~~Ext. Stdy~~. - DEVELOPMENT OF GERMAN AIRCRAFT ARMAMENT TO WAR'S END, by Oberst-Ing. a. D. MIX. TR. by Klamerth.

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5-1115-46

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FOREWORD

I. This study is intended to present a survey of the developmental work done in connection with aircraft armaments in the German Luftwaffe and a report on the status this work had achieved by the end of the war. The author has set himself the task of reporting on the motivation, purpose, and goal of the main developmental projects in this field, as well as on the difficulties encountered and the final results achieved in each project; detailed descriptions of the equipment involved have not been included. By means of this approach, the attempt has been made to present a complete picture of the status of development at the end of the war and thus to clarify the most important conditions leading to the planning of the various developmental projects. If, at various points in the study, reference has been made to future problems in the field of aircraft armament, then the opinions expressed are exclusively those of the author and are based on the premise that developments in this field have continued in line with the principles established during the war.

II. A. Rapid Firing Capacity

as a paramount factor, and other absolute performance increases in weapons and ammunition as a further basis for the development of German aircraft armament

There can be no doubt that in World War II the best aircraft was the one characterised not only by better flying performance but also by airborne armaments of high fire power and ammunition of devastating effectiveness. The chief demand to be made of such armaments was that they be capable of smothering an enemy aircraft with such a heavy hail of shells in such a short time that it was bound to be destroyed by one or several hits. This goal was usually attained by using a number of automatic, rapid-fire weapons, which -- in the later years of the war -- were further augmented by airborne rockets. The performance requirements described above were applicable to the offensive armaments carried by fighter aircraft as well as to the defensive armaments borne by the bombers. In the case of the latter, an additional requirement was that of deterrent effectiveness in any possible direction of attack, and these deterrent weapons had to be just as powerful and just as far-reaching as the offensive armaments of the enemy aircraft if they were to fulfill their purpose.

In Germany, there were periods when this deterrent requirement was sadly neglected. During the course of the war, the foreign press reported repeatedly that while Germany had very good aircraft armaments at her disposal, she did not know how to use them. The reason lay in the aircraft designers' exclusive interest in achieving the highest possible flight performance, although in this respect they were far more limited than the designers of other countries -- at least prior to the introduction of the jet propulsion unit -- since the German aircraft engines were less capable of holding their own against foreign models. It was precisely this factor which led German designers to dispense with airborne armaments because of their weight and the extra air resistance engendered by their installation. Then, too, in the opinion of the armaments experts, the military agencies responsible for these developments made the mistake of adapting the armaments of a new aircraft model too closely to the construction of the air frame. Increased flying performance was all too important to the tacticians, who regarded it as tactically more desirable, combined with barely adequate armaments, than additional safety in the form of stronger armaments. In order to maintain her lead in the field of flying performance, Germany concentrated on the construction of fast, twin-engine bombers and continued to equip her fighter aircraft with more modern and better engines, without giving sufficient thought to the armament aspect.

The agency responsible for the developments in the field of airborne armaments in the former Reichs Air Ministry (Reichsluffahrtministerium), later the Luftwaffe High Command (Oberkommando Luftwaffe), soon accepted the consequence implied by this situation -- to concentrate on achieving the highest possible performance in the newer weapons or in those capable of improvement and on developing specialized ammunition types. But this, of course, could compensate only in part for the inadequate armament capacity of the aircraft. On the other hand, the responsible development specialist was safe from any accusation of neglect on this sector.

B. Aircraft Armament in the Luftwaffe at the Beginning of the War

At the beginning of the war, Germany possessed two special offensive armaments for its fighter aircraft -- the 7.9 mm machine-gun (MG-17) and the 20 mm aircraft machine-gun (Oerlikon FF), the latter built in Germany under license. The Oerlikon model was modified to utilize ammunition with electrical detonation and was ordinarily employed with a thin-walled mine projectile (muzzle velocity = 1918.8 ft/second; explosive charge .0429 lbs. HA-41, 75% hexogen, 20 % aluminium, 5 % Montan wax as a cooling agent). The original Oerlikon ammunition drum, holding 60 rounds, was modified to hold 90 without increasing its overall size. In addition, a feeder belt was developed, which, however, was installed in only a few night fighter aircraft, since the Oerlikon FF model had been replaced by the Mauser machine-gun 151 in the meantime.

The 15 mm machine-gun (MG-151), a belt-fed weapon designed originally for directed fire with explosive and armor-piercing ammunition (muzzle velocity = 3148.8 ft/second), weighed 93 lbs. By changing the barrel and the belt slide, it could also be used as a 20 mm weapon. As such, it achieved a firing speed of 620 rounds per minute and was used successfully as a long-range defensive weapon against air targets with the same type of ammunition which had proved so effective with the Oerlikon FF model. It also proved satisfactory in employment as a 15 mm machine-gun.

As far as small caliber defensive weapons were concerned, at the beginning of the war the Luftwaffe had at its disposal the 7.9 mm machine-gun (MG-15), with a dual drum holding 75 rounds, and the 13 mm machine-gun (MG-131), a belt-fed weapon for use with a very effective type of incendiary ammunition.

C. The 30 mm Aircraft Cannon MK-103 and MK-108

a. Performance Requirements

As a logical further development in air-to-air defensive action against bombers, the 30 mm aircraft cannon MK-103 came into being, to be followed somewhat later by the MK-108. Inasmuch as no specifications had been established on the part of the military, the agency in charge of development had a completely free hand. It set the following requirements as its goal:

Primary Mission: It was to be a 30 mm belt-fed weapon with the fastest possible firing sequence, to be used in combat against modern bomber units. The ammunition used was to be the cartridge developed for the MK-101 (see page 14 of this study) with a muzzle velocity of 2952 ft/second, but fitted with an electrical detonation screw. The weapon was to be so constructed that it could be installed either in the fuselage or behind the engines. In addition to the mine ammunition, it was also to be able to utilize armor-piercing ammunition for use against armored targets and -- above all -- ground targets.

Secondary Mission: The weapon was to be as lightweight as possible and as easy as possible to manufacture. It was to be a rapid-firing offensive weapon for standard installation in fighter aircraft for effective combat against modern bomber units. Its ammunition was to have a muzzle velocity of at least 1312 ft/second for the first second after firing. The same mine ammunition was to be used as for the primary mission, above.

b. <u>Technological Requirements for Ammunition, Weapon, and Belt</u>

The ammunition and weapon for the primary mission were to fulfill the following technological requirements:

1) Ammunition

a) Muzzle velocity 2952 ft/second

b) Mine projectiles for offensive action against air targets.

c) Armor-piercing grenades with tungsten core and supplementary action for the combatting of armored tanks.

d) Explosive grenades, armor-piercing incendiary grenades, and armor-piercing incendiary explosive grenades for use against unprotected, i.e. ironplated, or armored ground targets, merchant ships, and light armored vehicles.

e) Mine projectiles with fourfold greater effectiveness than the 20 mm mine projectiles (the shell body of drawn steel; explosive charge 75% hexogen, 20% aluminum, 5% Montan wax as cooling agent). Percussion fuse with self-destroying mechanism set to go off at not less than 3280 feet after firing and 32.8 feet muzzle safety. Cartridge case to be made of steel if possible. Fuse cap for electrical detonation, to react without fail at 18 Volts and to be insensitive to jarring.

2) Gun

a) Weapon system optional; blowback or recoil operated, rigid or mass-locked

b) Firing speed at least 400 shots per minute

c) Smooth operation at accelerations up to three times ground acceleration, corresponding to a belt feed of approximately 6.6 feet static, and full functioning at -60° C.

d) Few movable parts, in the interests of high firing speed

e) Lightest possible total weight and installation length

f) Possible installation in the fuselage, at the base of the wings, or behind the engines

g) Belt feed either from left to right or from right to left

h) Electropneumatic cocking and firing mechanism

i) Electrical detonation.

j) Central positioning of weapon (zentrale Waffenlagerung)

k) Overall construction to be based on consideration of simplest possible manufacturing methods and least possible need for re-tooling; die-casting to be preferred to shaping by cutting.

l) Absolute interchangeability of functional parts.

m) Life of expendable parts to be at least 1,000 rounds without any disalignment incapable of being corrected by cocking.

n) Use of unrationed materials, such as substitute materials for steel alloys.

2) Belt

a) Collapsible link belt of sheet steel, in which the individual links are held together by the cartridge cases.

b) Dismantling of the belt into its individual links regardless of whether feeder activity takes place from right to left or from left to right.

c) No stiffness in the fully-loaded belt, i.e. it must remain flexible and be capable of being bent tightly in any direction.

The lighter weapon and its ammunition were to fulfill the following requirements:

1) Ammunition

a) Muzzle velocity 1640 ft/second, corresponding to a trajectory of 1312 ft during the first second.

b) Other specifications for mine projectiles and cartridge cases to be the same as for the primary mission weapon described above.

2) Weapon

a) Firing speed to be 600 rounds per minute.

b) Other specifications to be the same as for the primary mission weapon described above.

