CHAPTER II

GERMAN WEAPONS DEVELOPMENT

Forty years of hindsight has allowed me the opportunity to separate antitank weapons and strategic weapons development from the rest of WW II, a luxury that the participants did not have. World War II revealed that the tank was the pre-eminant weapon on the ground and armored warfare was the predominent tactic. Air Power, both close air support and strategic bombing were instrumental in defeating both the Germans and the Japanese. Naval Power was instrumental in keeping the sea lanes open for logistic support of the combat forces.

The preceding chapter presented an overview of the major events and campaigns of WWII as they occurred with a detailed explanation of the allied and U.S. intelligence efforts and organizations as they developed. The detailed discussion of the German campaigns and weapons was, of course, based upon the work of post-war historians but insofar as possible, I attempted to portray events as they unfolded before the eyes of allied military planners. It was not until after the war and the post-war analysis of events that has made possible an understanding of German intelligence and weapons development. In this chapter the development of German antitank weapons, atomic research, jet aircraft and rockets are examined as well as certain aspects of the German technical intelligence efforts since they became the basis for much of the United States post-war developments.

Long range forecasting of future developments is based upon an understanding of historical trends as modified by current developments. The United States was considerably behind in these areas at the start of the war. In the immediate post war years, the Air Force was in the forefront in this aspect of warfare, but even they had problems. The Army also had a similar requirement and capability but did not make extensive use of captured material for generation of historical data and both suffered from a lack of current intelligence. This chapter then points out some of the early efforts to rectify these problems.

World War I had brought into action two major weapons which entered the conflict too late to have been of significance, the Tank and the Airplane. Following the war, development of these weapons continued and almost immediately counter weapons were developed. The two principle antitank weapons were the "Shell Mine" and explosive charge planted in the ground and the antitank gun with a very high muzzle velocity. Some military theoreticians of the time felt that the ideal antitank weapon was another tank, but the militaries of most nations stuck to the conventional wisdom of the time and felt that an antitank gun was the answer.

In 1934, the German Army ordered Rheinmettal A.G. to develop a new 3.7 CM antitank gun. Rheinmettal ranked alongside the Krupps in the manufacture of guns. In WWI, they had developed the first rapid fire 3.7 CM gun in 1918. By 1935 they had finished designing the new gun and it had an overall weight of 450 kg. Having two rubber tired wheels, torsion bar suspension and two rear trail legs, it could easily be moved by a few men. The gun was 45 calibers long and had muzzel velocity of 762 meters per second and would penetrate 48mm of armor plate at a distance of 457 meters. The gun was quickly adopted as the Antitank Gun Model 35/36 (PAK 35/36). The weapon served as the basis of the American 37mm antitank gun. By 1938 the British developed a 6 pounder antitank gun, but none were produced until 1942, by which time the situation was almost desperate. This gun was then adopted by the Americans as their 57mm Gun M1. As German tanks became better, the U.S. hastily fielded an amalgamation of components into the U.S. three inch M5 antitank gun. By 1938 the Germans had also produced a new antitank gun, the PAK 38, a 5cm gun, but it appeared too late for the Polish and French Campaigns. Further German developments centered about larger caliber guns, some weapons made from captured Russian guns and some weapons made from their highly successful 8.8 CM gun.

Newer antitank weapons were under development, and by the end of the war, the antitank rocket became one of the principle anti-armor weapons, along with the Recoilless rifle. At the start of WW II, rocketry was in its infancy and it received little attention, hence our military attache in Berlin would have had little formal guidance on the subject, much less taken seriously any German experiments in rockets. It is important to note that there was no serious military development of rockets until after the war began and the Germans had been able to recover samples of the U.S. 2.36 inch rocket launcher. Confirmation of this came through the efforts of the Ordnance Technical Intelligence effort.

The principal antitank weapons in use today make use of a rocket motor to propel a shaped charge warhead to the target. The principle of the shaped charge was discovered by an American explosive expert, Professor Charles E. Monroe, as far back as 1887. Very basically, a hole could be blown or more accurately burnt, through armor plate by having an air gap between a bursting charge and the plate at the time of the explosion. The bursting charge is held contained in a steel casing with the front only lightly covered with thin sheet metal. An air gap is deliberately formed by making a conical depression in the explosive and the nose is tapered only for streamlining and holding the impact fuse at the correct distance from the charge. Despite widespread knowledge of the Monroe effect, little use was made of it prior to WW II. Since there was no tank threat in the late 1800's, there was no need for any military research in this area. During WW I, the early forms of tanks were introduced into combat, and briefly they were armor plated vehicles which could effectively be stopped by large caliber rifles.

Inasmuch as the United States had the lead in antitank rockets and there was a far greater threat posed by possible development of an atomic bomb by Germany and the probable threat posed by the development of long range rockets, allied intelligence efforts were directed toward these threats. The Enemy Equipment Identification elements sent to Europe did exploit captured German weapons and did advise American Troops on the use of these weapons; however, these weapons did not generate the same level of concern as the V1 and V2 rockets.

Despite General Eisenhower's comments on the shortcomings of our pre-war intelligence organizations, Col. Truman Smith, our Military Air Attache in Berlin, did achieve considerable success in determining the size and composition of the German aircraft industry, the existance and capabilities of German combat air force, the industrial production facilities needed to support the war effort and air fields as well as the principle technical strong and weak points of LUFTWAFFE equipment. In his memoirs, Berlin Alert, published in 1984, Smith indicated that the failures of air intelligence were their failure to obtain even a hint of jet engine developments and failure to follow up on several rumors of rocket development. They also failed to convey to Washington the emphasis of dive bombers and also a failure to obtain information as to the experience the Luftwaffe had in the Spanish Civil War.

During the same time frame, and apparently unaware of either German or Soviet research on tanks and antitank weapons, various people in the United States conducted research on rockets and shaped charges. Among these were Henry Mohaupt, a Swiss engineer and Les Skinner. The shaped charge was experimented with by the German firm of Westfalish-Anhaltische Sprengstoff Aktiengesellschaft but their research was for mining purposes. With the ending of WW I and the surrender of Germany, the Treaty of Versailles was signed which placed considerable restrictions on the size and equipment of the German army and resulted in much research being done in secret.

Completely unrelated, or so it would seem at the time to antitank weapons, Albert Einstein wrote to President Roosevelt in August 1939 that, "In the course of the last four months it has been made probable -- through the work of Frederic Joilet in France as well as Enrico Fermi and Leo Szliard in America -- that it may become possible to set up a nuclear chain reaction in a large mass of uranium by which vast amounts of power and large quantities of radium-like elements would be generated. Now it appears almost certain that this could be achieved in the immediate future.

This new phenomenon would also lead to the construction of bombs and it is conceivable -- though much less certain that extremely powerful bombs of a new type may thus be constructed. A single bomb of this type, carried by boat and exploded in a port, may well destroy the whole port together with some of the surrounding territory. However, such bombs might prove to be too heavy for transportation by air." Nuclear physicists in the United States realized clearly the implications of such a weapon and many hoped that it would be too difficult to achieve. As WW II progressed and allied intelligence began to learn of the progress on a similar project in Germany, along with the universal acceptance of German superiority in nuclear physics, coupled with a fear of what Hitler would do with such weapons drove allied scientists almost to panic.

Of the more famous German personalities to emerge from the WW II era, Dr. Baeumker who was war time Chief of Research and Development for the German Air Force, Dr. Wernher Von Braun and General Walter Dornberger of Peenumunde and Dr. Otto Hahn, who discovered uranium fission were probably the most notable. A young German physicist named Hans Bombke became a research associate of Dr. Hahn. Dr. Bombke's efforts dealt with abstract concepts such as producing a U-235 enriched uranium for use in testing chain reaction feasibility. In discussing atomic research with Dr. Bombke after the war, he indicated that some years before the actual discovery of nuclear-fission by Otto Hahn and H. Strassmann, a German chemist, Dr. Ida Noddack, wife of a well known chemist, Professor W. Noddack, had published a short note in which she suggested that uranium might, in addition to being radioactive, under favorable conditions also split into two new atoms of about half the uranium mass. This prediction of fission was, however, not taken seriously by anybody, in fact, it was hardly noticed in the scientific world.

In 1938, Professor Otto Hahn, who was director of the Kaiser Wilhelm Institute for Chemistry in Berlin-Dahlem, and who had spent more than 30 years investigating the chemistry of uranium and other radioactive elements, repeated experiments done, shortly before by E. Fermi in Rome and by Frederic and Irene Joilet-Curie in Paris, who had reported that they had created transuraniun new elements by irradiating uranium with neutrons. Around Christmas of 1938, Hahn and his assistant, Dr. H. Strassmann, found that one of the supposed transuranian elements was instead barium, an element of about half of the uranium's atomic weight. Thus confirming that uranium irradiated by neutrons splits into two atoms of about half the uranium's mass. Dr. Bombke was at that time an assistant of Dr. Hahn, however, not directly involved in the fission discovery. Naturally, we all (in the institute) got very excited about the discovery of fission and started experiments to find out more about the fission process. Hahn had, in the meantime, written about his discovery to his long-time research associate, Dr. Lise Meitner, who, being Jewish, had shortly before left the Kaiser Wilhelm Institute and emigrated to Sweden. There, she and her nephew, Dr. O. Frisch, immediately followed up Hahn's discovery by measuring the energy release by the fission of the uranium nucleus. It turned out that this energy was more than ten times larger than any radioactive decay energy. When Meitner and Frisch's paper and also Hahn and Strassmann's papers were published (in early 1939), everybody suddenly got into the new fission research. In Paris, Frederic Joilet-Curie, together with O. von Halban and L. Kowarski, found that in the act of splitting the uranium atoms several new neutrons were released. They suggested that for the first time a nuclear chain reaction was in principle possible. Hence, both an energy producing nuclear reactor and also an atomic bomb seemed to become feasible. At that time, Dr. S. Flugge wrote a review article about fission research and stressed in particular the possibility of making powerful atomic bombs. This article was read not only in the scientific community but also by many outsiders, in particular the military in Germany, which led to the German wartime uranium fission research.

In the USA, Dr. Leo Szliard and some other American physicists also recognized the great military potential of the uranium fission. They visited Einstein in Princeton and persuaded him to write his famous letter of 4 August 1939 (which Szliard and Associates had drafted) to President Roosevelt. This, as is well known, started the American Manhattan Project and led eventually to the atom bombs dropped on Hiroshima and Nagasaki. Shortly before the outbreak of WW II, Niels Bohr of Copenhagen and J.A. Wheeler of Princeton had published a very important theoretical paper in which they showed that most of the fission takes place in an isotope of uranium - U235. With natural uranium, which consists mainly of uranium 238, the critical mass required to start a self-sustaining chain reaction, is of the order of close to two tons. Thus, the idea of making an atomic bomb would, due to this large size, be extremely unpractical. After the Bohr-Wheeler paper, however, it should be possible by enriching the rare isotope 235 to reduce the required critical mass to such a degree that atomic bombs of small size could be conceived. A young German nuclear physicist, Dr. Kurt Diebner, (whom Bombke had known before the war; they both had worked in the German Bureau of Standards in Berlin-Charlottenburg) had joined the "Heereswaffenamt" (Army Weapons Office) as a scientific adviser, and briefed his chief, General Becker, on the possibilities of an atomic bomb. So, when the war started in September 1939, Diebner was ordered to organize, for the army, a central uranium research project that would include in it all German scientists who were engaged in uranium research or related fields. Dr. Diebner's first step was to sequestrate the world famous Kaiser Wilhelm Institute for Physics in Berlin-Dahlem and then to call a classified meeting of all well known nuclear physicists in Germany (for example W. Heisenberg, C. F. von Weiszacker, H. Geiger, W. Bothe, P. Harteck, etc.). Although Dr. Bombke was not well known, being very young, he was also present in this meeting. The scientists were requested to each look carefully into the possibility of building a uranium reactor and hopefully also an atomic bomb and to report their opinion as soon as possible to Dr Diebner. When Diebner got these replies, it turned out that nearly unanimously the German nuclear scientists stated that within a reasonable time a nuclear power reactor might be feasible, but to produce an atomic bomb, a decade or more of basic research would be required. After this verdict was in, the Heereswaffenamt lost interest in the uranium project. It returned the Kaiser Wilhelm Institute for Physics to its old owner, the Kaiser Wilhelm Gesellschaft (Kaiser Wilhelm Society) and instead of a centralized uranium project numerous research groups, sponsored by different government organizations and only very loosely coordinated, conducted the wartime uranium work in Germany. The most disastrous result of this development was that every uranium research group had used its connections to lay hands on as much uranium metal as possible and most jealously held on to its uranium. So throughout the whole war, no laboratory working on the uranium problem had actually enough uranium in its possession to assemble the critical mass of close to two tons of uranium.

Professor Heisenberg, at that time in Leipzig, concluded that heavy water was the best moderator for a reactor. He and Dr. Robert Dopel and Mrs. Dopel, (Dr. K. Dopel) built a small spherical miniature reactor, consisting of alternating concentric shells of ordinary 238 uranium and of heavy water (D_2O). Although this device was far below the critical mass, it showed a small but clearly measurable increase of the neutron density inside, much as theory predicted for this subcritical configuration. This was the first experiment ever to establish beyond any doubt that a chain reaction takes place in a uranium block. The Heisenberg-Dopel paper was never published. Only a classified report existed that was known to only very few people at that time.

Other German research groups that continued uranium research during the war were Dr. Deibner in Berlin-Gatow who conducted some follow-up research for the Army, Professor P. Harteck in Hamburg, worked on the problem of isotope enrichment, Professor Clusius in Munich also interested in the isotope enrichment problem, and also the German Postal Research Center in Berlin. In the early 1940's, Heisenberg was appointed director of the Kaiser Wilhelm Institute of Physics and there continued with a large staff of physicists (Dr. von Weiszacker, Dr. Bopp, Dr. Wirtz, Dr. Bagge, to name only a few) to work on the reactor project. The work was hindered in the later war years by the extremely difficult procurement situation, and by the air attacks on Berlin, by the difficulty of obtaining a sufficient amount of heavy water, and, last but not least, by the fact that Heisenberg's groups had not quite enough uranium for a practical reactor. Nevertheless, this group succeeded in demonstrating the feasibility of a large energy producing uranium reactor. Due to the worsening conditions in Berlin (the air raids had built up to such a degree that nearly every night hundreds of bombers flew either to Berlin or to cities in North Germany) Heisenberg's institute was transferred to South-West Germany, to the little town of Hechingen. The reactor itself was assembled in a deep cellar under the church of a small town called Haigerloch. In February 1945, a few months before the end of the war in Germany, the reactor which contained 1.5 tons of uranium produced seven times more neutrons than were put in at the start of the reaction. It was so close to self sustaining energy production that only about a hundred kilograms of additional uranium would have been required. This undoubtedly was the reactor seized by Col. Pash in Operation Alsos (page 38, Chapter I).

Returning to his discussion of nuclear research done by the German Postal Service, Dr. Bombke pointed out that the head of the Postal Service was minister Ohnesorge, an old hand in communication work and also a long time friend of Hitler. Another young inventor to appear was Manfred von Ardenne. In the first World War, his father had been the commanding officer of Dr. Ohnensorge, hence, Ohnesorge subsidized Ardenne's projects by giving him research contracts with the Postal Department. After the war with Russia had started, Dr. Houtermans, a noted nuclear scientist who had worked in Russia for many years, found himself as a fugitive in Berlin. Ardenne found him and learned from him about the uranium chain reaction possibility. He at once gave Houtermans employment and asked Postal Minister Ohnesoge to subsidize a uranium project to be conducted by him and Houtermans. Ohnesorge did indeed subsidize the Ardenne project, but being also a smart man, he thought that he could, since the project that Ardenne had proposed to him seemed promising, also get directly involved in the "to be anticipated," uranium boom. Hence, he set up, as part of the postal research, a new laboratory, the "amt fur physikalische sonderfragen" (office for special physical problems), which was housed in a nice building in Miersdorf, also 30 km southeast of Berlin and headed by Dr. Otterbein, a communication expert and administrator, but not a nuclear physicist. His associates, Dr. Salow and Dr. Peter, were also not nuclear physicists, but had worked for the Postal Research Laboratory designing television components. Bombke learned about this shortly after the new postal laboratory had come into being and being ambitious, thought that he could easily become the senior nuclear physicist in this laboratory. He was immediately hired by Dr. Otterbein and built up his own research team by importing an old friend, Professor Th. Schmidt, an internationally known nuclear scientist, Dr. S. Flugge (the one who in 1939 had written the famous review article) and Dr. D. Lyons, a former assistant of Professor Heisenberg. In addition, he had a number of engineers and technicians in his group. Although they did not know about the Heisenberg-Dopel experiment, they had no doubt that a reactor would work, and so they determined to immediately embark in trying to enrich the rare 235 isotope. If a sufficient amount of enriched uranium could be produced, without any doubt an explosive uranium device could be built. They knew that they were not the only ones who tried to enrich the uranium isotope 235, Dr. Harteck in Hamburg and Dr. Clusius in Munich worked on the same problem. They devised a new principle of isotope separation, the countercurrent ultra centrifuge and planned to use this device to concentrate the 235 uranium in gaseous UF_6 (uranium hexaflouride). They knew that under the wartime conditions in Germany, it would be impossible to build a big isotope separation plant, so they did not worry about the consequences of having the bomb. But they were much interested to see whether in principle a large-scale isotope enrichment would be technically possible. The computations which his associate Dr. Lyons made looked very promising. Design of a first experimental countercurrent ultra centrifuge was completed and machining of the parts of the device had begun, when circumstances forced Bombke to quit his work.

