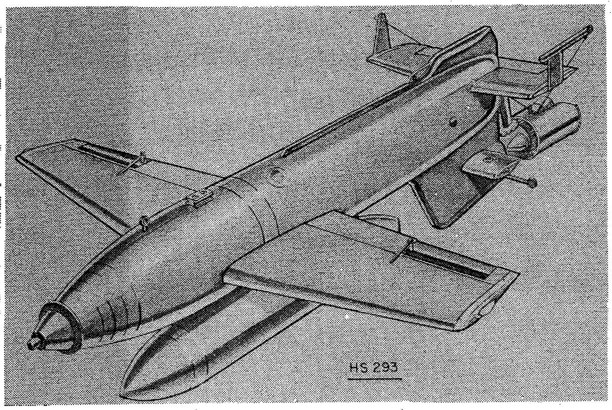

Figure 21
German HS-293

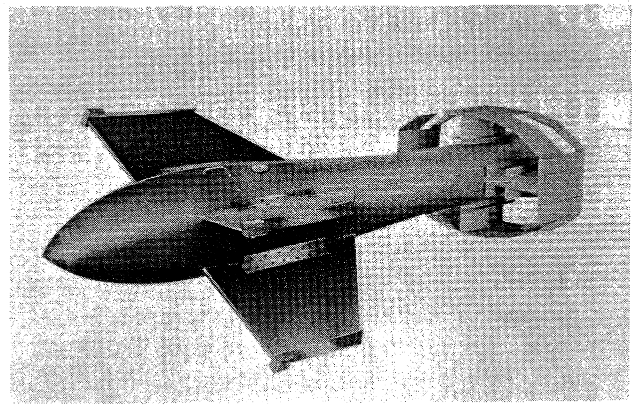

Figure 22
German XF-1400 (Fritz X)

HS-293

This was a bomb controlled in azimuth only like our Azon, but in addition had a small rocket boost which enabled it to travel at much higher velocities. It is shown in Figure 21. It was during late 1942 and early 1943 against allied fleets in the Mediterranean where a number of our ships were sunk and damaged by means of this bomb. It was guided by radio, being controlled by a bombardier on the mother plane who followed the flight of the missile by means of a flare located in the tail. It was eventually successfully countered by fighter patrols shooting down the mother plane and by the use of jamming equipment which was quickly installed on American ships to interfere with the radio control circuits. Approximately 160 of these missiles were dropped in a series of 12 attacks.

XF-1400 (Fritz X)

This was a high-angle 2,200 pound bomb which was controlled by radio in both range and azimuth and was thus analogous to our Razon. It was