3) Belt

a) Specifications to be the same as for the primary mission weapon described above.

c. The 30 mm Aircraft Cannon MK-101 as the Forerunner of the MK-103 and the MK-108

The development of the MK-103 and MK-108 was carried out by the Rheinmetall-Borsig Company. This firm was regarded as being particularly well-suited to the assignment in view of the fact that in 1936, acting on its own initiative, it had developed a 30 mm airborne weapon and ammunition, the MK-101. At that time, however, the MK-101 had been turned down by the military authorities because its size and weight (408 lbs. including gunmount) on the one hand, and its method of operation (detachable magazine with six rounds, 26 lbs. empty weight, and 13 lbs. ammunition weight = 39 lbs.) on the other hand would have required the complete rebuilding of a twin-engine aircraft and would have reduced its flying performance considerably. The necessity of combatting air targets with such large caliber was unquestioned at that time. During the war, the MK-101 was greatly in demand for installation in close-support aircraft of the Hs-129 type, to be used with tungsten-core ammunition (muzzle velocity 3148.6 ft/second;

armor-piercing effectiveness against armor plating of 220.5 lbs/mm^2 strength: 70 mm at a 60° impact angle and 100 mm at a 90° impact angle from a distance of 984 ft) against the Russian T-34 tanks. By that time, however, the MK-101's were available only in relatively short supply. The Rheinmetall-Borsig Company had switched its production capacity to other projects and was thus not in a position to make large deliveries of the MK-101, and no arrangements for its continued manufacture elsewhere had been made.

d. The Reasons for the Difficulties Encountered in Bringing Developmental Work on the MK-108 to a Close and in Getting it into Production

The Rheinmetall-Borsig Company developed the MK-103 as a blowback-operated gun and the MK-108 as a recoil-operated weapon with mass-looking breech. The required ammunition types for use against air and ground targets were developed from the ammunition designed for the MK-101, and were ready for use with the sample weapons. The difficulties encountered in bringing developmental work on the MK-108 to a close and in getting it ready for production were due in part to factors connected with the production aspect:

1) the sample equipment did not correspond entirely to the finished series product since certain parts which would later be die-cast in the mass production process still had to be manufactured by other means or cast provisionally.

2) the fact that the ammunition had been developed concurrently with the weapon often

made it impossible to tell whether certain defects in the test shots were attributable to the ammunition or the weapon itself.

There were also administrative factors responsible for the difficulties encountered:

3) premature promises regarding production deadlines and delivery figures were made by the Reichs Ministry for Armament and War Production (Ministerium für Rüstung und Kriegsproduktion).

4) as a result of these promises, the firms involved were placed under unhealthy pressure to bring the developmental work to a close at the earliest possible date.

5) the series production of the weapon was assigned exclusively to a secondary construction firm rather than to the firm which had been in charge of development.

6) production facilities in this secondary firm were set up in accordance with drawings which the developing firm had not even used in connection with its sample weapons.

e. Intervention on the Part of Superior Military Headquarters and the Ministry for Armament and War Production in Connection with the Final Development of the MK-103 and the MK-108

The tendency of military agencies to demand that new weapons developed by industry be put into full-scale series production as soon as the first sample weapons had been test-fired with satisfactory results was confirmed repeatedly in the case of the newly developed equipment, and -- just as repeatedly -- this habit gave rise to setbacks. There was little point in insisting that technologically complicated development processes could not simply be brought to a successful close upon demand. The author is of the opinion that the intervention of the Ministry for Armament and War Production towards the conclusion of developmental work was not favorable in the case of the MK-103 and the MK-108. His reproaches in this connection are directed not against the Ordnance Commission (Waffenkommission) and its special sub-committees, but rather against the office of the Specialist in Charge of Weapons (Sonderbeauftragter für Waffen) in the Ministry for Armament and War Production. This office, run on the lines of Party politics and staffed by non-experts, supervised developmental work with a peculiarly unhealthy kind of coordination. In this connection it may be worthwhile to mention that this agency took steps to have the developmental work on the MK-103 and MK-108 transferred to itself shortly before its scheduled conclusion, requisitioning one of the chief experts to take over on behalf of the office. Subsequently, developmental work was officially brought to a close under the auspices of the Specialist's office, without, however, absolving the Development Department (Entwicklungsabteilung) of ultimate responsibility for the equipment.

f. <u>The Elimination of Technical Difficulties in the Secondary Construction Firm Assigned to the Production of the MK-108</u>

Inasmuch as the MK-108 was ordered into production before it was completely finished and before it had been adequately tested, and inasmuch as the ammunition for it was also still in the testing stage, it was extremely difficult to trace certain functional defects apparent during the final testing to their ultimate sources, except in those cases where the reason for failure was clearly evident in the form of damaged parts. The fact that the Rheinmetall-Borsig Company, whose engineer and workshop personnel were intimately acquainted with the MK-108 and could have carried out whatever modifications might prove necessary and amended their blueprints without delay, was not assigned the task of manufacturing the weapon led to considerable difficulties in the early stages of production in the secondary construction firm, the former German Weapons and Ammunition Factories (Deutsche Waffen- und Munitionsfabriken) in Posen, where plant facilities were designed primarily for mass production. These initial difficulties could be overcome to some extent by the assignment of a team from the Rheinmetall-Borsig Company to the construction firm in Posen. The engineers from Rheinmetall-Borsig were assigned to provide whatever on-the-spot assistance might be needed and to make certain that the manufacturing specifications in use in the workshops corresponded to the latest stage of development.

g. The Ammunition for the MK-108

As far as the exterior ballistic performance requirements of the MK-108 ammunition were concerned, the developmental agencies had deliberately restricted themselves to medium combat range, since the technological requirements demanded that the weapon be kept as light as possible. After careful measurement and calculation, a 330 g projectile was developed. The weight of the cartridge, in keeping with the established muzzle velocity of 1640 ft/second, was 475 g. The mine projectile evolved by Rheinmetall-Borsig had an explosive charge of 72 g, combined with a tracer (i.e. night tracer) ammunition. The parallel projectile developed by the German Weapons and Ammunition Factories had an explosive charge of 85 g and no tracer ammunition. It could also be used as an incendiary grenade by lining the shell with an alloy of barium-aluminum-magnesium. Thus the two types of grenades supplemented each other in their effectiveness against air targets. The main disadvantage -- the fact that the mine projectile was designed primarily for use against an aircraft air frame (due to its intense blowback effect), while the incendiary filling released by the detonation of the incendiary grenade was effective only when it came into contact with gasoline -- was eliminated in 1944 by the development of a combined mine-incendiary grenade. The latter shell, also evolved by the German Weapons and Ammunition Factories, effectively combined the achievements of the other two. Since the problem of mine projectile development, including the necessary testing methods for mine projectiles had been solved completely in connection with the mass production of the 20 mm cartridges for the Oerlikon FF and the MG-151/20, no appreciable difficulty was encountered in the development of the 30 mm shells.

h. Evaluation of the Development of the MK-108

The MK-108 and its ammunition not only fulfilled the requirements set for them, but even exceeded them by achieving an average firing speed of 650 rounds per minute. The MK-108 was additional proof (after the 20 mm Oerlikon FF) of the fact that the mass-locking breech was an effective and reliable breech-locking system even for large-caliber, rapid-firing automatic weapons of limited ballistic performance for medium-range use against air targets. At any rate, it was clear that the system had no basic defects, as had been assumed previously in German ordnance circles and by the advocates of the rigidly locked weapons systems. It was proved beyond a doubt that there was no danger of premature detonation, with subsequent damage to the interior of the weapon, or of jammed cartridges or torn cartridge bases, even when cartridges of steel were used exclusively. This may have been a result of the extremely exact electrical detonation of the ammunition and of the generally followed practice of waxing the cartridges.

The unusually simple construction of the MK-108, with its mass-locking breech system, and the generous use made of die-cast steel parts represented a great advantage in the mass production process over all previous German airborne weapons. The number of manhours needed to manufacture a complete MK-108 in series production, including its drawn barrel, had been reduced to seventy-five by the end of the war, while the manufacture ~~xxxxxx~~ of the MG-151 in mass production still took ninety-five working hours.

The excellent qualities of the MK-108 -- its firing speed of 650 rounds per minute, its relatively light weight of 132 lbs, the ease with which it could be installed, and its highly effective ammunition -- soon gave it a good reputation in all quarters.

i. Evaluation of the Development of the MK-103

Chronologically slightly behind the MK-108 , in deference to which it had been relegated to the background a number of times, developmental work on the heavy 30 mm aircraft cannon MK-103 was also declared finished. The MK-103, constructed on the blowback-operation principle, also fulfilled all the requirements set for it (see page 1/12 of this study) with one exception -- the muzzle velocity had to be decreased to 2820.4 ft/second since the original velocity resulted in damage to the breech-locking system. Moreover, a special model was required if the weapon was to be installed behind the engines (a specialized purpose which had become rather obsolete in the meantime anyway), since the laterally-mounted gas lever of the standard MK-103 made it impossible to install the gun in the hollow engine centerline. The Rheinmetall--Borsig Company found a solution in the form of a model with a centrally-mounted gas lever, but since this construction seemed somewhat less reliable than the other, it could not be adopted for the standard model. The excessively wide dispersion patterns and shifts in these patterns which occurred when the weapon was mounted behind the engines created considerable difficulty in the beginning, but these defects were soon corrected by stabilizing the barrel and changing the method of suspension from the engines.

As regards manufacture, the MK-103, too, was designed to make use of die-cast sheet steel, insofar as construction, function, and durability did not absolutely demand the use of high-grade steel and specialized production methods. Although the developmental work on the MK-103 was rushed to a close under conditions similar to those prevailing in the case of the MK-108, its series production got off to a smoother start since production was assigned to the Rheinmetall-Borsig Company itself.