"I had, with the best intention and in the naive enthusiasm of a young man not experienced in the subtleties of diplomacy, in order to get better service and more support, stepped on some of my superiors' feet and also bypassed them in dealing with higher echelons, so I was forced to leave. I was thereafter first for a while with the Ammunition Department of Minister Speer's Ministery, where the emphasis was on developing antitank rockets. However German Intelligence began to learn of Scientific wonders being accomplished in the area of microwaves and I was directed to work in this area. This latter work was the reason that I could, after the war, come to the USA. After the war, I had written a book ("Theory of Propagation of Microwaves in Waveguides"), which made me known to the people in Ft. Monmouth who had me brought to this country and hired me as a research scientist. My centrifuge work died with my departure from Miersdorf. My friend Th. Schmidt left with me. I brought him later to my group in Oberpfaffenhofen. Dr. Lyons died and Dr. Flugge turned to other research activities. It gave me, however, a little pleasure to learn some years later that both in Germany and in the USA, experiments with countercurrent ultra centrifuges were being conducted, since the method seems to be more cost efficent than the diffusion method presently used for uranium isotope enrichment."

In contrast to the Germans' fragmented research and lack of coordination, the United States had consolidated all nuclear research in the Manhattan project and produced, in half the time estimated by the Germans, a nuclear bomb. Perhaps the most important lesson learned from the German experience was the German military's lack of enthusiasm for a long range project. A secondary lesson to be learned was that the publication of research reports in open scientific literature was the single most important fact in alerting U.S. physicists and getting the United States Manhattan project started.

Returning in time to 1936, the German Army had begun building up its Armored Force. In 1936, the Panzer Kampfwagen IV had come into service in the German army. The early versions were armed with a short-barreled 75-mm. gun designed to bombard many positions at long range because it was believed at the time that enemy tanks could be countered by the weapons of lighter vehicles. The Panzer IV had a crew of five men, weighed 24.5 tons, traveled at a speed of 25 m.p.h. (40 k.p.h.) on roads and at its maximum point had 50-mm. of armor plate. At the same time the Germans were developing this tank, they were also developing new tactics which have been termed blitzkrieg or lightning war. The Russians were also developing tanks, but at the time very little was known of Russian developments. In 1940, the German army rolled into France and very quickly took control. However, in the process the Germans encountered the heavily armed British and French "infantry tanks" and quickly realized that the Panzer IV required a more effective gun. Work on up-gunning the Panzer IV was begun immediately but was not considered urgent until Germany invaded Russia in 1941 as previously mentioned.

After the German-Soviet alliance of 1939, Soviet delegations visited German armament factories and examined the latest in German weapons. In spring 1941, a team headed by I.F. Tevosian visited German tank factories producing the most modern designs, including the PzKpfw IV. The Germans hoped that this confident display of military strength would intimidate the Russians, much as it had the earlier U.S. delegation led by Charles Lindbergh. The Germans were taken aback when the Soviets bitterly asked why they had not been allowed to see any heavy tanks or anything more modern than the PzKpfw IV. The Werhmacht attributed this outburst to the usual Russian suspiciousness. Col. Kinzel, head of the Intelligence section responsible for monitoring Soviet weapons development, assured his colleagues that while there were Finnish reports of a curious multi-turreted tank being knocked out during the 1940 war, it was nothing more than a derivative of the antiquated T-35, and certainly nothing to be afraid of. A month later, Operation "Barbarossa" confirmed the inadequacies of German Intelligence: reports, which verged on panic, spoke of the massive 50-ton tanks impervious to the fire of the PzKpfw IV, tanks which mockingly defied the Wehremacht's 37mm antitank gun by grinding it beneath its tracks. The Wehrmacht had just encountered the KV heavy tank, probably the most feared weapon in the Russian arsenal of 1941.

Operation Barbarossa, the German invasion of Russia, began on 22 June 1941. Based on erroneous intelligence estimates of the Russian army, the plan called for a five month campaign whose objective was the destruction of the Red army in the west to prevent its withdrawal into the interior, then to pursue the retreating Russians to the Volga River along three axes. The German campaign in Russia went well in early 1941 as did their campaign in Africa. As German forces advanced east in the summer of 1941, elated with victory, they began to detect ominious signs. Little by little, they were confronted by the partisan guerilla tactics of the Russian people and the new Russian T34 tank, as well as the KV Heavy Tanks. These ominious signs illustrated by official reports and communications sent in rapid succession from field forces which said that German weapons, then in actual use, had already become outdated. Periodical Report No. 156 from the Tactical Staff of the Third Tank Division discussed the toughness of the T34's armor as follows:

> "We had Second Lieutenant Steup shoot a T34 tank with his 50-mm. tank gun. One time at a distance of 20 meters and four times at a distance of 50 meters. As a result, we have found that even the armor piercing shell Model 40 is not effective at all against the T34. This is really worth noticing."

This report meant that even the 50-mm. antitank gun Model 38 -- the best antitank gun then used by German tank troops and antitank gun troops -- was no match for Russian main tanks. The German army ordered the Ordnance Bureau to develop new antitank weapons in haste and at the same time studied how to fill up immediate needs. It was necessary to help infantry divisions antitank gun battalions, then equipped mainly with 37-mm. antitank guns, out of their miserable condition.

On the other side of the world Col. Skinner, recalled from Hawaii in November 1940 to conduct Ordnance liaison with the National Defense Research Council Rocket Group, suggested that the M10 grenade could better be fired by rocket means and outlined the over-the-shoulder launcher. At Indian Head Col. Skinner in cooperation with Dr. Clarance Hickman of Bell Telephone Laboratories and Lt. Ed Uhl developed the 2.36" rocket launcher as well as anti-aircraft target rockets and the 4.5" aircraft rocket.

In the spring of 1942 Skinner decided to try and combine the M-10 grenade with his shoulder-launcher. He redesigned his prototype to accept the M-10 and arrived at an internal diameter of 2.36" which was large enough to allow the grenade to move without jamming. A piece of tube was made to this specification and fitted with two hand grips and an electrical firing mechanism using dry cell batteries. A dozen rockets were made up with dummy heads and three were fired successfully. With the remaining nine Skinner went to Aberdeen Proving Ground to try his idea on a proper range. To his surprise a demonstration was in progress involving a tank being used as a target for some other launching devices for the M-10 grenade. It was an auspicious moment and Skinner and his assistant, Lieutenant Uhl, took post at the end of the line without bothering to tell anyone who they were. The story is best told in Skinner's own words:

> "It happened that the target tank came up our way to make a turn, and we decided to fire at it. Uhl devised a makeshift sight for the launcher on the spot with a piece of wire he picked off the ground. He hit the tank with his first shot. Then, before it could complete its turn, I hit it with another rocket. By then, partly due to the unfamiliar noise of the rocket blast, the whole multi-starred audience was headed our way. General Barnes (Major-General Barnes of Ground Forces Development) took a shot and made a hit. The other staff people fired until all our rounds were gone. Right there and then the Bazooka was ordered into pilot production design and very shortly after, even before statistical test, into full production."

It was a momentous decision, and a correct one. On 19 May 1942, the Ordnance Corps contracted with the General Electric Company to make 5,000 Bazookas in thirty days. There was then another demonstration firing, this time rather more formally arranged, and scores of high-ranking officers and Allied Representatives watched. This is probably the point at which the Soviets first learned of the weapon because they asked for it immediately afterwards and several hundred of the first production batch were sent to Russia where they were straightaway committed to battle and captured by the Germans. Another large production order followed this second demonstration and most of it went direct from the factories to ships loading for the North Africa invasion. Some were actually flown to the ports to catch the ships before they sailed, and for 1942 this was pretty remarkable. The result was that the first troops to take the Bazooka into action did so with very little training, but even so they performed amazingly well. One of the first combat reports from North Africa told of a detachment of German tanks which surrendered after several rockets scored near misses at extreme range (obviously the gunners were nervous and firing too soon). On being interrogated the tank commander told his captors that he thought himself to be under fire from 105-mm howitzers and as a result it was foolish to go on fighting. The Germans called it at first the 'shoulder 75-mm'. The GIs were more prosaic and dubbed it 'the Buck Roger's gun' until some genius jokingly referred to the awkward tube as a 'Bazooka', after the name given to a homemade trombone played by the radio comedian of the era, one Bob Burns. The name stuck and became famous.

Prior to their capture of American-made rocket launchers and as an interim measure, the German army took captured Russian 76.2-mm. multi-purpose field guns and mounted them on the open top chassis of the now obsolete Pzkpfw II Version D and E. This was called the Marder II Tank Destroyer, and 150 were manufactured during the period December 1941 to June 1942. At the same time, efforts to develop a 75-mm. antitank gun continued and these were mounted on the open top chassis of the Pzkpfw II Versions A, B, C and F. This weapon was also designated a Marder II. Production of these anti-tank guns began in June of 1942 and continued until February 1943 when Adolph Hitler halted production to concentrate efforts on the development of a self-propelled howitzer to be called Wespe. A total of 531 75-mm. Marder II's were produced.

David Kahn, in his book "HITLERS SPIES" discussed briefly two of the more important sources of information for German Intelligence that were recovered by the combat units, documents and captured material. In the area of captured material, the Germans inspected and ran a captured U.S. Sherman tank at their tank testing area at the Berlin suburb of Kummersdorf to see both its weak points, enabling troops to know where to cripple it, and its strong points, helping German industry to improve its own armored vehicles. In 1942 Hitler ordered a gunfire test against the Russian T-34 tank. Foreign Armies West reported in September 1943, "A hitherto unknown apparently English mine has been captured in Russia." Its description -- diameter and height 20 inches, tapering to a point that is stuck in the ground, seemingly 11 smaller mines inside -- helped German troops to recognize and so avoid or destroy it.

The Luftwaffe enjoyed especially favorable conditions for obtaining enemy equipment: aircraft often crashed or landed within the Reich or occupied territories. Badly damaged ones the Luftwaffe examined on the spot. A week after a Russian TB-7 belly-landed in East Prussia, Luftwaffe chief expected a report that, on the basis of an analysis of the parts, would provide even such details as the plane's range. With other planes, the Luftwaffe often expended considerable effort to get them flying. When a Stirling bomber emergency-landed in Holland, the Luftwaffe built a runway, filling in several trenches to do so, delivered a new motor to replace the one that was damaged, and flew the plane off to a research station at Rechlin, north of Berlin. It was the first of this important English four-motored model to fall into German hands in impeccable condition with all its equipment. Norden bomb sights, found in fallen bombers, were cleaned, repaired, and examined. German experts regarded them as one of the factors of American bombing accuracy. Captured and repaired Allied fighters were flown to German airfields, where pilots flew them to gain a better feel for how these enemy planes handled.

This captured material came under the control of Colonel-Engineer Dietrich H. Schwenke, in charge of technical intelligence under Field Marshal Erhard Milch, the head of air armament. Schwenke was a smart, tough pilot with an engineering background and lots of foreign experience: he had served as an assistant air attache in Britain and had toured Soviet air plants just before the German attack. During the French campaign of 1940, he systematized the collection of captured enemy airplanes, sending them to the booty center he created at Rechlin. Eventually Schwenke had 200 Russian prisoners of war cutting the aircraft apart so his experts could analyze them in detail. He issued the results in reports to the troops and Foreign Air Forces and in oral presentations at conferences with Milch, other high Luftwaffe officials from Goring on down, and German manufacturers.

The Germans seemed to be especially interested in the Boeing B-17, the Flying Fortress. In August 1942, one of the first crashed on the eastern front. The Luftwaffe sent in a team of men to get it out. But it lay under artillery fire too near the Russian lines, gradually disintegrating, and despite an eight-day attempt, the team could not salvage it. A few weeks later, however, the Germans succeeded in examining another shot down. It showed by its equipment that the Americans were shifting to daylight bombing. Schwenke himself piloted one and found that it flew "extraordinarily easily. You can talk normally in the cockpit with the co-pilot." A comparison of the B-17 F with the earlier B-17 C showed that the later model carried a ton and a half more armor. This, and the fact that German fighters had fired long bursts at these planes without any apparent effect, led to a discussion at one of the air-armament conferences about how best to bring down this and other bombers. Here Schwenke's careful examinations came into their own.

"If I may show this," he said, "here is a presentation that

I've had made on the various installations of the [fuel] tanks in the six four-motored models that are present in England and in the U.S.A. and in a Russian." Milch picked this up. One promising form of air attack, he said, is: "Where are the tanks? Here you can say: in the four-motored airplanes, between the two motors. Only the [American B024] Liberator has nothing there."

Milch also wanted to know which munition would pierce the B-17's armor. Schwenke explained that "According to experience so far, with the larger calibers the inertia of the shot is greater, the deflection possibility lesser. The greater the caliber, the greater the probability that no ricochets will occur but that it will go through. What are the calibers?, Milch persisted. Will two centimeters [1 inch] punch through? Not always, but two centimeters is pretty good. Three centimeters [1 1/2 inches] seems to me to be always more substantial and better," Milch said. "I would propose that, when we have enough armor plates, we have them shot at in Rechlin with various kinds of munition and invite the general of fighter planes and men whom he suggests, doing this at various angles of fire. We'll get the original armor plates from the Tommies and from the Americans!"

In the 6th Army area in February 1945, captured weapons revealed that the Russian IVth Guard Mechanized Corps used animals as insignia -- a deer for the 13th Brigade, a horse for the 14th, an elephant for the 15th. This and other information helped the Germans determine the number of enemy formations opposite them and to identify many that had been shifted there from distant portions of the front. Analysis of the serial numbers of the weapons disclosed enemy formations, estimated the rate of replacements, suggested the refitting time of a unit, specified where and when the weapon had been produced, and computed the likely production volume. And many times, the weapons themselves provided some of the most valuable intelligence of all.

The analysis of these weapons allowed the Germans to quickly learn the vulnerabilities of the weapons and where to aim for the most effective penetration. This information was quickly transmitted to the combat troops. Sometimes this information was prepared by Division intelligence officers in little more than hand drawn sketches as shown on the next page, or in more formal printed charts such as the one on the opposite page.

Most of the German research and development on weapons was coordinated by General (Dr. Phd.) Walter Dornberger. In his 1954 book, "V2", he pointed out in Chapter 10 that the situation in the air went from bad to worse. An incessant stream of bombers roared over Germany day and night. German successes in defense meant relatively less and less. It could only be a question of time before all German cities, factories, and centers of communication lay in ruins.

Every time a bomber formation roared overhead, Dornberger was seized with impotent rage at the shortsightedness shown from the outbreak of war by those responsible for air armaments, and at the utter inability to realize the weakness of German industrial war potential compared with that of the United States.

"How many things we had tried to develop and introduce! As early as 1939 von Braun had designed a rocket interceptor capable of rising to a height of 35,000 feet in 60 seconds, to be vertically launched, piloted, and remote-controlled until it reached the level of the bomber formation to be attacked." Dornberger remarked that he could still see the disdainful smiles on the faces of the Air Ministry officials when the proposal was finally rejected in the autumn of 1941.

"Our fighters will look after air defense!" That had settled it. Even then he knew that the time was not far off when they would be crying out for these weapons and want them all to be ready in five minutes.

The same shortsightedness had also prevented the final development and mass production of a German antitank rocket that could be operated by a single man. In February 1942, after the first big setbacks in Russia, Dornberger had proposed such a weapon. They had carried out the necessary tests with rocket projectiles carrying shaped charges. All that was needed to manufacture hundreds of thousands of these cheap weapons was the approval of the Infantry

Board. The Infantry Board rejected the idea. They declared it impossible to equip front-line infantry with a rocket weapon because it would instantly be spotted and put out of action. It was not until the American bazooka proved itself conclusively on the Tunisian front that hesitation was thrown to the winds and the Panzerschreck and Panzerfaust were hastily developed.