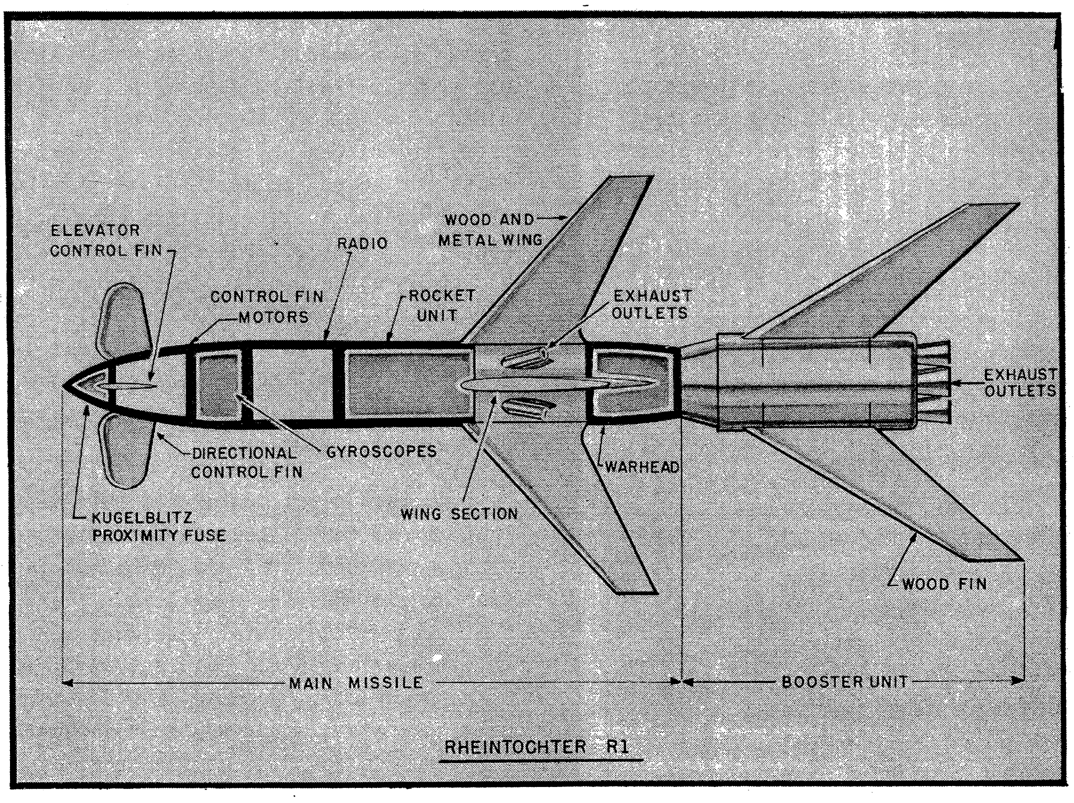

Figure 23
Rheintochter R1

steered by following the flight of a flare in the tail. This bomb sank the Italian battleship, Roma; damaged the British battleship, Warspite, and the American cruiser, Savannah. It had small wings but was not jet assisted. It is shown in Figure 22.

Wasserfall

This was an anti-aircraft rocket which was a small version of the German V-2, but was equipped with wings like the A-9 and designed to be guided by radar. It did not see operational use during the war, although some 34 test launchings are said to have been made. The Germans considered it their most promising guided missile. It was about 24 feet long and carried 230 pounds of explosive.

Reintochter

This was another Nazi anti-aircraft rocket shown in Figure 23 which was launched and initially propelled by a rocket booster unit which subsequently dropped off leaving the main part of the missile with its own propulsion unit. It was equipped with a proximity fuze, auto-pilot and controlled by radio. Some experimental models were made, but it did not see operational use.

Schmetterling

This was another ground-to-air anti-aircraft rocket developed by the Germans during the last stages of the war when their principal problem was defense against allied bombing raids. Schmetterling was a jet propelled missile controlled by radio or radar and equipped with a proximity fuze. It did not see operational use, but a captured sketch is shown in Figure 24.