The MK-103 had been designed as an offensive weapon for use against air targets at a maximum range of approximately 3936 ft, as well as against ground targets, particularly armored tanks and vehicles. Throughout the entire war, however, only a very few MK-103's were made available for use against tanks, and then only under very special circumstances. The MK-103 may be considered to have met the goals assigned to its designers, with its still acceptable weight of 309 lbs, with a muzzle velocity of 2820.8 ft/second, an average cartridge weight of about 1.8 lbs, and a firing speed of 450 rounds per minute. As far as construction was concerned, the designers of the MK-103 chose the safest way in order to avoid developmental difficulties and to make the best use of the time at their disposal. Nevertheless, the MK-103 was the most modern automatic 30 mm weapon to be introduced in its performance class -- in respect to production as well -- and at the time of its introduction the other Wehrmacht branches were greatly interested in it. In addition to its main area of employment as an offensive weapon, the developmental agency also considered it well adapted to use as a long-range automatic defensive weapon when installed on mechanically aimed flexible gunmounts.

j. The Ammunition for the MK-103

For use against air targets, the MK-103 was designed to utilize cartridges and mine projectiles of the same weight, with and without tracer ammunition, as the MK-108 and the same incendiary grenades (see page 19 of this study) as the MK-108. The MK-103 cartridges also had a muzzle velocity of 2820.8 ft/second, with an average weight of 1.8 lbs. No combined mine-incendiary grenade had been developed for the MK-103 as yet. We can assume, however, that it would have been introduced in time to replace the two ammunition types already available.

Thus, if the MK-103 was to be used effectively against armored tanks, there was no alternative but to resort to a projectile with a tungsten core and with a magnesium head to bring about the incendiary effect (at that time tungsten was practically unavailable in Germany). Fired at a range of 984 ft, this special projectile was able to pierce armor plating 70 mm thick and 220.5 lbs/mm^2 strong at an impact angle of 60°, and plating 100 mm thick at a vertical impact angle. The armor-piercing incendiary grenade designed for use against merchant ships and light armored vehicles was capable of penetrating marine construction steel (Schiffsbaustahl) 20 mm thick at a range of 1,000 meters and an impact angle of 60°, and the armor-piercing fragmentation grenade, designed primarily for use against ground targets, was able to penetrate steel plating 25 mm thick from a distance of 984 ft and at an impact angle of 60°. In their effectiveness and ballistic performance, the cartridges developed for use against air targets corresponded in general to the ammunition types used with the 37 mm antiaircraft artillery cannon, model 18. After the available supply of MK-101's had been exhausted (see page 14 of this study), a small quantity of this antiaircraft artillery ammunition had been taken over and, with minor modifications, used for airborne cannon. Only the 37 mm armor-piercing ammunition designed for use against armored tanks had greater penetration effectiveness (40 mm) than the 30 mm armor-piercing grenade. Quite apart from the increase in weight (304 lbs per weapon) when the 37 mm antiaircraft artillery ammunition was used, the 30 mm ammunition was perfectly adequate for use against the Russian T-34, the tank most frequently employed on the Eastern front. As a result of its threefold greater firing speed, the MK-103, used with the proper ammunition, was also preferable to the 37 mm airborne heavy cannon for use against light armored vehicles and iron-protected ground targets.

D. The Airborne Weapon MG-213 with 20 mm and 30 mm Barrel

a. Purpose of Development and Requirements to be Met

The MG-213 was designed originally as a 20 mm machine-gun for use against air targets with a 20 mm long-range mine projectile. It was intended to take the place of the MG-151/20.

The MG-151/20 had rendered satisfactory service at the front for years and at that time was still considered a good weapon. Nevertheless, on the basis of their knowledge and the experience gained so far, the weapons designers were convinced that it ought to be possible to increase the firing speed of an automatic, long-range 20 mm weapon -- which in the case of the MG-151/20 was 620 rounds per minute -- to more than 1,000 rounds per minute.

The 20 mm long-range mine projectile was already available in an experimental model. It was a new type of projectile of 55 mm barrel ~~strength~~ length in a cartridge with a muzzle velocity of 3280 ft/second. (This projectile could not be used with the MG 151/20 because the rate of decrease in muzzle velocity was too great).

The long-range mine projectile followed a perfectly stable course. Due to its extra length, the explosive charge could be increased to 24 g. The total weight of the projectile was 114 g, as contrasted with 92 g for the one used with the MG-151/20, and the weight of the cartridge was 340 g.

Since the superior military agencies once again played no part in establishing the need for development or the requirements to be met by the new weapon, the Weapons Branch of the Technical Office set the following goals:

An automatic airborne machine-gun with extra high firing speed was to be developed for use with a cartridge having a muzzle velocity of 3280 ft/second. The machine-gun was to be so designed as to make production as simple as possible. It was to be used primarily in mobile gunmounts against enemy aircraft. Thus, ideally, it was to be constructed in such a way that a number of weapons could be installed in a relatively small area in antiaircraft defense posts.

b. Technological Requirements to be Met by Weapon, Belt, and Ammunition

The following requirements were established:

1) Weapon

a) Basic type optional.

b) Feeder belt either left to right or right to left.

c) Firing speed 1,000 rounds per minute.

d) Smooth functionability at accelerations up to three times ground acceleration, corresponding to a belt feed of 6.6 ft static, and full functionability at -60° C

e) Simple construction and light weight

f) Shortest possible casing, permitting installation on flexible gun-mounts

g) Central positioning of weapon

h) Electrical detonation

i) Electropneumatic cocking and firing mechanism

j) Overall construction to take into consideration the simplest production methods and the shortest possible development period, with die-casting to be given preference over shaping by cutting whenever possible

k) Absolute interchangeability of expendable parts and functional reliability without the need for subsequent regulation

l) Life of expendable parts to be at least 1000 shots without any disalignment of the weapon which could not be corrected by cocking

a) Utilisation of unrationed steel and substitute materials.

2) Belt

a) Collapsible link belt of sheet steel.

b) Equally smooth dismantling into individual links regardless of whether feeder activity was from left to right or from right to left.

c) No stiffness in the fully-loaded belt, i.e. it must remain firm and flexible and capable of being bent tightly in both directions.

2) Ammunition

a) The available 20 mm cartridge with the long-range mine projectile fulfilled the following requirements:

b) Muzzle velocity 3280 ft/second.

c) Projectile shell of drawn steel.

d) Explosive charge of 24 g of hexogen-aluminium explosive (HA 41).

e) Percussion fuse with self-disintegrating mechanism set at approximately 6560 ft and 32.8 ft muzzle safety

f) Cartridge of drawn steel

g) Fuse cap for electrical detonation, regulated to work without fail at 16 Volts or more and impervious to impact vibration.

c. Problems Encountered during Development of the Weapon and the Tentative Results of the First Stage of Development (20 mm Barrel)

The development of the 20 mm MG-213 was first assigned to the

Krieghoff Company, and later to the Mauser Company, which -- to begin with -- designed and built three different models based on the blow-back-operation principle. Of these three models, the Development Department decided on the MG-213/0, which utilized the well-known revolver cylinder principle. Depending upon the regulation of the cylinder, the feeding of the long and relatively heavy cartridges was spread over several shots, thus giving the weapons an extremely high firing speed of 1,400 rounds per minute. Insofar as the tentative results achieved by the test models permitted a final judgment, the 20 mm MG-213/C not only fulfilled, but exceeded all the technological requirements set for it. Two problems remained to be solved during the subsequent developmental work:

1) the type of gasket to be used between barrel and cylinder;

2) an effective method of cooling -- or rather airing -- the cylinder in order to obviate any danger of the cartridge's igniting automatically during the feeding process when the weapon was required to fire more than 200 rounds in quick succession, either in the form of bursts of fire or continuous fire.

Both problems found adequate solutions which were also logical from the point of view of construction.

d. The Order to Adapt the MG-213/C to 30 mm and the Developmental Results Attained by the End of the War

At the same time, the Development Department decided in favor of the MG-213/C and requested that the weapon be adapted to 30 mm caliber, for a cartridge with a muzzle velocity of 1738.4 ft/second and a mine projectile with 85 g of explosive and an incendiary grenade. The decision to carry the development of defensive armaments, too, as far as possible into the 30 mm caliber range was considered necessary by the Development Department in view of the increased use of fighter escorts by the enemy. The Department championed the view, much disputed in the Technical Office, that bomber aircarft must have sufficiently powerful defensive armaments to ensure their being able to throw off enemy attackers on the way to their targets, and that the question of their speed should be subordinated to this security factor, in other words, that speed was of secondary importance. With the light and elegant MG-213/C at its disposal, the Department saw a way to push through this requirement, which had always been disapproved before because of the weight and space factors.

Adaptation to 30 mm could be achieved with relative ease by changing the barrel and a few functional parts of the weapon. As a 30 mm gun for use with a cartridge of 1738.4 ft/second muzzle velocity, the MG-213/C still managed to retain the very high firing speed of 1,100 rounds per minute; its weight was only 165 lbs. It was still in the testing stage when the war came to an end.

In both design and performance, the MG-213/C represented an appreciable advance over the achievements so far in the field of rapid-firing automatic weapons. In my opinion, it would have retained its head-start over the other available 20 mm and 30 mm weapons of the same performance class for years. The MG-213/C could also have been installed in fighter aircraft as a 30 mm offensive weapon.