Several books have been written in which the means by which the Germans learned about the 2.36 inch rocket launcher were discussed, however, the most thorough description of the entire process was in David Kahn's book, "HITLERS SPIES." In discussing the rocket launcher episode, Kahn stated that in North Africa in January 1943, the intelligence officer of the 10^{th} Panzer Division reported on a "new American anti-tank weapon." The information was commissioned, he said, on the 15^{th} from a captured American non-commissioned officer. According to the prisoner, American forces in the prisoner's sector had first used it in December 1942 in the battle for Hill 295 north of Madjez el Bab. "It apparently is a rocket gun, which can be fired by individual riflemen and reportedly has an enormous armor-breaking force. The weapon consists of a thin, light steel tube about 1.20 meters long and 8 centimeters diameter," the Ic wrote, and not only described it in detail, but sketched it as well. It was the bazooka, and this prisoner's information gave Germany some of its earliest news about this surprising and powerful American weapon.

Each division normally made five copies of each of the interrogation results. It retained one and passed the others up. Corps and army each got one; army group two. The thorough interrogation at division practically obviated the need for further tactical questioning. Corps headquarters seldom interrogated. Army headquarters largely limited itself to prisoners of particular importance, such as high-ranking commanders, general staff officers, and specialists. The army I c himself often particiated in these interrogations. Because of the far superior linquistic abilities of interpreters at this level, plus the much fuller information it could bring to bear in the questioning, the reliability of prisoner-of-war intelligence at army headquarters jumped to 90 percent. Army groups received and evaluated this intelligence, generally doing little interrogation of its own.

In France, however, the commander in chief west, who had two army groups under him, set up, after the invasion, an interrogation station at Chalons-sur-Marne. Its capacity was 6,000 prisoners, but in the first days of July 1944 it held only some 400. Prisoners were isolated in one of its 30 individual cells during their interrogations. Interrogators on the staff of his I c questioned them first on military and tactical matters. Sergeant Arnold F. C_____, a farmer, 34 years old, captured near Aachen on 12 October, detailed the equipment of his 9^{th} Reconnaissance Troop, 9^{th} Infantry Division: five officers, about 150men, two half-tracks, two jeeps, one 2-1/2 ton truck, a 1st Platoon with nine jeeps, three .30 caliber machine guns, three 2-inch mortars, three bazookas, and so on for the other platoons.

Prisoners with special knowledge were then made available to the specialist interrogators: two from the Foreign Office and two from RSHA VI Wi, the economic-intelligence element of party foreign intelligence. After the Allied advance compelled the removal of the Chalons camp, the commander in chief west set up at Diez, near Koblenz, a special interrogation group of 36 men -- 10 for administration and evaluation, 12 interpreters, and 14 guards.

Above this level, Foreign Armies East and West created their own interrogation units to obtain information of particular use to themselves. Foreign Armies East's Deck III a had a small interrogation camp for some 80 important prisoners, such as higher officers or officers reduced in rank, first near Lotzen (now Gizycko, Poland), in East Prussia near Fuhrer headquarters, then at Luckenwalde, near Berlin. In December 1944, its staff of 8 Germans and 19 Russians conducted 63 interrogations. Some of the prisoners wrote detailed reports on subjects about which they were knowledgeable and on which the Germans wanted information. Major Senikev produced a table of organization for a rifle replacement regiment and a list of intelligence personnel. Corporal Borodin described the medical services and training in the Red Army.

Foreign Armies West preferred mobile teams. Such a team submitted a report on the morale of British soldiers in Tunisia in 1943. Another, named Kommando Fritz, produced information on operations of the U.S. Office of Strategic Services. It questioned First Lietuenant Peter S_____ of the O.S.S. about his mission to spring Allied prisoners from German camps in Italy. S_____, a 32 year old Newark tree surgeon, parachuted with a small team into the Gran Sasso area 2 October 1943 carrying, in addition to a U.S. first lieutenant's insignia, a false identity card, two rolls of cigarette paper (which the Germans tested for secret ink), and tens of thousands of lire. He and his men were to lead the prisoners to the Adriatic coast. But they never found a single camp, and at the end of October S_____ ordered his group to break up and pass individually back through the lines. He himself lived for six months in the mountains, sleeping in huts and eating bread and potatoes, until German soldiers captured him on 16 April 1944 on the road toward Bisenti. In addition to Kommando Fritz, three mobile interrogation teams questioned Allied soldiers early in the Normandy invasion in a holding stockade at Alencon. By December of 1944, there were four such teams, each immediately subordinated to the chief of Foreign Armies West, operating in the western theater, each assigned to an army headquarters.

By December 1944, as hindsight reveals, the War in Europe was practically over, although the fighting had not stopped, as many who served in Europe will attest to. The impact, however of technical intelligence analysis of captured material and its use for development of newer weapons was over, both for the Germans and the allies.

Within a few months, Germany surrendered and both the Russians and the Americans were able to gain access to many of the research and development projects as well as weapons that were in their formative stages. In addition, the evacuation of many captured weapons and documents provided an archive of information on German production methods.

The Russians made extensive use of this source of information while the Americans neglected it for many years, concentrating their limited defense funds on weapons of strategic value.

The Russians, who during much of 1941 had been forced back, made many changes in many areas. As their industrial base was relocated further into the Russian interior, they became very dependent upon lend-lease supplies from the allies. Wheeled vehicles kept their supply lines open. Many unusual antitank weapons were developed to include mine-dogs. These were dogs which were trained to eat under a tank. After training, they were equipped with a high explosive vest and a detonation device which would cause the charge to go off once the dog had gotten under a German tank. Unfortunately once in combat, the Germans used machine gun fire to frighten the dogs and they ended up running back and hiding under and destroying Russian tanks!

Writing in the 1943 first edition of Small Arms of the World then called, "Basic Manual of Military Small Arms", W. H. B. Smith included three photographs received from Europe, "proof that the Germans are in possession of Bazooka's," the popular name for the 2.36" launcher. The Russians, based on combat experience, also began to make changes in their equipment. Most notably,the 76-mm. T34/76 was up-gunned to an 85-mm. gun. This new tank was designated T34/85 and had other changes besides the new gun to include better armor.

In July 1943, Russian and German tanks engaged in combat in the vicinity of Kursk in what was the largest tank battle of the century as was discussed in Chapter I. Although it would not become apparent for many years, the winter of 1942-43 marked the turning point in WW II. In Europe, the Russians had turned the tide of battle in the East and allied efforts in North Africa had forced a German withdrawal. Although there would still be several more years of combat before the eventual surrender of Germany, the fortunes of war were changing for the Nazis. This was not readily apparent to the Germans who were still engaged in combat and were forced to counter the threat posed by the new Soviet tanks. Many of Germany's scientists who had been working on the development of nuclear fission were diverted from their research. As previously mentioned, Dr. Bombke, who had been working on a form of enriched U-235 was directed to concentrate his efforts more on items of a "practical military nature."

Of the many antitank weapons developed by the Germans toward the end of the war, the 75-mm. HL gun projectile, the Panzerfaust and the hand thrown Panzerwurfmine were the most important. In addition, an 8.8-cm. (3.5") antitank rocket launcher was developed and fielded in late 1943. It was almost a copy of the U.S. 2.36" rocket launcher. In addition, the Germans also developed a complete series of "Panzerfaust" (tank fist) weapons. A Panzerfaust (Klein) 30-m., a Panzerfaust 60-m., and a Panzerfaust 100-m. These weapons were basically a throwaway tube which launched a shaped charge that was rocket propelled. The rocket had spring steel leaves which were wrapped around the tail and held in place in the launcher until firing when they sprang out to guide the rocket. The Panzerfaust could penetrate 200-mm. of armor sloped at 30° which meant that every allied tank was vulnerable. The whole Panzerfaust weapon series was designed for use after a minimum of training and experience. Instructions were printed on the bomb body so that anyone finding one in a battle area who had not been trained in its use could still fire it with some effect. The whole system was robust and portable but was extremely sensitive to moisture. Any moisture which penetrated could cause misfires or partial firing causing the rocket to fall short. Fuses also became a problem that caused malfunctions and premature firing. Tests were developed to determine the reliability of the fuse. The tester had to shake the fuse and any that rattled were not used. Another test involved dropping the round onto a hard surface from a height of about 50-cm. This was not a popular task as many of them went off injuring the tester. The problems that developed with these weapons led to the development of the Panzerfaust 150 by January 1945 and 100,000 were produced, but few, if any, reached the field.

Of no immediate value to the tank/antitank weapon system development was the development of the V1 and V2 rockets. These weapon development programs were not without their problems. General Dornberger, head of German rocket research pointed out that in the spring of 1930, after finishing his technical studies, he was appointed to the Ballistics Branch of the Army Weapons Department as assistant to Captain von Horstig. This branch, to which problems of rocket development had been transferred in 1929, was confronted at first by a muddle difficult to straighten out. Neither industry nor the technical colleges were paying any attention to the development of high-powered rocket propulsion. There were only individual inventors who played about without financial support, assisted by more or less able collaborators. They were forced to resort to publicity demonstrations and to write exaggerated newspaper articles to earn a living. This behavior naturally led to opposition by college professors and accredited scientists. Moreover, each individual inventor maintained a feud with everyone else who took an interest in rockets. Until 1932, no solid scientific research or development work was done in this field in Germany. It was not, for instance, possible before the middle of 1932 to obtain from the Raketenflugplatz, which was the name of the proving ground of the Society for Space Travel (VfR) in a northern suburb of Berlin, any sort of records showing performance and fuel consumption during experiments.

The Army Weapons Department was forced to get in touch with the individual inventors, support them financially, and await results. For two years the department tried in vain to obtain something to go on. No progress was being made in the work. There was also the danger that thoughtless chatter might result in the department's becoming known as the financial backer of rocket development. They had therefore to take other steps.

As they did not succeed in interesting heavy industry there was nothing left to do but to set up their own experimental station for liquid-propellant rockets at the department's proving ground in Kummersdorf near Berlin. They wanted to have done once and for all with theory, unproved claims, and boastful fantasy, and to arrive at conclusions based on a sound scientific foundation. They were tired of imaginative projects concerning space travel. The value of the sixth decimal place in the calculation of a trajectory to Venus interested them as little as the problem of heating and air regeneration in the pressurized cabin of a Mars ship. They wanted to advance the practice of rocket building with scientific thoroughness. They wanted thrust-time curves of the performance of rocket motors. They wanted to know what fuel consumption per second to allow for, what fuel mixture would be best, how to deal with the temperatures occurring in the process, what types of injection, combustion-chamber shape, and exhaust nozzle would yield the best performance. They intended to establish the fundamentals, create the necessary tools, and study the basic conditions. First and foremost came the propulsion unit.

It was not easy for Dornberger to get his young collaborators away from their space dreams and make them settle down quietly to hard research and development work. They began with the development of a rocket motor with a thrust of 650 pounds. They meant to bring this motor to a high level of performance, to gather experience, tabulate laws and principles, and so create a basis for further construction.

The Experimental Station West was situated between the two Kummersdorf firing ranges, about 17 miles south of Berlin, in a clearing in the open pine forest of the province of Brandenburg. To the already existing test stand for powder rockets were added the first two buildings for the new venture and then the first test stand ever established in Germany for liquid-propellant rocket development, which was fully equipped with all available resources of measurement technique. They improvised offices, a designing room, measurement rooms, darkrooms, and a tiny workshop. They drew up their first schedule of work in discussions that lasted for hours. In the months that followed, everyone was bent over a drawing board or busy at a lathe. There were delays from week to week and from day to day, but at last they were ready. The first firing test could take place.

The test stand was contained in a structure of three concrete walls, 18 feet long and 12 feet high, which were arranged in the form of a U, the place of a fourth wall being taken by folding metal doors. There was a sliding wooden roof covered with tarpaper, which could be moved on rollers by means of a small winch.

When doors and roof were both closed, the effect was of a big weatherproof testing room. In the back wall were a number of holes leading to an observation or measurement chamber. This mysterious room contained an incredible chaos of blue, red, green, and yellow pipes for measuring, feeding, and testing propellants and high-pressure nitrogen, in addition to valves, meters, and recording apparatus. This apparent confusion was at first bewildering. The experts of course considered it all very simple.

At the corners of the back wall there were two openings at eye level, fitted with mirrors to enable the testing staff to observe the rocket motor. In the middle of the same wall were two iron handwheels, their shafts leading through the wall to valves. The place was full of switches, little valve handwheels, reducing valves, three-way cocks, electrical instruments, clocks, and rows of meters and other gadgets connected with the fuel tanks and to critical points of the combustion chamber that needed careful watching.

They sought data on flow rates, pressures, and so forth, throughout the system, in the tanks, pipe conduits, cooling jackets, and at many points in the combustion chamber, for we had to ascertain temperatures and gradients to discover the best fuel-mixture ratio and to measure thrust performance. When the roof above the test stand was pushed back, the doors were wide open and one could see the test frame in the middle of the testing room, with the pear-shaped, silver-gray rocket motor, made of duraluminum, about 20 inches long. It was mounted vertically with the exhaust nozzle downward. Around the chamber were arranged four tubes. These would convey the power of the exhaust blast to a spring connected by thin steel wires running on rollers to a thrust-measuring instrument in the observation room. The combustion chamber, with its round head and tapering exhaust nozzle, was calculated to develop a thrust of 650 pounds.

On the right-hand side of the measuring room a big, spherical, ice-covered aluminum container with liquid ozygen was suspended from springs. The connecting pipes leading to the rocket motor were frosted too. Ice mist rose from them. A similar container for 75-percent ethyl alcohol hung on the left-hand side. The alcohol conduit forked into two branches, each connected to the bulbous edge of the exhaust nozzle. Thin piano wires from the tanks led over rollers through the concrete wall to instruments that would trace the graphs of fuel consumption during firing.

The rocket motor itself had double walls. Between them rose cooling alcohol at a high rate of flow from bottom to top. The alcohol, warmed to 158 degrees Fahrenheit, entered the inner chamber through small sievelike injection nozzles in the chamber head. It was met there by liquid oxygen ejected from a centrally placed brass sprayer, shaped like an inverted mushroom and perforated with many small holes. These jets, with an injection pressure of several atmospheres, collided with great force, were atomized and mixed, to increase the rapidity of combustion.

Under the nozzle a black opening yawned in the iron-plated floor to receive the blast. A blast deflector lined with firebricks would split the jet and divert it right and left at an angle of 90 degrees through brick-lined channels into two tall vertical shafts at the outer wall of the building, and so to the open air.

In the control room, the engineer, Walter Riedel, stood on a narrow wooden grating, grasping two big steering wheels. When pressure was right in the spherical containers, a turn of the wheels would open the two main valves and let the propellants into the combustion chamber. Riedel's eyes were on the meters. Beside him the mechanic, Grunow, was regulating the flow of nitrogen from the pressure flasks into the tanks by handwheels controlling the reducing valves. He kept his eyes fixed on the quivering needles of the gauges showing tank pressures.

At the main door of the test stand, von Braun, very cold, was stamping his feet. He was holding a rod 12 feet long with a can of gasoline fastened to the end. Riedel called out from behind the wall that pressure was now correct, and von Braun lit his gigantic match and held the flame under the exhaust nozzle. Suddenly a round white cloud appeared under the exhaust nozzle and sank slowly to the ground. A clear liquid, alcohol, came trickling after it. Riedel opened the valves and von Braun moved his rod to bring the flame into contact with the fumes. These was a swoosh, a hiss, and -- crash! Clouds of smoke rose. A single flame darted briefly upwardly and vanished. Cables, boards, metal sheeting, fragments of steel and aluminum flew whistling through the air. The searchlights went out. Silence. In the suddenly darkened pit of the test room a milky, slimy mixture of alcohol and oxygen burned spasmodically with flames of different shapes and sizes, occasionally crackling and detonating like fireworks. Steam hissed. Cables were on fire in a hundred places. Thick, black, stinging fumes of burning rubber filled the air. Von Braun and Dornberger stared at each other wide-eyed. They were uninjured. The test stand had been wrecked. Steel girders and pillars were bent and twisted. The metal doors had been torn off their hinges. Immediately above our heads sharp, jagged splinters of steel were stuck in the brown bark of the trees.

General Dornberger continued by discussing some of the people who had been recruited to work in the project. Our nineteen-year-old "student," Wernher von Braun, had come to us fresh from his work on the Raketenflugplatz in Berlin Reinickendorf. That enterprise was slowly dying of chronic lack of money, so he had joined the Army Weapons Department on October 1, 1932. He now belonged to Dornberger's specialist staff. The first assistant, most enthusiastic and able, was the mechanic Heinrich Grunow. And on November 1, 1932, Dornberger had succeeded in obtaining a third man, Walter

Riedel, an engineer from the Heyland Works at Brietz near Berlin. In association with that firm in 1929 and 1930, Max Valier had been one of the first to experiment with a liquid-propellant rocket motor, which he used to drive a small racing car. Valier had met a pioneer's death there on May 17, 1930.