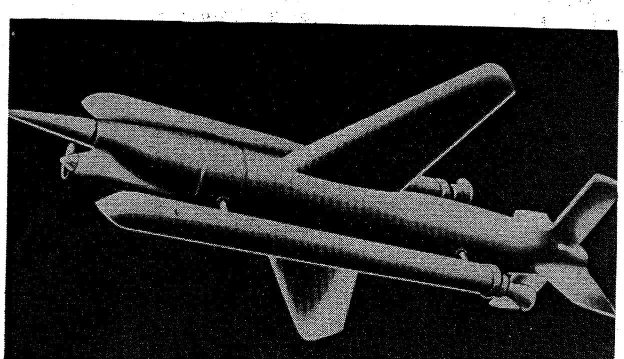

Figure 24
Schmetterling

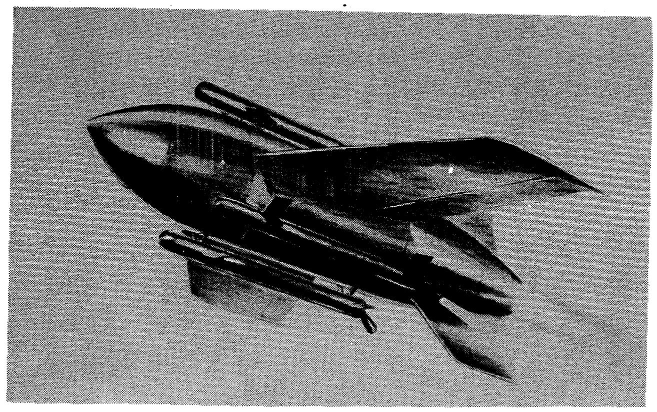

Figure 25
Enzian

Enzian

A sketch is available, Figure 25, of this radio controlled missile designed to travel at supersonic velocities, but which did not get into production. An unusual feature of this missile is the mounting of four auxiliary launching rocket jets placed at an angle to the main jet.

X-4 (Ruhrstahl)

This was one of the most unusual of the German missiles, a sketch of which is shown in Figure 26. It was intended to be launched from an aircraft as a weapon to attack other aircraft. It was about 6-1/2 feet long with a body 8 inches in diameter with four plywood wings. It was rocket propelled with a top speed of approximately 700 miles per hour. In most guided missiles the general practice is to stabilize them against roll by means of gyros, so that the control surfaces will always have the proper orientation with respect to the control signals. However, this missile was made to rotate, and a commutator was placed on an internal gyro so that control impulses were always transmitted to the proper set of controls at the proper time.

Another novel feature of this missile was that it was controlled electrically by means of wires. Two spools of wire were mounted, one on each of two opposite wing tips. These bobbins contained a fine enamel insulated wire 0.008 inches in diameter which was paid out as the missile flew through the air. Because of the spin of the missile, the wires were twisted together behind. Wires were also paid out from the mother airplane as soon as the missile was launched. Seven or eight miles of wire was carried in these spools,