III. A. The Need for a Further Increase in Caliber

In the preceding pages of this study, I have already mentioned that a bomber aircraft of the Flying Fortress type could be brought down by 20 mm or 30 mm weapons only by an entire series of direct hits. Even the introduction of special offensive tactics, eg. attacking from the front and aiming at particularly vulnerable points (engines, unprotected fuel tanks, etc.) had no more than temporary influence on this unsatisfactory state of affairs. Thus, the Development Department was faced with the necessity of developing more effective ammunition and thus with the task of increasing the caliber once more. The effectiveness of the ammunition already in use had been investigated in systematic firing tests and was a matter of record. Tests had disclosed that it was not the grenade splinters but the blow-back effect of the thin-walled mine projectiles which brought about large-scale damage combined with incendiary effect in the aircraft hit. The effectiveness of 20 mm, as compared with 30 mm mines, was approximately 1:4, and in 1944 four or five hits by 30 mm projectiles, concentrated in a relatively small area, were necessary to bring down a four-engine bomber. Inasmuch as the demand for larger caliber precluded in any case fulfillment of the requirement of the highest possible firing speed, the designers went to the other extreme and set themselves the following task:

B. Development of the 55 mm Caliber

a. Goals of Development

By means of exhaustive experiments, it was to be determined how much of the hexogen-aluminum explosive was needed to destroy a large bomber. Next, a projectile was to be developed for the required kind and amount of explosive; the blowback effect of the projectile was to be so powerful that only one direct hit would be necessary to guarantee the destruction of a four-engine bomber.

b. Results of Development

The initial experiments revealed that 420-450 g of explosive were needed in order to bring about the desired total damage to the fuselage or wings of a large bomber; in other words, this amount of explosive would ensure that the aircraft would be so badly damaged at and around the point of impact that its crash would be a foregone conclusion. For an explosive charge of this size, however, a 55 mm cartridge was necessary. The Development Department was well aware of the fact that an automatic weapon of this caliber, because of its size and weight, would be dangerously near the limit of the carrying capacity of the single and twin-engine fighter aircraft. The Department had already had some experience, on the other hand, with the installation of cannon of this size in close-support aircraft, in some of which 75 mm antiaircraft guns had been mounted experimentally for use against tanks. The 55 mm caliber was best suited, however, for rocket projectiles, whose utilization as airborne weapons against air targets had been so far neglected by German military leaders, largely because the central agency in charge of rocket development (in the Army Ordnance Office (Heereswaffenamt)) had no suitable airborne rockets available.

C. The 55 mm Airborne Cannon

a. Goal of Development

The following two goals were established for the development of the 55 mm airborne weapon:

Corresponding to the developmental goals of the 30 mm cannon, the following were set as requirements:

1. a lightweight automatic 55 mm airborne cannon

2. a heavy, i.e. long-range automatic 55 mm cannon.

As regards 1, above, a lightweight automatic 55 mm airborne cannon was to be developed as an offensive weapon for use at a range of up to approximately 3280 ft. Every effort would be made to achieve the highest firing speed and the lightest weight possible, combined with maximum ease of installation. The ammunition was to have an effective range of up to 6560 ft, and the explosive charge of the cartridge, to be designed for a mine-type projectile, was to be at least 420 g. If at all feasible, the same cartridge, utilising 450 g of explosive, was to be used for the heavy 55 mm airborne cannon as well.

As regards 2, above, a heavy 55 mm airborne cannon was to be designed for cartridges with high muzzle velocity, so that it could be employed as a long-range weapon for distances from 3280 to 6560 ft.

Moreover, the weapon was to be designed for semi-rigid, i.e. stabilized installation, so that artillery firing methods could be applied. It was to be for use against air and ground targets. Its maximum permissible weight was set at approximately 1543.5 lbs. Depending upon the mission at hand, two types of ammunition were to be developed, mine projectiles with an explosive charge of 450 g against air targets, and fragmentation grenades and armor-piercing projectiles against ground and naval targets.

b. Technological Requirements for Weapon, Ammunition, and Belt

1) Ammunition

a) Muzzle velocity = 1968 ft/second.

b) Minimum explosive charge of 420 g hexogen-aluminum.

c) Percussion fuse with self-disintegrating mechanism set for 6560 ft and 32.8 ft muzzle safety

d) Cartridge of steel

e) Fuse cap for electrical detonation, regulated to work without fail at 18 Volts and relatively insensitive to impact vibration

2) Weapon

a) Weapon system optional; movable parts to be kept to a minimum in the interests of maximum firing speed.

b) Muzzle brake to ensure effective neutralisation of recoil forces which might disturb the balance of the weapon.

c) Design to permit installation in the fuselage of a twin-engine aircraft.

d) Feeder belt to function either from left to right or from right to left.

e) Electropneumatic firing and cocking mechanism.

f) Electrical detonation.

g) Functional reliability at acceleration up to three times ground velocity and at -60°.

h) Design to be developed with an eye to the simplest possible production methods.

i) Die-cast parts and welded sheet steel to be given preference over shaping by cutting.

j) Life of expendable parts to be at least 1,000 rounds without any disalignment of the weapon not capable of correction by cocking.

k) Use of unrationed and substitute materials.

3) Belt

a) Collapsible link belt of sheet steel.

The following requirements were set for the heavy 55 mm airborne cannon:

1) Ammunition

a) Muzzle velocity = 3280 ft/second.

b) Mine projectile with 450 g explosive charge for use against air targets.

c) Armor-piercing or hollow-charge projectiles for use against air targets.

d) Armor-piercing or hollow-charge projectiles for use against tanks.

e) Armor-piercing fragmentation grenades for use against ground targets, merchant ships, and light warships.

f) Other requirements regarding projectiles, cartridges, etc. were the same as for the lightweight 55 mm airborne cannon.

2) Weapon

a) Firing speed 150 rounds per minute.

b) Maximum weight of mounted weapon 1543.5 lbs.

c) Other requirements were the same as for the lightweight 55 mm airborne cannon.

3) Belt

a) Requirements were the same as for the lightweight 55 mm airborne cannon.

c. Results Achieved in the Development of the 55 mm Airborne Cannon by the End of the War

Developmental work on the 55 mm airborne cannon was carried out by the Rheinmetall-Borsig Company, with its models MK-112 and MK-114; by the Mauser Company, with its MK-214/B and with an interesting intermediate-stage model, the automatic KWK-39, also called the MK-214/A; the Krupp Company, with its experimental model MK-412; and -- once again -- the Rheinmetall-Borsig Company, with a recoilless jet cannon, the MK-115, which represented an appreciable scientific advance.

As was the case with the MG-213, developmental work was carried out under the supervision of the Special "Automatic Cannon" Commission (Sonderkommission für "Automatische Kanonen") in the Ministry for Armament and War Production, which was in charge of directing development for all the Wehrmacht branches with a view to standardising design whenever possible and which was authorised to determine priority.

Only in the case of the 50 mm MK-214/A was the developmental work actually concluded, and this was the only one of the six which reached the stage of employment -- at the very end of the war. Other models were finished as far as the workshop was concerned, but were still being tested by the firms in charge of their development. During the last years of the war, work could be continued only at a very slow pace, because of other, more urgent development projects within the framework of an all-out program sponsored by the Special "Automatic Cannon" Commission. The 55 mm cannon was relegated to the background in view of the fact that there was no longer any hope of completing it in time for its effective employment at the front and, in part, because advances in the rocket field had rendered it obsolescent. By the time the war came to an end, however, there had still been no final decision as to which of the two parallel lines of development ought to be dropped in favor of concentrating on the other one.

1. <u>The 55 mm Airborne Cannon, MK-112</u>

The MK-112 was a recoil-operated weapon with mass-locking breech like the MK-108, which the designer had used as a model. On the whole, its technological specifications fulfilled the established requirements: firing speed 300 rounds per minute; weight 606.3 lbs; mine projectile with 420 g explosive charge; total weight 3.26 lbs; muzzle velocity = 1968 ft/second. No way had been found as yet, however, to standardize the projectile with that of the heavy 55 mm airborne cannon.

2. The 55 mm Airborne Cannon, MK-412

The experimental model MK-412 had approximately the same performance characteristics as the MK-112, and was even more advantageous in that it weighed only 397 lbs. It was designed as a blowback-operated weapon. The muzzle velocity had been increased by 164 ft to 2132 ft/second.

3. The 55 mm Airborne Cannon, MK-114 and MK-214/B

The heavy 55 mm cannon MK-114 and MK-214/B had been designed to fire a standard cartridge intended for use by the antiaircraft artillery forces and the Navy as well. The mine projectile to be used had an explosive charge of 0.99 lbs, a weight of 3.96 lbs, and a muzzle velocity of 3280 ft/second. The weapons themselves were within the established weight limit; the Mauser MK-214/B weighed 1433.5 lbs, and the Rheinmetall-Borsig MK-114, 1543.5 lbs. Both weapons had a firing speed of 180 rounds per minute.