Three weeks after the first unlucky experiment, the first rocket motor was burning at the test stand, now rebulit. Unfortunately it burned in the literal sense of the word. It had been working flawlessly for a few seconds when a dazzling white light appeared in the bluish-red gas jet, indicating a surplus of oxygen. The light grew brighter and brighter. Aluminum was on fire. The chamber burned right through. Thus, they encountered the first cooling problem. New chambers and new injection nozzles were designed and welded together in the tiny workshop. For some weeks all went well and they made progress. Then they had setbacks again. No motor seemed to stand up any more. The pendulum swung from success to the most dismal failure, from desparation to optimism. After months of work they hit on a form of 650-pound-thrust chamber that gave consistent performance. But it was still a very bad one. It had an exhaust velocity of 5,570 feet per second. They measured the flame temperature, took samples of the gas jet, analyzed the gases, changed the mixture ratio, and still couldn't get more than 5,900 and 6,200 feet per second. They then tried different propellants. In 1931, they had given Heyland's an order to develop a small liquid-propellant rocket motor for basic experiments. It had a thrust of 45 pounds, was double-walled for cooling, cylindrical in shape, and made of steel. It was now handed over to the Research Branch of the Army Weapons Department for basic research and experiments with different propellant mixtures. Dr. Wahmke, in charge of experimental work, Voellmecke, chief pyrotechnician, and some students from the Research Branch conducted these tests in a small test stand hastily improvised near the old one out of boards and planks sheathed with armor plate.

In March 1934, Dr. Wahmke decided to mix the two fuels in a steel tank, feed them into the rocket chamber through a single valve, and then ignite. He was well aware of the risk he was taking; no safeguards had been installed in the pipe leading from the tank suspended just above the motor. He was obsessed with the idea of finding out whether there was any danger in using propellants already mixed before combustion. Then he told his colleagues to leave the stand. They refused to do so, and all smoked cigarettes. At last they fired the chamber. The little ignition explosion in the chamber ran through the conduit to the tank. When help came a few minutes later, nothing was left of the test stand except the lead pipe of the the water supply. Of the four who had shared the experiment, three were dead, including Dr. Wahmke. They were the first but also the last to give their lives in the course of rocket development under the Army Weapons Department.

In those first years, in addition to the department, an immense number of individual inventors were busy on rocket problems. Most of them came and offered their ideas. It was Dr. Dornberger and his staff's job to separate the wheat from the chaff, and that was no small task in a sphere of activity so beset with humbugs, charlatans, and scientific cranks, and so sparsely populated with men of real ability.

An engineer named Pietsch, formerly employed at the Heyland Works, offered the Army Weapons Department a fully automatic liquid-propellant motor with a thrust of 650 pounds and a burning period of 60 seconds. His proposal was checked and found to be practicable. He was given advances for materials and received repeated subsidies. One day he disappeared, leaving behind a colleague, one Arthur Rudolph, a lean, starved-looking engineer with reddish-blond hair. Rudolph turned out to be the real inventor of the motor. They invested more money in the affair and helped him with their own facilities, and after a few weeks he demonstrated his motor to them at Kummersdorf. It was made entirely of copper, with the oxygen tank above and the alcohol tank, enclosing and cooling the combustion chamber, below. The tanks were spherical in shape. The specifications were met. They found they could use Rudolph and took him into their organization, where he became one of their top experts.

By 1934, Dr. Dornberger and his small staff had created at Kummersdorf the best testing equipment and testing methods for both solid- and liquid-propellant rockets. Inventors who traded on the presumed ignorance of the department and the difficulty of investigating their claims, and made exaggerated and fantastic ones, were quickly exposed. But from among the many who came with rocket ideas, they did get some outstanding men. The work went on and they designed all sorts of injection systems and tried them out, without any improvement in performance. The ratio between fuel consumption and thrust was not changed either. But at least they managed to avoid burning out the chamber and setting the injection nozzles on fire, and could now carry out as many as three or four test firings of the same motor, obtaining uniform performance each time. Thus after a very hard year's work they had laid a frail foundation on which they could build. Their need now was for higher authority to give their work due recognition and to provide them with money -- a great deal of money -- and with the staff for carrying on. But first they had to provide conclusive evidence that a liquid-propellant rocket could hold to its prescribed trajectory.

Only then did they begin to give any serious consideration to all the problems involved in making the projectile fly. They had experience with powder rockets only and knew the difficulties of stabilization, how such a projectile could be affected by wind, angle of launching, the shift of the center of gravity as the propellant was consumed, and other adverse factors. However, they finally decided to plan the first complete missile, Aggregate 1 (A-1).

They aimed at a high-speed rocket. They did not intend, as the Berlin Raketenflugplatz had, to build a nose-drive rocket; in other words, to put the motor in front so that the exhaust surrounded and warmed the fuel tanks mounted behind. The 650-pound-thrust motor either would have burst the tanks in a few seconds or else would have had to be mounted too far forward for any kind of stability. Air resistance, too, would have been considerably higher.

They designed the A-1. The rotating section, weighing 85 pounds, was placed at the nose of the missle, which was about 4.6 feet long and 1 foot in diameter. Approximately 85 pounds of propellants were to be forced by nitrogen pressure from the tanks into the combustion chamber, which developed a thrust of some 650 pounds and was built into the fuel tank at the rear of the rocket. The rotating section, made to form the rotor of a three-phase current motor, was to be brought up to its highest speed before launching. The A-1 would be fired vertically from a launching rack several yards high. With a take-off weight of about 330 pounds, initial acceleration would be practically equal to the ordinary acceleration due to gravity at the earth's surface -- that is, to 1 g.

The motor was constructed and, after breaking down a few times, worked perfectly. But before the outward shape of the A-1 was finished it was decided to go on at once to the next stage in the development of the rocket motor. Shortly afterward they had ready the first design for a new motor, made of duraluminum, with a thrust of 2,200 pounds. They meant to build bigger rockets, but it was important to find out whether their experience so far was valid for them too.

The one and only test stand was by now inadequate. It was fully occupied with trials of the 650-pound motor. In 1934, they built a new test stand for high-performance motors, incorporating the results of experience to date. They were planning a third stand for tests with complete rockets.

At the same time they were busy with a whole series of other important problems, for instance, stabilizing the bigger rockets. Von Braun got in touch with the Kreiselgerate G.m.b.H. (Gyroscope Company) at Brietz near Berlin. One of their directors was a former Austrian naval officer named Boykow, a tall, robust man with bright eyes in a shrewd face dominated by a tremendous nose. He was the leading spirit of the firm, an expert full of ideas and far ahead of his time in all questions relating to gyroscopes. When von Braun told Boykow what he wanted Boykow answered with a smile, "I've been expecting a call like yours for many years and I've prepared for it." It turned out that in addition to thinking about it he had already made some sample and detail models. An intimate exchange of ideas followed. This clear-thinking scientist and practical man was the best help they could have dreamed of. They learned that the point was not merely to correct deflections of the rocket's axis from that of the gyroscope but to check the tendency to deflection as it arose. Only if they initiated an immediate countermovement could they prevent a divergent trend in the oscillations. Stabilization equipment would have to be sensitive to acceleration. They thus gradually came to see realized their vague hope of stabilizing fair-sized rockets during the fighting period with a gyroscope system working on three axes.

The external shape of the big rocket was still quite undetermined. It was clear that it must have "arrow stability"; in other words, the center of gravity must be situated in front of the theoretical center of pressure of all the aerodynamic forces operating. In order to shift this point back, the missile would have to be provided with tail fins. According to the standard textbook, Ballistics, by Professor Cranz, relating to projectile ballistics, experience had proved that it was impossible for bodies with arrow stability to accomplish perfect flight at supersonic speeds. But supersonic speed was needed to obtain access to space. Nor was that all. They had to be prepared to go up the whole scale of speed, from zero to many times sonic velocity, with a projectile stable throughout.

The problem was to find such a configuration. No excessive air drag must take place and no excessive control forces must be required. They knew that it would be a long and difficult business and that a wind tunnel would be needed for it.

The next question was automatic stablization. Were they to use air rudders operated by servomechanisms? It would be impossible to do so at the beginning of the trajectory, for at the low take-off velocity the aerodynamic forces on the rudders would be negligible. Afterward the steady velocity increase would cause a steady change of the forces. This had to be taken into account. The power required for steering would therefore have to be varied constantly to suit changing speeds -- a serious complication.

They considered mounting the motor in gymbals, thereby obtaining the required control. It was theoretically feasible, but the motor would then have to be placed behind the tanks, and this would make the missile too long. Since motors were still very long. For the next project they provided, as before, for the motor to be placed inside the alcohol tank.

They might have developed four small steering motors arranged in the form of a cross and so steered big rockets even in empty space, but that too seemed too bold an initial step. The solution of this difficulty was a simple one that came quite of its own accord. The exhaust speed of the combustion gases was practically unchanged during the whole period of burning. Could not the control vanes be inside the gas jet? Was there any material which would resist exhaust-flame temperature throughout the burning period and which possessed such high thermal resistance that it would not melt, like butter in the sun, at an exhaust velocity of almost 6,500 feet per second?

They believed that with the A-1 they had completed the first of their tasks. After various checks and tests, however, they found that the A-1 was too nose-heavy. The center of gravity lay too far ahead of the center of pressure. The A-1 could not therefore be wholly reliable in flight. They got out a new design. The result was the A-2. So far as the motor was concerned, it was a replica of the A-1, but the gyroscope had been moved from the nose of the missile to the middle, between the oxygen and alcohol tanks. By October 1, 1934, the static tests and assembly were completed. At the beginning of December 1934, the first two A-2 liquid-propellant rockets developed by the Army were successfully fired from the island of Borkum in the North Sea. The maximum altitude reached was 1.4 miles. They had made a beginning.

By 1935, with rocket research expanding, it became obvious that additional facilities were required. By December 1935, Von Braun's attention was directed toward Peenemunde, North of Berlin on the Baltic Sea. Work continued on rockets and between 1936 and 1943 German scientists perfected two death dealing weapons, the V1 or flying bomb and the V2 or rocket, which was the brainchild of Dr. Von Braun, but munitions chiefs were frustrated by Hitler's changing demands. At Peenemunde, the experimental test station, an inter service rivalry between the Luftwaffe who was supervising the development of the V1 and the SS who were supervising the V2 program caused delays in both programs. As discussed in Chapter I, the allied underground had finally been able to infiltrate the weapon factories and submitted a constant flow of intelligence on the weapons. The British, slow to realize the implications of these weapons, had taken little action, being more concerned with other projects. Finally on August 9, 1943, the threat was recognized and they bombed the test site resulting in the death of many of Germany's best scientists. Germany moved the V2 testing ground to Poland and moved the factory to Camp Dora, a sub camp of Buchenwald hidden in the Harz Mountains. The Polish underground began efforts to recover fragments of fired missiles and finally succeeded in actually seizing two misfired rockets which they dismantled and packed off to London.

The United States, which had not officially entered WW II until the Japanese attack on Pearl Harbor in December 1941, and had spent most of 1942 gearing up its industrial production base, expanding its Army and finalizing the design of its military hardware had very little time to spare on planning beyond WW II as far as intelligence support of munitions design. Early in 1942 it became very evident that our knowledge of the capabilities of Japanese Ordnance was also very inadequate. To meet the need for more information, the Ordnance Research and Development Department's Military Intelligence Section became the Ordnance Intelligence Unit and its operations were expanded. Accelerated two week training courses in Technical Intelligence were started at Aberdeen Proving Ground. Basic Technical Intelligence Units varied in size from five officers and ten enlisted men for Europe to slightly larger units for the Far East as previously mentioned. Lt. Col. George Jarrett had been returned to the United States and made Commanding Officer of the Foreign Material Branch. All items received were reported to the Ordnance Intelligence Unit with a suggested program for test or study however there did not appear to be any system for passing these recommendations to weapons R&D centers. One of the officers assigned to this section was Lt. Rudi Nottrodt. His duties consisted of briefing new officers on German weapons.

The U.S. Army Ordnance Department, because of Technical Intelligence Reports on new German tanks, quickly saw that although the Bazooka was a marvelous invention, it was too small and would soon be out of date on the battlefield. They designed and built a bigger and more effective model which was 3.5 inches in diameter, but the War Department would have none of it and the design was shelved despite the evidence of successful firings. The Bazooka continued in service with its 3 1/2 pound rocket and its muzzle-velocity of 300 feet per second and sure enough, exactly as the Ordnance Department prophesied, by 1945 it was proving to be too small and too weak for the last versions of the German tanks. As WW II ended, further work on the 3.5" was discontinued, however, work continued on the analysis of captured German weapons. Of interest was a 1947 report prepared for the Technical Division of Picatinny Arsenal on the shaped charge warhead. An interesting experiment that had been carried out by the Germans made use of a tandem shaped charge. This would result in the second charge burning through the hole made by the first charge. Regrettably, U.S. engineers failed to recognize the opportunity that this would present and the concept laid dormant for many years. The Soviets, on the other hand, took many items of captured German material and incorporated the concepts into new equipment. They quickly recognized the potential of the Panzerfaust and fielded their own design, the RPG-2 antitank rocket and launcher. While the German weapon was a throwaway launcher, the Soviet weapon was reusable.

The main emphasis within the United States was the analysis of the captured V2 rockets and development of U.S. missile systems, and the design and development of jet aircraft. "Project Paper Clip" was the evacuation to the United States of German rocket scientists. These scientists and their background in physics were instrumental in the development of the atom bomb, long range rockets and antitank rockets. In setting American military priorities, antitank rockets received little effort or attention. Even less attention was paid to Soviet developments in this area, however, it is important in understanding future Soviet developments to understand developments in Germany and the United States during and after the war.

There was also an in-depth investigation of the Japanese arms industry. On March 13, 1946, ORDNANCE TECHNICAL INTELLIGENCE REPORT No. 19 on the subject of Research, Development and Production of Small Arms and Aircraft Armament of the Japanese Army was released. Prepared by 1st Lt. Edward B. Bruderlin and 1st Lt. Robert S. Nelson of the Ordnance Department.

This investigation was conducted under the provisions of General Order No. 9, GHQ, SCAP, dated October 1945, and G-2 Technical

Intelligence Instruction No. 1, dated 20 November 1945. These directions were supplemented by instructions from the Chief Ordnance Officer, GHQ, AFPAC (ADV).

It was the purpose of the report to present a general outline of significant features of research and development of Japanese small arms and automatic cannon during the period from shortly before and during the war. This includes some design details, the type of research carried on and the problems that occurred concerning mass production methods.

In an abstract of the report, it was pointed out that most of the progress of research and development of Japanese Small Arms was accomplished prior to World War II. Up to this time, the Japanese had maintained a constant survey of the development of small arms in foreign countries. With very few exceptions, such as the Nambu, Model 14 and Model 94 pistols, nearly all the Japanese Small Arms were closely patterned after similar weapons of other countries. For example, the action of the Model 38 and 99 rifles is similar to that of the German Mauser Rifle; the Type 92 heavy machine gun is almost an exact copy of the French Hotchkiss. Thus, it can be said that the Japanese were not especially original in their design of most of their small arms. Even at the beginning of the war the quality of their weapons was good; research was directed toward the improvement of standard weapons as well as new developments.

By accepting a lowered muzzle velocity (and chamber pressure) the muzzle flash of rifles was practically eliminated. The functioning parts of automatic weapons could also be made of lower grade materials and still operate satisfactorily.

As the war progressed, a critical situation arose in respect to an acute shortage of strategic materials and the inability to tool up for mass production. For these reasons the trend changed toward simplifying existing weapons and substituting inferior materials. Toward the end of the war with the realization that the invasion of their homeland was inevitable, the Japanese efforts became almost frantic and simple weapons for defense became the foremost projects for development. This included the crudest types of rifles and even bows and arrows and bamboo spears.

The development of aircraft armament and automatic cannon also showed very little originality. Nearly all weapons in this category were either direct or very close copies of similar weapons of foreign nations. Many of their designs were based on the Browning Machine Gun, others were patterned after the German Rheinmetall Guns and the Swedish Bofors. The major problem of the Japanese with automatic weapons was the supply of critical materials and their inability to tool up for mass production. For this reason research and development during the war was directed toward the simplification of existing weapons, the standardization of parts, and the development of substitute materials.

Other United States Government Agencies conducting investigations concerning Japanese Ordnance material and activities are listed as follows: Economic and Scientific Section, Supreme Command Allied Powers; Naval Technical Mission, Japan; Air Technical Intelligence Group; U.S. Strategic Bombing Survey; and the Japanese Anti-aircraft and Seacoast Artillery Research Board.

The information for this report was obtained both through interviews with Japanese personnel and documents written by them relative to the subject which corresponded to their work before and during World War II. The information regarding the research and development of Small Arms of the Japanese Army was presented by Lt. Col. Toshinao Maeda, Chief of the 1st Section of the 1st Army Technical Research Institute, Koganei, Tokyo. The information regarding aircraft armament was presented by Lt. Col. Eichi Okamoto, Head of machine gun development, 3rd Air Technical Laboratory, Tachikawa. Information regarding the manufacture of subject weapons was obtained on field trips to the factories covered in this report. During these trips, Japanese officials who had been in charge were present and supplied desired information.