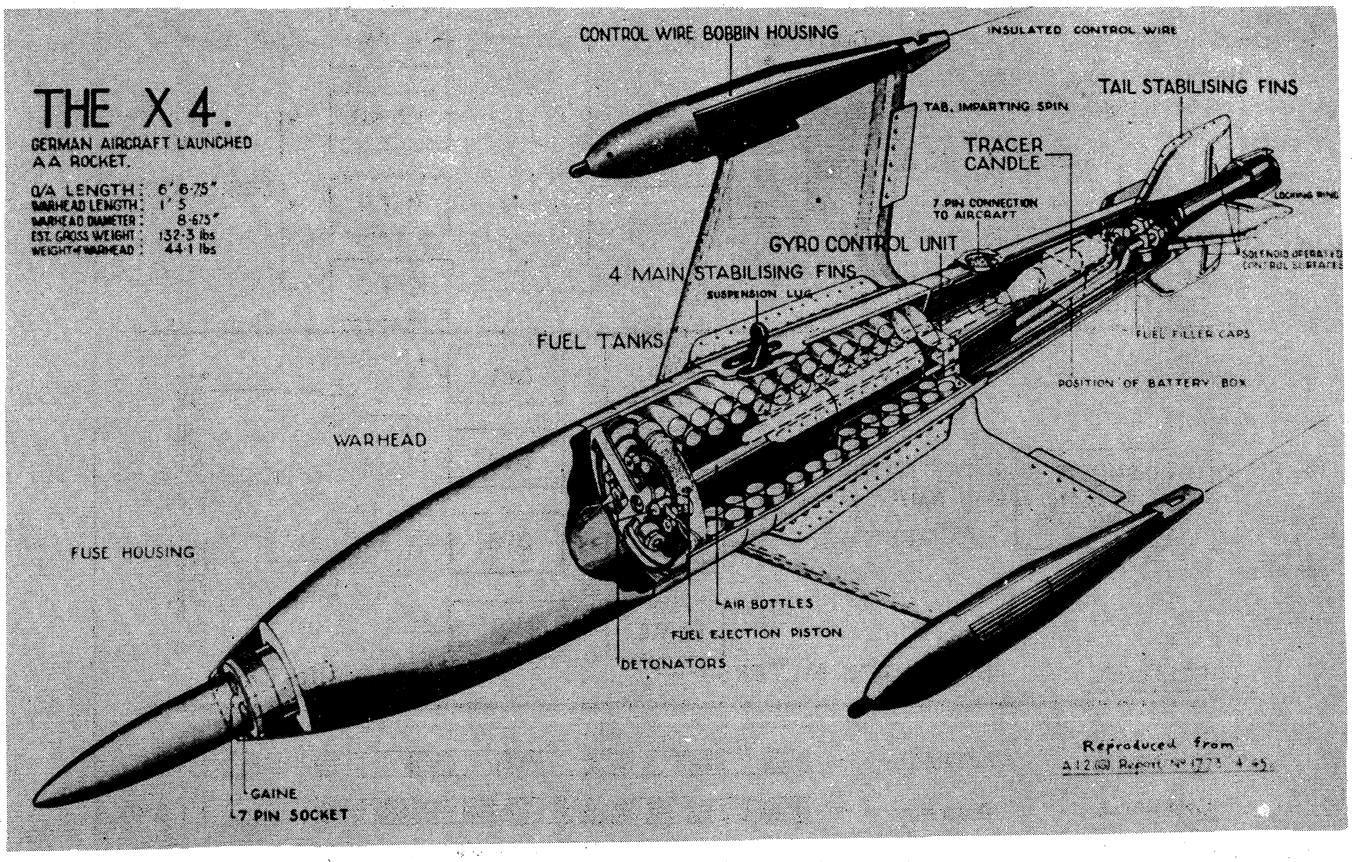

Figure 26
X-4 (Ruhrstahl)

and the missile was guided by an operator on the mother plane who watched a flare mounted on one of the wing tips. The same control impulses which were sent by radio to the HS-293 and FX-1400 were sent via the wires to the X-4. An outstanding virtue of this control system is that it would be impossible to jam by enemy action unless the wires were cut. Several hundred of these missiles were made and tested, but they did not get actual use against our aircraft.

German Guidance System

Security regulations still prevent the discussion of details of American guidance and control systems. However, information has been released on a German command system called the Strassburg-Kehl. Figure 27 shows a block diagram of this system, which was used to control the HS-293, FX-1400 and X-4 described above.

While some missiles may be guided by moving the controls into either an "off" or "on" position with no intermediate steps, it is usually desirable to have what is called a proportional type of control system which is one in which the control surfaces are moved an amount proportional to the required correction. The Strassburg-Kehl system utilizes a vibrating type of control surface which rapidly changes its position from, for example, right to left in the absence of any control signal. Equal times are spent by the control surface in both the right and left positions. A signal is then sent which orders the control surface to spend more time on one side than on the other thus effecting proportional control and steering. The means for accomplishing this are illustrated in the Figure.

Two pairs of audio oscillators are used on the transmitter, their outputs being fed to a control box where a control stick moves brushes along shaped commutator segments which are driven by a motor at five revolutions per second. With the control stick in neutral position, alternate one-tenth second pulses of audio signal are given from each half of each pair of oscillators. If the control stick is moved in the down position, the