4. The 55 mm Airborne Cannon, MK-214/A

The Mauser Company was assigned the task of developing its 50 mm antitank gun, the KWK-39, into a possible temporary answer to the need for a 55 mm airborne cannon. The KWK-39 was to be changed into an automatic weapon by the addition of a loading lever (Ladeschwinge). The weapon had a weight of 1058.4 lbs. With the new loading mechanism, a firing speed of 145 rounds per minute was achieved. In my opinion, this method of development -- followed for the first time in the case of the MK-214/A -- was the beginning of a kind of building-block system in ordnance design. I believe that, if constructive solutions of this type had been pursued systematically, a high degree of standardization and consequently an appreciable simplification of the production processes applicable to the various categories of weapons used by all the Wehrmacht branches might have been attained. The prerequisites, namely the standardization of caliber and -- insofar as standardized projectiles were out of the question -- at least the use of standardized cartridges, had been created for the German Wehrmacht by the Ammunition Commission (Munitionskommission). The MK-214/A had been developed originally as an airborne weapon for use against air targets; it utilized a mine projectile with an explosive charge of 0.77 lbs. and a muzzle velocity of 2967.6 ft/second. It was also designed for installation in close-support aircraft as an antitank gun, utilizing armor-piercing fragmentation grenades capable of penetrating armor plating 65 mm thick and with a strength of 220.5 lbs/m^2 when fired at an angle of 60°.

5. The Jet Cannon, MK-115

In my opinion, the basic principle of the jet cannon represents a highly elegant and promising solution to the problem of large-caliber airborne cannon. To be sure, this principle, familiar since Davis' work, necessitates certain limitations as far as installation is concerned, inasmuch as there has to be a way for flare-back gases and cartridge bits to escape unhindered. In addition, more powder is required, which means that the ammunition weighs approximately twice as much as a normal cartridge of the same capacity. The system of the recoilless barrel, however, has the great advantage that the gunmount can be designed without any regard for recoil reaction. Thus, even a 55 mm weapon of this design would not have been too heavy to preclude installation in the wings of an aircraft. Provided that a workable jet cannon can be developed for the combat range between 3280 and 6560 ft, it seems likely that weapons of this type must be given continued consideration because of their better ballistic characteristics, unless rockets with comparable firing accuracy can be developed.

The MK-115 met the requirements established for the lightweight 55 mm airborne cannon, with one exception -- the gas jet had to escape unhindered from the rear. Its weight was 397 lbs; its firing speed 300 rounds per minute; and it achieved a muzzle velocity of 1968 ft/second with a projectile weighing 3.3 lbs and carrying 0.93 lbs explosive charge. The cartridge case, except for a short metal base cap, was made of combustible cardboard -- something entirely new in the field of air armament design.

IV. A. The Demand on the Part of the Day Fighter Forces for an Increased Firing Range of 4920 to 6560 feet

As the enemy bomber invasions continued, the concentrated defensive fire of the large bomber units forced the German fighter units to carry out their attacks from farther and farther away and to discontinue them at a much earlier stage. It is immaterial from the point of view of the construction engineer whether or not other factors may also have played a decisive role. During the second half of the war, after Germany had discontinued her own bomber attacks on England, the fighter forces were made up to a not inconsiderable degree of former bomber pilots who had been reassigned as fighter pilots and who were often accused -- fairly or not -- of not achieving adequate results in their new capacity. In order to facilitate their offensive activity, the fighter forces requested offensive airborne armaments capable of being used effectively from outside the range of the enemy's defensive armaments.

B. The 210 mm Airborne Fragmentation Rocket

At that time the units at the front were also experimenting with a view to devising some means of dispersing the enemy bomber formations at a range of 4920 - 6560 ft, so that the real attack, carried out by the fighters' airborne armaments, could be launched against a disorganized formation, i.e. against isolated aircraft within such a formation. For this purpose, they selected the 210 mm mortar shell used by the Army, modifying it for the Luftwaffe into a 210 mm airborne fragmentation rocket with a time fuse which could be regulated. This rocket, weighing 247 lbs and equipped with an 80-lb explosive head, was suspended experimentally under the fuselage of a number of fighter aircraft and then fired from a range of 4920 - 6560 ft at the bomber unit under attack. The distance was calculated with a reflector sight according to the target basis method (Basis am Ziel Methode). According to the reports received from the front at that time, this method of attack proved unsatisfactory because of the fuse range, which was too inexact for airborne armaments, and because of the method of range calculation, which was simply too primitive for long distances. As was the case with antiaircraft artillery ammunition operated by delayed-action fuse, good results could be achieved only when the warhead exploded in the immediate vicinity of the target.

V. A. The Significance of the Rocket as an Airborne Weapon in Comparison with the Automatic Airborne Cannon

I have already stated in Section III, B, above, that German experts considered the limit imposed by the factors of weight and feasibility of installation to have been reached by the 55 mm airborne cannon, and that, therefore, in view of the stage achieved in the field of firing techniques, the airborne rocket was of great importance for weapons of larger caliber. In my opinion, the German rockets then available could have been improved with respect to exterior ballistic performance and firing accuracy, and although no definitive evaluation of the potential improvement could be made before Germany's capitulation, I am convinced that they could have been developed to the point where they could have competed seriously with the 55 mm airborne cannon, the MK-112 etc. My statement should not be interpreted to imply that the heavy cannon, the MK-114 and the MK-213/B, would necessarily have forfeited their importance for special types of missions. Still, I considered that these heavy cannon could be of real value only in combination with artillery firing procedures and methods, the application of which in airborne armaments could be of great significance. Germany, however, in the sixth year of the war, had neither the time nor the capacity to carry out effectively the developmental work required by a project oriented towards the future. Nevertheless, in my opinion, this is the only line of development which offers any prospect of success for the future, when a fighter arm will be forced to do combat against super-fast atomic bombers which will not only carry long-range defensive weapons capable of meeting attack from all directions but will also probably fly at altitudes bordering on the stratosphere. In order to prevent unbearably heavy losses, combat of this type will have to be carried out from a great distance, i.e. from outside the range of the enemy's defensive fire. It seems clear that the rigid firing methods used by the fighter pilots heretofore will no longer be adequate under such conditions.

Quite apart from the advantages of lighter weight and its favorable implications for the performance of the aircraft, there are important technical advantages which argue for rockets as the airborne weapon of modern times.

1. Manufacture

The complete rocket armament for an aircraft is easier to manufacture than the armament consisting of an automatic cannon and its ammunition. Thus, the production process is faster, cheaper, and requires fewer workers -- particularly highly-skilled workers. In addition, insofar as my information is accurate, it requires only a fraction of the machinery needed by a plant devoted to the manufacture of automatic weapons.

Moreover, the manufacture of rocket armaments requires a far smaller number of raw materials -- especially construction materials -- than that of automatic weapons.

2. Operation and Maintenance

Rocket armaments require fewer personnel and less time in both operation and maintenance while in action. They are less vulnerable to the influence of climatic facters and extreme cold and are thus more reliable. Wear and tear on the launching mechanisms cannot possibly reach the scope encountered in the case of automatic weapons. For this reason the need for continual supply of spare parts is not so great.

3. <u>Modifications</u>

Rocket armaments can be more easily modified to incorporate technological advances. Conversion to a more powerful and more perfect model can be achieved more rapidly due to greater ease of manufacture, and new models can be better integrated into armament planning than the introduction of a new automatic weapon and the conversion of the aircraft for its installation.

B. <u>Airborne Rockets</u>

a. <u>Rockets Taken Over from the Army Ordnance Office for Use as Airborne Rockets</u>

Even prior to the war, Germany had experimented with rockets launched from aircraft, specifically with the Rz-65, which had been taken over from the Army Ordnance Office. The Rz-65 was a forerunner of the antiaircraft artillery rocket Rz-75, which was utilized to some extent during the last months of the war as a part of the armament of the rocket-propelled fighter "Natter" (Adder). The smoke cylinder+ R-65 was a spin-stabilized rocket of 65 mm caliber with electrical launching mechanism. With a thrust duration of one-third second, it could achieve a maximum speed of 902 ft/second. During the course of the war, experiments on this rocket were discontinued, after

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\+ - Translator's Note: The term "smoke cylinder" is based on Leidecker, German-English Technical Dictionary, Volume II, page 647: "Rauchzylinder - CODE for rocket released from a fighter aircraft."

numerous recommended modifications failed to bring about the desired degree of firing accuracy. The main reasons for its insufficient accuracy at that time were the uneven consumption of the propellant charge and the consequent one-sided drift effect, which resulted in a corkscrew-shaped trajectory. Because of these early experiments, later development was restricted to surface-stabilized rockets.

Apart from the 210 mm airborne rocket (see page 43 of this study), rocket armament in Germany was needed the most urgently for use against the Russian tanks, due to the inadequacy of supply shipments of cannon and armor-piercing shells. Moreover, the 30 mm and 37 mm tungsten-core ammunition was able to achieve its full penetration effectiveness only upon direct impact on unprotected armor plating. Thus it would have been obsolete in any case after the introduction of screens for the Russian tanks. This would have meant that the only weapon available was the 50 mm airborne cannon with armor-piercing fragmentation grenade shells. These shells were capable of penetrating steel plating 65 mm thick with a strength of 220.5 lbs/mm^2 at an impact angle of 60°.

In the beginning, the developmental work on antitank rockets took recourse to the equipment and individual parts of such equipment already developed by the Army and then sought to modify it for use as airborne equipment. The rockets "Panzerschreck" (tank terror) and "Panzerblitz" (tank lightning), both surface-stabilized by rigid tail assembly, were examples of such Army equipment. Designed with a head of larger caliber (warhead constructed on the hollow-charge principle), both possessed satisfactory armor-piercing capability, but were incapable of developing sufficient velocity. These rockets were launched from the air-craft from rails attached to the undersides of the wings. As many rails as were desired or as had room under the wings could be mounted and the rockets were suspended from them by shoe mountings. The rockets were fired by electrical detonation from both wings at the same time, either in pairs or in series.

b. The Goals Set for the Development of the Luftwaffe's Own R-4/M and R-4/HL (Panzerblitz - Tank Lightning, Pb-III)

Within the framework of its own program, the Luftwaffe established the following goals for rocket development:

The main premise in the development of rocket armaments was to be the achievement of a warhead containing sufficient explosive to ensure the destruction of a heavy bomber by a direct hit; the amount of explosive needed was that which had led to the 55 mm cannon as an airborne weapon (see page 34 ff).