In many cases information was supplied from memory either because the weapons themselves or the corresponding documents had been removed after the surrender, destroyed during the war by the bombing or destroyed by occupation forces. Therefore, although the general information is accurate, details concerning exact dates, et cetera, may not be exactly correct.

Because of the poor quality of Japanese weapons made in the latter stages of the war, all Japanese products were considered inferior and by comparison to German products were inferior. A good deal of Japanese weapons were captured by the Chinese and Soviets and were studied and reported on along with American weapons.

One of the more interesting antitank weapons developed by the Japanese was the lunge mine -- a suicide weapon consisting of a shaped charge mounted on a pole. The soldier was to ram the weapon against a tank. Such weapons, while interesting, provide very little information to weapon designers.

The other remaining antitank weapons that came into service during the latter stages of the war was the recoilless rifle. There was nothing new in the idea of a recoilless gun--engineers had been searching for it for centuries--but the need had become acute after the introduction of smokeless powders and the consequent drastic increase in propellant pressures. Apart from such peculiarities as elastic breech linings which a well-known American charlatan proposed--along with several other equally impractical ideas--the only solution seemed to be to put two guns together facing in opposite directions and fire them simultaneously. The recoil of one would then exactly match that of the other and so the contraption would stay still. This was so absurd that it was never considered for an instant, yet it is precisely the way that all present-day recoilless guns work, with modifications naturally. The solution was found in 1910 by an American naval commander, one Davis. He proposed to use one barrel and fire two shots in opposite directions using a single charge of powder. He thus did away with the need for two guns and two breeches. What he did was to combine the barrels into one and to put his two propellant charges back to back in the middle. It was a brilliant inspiration and it worked perfectly from the very beginning. Davis quickly overcame the problem of firing two identical shells by using a charge of buckshot at the rear. By carefully selecting the right weight, he still had no recoil and the buckshot only flew a short distance. However, it was highly unattractive as a ground weapon and Davis turned his thoughts towards the air stream. After a few other tries at air mountings, the Davis gun was allowed to lapse and aircraft armament remained wedded to rifle-calibre weapons.

The story now shifts to Germany in the 1930s where Krupps were trying to find a way to make infantry-support guns that would fire a big shell, yet not weigh very much. The Davis idea was revived and the Krupp engineers reasoned that it did not matter at all what was fired back for the balancing shot--buckshot was one thing, but a mass of gas would do just as well. To give the same momentum the gas would have to travel fast, but that was no great difficulty and could easily be arranged with a nozzle of the right size. Very secret experiments confirmed that this theory was right, although the muzzle-velocity of the shell would not be high. However, this was not important since the shell could be as big as the user was prepared to accept. In fact its size was more likely to be limited by what could be carried rather than by what could be fired.

The attraction of gas was that it could easily be produced by burning propellant, and it was found after some trials that a suitable weight of gas was one-third of that of the shell. In order to balance the momentum, the gas was required to travel at three times the muzzle-velocity, but this was not excessive and would not give trouble. Any faster was found to cause wear on the side of the chamber. To speed up the gas, a choke or venturi was used. This was a restriction in the breech which flared out into a cone shaped funnel at the rear. The weight of gas was produced by burning the same weight of propellant, so that the cartridge case for a Krupp recoilless gun contained five times as much propellant as did one for a normal gun firing at the same muzzle velocity. Of these five parts, one pushed the shell forward and one pushed the counter-weight back, so achieving a Davis recoilless effect. Three parts burned up to provide the counter-weight and this was the great breakthrough that the Krupp engineers made for in a Davis gun, three separate items had to be loaded: the shell, the propellant, and the counter-weight. In the Krupp gun only two were needed and these were capable of being loaded in a conventional case just like any other round, albeit rather bigger.

There were two difficulties. Propellant will only burn properly when under pressure and shells are reluctant to start moving.

This was overcome by providing an opening in the base of the shell for the counter-weight gas to flow out and then closing it with a bakelite disc. When the gun was fired, the disc held firm and allowed the pressure to build up until the propellant was burning well and until the shell had been given a sufficiently sharp kick to start it on its way up the barrel. The disc then blew out into fine powder fragments that were harmless at a few feet and the gas then began to work on the normal Davis principle: gas one way, shell the other. It is the way every single recoilless gun works today.

Krupps quickly found that it was not necessary to have a central breech as with the Davis gun and the venturi could be put on to the back of a conventional breech block without too much trouble. This was a tremendous advantage since it meant that conventional gun-making techniques could be used and less specialized machinery was needed. They also put the firing cap in the middle of the bursting disc in the same relative place as it is in conventional cartridges and so simplified the ammunition manufacture. Since there was no recoil, the carriage could be light and need carry only the weight of the gun and sighting gear. It was evident from the start that recoilless guns were going to find a ready use with airborne and mountain troops.

The first gun was called the LG 40 (Leicht-Geschoss--light gun), and it was 75mm. It weighed 320 pounds or about one-sixth of a conventional gun of the same calibre. It had motor-cycle wheels and broke down into four loads so that parachutists could fit it into their containers. It fired a 10 pound shell with a hollow-charge head. The hollow charge was quickly to prove a Godsend to the recoilless designers as they could never get enough muzzle-velocity to punch a hole in armour with conventional AP shell, but a hollow charge simply needed to be carried to the target when the explosive did the rest. Another attraction was that hollow-charge shells are light for their size. LG 40 was tried out in the Crete airborne operation and was found to be perfectly satisfactory. It went into limited production as a weapon for airborne and special forces, but as neither of these types of unit was much used after Crete the LG 40 never got a chance to prove itself in its proper environment. Some went to North Africa and a small number were captured by the British Eighth Army and sent to the U.K. and U.S.A. where they aroused considerable interest.

The United States took up the design of recoilless guns much later than did Britain, but was able to work from a firmer foundation. Research was sparked off by a captured 10.6cm LG 40, taken in the Western Desert. After some delay a more or less exact copy was produced, chambered for the U.S. 105mm round. At the same time the infantry took the principle for an antitank gun and by late 1944 the first one was undergoing trials. This was the 57mm, a 5 foot-long tube weighing 40 pounds. The difference between this and other recoilless guns of the time lay in its breech and venturis. The chamber was an enlarged cylinder with a fairly large air space around the cartridge case. At the front end it tapered into the barrel where the shell was lodged. At the rear it was closed by a circular flat plate with scalloped holes around the rim. The plate locked against the breech by a bayonet joint. The cartridge case was perforated in the same manner as the Burney guns, but differed by having a multitude of small holes rather than a few large ones. On firing, the gas first of all filled the chamber space and then forced its way out through the holes in the breech closure plate, thereby forming the reaction to the recoil. At first sight, it seems as though the plate must wear out in the first few shots, but it does not and there seems to be hardly any wear from gas and wash.

The first guns had a special feature all of their own, and it has not been repeated. The driving band of the shell was pre-engraved with the rifling. The idea behind this was to try to cut down the pressure needed to get the shell moving and to smooth out some of the variations in muzzle-velocity caused by uneven powder loadings and by temperature changes. In fact, it did none of these things and only complicated the loader's task as he had to "feel" for the rifling grooves while loading. As we have seen, some initial pressure is necessary to ensure that the powder burns properly, and allowing the shell to move more easily does little to help this. Anyway, whatever the part played by the pre-engraved bands, the 57mm was a success and it still is in use in some of the National Guard units in the U.S.A. The Chinese made their own exact copy of it.

The original, however, was ordered in large quantities and was one of the few recoilless guns to see service in World War II since it was taken to the Pacific and employed as a general close-support infantry gun in the closing stages of the campaign and particularly in the Philippines. Few, if any, tanks were met but the gun proved its worth and two more projects were immediately put in hand. The first was to manufacture a wide range of ammunition for the 57mm, including HE, white phosphorous smoke, and canister. The second development was to make a larger version, this time 75mm, and this too had the complete range of ammunition. The 75mm saw a very little action in the Philippines.

The Soviets never showed much enthusiasm for the recoilless principle, preferring to put their trust in either rockets or conventional guns. After the war they produced an 82mm recoilless gun of undistinguished appearance with a single jet venturi through which the rounds were loaded. It was a heavy weapon and it did not stay in service in Russia for many years. It was followed by a larger version of 107mm calibre which for some reason was never popular and has now disappeared altogether. Even the Satellites did not take it in quantity and it must have been a bad design to have been so completely dropped. The Czechs took the 72mm and built their own versions of it, one of which was much lighter and smaller called the Tarsnice. This had about half the range of the original model but was much handier. The other version was a streamlined model of the Soviet gun, four times as heavy, but with twice the range (to 1,000 yard). The Czechs must have thought that even this was not worth the effort for it too went out of service indecently quickly.

Finland is another country which built its own design of recoilless gun, though it was never produced in any great quantity. It was known as the Model 58, from the year of its birth. It came a little late in the day since by 1958 most countries had had their guns in service for at least four years but there are signs that the Finns gained from the experience of their rivals and may well have produced one of the best of them all. The Model 58 is a 95mm gun of the remarkably low overall weight of 308 pounds, a substantial advance on the 572 pound of the Bofors 90mm and perhaps explained in part by the fact that the Finnish gun has no spotting rifle to assist in aiming. This detracts sharply from its tactical advantage of the low weight, but even so to have produced such a light gun is an unusual achievement. It resembles the U.S. 106mm in general outline and the breech is quite obviously a copy of the Kromuskit type used in the U.S. series. It fires its 22 pound shell at a muzzle-velocity of almost 1,800 feet per second, a high figure for a recoilless gun and only exceeded by the Bofors 90mm. One would like to know more of this interesting gun, but it was obviously never made in large numbers nor was it sold to any other countries -- a penalty for being late into the field. With a spotting rifle it looks as if it would have been a useful weapon.

The only other recoilless antitank gun which showed any originality of design was a Japanese experimental model of late 1945. It was intended as a one-man portable system and tried to combine the best features of the then current German weapons. It was a cross between a Panzershreck and an LG 43 and with luck and some sensible development might well have become a useful weapon. The calibre was 82mm which was just about adequate for the time, and the weight of the experimental model was 90 pounds, which again was reasonable. The breech was an almost exact copy of the LG 43 with a central firing pin and a short venturi cone. Maximum range was quoted at 850 yards, but for tanks it would have been much less. There was a light tripod and an optical sight and although the general standard of engineering and finish is nowhere near that of the American 57s and 75s, the principle seems to be right, but only one was made. No ammunition survived and so no firing was done by the U.S. Army.

With the end of hostilities in WW II, all aspects of the military were scaled back to include intelligence operations. As a result, there was little information on current weapons development overseas reported to the remaining intelligence operations and no effort to provide the information to weapons research and development organizations. During the period following the defeat of Germany, the primary emphasis seemed to be punishment of Nazi war criminals, obtaining information on political developments in Russia, and the status of the Russian military, and the publication of official and private military histories.

It was not until the late 1950's that books began to appear on German weapons research and development and not until the late 1970's was the data on allied intelligence operations declassified and the two could be correlated and by then it was too late to have much effect on current weapons.

In passing, I would like to mention a few of the German developments which served to influence or inspire both American and Russian developments in later years.

German rocket research began in the 1930's, as previously mentioned. In 1933, the A1 rocket was developed, followed by the A2 in 1934 which flew to a height of 6,500 feet, and this was followed by the A3 in 1937. The German High Command was reluctant to provide scarce raw materials to a program which might not become operational until the war was over. However an A4 rocket was developed and after a successful firing on October 3, 1942 the situation changed. The A4 was later designated V2. The other major German rocket weapon was the V1 which was originally designated Fi103. The first Fi103 flight occurred in December 1942 and the weapon was placed in full production in mid 1943. The Luftwaffe opened its V1 offensive on June 13, 1944, six months later than planned.

The "terror weapons" program concentrated on two extensions of the A4, the A4-B and the A9/A10, which were to enable Germany to bombard the U.S.A. This requirement had previously led to the "LAFFARENZ PROJECT" -- a special container with three V2 rockets which would be towed across the Atlantic by submarine to within range of the American seaboard.

Other rocket development programs resulted in the C2 Waterfall and Typhoon rockets which were designed as anti-aircraft rockets. Albert Speer, the minister of armaments, wrote after the war that "To this day I think this rocket (Waterfall), in conjunction with jet fighters, would have beaten back the Western Allies air offensive."

The Rhine Gate was the only other ground to ground rocket to be used operationally. It was a four stage solid fuel rocket with a range of 135 miles. At least 220 were fired against the port of Antwerp.

Several ground to air rockets were developed, but none were used operationally. Two notable aircraft rockets were under development, the BV143 and the BV246. While good on paper, they did not work in practice and the project was scrapped. The SD1400 "FRITZ X" was a similar weapon. The aimer situated in the aircraft could direct the "FRITZ" by means of a joy-stick control and a bright tracking flare in the missile's tail. It was not a particularly efficient weapon, but it did achieve the sinking of the battle ship Roma. Its successor was the X4, a 6 2/3 ft. long missile guided by pulses sent along a wire unspooled from the wing tip. There was also a similar weapon, the X7, designed for land use.

The final area in which Germany led the United States was jet powered aircraft which are a study by themselves. As with rockets, Germany's leaders failed to grasp the importance of the jet engine until too late for it to have any impact on the war. Ernst Heinkle developed the HE178, the world's first operational jet aircraft which flew on August 27, 1939. Heinkle continued work, but by 1943, the Luftwaffe had decided to concentrate on the ME262, developed by Prof. Willy Messerschmidt. There were other plans for jet powered aircraft which included the JU287-V1 with swept forward wings and powered by four JUMO 004 engines. There was also a V3 version. In addition, there were swing wing bombers and vertical take off fighters.

Charles Whiting, in his 1985 book, ARDENNES, THE SECRET WAR, discussed to some degree the allied dependence upon Ultra, the radio intercepts of the German high command. Shortly before the Ardennes offensive, there was a lack of radio transmissions by the Germans, especially the Army. The Luftwaffe was not as cautious and on 17 November 1944, the Ultra intelligence picked up from the Luftwaffe circuit a detailed account of all that service's top secret jet aircraft and their code names, as well as a great deal of priceless technological data. Unfortunately, there were a limited number of personnel in the field who were authorized to receive this information.

As it was pointed out, only a few of the senior American Commanders were aware of ultra, Clark, Patton, Hodges and Bradley among them as well as certain special U.S. officers trained by the British as "Ultra Advisors" to be attached to major U.S. Headquarters. When Gen. Hodges took over command of the First Army in France, he, his chief of intelligence, Col. Dickson, his ultra advisor, Captain Adolph Rosengarten and a handful of men in the British Special Liaison Unit were the only ones who knew the secret. With such tight security on the system, it is doubtful that anyone would have seen a value in releasing such information to engineers and scientists in the rear area to work on counter measures. Instead they would have to rely on an analysis of captured material, which in most cases would be somewhat late, if a new technology were involved. Perhaps the best example of this is the Me 262 jet aircraft. The entire history of the Messerschmitt Sturmvogel is best characterized by vacillation and indecision on the part of the Nazi High Command. The design concept evolved during 1938 when the Air Ministry requested the Messerschmitt Company to design an airframe to carry two radically new axial-flow turbojet powerplants in the form of an attack-fighter. In the summer of 1939 the order was given to Messerschmitt to build the first mock-up, on 1 March, 1940 some six months after the invasion of Poland, the production order was issued by Goering's Air Ministry for three prototypes to be built to accommodate the Junkers Jumo turbojets. The first of many delays came at this point in time. Most likely this was due to the belief of the Nazi Powers that the war would be over within months, and thus there would be no need to expend valuable time, effort and critical materials on a project that reasonably could require years of development. The Germans had not suffered nor experienced any setbacks up to this time, therefore, a very low priority was assigned to the project.

At the time of completion of the first three prototypes the promised Jumo turbojet engines were not delivered, and the decision was made to flight test the airframe with its revolutionary swept-back wings by incorporating a 700 h.p. Junkers piston driven engine. On 25 November, 1941 the first trials of the turbojets were attempted. They ended in failure when the turbine blades broke off at the very high r.p.m. rate required for take-off. The first satisfactory test flight was made on 18 July of 1942, this being also the first recorded flight made entirely on jet power. On 11 August of this year a test pilot was killed during take-off, resulting in a cooling of enthusiasm for the entire project by the Air Ministry. By December, 1942 the vacillation by the Luftwaffe had again had changed direction and a production order for thirty units was issued, and a further directive was issued that a monthly production of twenty units was to be attained by 1944. The thinking of the Air Ministry still considered this a non-essential project; probably since the German Homeland had not yet experienced the devastation wrought by the British and American high-accuracy bombing and the fact that the German side of the war was still very much offensive in nature.