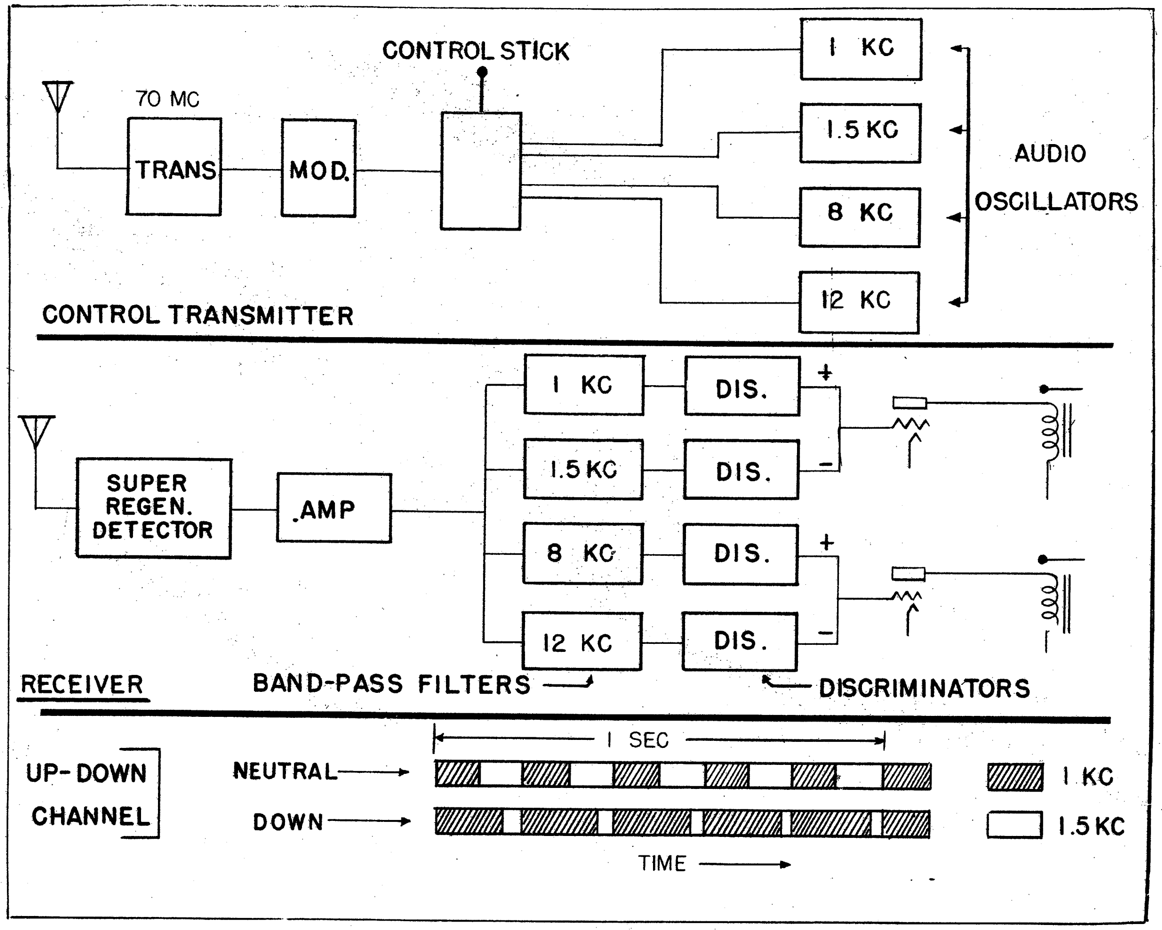

Figure 27
German Control System

brushes are moved along the commutator in such a fashion that the 1.0 kilocycle tone is on longer than the 1.5 kc as shown in the Figure at the bottom. The output from this control position is fed through a modulator to a transmitter which normally operated on 70 megacycles.

On the missile the signals were received by a super-regenerative detector, then amplified and selected by means of four bandpass filters and applied to two pairs of discriminator circuits. These discriminators were connected with their outputs opposed so that, for example, the d-c output from the 1.0 kc discriminator has a polarity to drive the tube grid positive, while the output from the 1.5 kc discriminator drives the tube grid negative. Thus the plate current is alternately turned on and off for a length of time proportional to the length of duration of the applied audio signals. This pulsating plate current is used to operate a relay which in turn controls the operation of the surfaces.

This system was successfully jammed by the allies and at the end of the war the Germans were developing a similar unit to operate at about 1250 Mc in the hopes of thus attaining greater freedom from jamming.

SUMMARY

The above list includes only a few of the guided missiles which have been developed or are in the stages of development at the present time. Some of the projects not described were unsuccessful, and some hold too much hope for the future to be released at the present time. As stated in the beginning, most of the ones which have been described are at least in part obsolete. An analysis of these will indicate that while, in some form or another, we know all of the essentials for a true push-button war, the actual realization of this is still some time in the future. Undoubtedly the trend will be toward better guidance and control and much higher velocities for the missiles of the

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