In order to fit it for the desired tactical employment, the rocket was to be equipped not only with the warhead designed for use against air targets (rocket designation R-4/M), but also with an alternate warhead for use against tanks (rocket designation R-4/HL-Pb III). The antitank warhead was to be so constructed as to ensure the destruction of any tank suffering a direct hit at any point.

Because of technical factors connected with the aiming accuracy of the rockets, they were to be developed as surface-stabilized projectiles with the highest possible maximum velocity.

Moreover, in the interests of easy installation, the dimensions of the warhead and the propulsion unit were to be of the same caliber. Thus, the tail assembly was to be designed as a collapsible unit, so that it was no larger in diameter than the rest of the rocket when folded together.

The rockets were to be so designed that they could be fired from rails and screens as well as from tubes and grids, and in the construction of these launching mechanisms special consideration was to be accorded such factors as ease of construction, lightest possible weight, and a form designed to jeopardize the wind resistance of the aircraft as little as possible.

8. Technological Requirements Established for the Rockets R-4/M and R-4/HL (Pb-III) and their Launching Mechanisms

1) Rockets R-4/M and R-4/HL (Pb-III)

Both rockets were to have a maximum velocity of approximately 1640 ft/second with a thrust duration of approximately one second. The warhead for use against air targets was to carry 1.1 lb explosive charge, and was to be fitted with a percussion fuse with self-disintegrating mechanism regulated to go into action after 4920 ft.

The warhead designed for use against armored targets was to be capable of penetrating armored plating 90 mm thick with a strength of 220.5 lbs/mm^2 at an impact angle of 60° (hollow-charge principle).

The rockets were to be stabilized by means of surface fins, which, in turn, were to be designed as a collapsible tail assembly. This collapsible tail assembly, when retracted, was to be no larger in diameter than the body of the rocket.

Electrical detonation was to be employed.

Shoe suspension was to be utilized so that the rockets could be carried along rails as a supplementary, easily mounted element. In this way, the rockets could be launched from tubes and grids even without shoe fittings.

As far as mass production methods were concerned, the rockets were to be designed for easy manufacture in that so-called bottleneck parts, with their complicated production methods, were to be avoided. For example, the case was to be made of welded sheet metal rather than as a seamless drawn tube.

2) Launching Mechanisms

The launching mechanisms, fitted with an adjustment device, were to be designed for installation underneath the wings or under the fuselage of the aircraft. They were to be of the following types:

a) individual launching mechanism (for single rockets)

b) launching rails (for several rockets arranged in a row)

c) honeycomb grid (for several rockets arranged in a bundle)

The last two mentioned above were to be equipped with a relay switch in order to permit the firing of a series of rockets in close succession in such a way that the launching of one could have no detrimental effect on the next one.

As regards the grid, it was to be designed with aerodynamic casing and with a view towards the cheapest possible manufacture, since it was to be treated as an expendable part, to be discarded after the firing of the rockets.

d. The Tentative Results of Development

1) The Rockets R-4/M and R-4/HL (Pb-III)

Despite the fact that developments were greatly hindered during the last months of the war by the enemy's disruption of production and transport facilities, the detailed work on these two rockets was practically completed. Nonetheless, it was the inadequate production and transport facilities which made it impossible to manufacture enough rockets for really effective testing and -- later on -- to provide a basis for mass production. Not even the Specialist in Charge of Weapons and Ammunition (Sonderbeauftragter für Waffen und Munition), Reichs Ministry for Armament and War Production, who ordered the Rocket Development Chief (Entwicklungsreferent für Raketen) to work with him, i.e. with the Kammler Project Staff (Arbeitsstab Kammler), during the last months of the war, was able to accelerateproduction, although he possessed considerable influence in this field. Under the circumstances, of course, it was impossible to reach a definitive evaluation on the basis of extensive testing; nevertheless, I believe that this rocket with its two warheads -- with a 1.1-lb. explosive charge for use against air targets and a hollow-charge head for use against tanks -- could have been developed into a highly effective weapon for medium and close-range combat. Both rockets (R-4/M and R-4/HL (Pb-III)) weighed 7.7 lbs, were 809 mm long, and were capable of achieving a maximum velocity of 1804 ft/second. The dispersion pattern resulting from a salvo of eleven rounds (rockets stored next to one another in a frame installed under the wings of the aircraft) at a distance of 656 ft. was 12.5 x 13.4 ft. This was considerably better than the results attained by any previous German rocket; moreover, the R-4/M (R-4/HL) had an added advantage in that almost twice as many rockets as of any other type could be stored in the same space in or under an aircraft. The only prerequisite was that rockets stored next to one another had to be fired in exact succession, in order to avoid their having any effect on each other during and after the opening of the collapsible control surfaces. This lateral shift in the moment of firing was compensated for very simply with the electrical launching mechanism by means of the already mentioned relay circuit.

2) b. The Launching Mechanism

1) Frame, Grid, Rocket Launcher

The individual launcher and frame for thirteen rockets stored one next to the other show no innovations as far as design is concerned. They had the disadvantage of offering quite a bit of wind resistance. In my opinion, the honeycomb grid which could be permanently installed in the aircraft or the one in which the rockets could be stored in disposable, streamlined, tear-shaped containers clustered around a center spindle were rather good proposed solutions to the problem. The cap and tail units of the streamlined hull were to be disposed of immediately before the aircraft engaged in combat. In its ultimate design, the honeycomb grid was to be made of cardboard tubes. Considerable thought had been given to the possibility of designing a cardboard case in which the rocket could be packed and which, at the same time, might be used as a launching tube as well as as an element of an appropriately designed rocket frame. By the time the war came to an end, there had still been no attempt at an objective comparison of the influence of the various types of launching mechanisms on the firing accuracy of the rocket.

In addition to the launching mechanisms described above with their technical requirements, the Siemens Apparate- und Motorenbau G.m.b.H. (Siemens Equipment and Engine Company, Ltd.) had constructed an automatic rocket launcher. The first model had been completed shortly before Germany's capitulation and was being tested by the company. This launcher was relatively simple and, in comparison with automatic weapons, comparatively cheap to manufacture. It was a device from which the R-4/M rockets as well as the ammunition of an automatic cannon could be launched in consecutive bursts of fire. The RA/55 was designed for installation in the wings, to avoid the sacrifice in flying speed otherwise occasioned by the usual external suspension of the rockets. The rockets were fed into the launcher by means of a disintegrating belt. The thrust of the R-4/M was great enough to permit the carrying of twenty-five rockets in one belt. Any longer belt than this would have required feeding by means of an external propulsion unit. The functioning of the automatic launcher was as follows: the warhead of the first rocket in firing position rested on a lever which activated the feeder mechanism as soon as the rocket was fired, thus automatically bringing the next rocket into position. The electrical detonation took place by means of a stepping relay adjusted for intervals of 100 milliseconds. From the first contact of the fuse to the departure from the launcher, the R-4/M took about 50 to 60 milliseconds. Oscillographic measurements showed that the firing velocity of the RA/55 was approximately 500/600 rounds per minute. Completed shortly before the end of the war, the launching device had a weight of 55.1 lbs. Assuming that the firing accuracy of the R-4/M rocket was adequate, it can be taken for granted that this type of automatic-firing airborne armament, because of the considerable saving in weight it permitted and because of its doubly-high firing performance at a medium range of about 1968 ft., would have replaced the 55 mm light aircraft cannon in the beginning. As the R-4/HL (Pb-III) rocket, it presumably would have been a welcome addition to the airborne armaments of the close-support aircraft as well.

e. The 220.5-lb. Incendiary Shrapnel Rocket (R-100/BS)

By the time the war came to an end, the development of the R-100/BS, a 220.5-lb. surface-stabilized 210 mm rocket with maximum muzzle velocity of 1476 ft/second and an incendiary shrapnel charge, was running parallel to that of the R-4/M and the R-4/HL rockets. The R-100/BS represented a new development in the 210 mm airborne incendiary rocket (see page 43 of this study), and was also designed for employment against enemy aircraft flying in close formation from a range of about 6560 ft. At the urging of the research directors, experiments had been carried out to test the value of a suggestion to the effect that approximately 750 bits of shrapnel, filled with an incendiary charge, might be released from the warhead of the 210 mm airborne shrapnel rocket, simultaneously with its detonation. In contrast to the spin-stabilized 210 mm airborne explosive rocket, in the case of the surface-stabilized R-100/BS rocket there was an additional problem, in that the incendiary bits, by the time they were ejected, were no longer flying along a stable path and thus forfeited too much of their penetration force as a result of their gyrations. The aim of this developmental work was to devise a method whereby the entire shrapnel charge of a rocket could be discharged from an aperture angle of 120° and would still retain sufficient penetration power and incendiary effectiveness at a range of 328 ft to ensure the destruction of a bomber.