By early summer of 1943 the tides of the war were changing rapidly against the Third Reich, and it then became quite evident that a defensive war would have to be fought. Consequent with this, there was a renewal of interest in the developmental work going on at the Messerschmitt testing grounds located at Lechfeld. Field Marshall Milch was convinced that this new weapon, if produced in sufficient quantities, could quickly reverse the declining fortunes of the Nazi war efforts. Milch filed a report with Hitler stating that all efforts should be expended to commence full production of this aircraft. Hitler categorically refused to modify the low priority given this Messerschmitt project. Nevertheless, work continued on design improvements and by early November, 1943 the sixth prototype (Me 262V6 with the Jumo 109-004B turbojet of 1,980 lb. thrust) was demonstrated before Reichsminister Goering and Field Marshall Milch. Immediately upon seeing this very successfully completed series of tests, Goering promised his full support to Prof. Willi Messerschmitt to obtain full production authorization from Hitler.

At this point the inflexible iron will of Hitler intervened to change forever the possibility of a renaissance of the fortunes of the Luftwaffe, and possibly of the entire Third Reich war effort. On 26 November of 1943 Hitler personally viewed flight tests of the sixth prototype of the Me 262 and immediately decreed the plane to be a BOMBER! An analagous decree today would be a dictator ordering that henceforth all Ferrari automobiles were to be used as delivery vans, and that no reference ever be made to their use as race cars. The Me 262 had been called the SCHWALBE (the Swallow) prior to

Hitler's ridiculous order. Now it was to be called the STURMVOGEL, or the Stormbird. The dictator adamantly refused to reason with anyone on this point, causing an addditional delay of several months necessitated by the design changes required to make the craft into an ill-suited bomber. As designed, the plane lacked the range, weightlifting capacity, structural strength as well as the bomb sighting mechanisms to be deployed as a bomber. When modified in accord with Hitler's directive to carry a one-thousand kilo bomb load, the plane was slowed by as much as 200 km.p.h., which easily put it in the velocity range of the Allied Spitfires and Lightnings.

By January of 1945 the Nazi Machine was on the run, seven months prior the Normandy Invasion had put land troops within striking distance of the homeland and were pressing toward the Rhine River. The devastation of the Allied bombing became more serious daily, to the point of hindering the manufacture of war materiel. All critical raw materials were in extremely short supply, internal transportation was difficult at best, the Luftwaffe was often grounded due to lack of vital petroleum products. As the winter progressed the High Command was truly "grasping at straws in the wind". Evidence of this is the experiments conducted on the Me 262. One plane was equipped with a 50 millimetre cannon, others were equipped with rocket boosters to lengthen the flying time. Different armament configurations were attempted such as radar equipped night fighters, racks and firing mechanisms for 50mm. rocket shells, mortar shells in the nose, and various modifications for carrying heavy bomb loads.

In March, 1945 Hitler did a quick turnabout and changed the low priority to the highest production authorization of any project in Germany. The order was too late! The collapse of the Third Reich was imminent -- the destruction wrought by the Allied bombing had so severely damaged the work on the Me 262 that not more than one hundred of the total production of a fantastic sum of 1,433 reached operational status in time to help the Luftwaffe. It is not to be implied that the aircraft was ineffectual. The one hundred units that did enter active service played absolute havoc with British, American, and Russian aircraft late in the war. A special jet fighter unit called J.G. 7 took a heavy toll of Boeing B-17's in flying later models equipped with 50mm. R4M missiles. The tactic employed was to remain well beyond the range of the defensive fire-power of the Fortresses and attack only with the rockets. Several B-17's were destroyed in this manner.

This jet was never an easy plane to fly, not that it was not well designed, rather it required extensive pilot training, a luxury which the Luftwaffe did not have late in the war. Many problems were inherent in the turbojets themselves. Life expectancy of the turbojet was only 25 hours and a full overhaul was needed after only eight hours of use. This is an example of an experimental engine being rushed into production with insufficient time allowed for corrections, demonstrating the absolute desperation of the Nazis late in the war. The technical aspects and the flying characteristics are better explained in the interrogation report of Hans Fay. Hans Fay, who flew the first Me 262 that fell intact into allied hands.

About 1345 hours on 30 March 1945, a strange aircraft with wheels down circled Rhein/Main airdrome. Occupying American troops on the field tried anxiously to identify it. The pilot carefully picked the only available field strip among the bomb craters, brought his ship in for a perfect landing, and stepped out of the cockpit.

He was Hans Fay, veteran Messerschmitt test pilot and technical inspector, with approximately 11,000 starts (80 in jet planes) to his credit. Fay had waited a long time for an opportunity which came as the result of two factors: first, the home town of his parents, near Lachenspeyerdorf, was at last in American hands, and second, 22 new jet planes which were in danger of capture at Schwabisch-Hall were ordered to be flown to Neuburg a/d Donau. When his family would no longer have to fear retaliation for his act, and when orders came on 30 March 1945 to proceed from Neuburg to Schwabisch-Hall to help ferry away the endangered jet planes, Fay saw his chance. He would fly his plane from Schabisch-Hall to Lachenspeyerdolf instead of Neuburg, turn it over to the Americans, and join his parents. Fay's account in this respect has been checked, and it is known that he informed his family of it at Christmas and again in January. They in turn had told U.S. authorities to be on the lookout.

Officials at the final assembly plant at Schwabisch-Hall had at first decided to destroy all jet planes on hand, since bombing had made the runways unusable. But at the last moment such repairs were completed as to justify a change of orders and an effort to ferry the planes out to safety.

Fay took off, fourth, and on gaining altitude, retracted his landing gear. But it was faulty, and failed to lock securely into place. For a moment Fay hesitated, then decided to go ahead with his plan. He flew on with landing wheels down at about 300-400 feet. His efforts to retract the landing gear brought him off course. Also, being slowed down considerably by the lowered landing gear, the pilot began to doubt his ability to reach Lachenspeyerdorf. He quickly chose Rhein/Main as a substitute field, circled, picked a runway among the craters, and landed with a run of only 400/500 yards.

Fay was immediately interrogated and a report was prepared by Major Ernst Englander for LTC Eric M. Warburg, both Air Corps officers. The aircraft was sent back to Air Material Command at Wrigth Field in Dayton, Ohio and a Pilot's Handbook was prepared by 10 January 1946 and released by July 15th, some six months later. The handbook provided a pilot with all the details that were needed to understand the controls and take off procedures. This type of handbook was needed as the first operational jet aircraft unit of the Air Corps was equipped with Me 262's which had been captured after the war.

Although not connected in any way with the Messerschmitt Sturmvogel, mention should be made of another jet propelled fighter developed in Germany late in the war, but which never saw action. The Heinkel 162A, called the Volksjager or People's Fighter, was to have been produced in large numbers and flown en masse by inexperienced pilots of the Hitler Youth. It was constructed in large part of wood and had a B.M.W. turbojet mounted slightly above and behind the cockpit in a separate pod. The ejection system was most ineffectual and dangerous. It seems that this airplane possesses a strong similarity to the Japanese Zero's deployed as Kamikazes.

Detailed analysis and exploitation of these weapons of aerial warfare were done by personnel of the U.S. Army Air Corps, such as Gus Simpson of Cape May, New Jersey. In quoting from a brief biographical summary of Gus Simpson, prepared in 1980:

> "In 1945-46, Mr. Simpson was engaged in analyzing the technical characteristics of German jet engines and rocket motors and segments of Japanese aircraft while an officer in the U.S. Army Air Force. In 1946 he joined the embryonic Air Force technical intelligence cadre (now the Foreign Technology Division, W-PAFB), as an Intelligence Analyst, where his assignments included travel throughout Europe on Technical Intelligence activities as well as work on Project Football and Project Paper Clip. In 1948 he was among the first Air Intelligence Specialists in Scientific and Technical Intelligence to be cleared for SI and to develop methods for using SI in scientific and technical intelligence. During his years as an Intellignece Analyst, Mr. Simpson produced numerous Intelligence products and designed a comprehensive long range program for analyzing foreign advances in materials sciences and technologies. The program was implemented.
>
> Mr. Simpson joined the Battelle staff in 1951 as Deputy Project Director of an FTD sponsored program. From 1951 to 1969, he was sent on numerous foreign missions for DoD Intelligence, including the establishment of a Scientific and Technical Intelligence System for the Free Chinese Air Force (Taiwan), to Hong Kong, Japan (6499th & 500th), to Saigon, Bangkok, Berlin, Site 23 Turkey, Korea, Hawaii, and MOD (DSTI) London. Mission assignments involved specific tasks as well as orientation and education at the all-source level.
>
> Mr. Simpson's professional interests have been devoted to scientific and technical intelligence since 1945. Upon joining Battelle in 1951 he was made respon-

sible for managing programs that apply Battelle's extensive and wide-ranging expertise in science and technology to the solution of problems of intelligence collection and analysis. These programs have been sponsored by the Foreign Technology Division (FTD) of the U.S. Air Force, OTS, ORD, OSI, OD&E, NPIC, and the Advanced Research Projects Agency (DARPA). Currently he is directly involved in managing several research programs that have the improvement of U.S. intelligence collection capabilities as their long-range objective, and he is responsible for an FTD-sponsored program that involves the preparation of 20 to 30 technical analysis products annually. This program usually requires contributions from several Battelle research departments."

Shortly before the end of WW II, a select group of Air Corps officers were instructed to "divorce themselves from the current war" and begin planning for the role of air power in the future. This was the beginning of the Rand Corporation. Rand had its origins in the military planning rooms of World War II. It was a war in which the talents of scientists were exploited to an unprecedented, almost extravagant degree. There were all the new inventions of warfare --radar, infrared detection devices, bomber aircraft, long-range rockets, torpedoes with depth charges -- and the military had only the vaguest of ideas about how to use them. Someone had to devise methods for assessing the most efficient way to employ these new weapons. It was a task that fell to the scientists.

The result was a brand-new field, called "operational research" in Britain, "operational analysis" when it was picked up in the United States. The questions its practitioners had to answer were crucial to the war effort: How many tons of explosive force must a bomb release to create a certain amount of damage to certain types of targets? Should an airplane be heavily armored or stripped of defenses so it can fly faster? How many antiaircraft guns should be placed around a critical target?

The operational research groups were composed of scientists from all fields -- physics, astronomy, chemistry, physiology, zoology, economics, mathematics -- and were called "mixed teams." When P.M.S. Blacket, one of the founders of operational research (OR) explained the British experience to American officers early in the war, he told them that every type of profession had been tried for the job except lawyers. Misunderstanding the point of the remark, the U.S. Army Air Force hired as its first OR chief John Marshall Harlan, a lawyer who later became an associate justice on the Supreme Court.

The scientists working on OR carefully examined data on the most recent military operations to determine the facts, elaborated theories to explain the facts, then used the theories to make predictions about future operations. In assessing the air campaign against German U-boats, for example, they analyzed every possible detail of past campaigns. By calculating the effect and importance of each variable, the scientists could predict what effect a change in any one of them -- a new kind of radar, better accuracy, better camouflage, different altitude -- might have on the outcome of the campaign.

One example: When Blackett first joined the British coastal command in the spring of 1941, the air campaign against U-boats was proving curiously unsuccessful. Command officers had observed that as soon as a U-boat captain spotted an aircraft, he dived as deep as possible. Consequently the coastal command would set its depth charges to explode one hundred feet below the surface of the water, assuming that the U-boat could sight the airplane two minutes before the attack and could, in that period, dive one hundred feet. Yet they were damaging only a few submarines.

Blackett and some colleagues discovered from combat data that the command's assumptions were true on average, but not nearly all the time. Furthermore, in those cases where the U-boat dived one hundred feet, the airplane pilot could no longer tell just where the submarine was and would, therefore, almost certainly miss. In some cases, however, the warning time was much less than two minutes, and the U-boat could descend only about twenty-five feet before the aircraft dropped its load: in those cases, the sub could still be located and hit. Therefore, if the depth charges were set at twenty-five feet instead of one hundred, the percentage of submarines actually damaged or destroyed would be much higher.

The coastal command followed the recommendations, and results were so spectacular that captured German U-boat crews thought that the British had started using a powerful new explosive. But of course the cause was simply a slight change in tactics, systematically calculated by OR scientists engaged in nothing more complicated than standard scientific methods of investigation -- with the difference that they were being applied to military tactics in wartime.

Similar techniques were developed to show that, contrary to conventional military wisdom, large naval convoys are safer than small ones, that fighter planes should fly everyday they are serviceable regardless of whether enough can be put up in the air to fly in large formations.

By the end of the war, every U.S. Army Air Force unit had its own operational analysis division. The scientists not only worked on calculations in the home office but also went out to the fronts to gather data and make suggestions on how new tactics might be applied to the new weapons. Toward the latter part of the war, scientists were not just asked for advice; they were invited to sit alongside the generals and colonels in Washington headquarters and to participate directly in war planning.

A key player in this new phase of civilian involvement was Edward Bowles. Bowles had come to the Office of Scientific Research and Development from the MIT Radiation Lab at the start of the war, then transferred to the War Department to serve as special consultant to the secretary of war, Henry Stimson, and to Gen. George Marshall. Starting in 1943 he worked on adapting techniques of air warfare to the possibilities offered by the new scientific devices. Bowles had a tremendous faith in the power that comes from the fusion of military might with scientific brilliance.

But Bowles was practically a skeptic in this faith compared with Gen. Henry Harley Arnold. Everyone called Arnold "Hap" because he was steadily amiable and nearly always wore a broad smile. Yet behind the smile was a mind obsessed with destructive power and with the role that scientists might play in making future weapons still more destructive. When he heard that Secretary of War Stimson had doubts about the bombing of Dresden, Arnold wrote a memorandum: "We must not get soft. War must be destructive and to a certain extent inhuman and ruthless." He wanted his scientists to invent "explosives more terrible and more horrible than anyone has any idea of."

Arnold considered himself a visionary. Four months before Germany was defeated, seven months before Japan surrendered, he called in his top officers and said: "We've got to think of what we'll need in terms of twenty years from now. For the last twenty years we have built and run the Air Force on pilots. But we can't do that anymore." Arnold said he foresaw an age when intercontinental missiles would dominate warfare and that the Air Force would have to change radically to confront the challenges of this new age. His small audience sat in stunned silence. Every man in the room was a pilot.

Hap Arnold was worried. He was fifty-five when the war began. He was among those responsible for making something of air power, and he wanted to leave a legacy. The future he saw would be an age of intercontinental missiles, robots, super destructiveness; but what would happen, he wondered, to all the scientists who were proving so valuable to the present war effort? After the war, peacetime demobilization would quickly spread to their ranks as well; they would go back to lucrative jobs in universities and industry; certainly the meager salaries of civil service would hardly serve as incentive for them to stay in and help their country prepare for World War III.

On November 7, 1944, Arnold wrote a memo to his chief scientific adviser, a brilliant Hungarian refugee named Theodor Von Karman. "I believe," it began, "the security of the United States of America will continue to rest in part on developments instituted by our educational and professional scientists. I am anxious that the Air Force's post war and next war research and development programs be placed on a sound and continuing basis..."

Over the next thirteen months Von Karman and his Army Air Force

Scientific Advisory Board produced -- and distributed piecemeal -- a multivolume report called "Toward New Horizons". It was music to Hap Arnold's ears. "The scientific discoveries in aerodynamics, propulsion, electronics, and nuclear physics open new horizons for the use of air power," the report (which was based in part on the reports of the various Technical Intellignce operations) declared. Even greater advances, including the development of intercontinental ballistic missiles, lay just over the horizon. Therefore the air staff must "be advised continuously on the progress of scientific research and development in view of the potentialities of new discoveries and improvements in aerial warfare." The important thing was to maintain "a permanent interest of scientific workers in problems of the Air Forces."

Thus Von Karman laid out the blueprint for what would be called Air Force Project RAND.

Von Karman was reinforcing a movement already afoot under the sturdy guidance of Arnold, Bowles, and a few others, most notably Arthur Raymond, chief engineer at the Douglas Aircraft Company in Santa Monica, and his assistant Frank Collbohm.

Collbohm had met Arnold in 1942, when Douglas Aircraft was building A-20 airplanes for the British. The British wanted some night-flight capability but had only primitive radar installations, which could barely make out the targets. Collbohm, who had heard something about a radar project going on at MIT, visited the school's Radiation Lab in Cambridge. Ed Bowles and another scientist at the lab took him up on the roof, where they had the radar operating. The day was extremely foggy. All pilots were grounded, except for a physicist at the lab who owned a private plane and had been given an exemption. At the moment, he was flying over the MIT campus. Collbohm could not see him, but the radar was tracking him perfectly.

Collbohm repeated the tale to Donald Douglas, president of the aircraft company, and General Arnold; both men were highly impressed. From that point on, Ed Bowles and the MIT Rad Lab were in with the Army Air Force, and so was Frank Collbohm. He was already a dollar-a-year consultant to the Secretary of War. Now he started to consult for Arnold, too, mostly on tactics and economics.