By the time it had reached the final stage of development, the R-100/BS rocket still contained approximately 400 incendiary particles of the BR/44 type, each one weighing 56 g.

VI. Special Weapons

The result of recommendations coming from the front and arising out of the dissatisfaction prevailing because of the rapidly sinking figures on enemy aircraft downed during the last years of the war, the first special weapons made their appearance in the form of multi-barrelled 20 mm firing tubes, some of them even recoilless, which were designed to be vertically installed as supplementary weapons. The planned method of employment was as follows: after the initial attack on the enemy airplane, carried out with armaments mounted in the nose of the German aircraft, the latter would fly under the enemy machine, using up all its remaining ammunition at once as small shot. These suggestions were taken up by the development team and the armament industry. Inasmuch as the planned method of employment proved to be impracticable in connection with the 20 mm ammunition selected (since its effects were inadequate), the Rheinmetall-Borsig Company began work on a 30 mm multi-barrelled tube for use with MK-103 and MK-108 ammunition. The second stage of development brought forth a 50 mm multi-barrelled tube. The technical data of these special weapons were as follows:

Name	Caliber mm	Muzzle Velocity ft/sec	Weight of Shell /lb	Length of Barrel mm	No. of Barrels	Weight Loaded /lb
SG-116	30	2761.6	0.73	1600	3	211.7
SG-117	30	1574.4	0.73	590	7	154.3
SG-118	30	1574.4	0.73	590	7	154.3
SG-119	30	1574.4	0.73	590		108
SG-500	50	1312	3.30	515	5	88.2

The superiority of the last of these to be developed -- the SG-500 with its five 50 mm drawn-metal tubes, which were ejected towards the rear after firing in order to eliminate recoil -- was clear, not only in respect to weight and laid length, but also in respect to the devastating effectiveness of the single 50 mm shell with its explosive charge of 350 g.

The recoilless tubes had the advantage of being easy to produce, so that they could be treated as expendable supplies. They could be installed either horizontally or vertically and could be utilized with the appropriate ammunition against either air or ground targets. When used against air targets, with the direction of fire above the aircraft, the ammunition was automatically released by means of a photoelectric cell. When the vertically installed tubes were employed against tanks, an electrically operated firing mechanism was to be used. By the time the war came to an end, the 50 mm weapons for use against air targets were just ready for introduction at the front.

VII. Sights for Use with Rigidly and Flexibly Mounted Weapons

In addition to the development of rapid-firing, large-caliber, automatic weapons and effective ammunition types, German designers also gave a good deal of time and attention to the task of increasing the combat effectiveness of the aircraft by finding a practical solution to the gunsight problem, in other words by improving their firing accuracy.

It is common knowledge that the effectiveness of the bombsight in promoting firing accuracy depends upon a number of factors -- deflection, directional accuracy, sighting accuracy, coincidence error, adjustment error. (In addition, factors connected with the gun can also play a role -- errors in either the weapon or the carriage, backlash in the case of mechanically operated gun stations, or transmission error in the case of remote-controlled movable stations.)

A. The Linear V_E-Controlled Gunsights for Flexibly Mounted Weapons

The design factors pertaining to deflection in connection with movably-mounted weapons led first of all to the construction of a linear V_E-controlled gunsight which was not affected in any way by the distance of the enemy target. Originally it was equipped with mechanical line of sight, which was later altered to optical line of sight. Due to their construction, gunsights of this type were coupled with the individual gunsights. By means of appropriate adjustment of the line of sight depending upon the firing position and the variable design factors of muzzle velocity and the specific velocity of the sight, the sight took into consideration only that degree of deflection caused by its own motion. For the construction of this type of sight, the requirement was set for a vector-based deflection triangle, in which the muzzle velocity and specific sight velocity vectors showed the right size and location for every possible position of the weapon, making it necessary only to add the two together in order to obtain the correction course. This construction was defective in that the specific sight velocity vector set for any given aircraft speed naturally remained constant even while the aircraft was engaged in combat, and, as a result, the correction for the velocity of the target had to be computed over the lead circle of the sight in accordance with the estimated target velocity and the angle of flight. The direction involved in the correction for target position lay along the general course of the aircraft's longitudinal axis. The fire cone was aimed in such a way that the target ran through it.

The problem of installing sights of this type in the existing gunmounts without limiting the field of fire and without jeopardizing their aerodynamically favorable form led to a number of experimental constructions, each based upon and made subordinate to the type of mount concerned. In later models of the V_E-sight, the mechanical line of sight consisting of a backsight and a circular or tubular muzzle sight was replaced,

by a reflector sight of extremely simple design (Revi-16) in an effort to improve the accuracy of the instrument. The new construction had the advantage that the operator could see the backsight and the target with equal clarity and that his eye was not limited to a single point, as was the case with the backsight and muzzle-sight construction, but could rove about within a restricted area. The disadvantage inherent in all the V_E-sights was due to their position (necessitated by their construction), which made a margin of error of ± 4 unavoidable.

B. <u>The Combination of the Reflector Sight and the Telescopic Sight</u>

For many years the fighter aircraft were equipped with reflector sights of familiar design. In order to make it easier for the fighter pilot to recognize and observe remotely-located targets, a new reflector sight combined with an enlarged telescopic sight was devised on the basis of requirements stemming from experience gained at the front. The telescope unit was bent so that the viewpiece lay directly under the reflector sight. In this way, the pilot could identify the magnified image through the telescope and could follow the lighted lead mark of the reflector sight simply by moving his eyes, i.e. without having to move his head at all. As heretofore, the actual firing was based on the reflector sight. Although the original requirement specified a telescope with threefold magnification, and although such a sight was actually constructed and issued for testing at the front, the sights finally introduced had a telescope with twofold magnification. The evaluation of the front units on the new sights was extremely favorable. The increased difficulties in installation caused by the arrangement of the telescope unit simply had to be accepted as a necessary evil.

C. Automatic Gunsights for Use with Rigidly and Flexibly Mounted Weapons

In order to relieve the gunner of any need to think while operating either a rigidly or a flexibly mounted weapon, automatic gyro gunsights were developed (the Revi-EZ-40, 41, and 42) which were capable of computing the necessary correction during rapid aiming and firing from the relative angular velocity and the distance (which could be adjusted on the gunsight) without reference to the position of the aircraft itself. Computation of the distance was carried out in accordance with the target basis method. In the Revi-EZ-40, the telescopic sight, the gyroscope unit, and the distance meter were all contained in one case. The correction was computed from the relative angular velocity and the distance adjusted on the sight by means of a rotary current gyroscope operating on two levels, whose functioning was slowed or speeded up depending upon the time of trajectory flight of the projectile. In the Revi-41, and also in the newer, improved version, the Revi-42 (which was also far less complicated from the manufacturing standpoint), the individual functional units of the sight were separated from one another in order to keep the actual aiming device as small as possible (in the interests of operational ease) and in order to permit the feeding of the correction data into the remote control unit when an independent line of sight was employed with remote-controlled, flexible gun stations. As far as these automatic sights were concerned, neither the EZ-40 nor the EZ-41 had succeeded entirely in solving the problem of a shifting in the line of sight, inasmuch as the stabilization of the optical line of sight after each deviation of the gyroscope took far too long. The EZ-42, on the other hand, which was introduced during the last year of the war for use with the rigid weapons of the fighter aircraft and which was designed to compute a maximum correction of $\pm 12^{\circ}$ at a distance of up to 3280 ft, was so perfect technically that -- so far as I am informed -- its use resulted in a quadrupling of the hits scored. The total weight of the equipment -- comprising gunsight, adjustment case with two potentiometers for calibration of the set in accordance with flight speed and type of weapon as compared with combat altitude, two correction indicators with spring-restraint rate gyroscopes, amplifier and switch boxes, two alternating/direct current transformers, and the lever for adjusting distance (which was installed on the throttle) -- amounted to 30.57 lbs. and represented, in my opinion, a significant technical achievement.

D. The Electrical Range Computer and Fire Release Mechanisms, Blind Firing Equipment

As a logical continuation of the developmental program just described, as the next step designers devoted themselves to the development of an electrical distance computer, which was later coupled with an automatic fire release mechanism designed for use with the 210 mm airborne explosive and shrapnel rockets. The requirements set for the experimental device included automatic range computation with continual superimposition of range data on the EZ-42 reflector sight, with an overall capacity range of from 820 to 6560 ft. and accuracy of measurement down to 164 ft. The problem was solved by recourse to the impulse method, whereby a transmitter sends out short wave groups in regular sequence, which are reflected from the target, picked up by a receiver, and transformed into impulses which are fed directly into the receiver together with the wave groups coming from the transmitter. The intervals between the original and the reflected impulses give the scope of the double distance. The necessary power for the adjustment of the distance set on the gunsight was obtained from a special amplifier which transmitted it to the automatic sight. In addition, the distance could be read from a dial attached to the amplifier. This equipment was perfected by the end of the war and was already in process of being tested.

The gunsight with automatic range computation was developed further (with the help of methods based on visible ultraviolet light) into a blind firing instrument to be utilised in non-illuminated night fighter operations. By the end of the war, an experimental model was ready for testing.