As Collbohm gained a broader perspective on war planning, he grew disturbed that many high-ranking military officers were winning the military phase of the war but losing sight of the larger objectives. For example, in their obsession with measuring effectiveness by gauging damage of production facilities, many officers wanted to bomb the coal mines of the Ruhr Valley. Collbohm and many other civilian consultants argued that, with the Germans practically defeated, such rich resources should now be protected, not destroyed. Collbohm talked the situation over with Ed Bowles and others. They all agreed that the military could not afford to lose the technical and scientific community they would so much need after the war.

When Collbohm aired his concerns to Arnold, the general agreed. "We have to keep the scientists on board," he said. "It's the most important thing we have to do." Arnold immediately sent Collbohm back to Santa Monica to calculate how much money and what sorts of facilities and personnel would be needed for a new organization of scientists, similar to the one urged by Von Karman, that would work for the military.

On September 30, Collbohm came to Arnold with a proposal from Donald Douglas: Douglas Aircraft would agree to house an independent group of civilians to assist the Army Air Force in planning for future weapons development. Arnold was excited by the idea. Douglas had served the nation well in war, and he was a man Arnold could trust. They were longtime hunting-and-fishing friends, and two years earlier Arnold's son had married Douglas' daughter. Arnold had already concluded that this new scientific organization probably could not be set up at a university, owing to the need for classified information; nor could it be inside the government, due to the relatively low pay scales of civil service. He had thought industry was out of the question too; possible conflicts of interest would make life difficult for the fledgling outfit. But if Don Douglas was willing and eager to take this thing on and get it moving, then maybe an industry connection would work after all. (In the end the relationship did not work out, and in May 1948 RAND became an independent non-profit corporation.)

Arnold called for a lunch meeting to be held the very next day at Hamilton Field, an Air Force base just outside San Fransisco. There he joined Frank Collbohm, Ed Bowles, Don Douglas, Arthur Raymond, and a few other representatives of Douglas Aircraft. The meeting was to the RAND Corporation what the Continental Congress had been to the United States. Years later, in fact, the group that met at Hamilton Field would be referred to in RAND folklore as the "founding fathers."

Arnold announced to those assembled that he had thirty million dollars left over from his wartime research budget. He wanted to divide that into three packages of ten million dollars each for projects that would study techniques of intercontinental warfare. He pledged one of the packages to Douglas: that would be enough to finance the new group and to keep it going for a few years, free from pressures to exhibit its achievements prematurely. Douglas wanted to start quickly, before the inevitable peacetime economy measures drastically reduced his company's output. Frank Collbohm said that he would hunt around for someone to direct the outfit and would lead it himself in the meantime. Arthur Raymond came up with the name RAND, standing for "Research and Development." Later, Gen. Curtis Le May, noting that RAND never produced any weapon, would say that it should have stood for "Research and <u>No</u> Development."

By the fall of 1947 the RAND staff had grown to one hundred and fifty. For anyone interested in some vague combination of mathematics, science, international affairs, and national security, RAND offered an ideal setting. There was an intense intellectual climate but no teaching obligations or boring faculty meetings. There was access to military secrets but no military officers from whom to take direct orders. There were brilliant minds working to solve fascinating problems. It was freewheeling, almost anarchic, virtually without hierarchy or separation among disciplines. One man invited to RAND in 1947 wrote in a memo: "I have been at RAND for three exciting days and I would like to become part of it. Right now RAND is part solid, part liquid, and part gas..." It was run under Air Force contract, but that was all right. The Air Force was the only service that had the atom bomb; American security policy was based almost entirely on the bomb; therefore, the Air Force policy was essentially national security policy, and RAND was the Air Force center of ideas.

Early in 1947 Olaf Helmer of the RAND mathematics division came up with an idea that would change the complexion of the project. Helmer was a German refugee with two Ph.D.'s, in mathematics and in logic, who emigrated to the United States in 1936, taught mathematical logic at the New School for Social Research and City College of New York and during the war worked for a group on 57th Street in New York called the Applied Mathematics Panel, the OR unit of the Office of Scientific Research and Development. Helmer had been at RAND for a short time when he reflected on the possibility that the organization might be too limited in its outlook. Military problems, after all, were not just engineering or mathematical or physics problems; they involved questions that might better be investigated by economists or political scientists as well.

John Davis Williams, head of RAND's math division and a former colleague on the Applied Mathematics Panel, particularly liked Helmer's idea and made it his own. Williams, who had come to RAND in 1946 -- he was the fifth employee -- weighed close to three hundred pounds. Trained as an astronomer, he was also an excellent pool shark; he would later write an article on TV wrestling for the promotional issue of Sports Illustrated, and he loved to supercharge and drive fast cars. He had loaded a Cadillac engine into his brown Jaguar sports coupe and relished few things more than taking it out on midnight test runs at 155 miles per hour. (Williams might also be credited with being the man who first applied radar to automobiles, building his very own "fuzz-buster.")

Williams had for some time been particularly keen on a mathematician named John von Neumann. One of the broader intellects of the twentieth century, von Neumann was a cheery, roly-poly man, short and round-faced as a cherub. As a teenager, he was known to his friends as "Mr. Miracle" because of his great love for inventing mechanical toys. During World War II he was chief mathematical wizard at the Manhattan Project. After the war he taught at Princeton but still served as a consultant at Los Alamos in the Theoretical Division, or T-division, where -- along with Edward Teller, Enrico Fermi, Lothar Nordheim, and others -- he became enraptured with the problems and principles of fusion energy and the hydrogen bomb.

At one point fusion experiments were bogged down by the almost impossibly complicated mathematical calculations that the scientists had to work out. For assistance, they had only the ENIAC computer, whose memory could hold a mere twenty-seven words and which was constantly on the blink. Von Neumann invented a new electronic computer that could hold forty thousand bits of information, recall them later, and identify errors in the instructions that anyone fed it and then correct them. When von Neumann displayed the machine to the Atomic Energy Commission, he gave it the high-sounding name of Mathematical Analyzer, Numerical Integrator and Computer. Only later did officials see that von Neumann, forever the practical joker, had dubbed the machine with a picturesque acronym.

A problem that previously would have taken three people three months to solve could now be worked out by the same three in ten hours. The research on the H-bomb was, thanks to MANIAC, lifted out of its slump.

Throughout the late 1940s and early 1950s von Neumann made frequent trips to RAND. John Williams adored him and was "delighted" when, in December 1947, he convinced von Neumann to join the organization as a part-time consultant. Williams, who loved games, would try out immensely difficult math problems on von Neumann but never stumped him. Von Neumann could solve in his head the most elaborate calculations to the second or third decimal point.

Von Neumann liked games, and in 1928, when he was twenty-four, he had sat in on a fateful bout of poker that set in motion a remarkable train of logical observations. First, he noted that a player's winnings and losses depended not only on his own moves but also on the moves of the other players. In devising a strategy, he had to take into account the strategies of the other players, assuming that they, too, were rational; that, therefore, the essence of the good strategy was to win the game, regardless of what the other players did, even though what the other players do determines, in part, the playing of the game.

Von Neumann then realized that the game of poker was fundamentally similar to the economic marketplace. Economists had been attempting to impose mathematical models on classical economic theory, but with no success. The reason for their failure, von Neumann reflected, was that the theory assumed an independent consumer trying to maximize his gains and independent sellers trying to maximize theirs -- whereas, in fact, just as in the game of poker, the consumer and the seller formed a unit, competing but interdependent, and the moves of one could not be systematically analyzed or strategically planned except in the context of the other's. So it goes with any situation in which two or more players have a conflict of interest and in which a good deal of uncertainty is involved.

Von Neumann developed what came to be called "game theory" as a mathematically precise method of determing rational strategies in the face of critical uncertainties.

Von Neumann wrote a scholarly paper on game theory in 1928 and created a minor sensation in the scientific and mathematical communities of Europe. The sensation exploded in 1944 when he and a Princeton economist named Oskar Morganstern collaborated to write an enormous volume called "Theory of Games and Economic Behavior," offering mathematical proofs and suggesting applications of the theory to economics and the entire spectrum of social conflict.

It was a conservative theory and a pessimistic one as well. It said that it was irrational behavior to take a leap, to do what is best for both parties and trust that one's opponent might do the same. In this sense, game theory was the perfect intellectual rationale for the Cold War, the vehicle through which many intellectuals accepted its assumptions. It was possible to apply the Prisoners' Dilemma, for instance, to the Soviet-American arms race -- substituting "build more" for "talk" and "stop building" for "silence." It made sense for both sides to stop building arms, but neither could have the confidence to agree to a treaty to stop, suspecting that the other might cheat, build more, and go on to win. Distrust and the fostering of international tensions could be elevated to the status of an intellectual construct, a mathematical axiom.

Game theory caught on in a very big way at RAND in the late 1940s. John Williams was particularly entranced with it and wrote a lively compendium of dozens of cases -- pulled out of real life -- in which game theory could play a valuable role in guiding decision makers. But there was a major limitation to game theory. For it to be used precisely, as a science, the analyst had to have some way of calculating what numbers represented the probabilities. And what about those games that involve not just two players but three or four or more? Then there were games where certain moves might be optimal 60 percent of the time, but other moves 40 percent of the time. In these cases the players would have to play according to a mixture of random selection and the laws of probability, just as a good poker player bluffs systematically but randomly, so that his strategy is not discovered.

In brief, Williams realized that if game theory were to grow and have true relevance to economics problems or international conflict, and if RAND were to lead the way, then RAND would have to hire social scientists and economists who could study the "utility functions" of consumers and the actual behavior and values of various nations. The mathematicians, who certainly knew nothing of such things, could then make use of the findings.

So it was that John Williams -- through the combination of Olaf Helmer's original suggestion and his own fascination with game theory -- proposed that two new divisions, one for social science and the other for economics, be created that would broaden the range and scope of RAND. At first Collbohm failed to see much use in having such things, nor could many of the other RAND scientists, especially the engineers, to whom the social sciences represented something soft and unscientific. But Williams was brilliant, no doubt about that, so Collbohm became convinced. Williams eventually won approval for his new division from RAND's immediate Air Force boss, Gen. Curtis Le May.

A turning point in the progress of Williams' new departments, and of RAND in general, came in 1947 when Williams arranged a conference of social scientists to be held in New York from September 19 to 24. It had become clear that even fairly crude economic and statistical computations could contribute substantially to the formulation of strategic military policy, and there was a good turnout at the New York Economic Club the first day of the RAND conference.

John William's mentor and idol, Warren Weaver, who was social science chairman of the Rockefeller Foundation as well as a RAND consultant, delivered the opening address. He talked about his having spent nearly one-fourth of his life working for the military in two world wars. He talked about the work in operational research during the last war. He explained that RAND was greatly interested in the concept of "military worth," in seeing "to what extent it is possible to have useful quantitative indices for a gadget, a tactic or a strategy, so that one can compare it with available alternatives and guide decisions by analysis..."

At the conference, Warren Weaver made a particular revealing remark early in his opening address. "I assume that every person in this room is fundamentally interested in and devoted to what can broadly be called the rational life," he said. "He believes fundamentally that there is something to this business of having some knowledge...and some analysis of problems, as compared with living in a state of ignorance, superstition and drifting-into-whatever-may-come."

The "rational life" might have served well as an emblem of the RAND style. And with a social science and an economics division, RAND was about to start pursuing it along slightly different lines. Before, RAND had confined itself essentially to studying the technical aspects of the instruments of warfare. Now some of the people at RAND would start to study the strategy of warfare, would try to impose the order of the rational life on the almost unimaginably vast and hideous maelstrom of nuclear war.

In the late 1940's, the North Atlantic Treaty was signed which created NATO, with most of the allies pledged to come to the aid of each other, if attacked. The prime fear was the Soviet Union. NATO's primary source of intelligence on the Soviets was provided by Reinhard Gehelen and his organizations. Gehelen had been in charge of the German Intelligence effort directed against the Soviet Union.

At the end of the war, Gehelen began work for NATO. Nazi Germany was divided into sectors and each nation of the Big Four established liaison teams in each other's sectors. These reported to the Supreme Headquarters through channels. They primarily kept track of Soviet military units and their movements. There appears to have been very little effort by the U.S.A. expended to determine what the Russians were doing with captured German weapons and equipment.

During the late 1940's, Julius and Ethel Rosenberg and others were accused of supplying the Soviets with the details of U.S. nuclear weapons. How ironic it was, we had "given" them long-range rockets and now we had "given" them nuclear weapons!

The Army also began thinking about the post war era, but in a more conservative manner. Weapons development proceeded as it had in the past, upgrading or refining existing systems primarily for combat in the European theater.

While the public's attention was directed to the Rosenbergs, atomic weapons and strategic missiles, work continued on developing new weapons. In 1948, the Operations Research office emerged as the first manifestation of a postwar struggle over how the U.S. Army would deal with the growing role science and scientists were coming to play in planning for warfare. President Roosevelt's National Defense Research Council (NDRC) had proved that the sort of research and development carried on by civilian scientists and operations research personnel could be of enormous value in wartime. In the aftermath of World War II, civilian scientists lobbied for the creation of an independent, high-level Army research and development (R&D) command. Significantly, the Army's own Stillwell Board made a similar recommendation in 1946. Neither proposal was well received by the Army's technical services, Ordnance chief among them, nor did either make headway in the face of substantial postwar budget cuts. The ORO was established as a compromise; ORO's mission of applying operations research to tactical doctrine and new weapons promised to keep it safely out of the materiel R&D area in the short run, while the organization itself clearly fell short of meeting demands for independent management of R&D.

Much of the postwar effort in small arms development was conducted without the benefit of the Walther assault rifle as previously mentioned, hence Ordnance Technical Intelligence played almost no role.

The Army traditionally sought to produce casualties by training its soldiers to fire a marksman's rifle with effect; ORO's tests suggested that combat conditions made this a losing effort. Thus, ORO sought rifles that fired several projectiles in shotgun-like patterns sufficiently dispersed to compensate for expected aiming errors. Two technologies immediately suggested themselves; either small-caliber automatic rifles which because of their low recoil allowed for controlled disperson, or standard cartridges loaded with two or three bullets -- so-called duplex rounds. Either technology promised to increase the probability of a soldier's getting a hit in combat (P_h), much as a shotgun gives the duck hunter a greater chance of bagging his quarry. From early on in the decade ORO personnel pushed the Army to fund realistic tests of these technologies.

The Ordnance Department is normally cast as the villain of many weapons stories over the course of the U.S. Army's history. Dominated by a relatively small, close-knit cadre of officers, and close to the centers of power in Washington, the department was in a position to control materiel developments in a way no user organization could match, even if it had to resort to nefarious means on occasion to do it, but it nonetheless is important to understand the Ordnance Department's perspective. As the Army's materiel developer, the department needed a stable environment in which to develop, test, and perfect candidate rifles. Yet this is precisely what its nominally co-equal relationship with user organizations -- in this case the Infantry Board -- denied it.

From the department's perspective, users could be irritatingly flighty. This was in fact the case in the early 1950s. In 1950 the Board had urged that further rifle developments in the United States be focused on Britain's .280 round, presumably in response to the weight savings and automatic fire capability achievable with this smaller, less powerful cartridge. Just three years later, after the Korean War, the board waxed equally enthusiastic about the T48, a rifle Belgium's Fabrique Nationale (FN) had designed to fire the 7.62mm NATO round. Yet the T48 weighed nearly ten pounds, a fact the Inquiry Board downplayed in view of the weapon's "simplicity, reliability, ruggedness, and ease of handling." The Ordnance Department was then offering early versions of the M14 (then called the T44) from which it had tried to pare as much weight as possible. Between the EM2 and the T48, the board's priorities had clearly shifted, relieving ordnance experts of precisely the stable priorities they felt they needed to develop a weapon.

With the advent of the missile age, as well as the atomic bomb, small arms development took a "back burner" priority to the development of rockets.

Redstone Arsenal had been activated in October 1941, as an Army Ordnance ammunition loading plant adjacent to the Chemical Corps' Huntsville Arsenal. During World War II, these arsenals complemented each other in producing millions of rounds of conventional chemical ammunition. After the war both installations were placed in standby status and later became available for other purposes.

Although American scientists were actually the first to outline basic principles of jet propelled guided missiles, the Germans had developed the first long range, surface-to-surface missile that was operational. By the time the German V-1 and V-2 missiles appeared in 1944, America had already recognized the great potential of these weapons and had made a good start in the research effort.

Proposals to develop a V-1 type of missile had been advanced as early as 1941, but it was not until the German V-1 attacks on England that the War Department officially initiated the development project. Known as the JB-2, or Loon,, this 450-mph pulse jet was very similar to the German V-1. Large scale production was well under way when V-E Day led to the cancellation of most of the procurement order. The available JB-2s, together with captured V-2 missiles, were used by the three services for experimental work and for training.

Meanwhile, the Army Ordnance Department began a long range R&D program in the field of guided missiles. The Ballistic Research Laboratory at Aberdeen Proving Ground, Maryland, and the Guggenheim Aeronautical Laboratory of the California Institute of Technology (GALCIT) conducted preliminary feasibility studies of surface-to-surface guided missiles. Impressed with favorable results of these studies, the Ordnance Department requested California Institute of Technology to undertake an R&D program on long range rocket propelled guided missiles. This request led to the ORDCIT project, the first of its kind in the United States and the oldest of the Army's missile projects.

In June 1944 the Office, Chief of Ordnance awarded GALCIT a $3.3 million contract for general research leading to the development of long range guided missiles. Later that year the GALCIT activity was reorganized and designated as the Jet Propulsion Laboratory (JPL) of California Institute of Technology. By December 1944, experimental work at the JPL had confirmed the feasibility of jet propelled missiles, and the Ordnance Department established two more R&D programs; the Hermes surface-to-surface missile project at the Bell Telephone Laboratories of the Western Electric Company.

In 1945, the JPL research facilities which had been expanded and largely financed under wartime defense contracts with the GALCIT research group were acquired by the Army Corps of Engineers and became a Government owned activity operated by California Institute of Technology. The ORDCIT project, in effect, supported all other guided missile contracts for specific missiles. It embraced fundamental R&D and testing of solid and liquid propulsion systems, guidance and control techniques, guided missile research test vehicles, and other related subjects. Objectives were to increase progressively the size complexity of the various missiles, beginning with the experimental Private series and continuing through the Corporal and Sergeant guided missiles.

In 1946, the Ordnance Department established the Ordnance R&D Division Suboffice (Rocket) at Fort Bliss, Texas, to provide working facilities for the team of 130 German rocket scientists who had been brought to the United States in "Operation Paperclip" following Germany's surrender in 1945. The German scientists also worked on the Hermes II project, the object of which was to develop a ramjet missile as a research test vehicle. Ordnance personnel and General Electric Company employees who worked directly with these men learned the extent of the German missile technology and applied it to hasten American missile development, thereby saving many years and dollars in the establishment and development of the United States' guided missile program.

During the 1944-48 period, numerous research test vehicles were developed under the ORDCIT project and flight tested at the White Sands Proving Ground (now White Sands Missile Range). Among these were the A4(V2) missile; the Private "A" and "F"; the WAC (without altitude control) Corporal; the Bumper (a modified V-2 and WAC Corporal) -- the free world's first two stage liquid fueled rocket; the Corporal "E" which was later developed and produced under a crash program for tactical use; and various designs of the Hermes surface-to-surface missile, the C-1 model of which was later developed into the tactical Redstone ballistic missile.

As part of the Hermes project, the General Electric Company pioneered in the development of guidance equipment to insure greater accuracy of a missile's flight path. It invented a coded, command-guidance radar that was adapted for use in the Corporal system. the first inertial guidance quipment used in any missile system was devised for the Hermes A3. A similar guidance system was later used, effectively, in the Redstone.

Thus, the Ordnance Department could very well have looked upon the Department of the Army's investment in the Hermes projects as one that had paid dividends in knowledge, equipment, and experience even though the desired tactical missile failed to materialize.

Quickly realizing the need for adequate facilities to support the necessary research program, the Ordnance Department turned to its own laboratories and arsenals. Of the then existing installations, the Aberdeen Proving Ground, the Picatinny Arsenal, the Frankford Arsenal, and the Watertown Arsenal were the best equipped and qualified for providing the required support. No feat of the imagination was required, however, to recognize the inadequacy of these existing facilities in respect to a proper performance of the developing missile program. Consequently, the Ordnance Department provided new facilities as they were required. As an example, it acquired the White Sands Proving Ground in 1945 as a flight-test range for the Army's missiles.

Of most importance to the future Redstone missile, however, was the facility that became known as the Ordnance Research and Development Division Suboffice (Rocket) at Fort Bliss, Texas. This installation, established primarily to provide working facilities for the German rocket experts recruited in Operation Paperclip, had its own chemical, material, and electronic laboratories, component testing facilities, and a small production shop. While here, the group concentrated its work on the Hermes II project.

While all these facilities first proved to be adequate, by 1948 the Ordnance Department found its rocket and guided missile program jeopardized by their inadequacy. During April 1948, Col. H. N. Toftoy, as Chief of the Rocket Branch in the Office, Chief of Ordnance, revealed that the Ordnance Department was unable to meet its responsibilites in rocket and guided missile research and development. He placed the responsibility upon the Ordnance Department for failing to establish a rocket arsenal, to employ adequate numbers of skilled personnel, and to secure adequate program funds. Colonel Toftoy recommended, in the conclusion to his report, that the Ordnance Department take immediate steps to establish a suitable Ordnance Rocket Laboratory as a beginning step in providing the required facilities and personnel for the supporting research program.

The Ordnance Department supported Colonel Toftoy's position and began surveying possible sites for locating the proposed arsenal. Then, on 18 November 1948, the Chief of Ordnance announced that the Redstone Arsenal, at Huntsville, Alabama, then in standby status, would be reactivated as a rocket arsenal. By February 1949, the Ordnance Rocket Center was established there on an interim basis. Subsequently, the Redstone Arsenal officially returned to active status on 1 June 1949.

During the establishment of the Ordnance Rocket Center, other events that related directly to the future Redstone program transpired. In early 1949, the Commanding General, Third Army, decided to inactivate the Huntsville Arsenal, a Chemical Corps installation, adjacent to the Redstone Arsenal. Interest in the possible use of these facilities led to a survey of them by representatives of the 9330th Technical Support Unit, Ordnance Research and Development Division Suboffice (Rocket), Fort Bliss. Inadequate facilities and lack of room for expansion at Fort Bliss severely hampered the activities of this group in the Hermes II project. So, they were looking for a place to relocate.

The promising results of the survey of the Huntsville Arsenal facilities resulted in the proposal that the guided missile group be moved from Fort Bliss to the Redstone Arsenal and that it establish an Ordnance Guided Missile Center utilizing the former Huntsville Arsenal facilities. The Secretary of the Army approved the proposal on 28 October 1949; the Adjutant General issued the movement directive on 21 March 1950; and the Ordnance Guided Missile Center was officially established at the Redstone Arsenal on 15 April 1950 as the Ordnance Department's center for research and development of guided missiles. However, the transfer of personnel, laboratory equipment, and tooling equipment continued for another six months, being completed in October 1950.

Although consolidation of the Ordnance Department's far-flung activities in rocket and guided missile research and development in these two installations was no "cure all" for the many problems plaguing the program, it was one step in the right direction. With the Ordnance Guided Missile Center now established; with adequate facilities being constructed; and with a recruiting program authorized for skilled technical and scientific personnel, the group that would soon receive the responsibility for designing and developing the Redstone missile system was in a better position to follow through on its mission.

At Redstone Arsenal, COL Carroll D. Hudson assumed command in November 1948, and had some 250 employees. By 31 December 1950, after the establishment of the Ordnance Rocket Center and the Ordnance Guided Missile Center, there were 2,960 persons working at Redstone Arsenal. The number climbed throughout the decade, reaching 16,962 by 30 June 1960.

Redstone Arsenal's missile era actually began on 1 June 1949, when the Chief of Ordnance (COFORD) officially reactivated the arsenal as the site of the Ordnance Rocket Center. Ordnance's desire to consolidate rocket activities, then divided among the Research and Development Division, Office, Chief of Ordnance (OCO); Picatinny Arsenal; Rock Island Arsenal; and Aberdeen Proving Ground, prompted the decision to reinvigorate the former Ordnance assembly plant. The Ordnance Department had chosen Redstone in October 1948 because the arsenal, with its abundant land and suitable facilities, could be activated earlier, and at less cost, than any other available site.

Preparations for RSA's new function began in 1948. On 30 November 1948, COL Carroll D. Hudson, who had guided the arsenal through the war years, returned to lead it into the rocket and missile era. Recruiting of civilian personnel for research and development activities began in January 1949. The next month, a Research and Development Division, the forerunner of the Ordnance Rocket Center, was established.

In early 1949, the Ordnance Department successfully negotiated with both the Thiokol Corporation of Trenton, New Jersey, and the Rohm and Haas Company of Philadelphia, Pennsylvania, to establish facilities at Redstone Arsenal for supporting research. By August 1949, Thiokol had relocated their Elkton, Maryland, plant into existing buidings at the "old" Redstone Arsenal, and Rohm and Haas was drawing up construction plans for their facilities.

Meanwhile, the Chemical Corps' attempts to dispose of Huntsville Arsenal, which adjoined Redstone Arsenal, proved unavailing. (The property had been declared surplus in 1947.) Therefore, on 1 July 1949, the Ordnance Corps became the caretaker of the 35,000-odd acres comprising Huntsville Arsenal, pending final disposition of the land. This addition brought the total land area under the jurisdiction of Redstone Arsenal to roughly 40,000 acres. By 1959, the Army rocket and guided missile programs had progressed to the point where it was necessary to decentralize management and operational activities of these programs from the Pentagon and other agencies to an appropriate field establishment. The Redstone Arsenal-Huntsville Arsenal complex was selected as the most suitable site for the rocket and guided missile mission. The same year the

Department of Army returned Redstone Arsenal to active status for rocket R&D.

On 28 October 1949, the Secretary of the Army approved the tansfer of the Ordnance Research and Development Division, Sub-Office, Rocket, from Fort Bliss, to Redstone Arsenal. The Fort Bliss group included some 120 German scientists and technicians who had come to the United States in "Operation Paperclip" during 1945 and 1946. "Operation Paperclip" began with a 1945 OCO directive to COL Holger N. Toftoy and MAJ James P. Hamill to investigate German progress in the rocket field. A selected number of German rocket specialists, who had surrendered to the U.S. forces after V-E Day, were offered 5-year contracts to work with the American rocket and missile program. In 1946, this group, under the direction of Major Hamill, became the Ordnance Research and Development Division, Sub-Office, Rocket. On 15 April 1950, the sub-office, after its transfer to Redstone Arsenal, was redesignated the Ordnance Guided Missile Center.

The addition of the missile group made necessary the acquisition of more land for the arsenal complex. Accordingly, on 14 June 1950, the Chief, Chemical Corps, officially discontinued Huntsville Arsenal and transferred the land to Redstone Arsenal effective 1 April 1950, and the two installations were consolidated for use as an Ordnance Guided Missile Center.

With the demise of the O.S.S. and the reduction of the military, the nation was again "running blind" with respect to developments in the Soviet Union. Assessments of foreign governments was again the almost exclusive function of the state department. The diplomatic service was not likely to attract weapons designers or weapons experts. It appears that the State Department was somewhat slow to recognize the Soviet threat and even slower to respond or even inform the president and congress. The military services were also not very interested in economic analysis and in all probability lacked the raw data needed to conduct any meaningful assessment.

In 1942, the New York Times published a book entitled, "The War in Maps," which was a compendium of the maps that they had published up to 1942. Included was one map showing the location of Soviet industry and raw materials. The map appeared to be more accurate than the map which German intelligence had prepared for Hitler, however, the Germans had begun to recognize the need for better information on Soviet industrial production. This area of intelligence was considered economic intelligence. In his 1978 book on "Hitlers Spies," David Kahn provided an in-depth look at the German economic intelligence operations.

Colonel Walther Nicolai, head of German espionage in WW I, admitted in his memoirs, that he had not prepared his agency to spy out enemy economies, and economic strength contributed greatly to Germany's defeat. In the 1920's, T 3, the intelligence branch of the

Troops Department, extended its evaluations to such matters but by 1934 this work was moved to an agency that was preparing Germany's own economic mobilization. This was the War Economy and Armaments Department. Its long time chief was General Georg Thomas who was replaced by Albert Speer in 1942 as armaments minister. One function that Speer did not take over was the foreign intelligence unit. From 1939 until 1942, this War Economy Branch was one of the department's five branches and started with 73 of the department's 322 desks, however, by November 1944, it had been reduced to only 22 desks with 52 people.

Early in the war, the War Economy Branch depended for its raw data mainly upon large drafts from other agencies. Except for its reading of the press, it did not itself acquire information. But in the fall of 1941, General Thomas concluded that the loss of all Russian territory and industry from Leningrad through Moscow to the Crimea "need not necessarily lead to a breakdown" of the Russian war economy. Perhaps to gain more information on the industry that was left, the War Economy Branch dispatched specialists to the front. The first group, under Major Prince Reuss, who had worked in Asia as a businessman, went to Army Group South; others later went to army groups Center and North.

At first, they interrogated prisoners of war. Reuss, an excellent organizer, had a list of the most important factories and their locations, and his men picked out prisoners from these towns for questioning. Seven to eight hundred a month talked volubly about matters they knew from their jobs at home -- the location, products, output, and needs of factories, mines, and other sources of production. This soon proved the most valuable information of all. The military economists summed prisoners' statements of the daily production of T-34 tanks in the individual factories and multiplied these by 30 to estimate production at 1,000 a month for the spring of 1943 and 1,500 for the summer and fall, making a total of 15,000 for 1943. Other data led Zinnemann's subgroup east to conclude that the Russian coal requirements had reached 101,300,000 tons in 1942 and would probably rise to 123 million in 1943 -- a figure that it said would probably not be met.

Equally solid, if less copious, material came from the branch's analysis of the serial numbers of captured weapons. The teams at the front had been empowered to offer leaves to any soldier who brought a brass number plate from the underside of a Russian tank. Soon their quarters, as well as the head office's, were overflowing with the 5-by-8-inch plates; some of the officers used them as paperweights. These plates gave the serial number, factory, and date. One of the branch's young statisticians, Specialist Dr. Jordan, intercalated and interpolated the numbers with series from motor works, gun works, and chasis works, using such tank-plate figures as those from nine T-34's from a factory in Nizhniy Tagil, which went from T 47,068 to T 49,181. He eventually reckoned an annual production of 16,500 T-34s -- an improvement in accuracy of 9 percent over the prisoner figure.

The fullness of this intelligence and its refinement through computation enabled the foreign section to determine with astonishing accuracy the quantity of supplies that Lend-Lease sent to the Soviet Union. On 10 August 1944, for example, it stated that the total number of passenger cars, trucks, and prime movers that had gone to Russia under the program as of 31 March 1944 was 202,000. In fact the figure stood at 200,793 -- an error of only 0.6 percent.

Economic intelligence could not by itself enable the Germans to win any battles. But it contributed to operational decisions.

In the summer of 1942, it helped the navy decide whether U-boats should be committed in the eastern Mediterranean when it reported on Egypt's tonnage requirements for its trade with neighboring countries. It advised the Luftwaffe on the most economically worthwhile bombing targets. In July 1943, the Rolls-Royce motor factories in Derby, Crewe, and Hillington with target numbers GB 73 19, GB 73 20, and GB 73 58 constituted the production bottlenecks, it reported. It warned against trying to halt British air production by attacks against the light metal industry. "The domestic production of raw aluminum [in Great Britain] is estimated at 50,000 to 60,000 tons, divided among three works. Even if all three were completely destroyed, the replacement of 5,000 tons a month by imports from the U.S.A. and Canada poses no problem." Jordan's calculations of tank production, added to the Lend-Lease imports, plus the section's knowledge of how long it took tanks to reach the fronts from factory and port, divided into the Red army's tank strength tables of organization as modified by Foreign Armies East's knowledge of the degree to which they were fulfilled, enabled the bureau time and again to predict almost to the day when Soviet units would be refitted and so ready once again to attack.

But if the section's intelligence was nearly always welcomed at the operational level, it was not at the Fuhrer's. When it fit his ideas, he accepted and even exaggerated it. In the spring of 1943, the unit was demonstrating that it was essential to hold the Axis bridgehead in North Africa because its loss would free some 2 million tons of ship capacity for the Allies. At the same time, Hitler was telling his admirals the same thing -- with the figures upped to 4 to 5 million tons. But when the unit's reports countered his views, he ignored or rejected them. A few days after Thomas warned him that conquest of most of industrialized European Russia might not cause the Russian war economy to collapse, Hitler was boasting that Russia was losing 75 percent of her aluminum and 90 percent of her oil and "had reached the end of her strength." Later reports increasingly presented uncomfortable information to him. He could not have been happy to learn that the Allies had enough chromium ore not to have to depend on Turkey. More and more, Keitel refused to pass on such informatin. He sent back one report dealing with Lend-Lease to Russia with the scrawl, "The Fuhrer . . . will doubt . . . the information." Finally he ordered the section to stop submitting its reports to Hitler at all.

This procedure was not unlike the American system of analyzing the data plates on downed Japanese aircraft, however, in the American intelligence effort, the experts had been concerned with Japan and Germany, not the Soviet Union. It is also doubtful, based upon later experience, that any of this information was communicated to the military. Since there was no professional military intelligence officers, intelligence training, if any, revolved around combat intelligence. It would be several years later before the American intelligence effort would begin to understand the importance of this type of intelligence and several decades before any effort was made to include this information in routine training.