E. Periscope Sights for Flexibly Mounted Weapons and Reflector Telescopes for Rigidly Mounted Weapons

As a result of such factors as more favorable aerodynamic design of bomber aircraft fuselages (elimination of the bottom gondola, etc.), more simple armor plating, and enlargement of the sighting and firing fields of the flexible gun stations, periscope sights (panoramic telescopes) with a single field of vision were developed for remote-controlled gun stations (in order to eliminate the need for a gunner). Panoramic telescopes were also needed for use with rigidly mounted defensive weapons designed to be operated by the pilot and pointed towards the rear. Since the installation of periscope sights was complicated and costly, they were not used in flexible gun stations unless other types of sights had been tried and found unsatisfactory.

It was impossible to set up complete technical specifications for periscope sights in the beginning, since there was no body of experience to draw on. As far as optical aspects were concerned, a relatively slight magnification was specified inasmuch as a scale of 1:1 seemed to reduce the size of the image. It was found that 1.5-fold magnification and a field of vision of 45-50° were most favorable for the reflector telescopes, while 1.8-fold magnification seemed to be best for periscopic sights. Experiments carried out at dusk and during the night had proven that magnification was highly significant, since it facilitated the identification of objects weak in contrast in the dark. The field of vision of the experimental periscope sights ranged from 40 to 55°. Testing had also revealed ~~that~~ the necessity for retaining unobstructed natural vision in the use of these periscopic sights. Moreover it was found that periscopes with rigid eyepieces were more comfortable and easier to use than a gunsight stand equipped with reflector sights, in other words that the former permitted the gunner to concentrate better on the activity of the target. Thus the periscope sight contributed to increased aiming accuracy. In addition, the use of periscopes ensured a higher degree of firing ~~xxx~~ accuracy in that they eliminated errors due to deflection from the line of sight, errors which were unavoidable with other gunsights due to the fact that the line of vision was slanted and the lenses were not absolutely parallel to one another.

When the war came to an end, there was still a good deal of work to be done in the development of the periscope sights, particularly in respect to ease of their manufacture and the problem of standardizing the various parts so that they could be used interchangeably in the periscopic sights to be installed in the different gun stations of a bomber. A beginning had been made in building-block construction, which meant that the same parts could be combined in different ways to build the various kinds of sights needed for the top gun position, the gun turret, and the belly gun station.

The simple reflector telescopes for use with rigidly mounted, rear-aiming weapons were introduced in a variety of different models, some with retractable eyepiece shanks and some as standard telescope barrels, all designed to be out of the gunner's way during take-off and landing operations. In order to enable the pilot to follow a target approaching from behind with the same degree of certainty, a requirement was established to the effect that the sight must also provide lateral images, which -- however -- could be upside-down.

VIII. A. Small Shot, Shrapnel, or Fire Salvo

a. Definition and Application

In the present section, the terms small shot, shrapnel, and fire salvo are used in accordance with the following definitions, which reflect their meaning in connection with the field of airborne armament:

1. The small shot volley depends upon the effectiveness of a large number of projectiles and projectile particles fired simultaneously, or rather within a fraction of a second after one another, by the discharge of a single shot.

2. In the case of a shrapnel shot, the shrapnel charge of a grenade fitted with a time fuse is hurled violently in the general flight direction by the self-disintegration of the fuse.

3. The term salvo refers to the discharge of individual shots from a number of weapons, either simultaneously or in very close succession.

<u>In connection with 1 and 2, above:</u>

Prior to World War II, the use of small shot was restricted to hunting -- with the exception of the old-fashioned shrapnel shell. Small shot is the layman's best choice for the hunting of partridge, ducks, and hares, for it is common knowledge that the chances of hitting a flock of partridge frightened into the air or small game on the run are most favorable with small shot. Applying these conditions to the field of aerial combat, it seems logical to expect that here, too, small shot might offer prospects of success. (Prior to this time an attempt had been made to achieve the desired effect by firing six to eight rigidly mounted weapons simultaneously.) In the case of aerial combat, however, the individual small shot or shrapnel particles had to be so constructed that they were really capable of causing the necessary degree of damage. We have already mentioned the BR/44 incendiary particles used in the 220.5-lb. shrapnel rocket (see pages 54 and 55 of this study) as Germany's first application of this principle in aerial combat.

Beginning his work in 1943, the Hungarian 2/Lieutenant Zettl had been experimenting with the possibility of a small shot cartridge for airborne armaments and had reached a rather interesting conclusion. He had discovered that seven to nine fairly small shells,

arranged within a spiral-shaped casing, could be packed into a large cartridge in such a way that the blowback would affect only the free half of the last, outermost projectile (as in the case of a sub-caliber projectile), while the barrel of the first projectile was in position in the middle of the shell. At the moment of firing, all the projectiles were set in motion inside the spiral-shaped casing and were discharged from the barrel in rapid succession. In Germany this discovery was tried out experimentally with seven 15 mm incendiary grenades (for use with the MG-151), which were arranged in the above fashion in a 50 mm cartridge (50 mm airborne cannon). The muzzle velocity between the first and last grenades showed no more than a minor variation of a few feet in the trial shots. The dispersion pattern was like that of a machine-gun. The application of this principle to live incendiary grenades was dependent only upon the devising of a fuse impervious to blowback. After a number of preliminary experiments, a new, liquid-activated fuse sensitive to gasoline was selected for further development.

The small-shot theory also found application in the multi-barrelled special weapons developed on the Davis principle during the last year of the war (see pages 56/57).

Re 3, above:

With the introduction of rockets in firing tubes for use against armored vehicles, the application of the fire salvo principle was automatic in the Luftwaffe. It was a logical next step to shoot off these rockets in series in order to increase their firing accuracy.

b. Conclusions

For purposes of comparison, the necessary technical data for the weapons described above are given below. If we include the 55 mm aircraft cannon in this category in the interests of completeness, we have the following picture:

Type of Weapon	Weight in lbs.	Combat Range ft.	Type of Effect/ Weight (lbs) of Explosive or Incendiary Charge	Type of Fire
MK-112 + 30 rnds	826.8	3280	mine/ 0.926	bursts of fire
MK-114 + 30 rnds	1730.9	4920	mine/ 0.992	bursts of fire
R-4/M (automatic rocket launcher) + 30 rnds	286.6	1968	mine/ 1.10	bursts of fire
R-4/M (launching grids (2)) + 26 rnds	257.9	1968	mine/ 1.10	fire salvo
R-100/BS (launching rails) + 1 rnd	253.5	6560	incendiary fragmentation	shrapnel
"Zettl" weapon (grenade with 7 projectiles)	-	1968	incendiary	small shot
SG-117/118 (round billet + 7 rnds 30 mm ammunition)	154.3	1968	incendiary/ 0.308; mine/ 0.187	small shot
SG-119 (battery of tubes + 49 rnds 30 mm ammunition)	-	1968	incendiary/ 0.308; mine/ 0.187	small shot
SG-500 (5 tubes + 5 rnds 50 mm ammunition)	88.2	3280	mine/ 0.771; armor-piercing	small shot

Taking into consideration the experience gained with the automatic cannon, the following conclusions were drawn from the data contained in the above table:

If a fighter aircraft would be armed with twenty-six rockets, mounted on rails or grids and fired in salvos of six to eight units with target correction, then it was fairly certain that any large bomber receiving a hit could be completely destroyed. The same result could be achieved with two automatic rocket launchers using approximately the same amount of ammunition and fired in bursts. While external suspension of the rockets created additional wind resistance, there was a chance that the 308.7 lbs of extra weight (two launchers, each with thirty R-4/M rockets) could be compensated for by the more favorable method of installation in the wings or in the cockpit of the aircraft, not to mention the extra dividend represented by the other thirty rockets. In both cases, of course, the firing range was limited to approximately 1968 ft.

In spite of the better ballistic qualities achieved by the MK-112, the equipment of the fighter aircraft with one or two of these weapons seemed less desirable than the installation of rocket launchers as described above, so long as the combat range was limited to 1968 ft., due to the fact that the cyclic rate of 300 rounds per minute for the MK-112 was considerably less than the 600 rounds per minute achieved by the R-4/M rockets in their grid-type launchers, and that the salvo fire of the rockets was more effective. Moreover, the 55 mm cannon was so heavy that its installation precluded the installation of a rapid-firing 30 mm MK-108 in the fuselage. It was a common practice, however, to combine the MK-108 in the fuselage with R-4/M rockets installed in the wings.

In my opinion, the utilization of small shot against air targets would have led to very favorable results. The small shot weapons were on a par with the specialized weapons as frontal guns or as supplemental vertical armaments. It is true, of course, -- as experience has shown -- that successful utilization of the SG-119 (battery of tubes with 30 mm ammunition) as a frontal weapon (as proposed in the Julia project+) presupposed that at least four of the grenades must land within a small area of a bomber in order to ensure its destruction (see page 32 of this study). The 50 mm SG-500 was by far the most promising, inasmuch as it could be used at a range up to 3280 ft. It was not possible to accumulate an adequate body of experience on those specialized weapons by the time the war came to an end. I suspect that fifteen SG-500 launching tubes with fifteen 50 mm mine projectiles would have been far superior to

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\+ - Translator's Note: Julia = CODE for a liquid-rocket motor powered Heinkel single-place target-defense aircraft in which the pilot lies in a prone position and the wings are downward inclined (Leidecker, op. cit., Volume I, page 427).

two grid launchers with twenty-six R-4/M rockets, which weighed just the same. Zettl's small shot shells, developed for a 15 mm weapon, had to be abandoned due to the inadequate overall effectiveness of the individual projectiles making up each shell. In addition, the breechlock represented a good deal of useless weight. Rather than enlarging the individual projectiles, it would have been better to use shrapnel grenades to achieve the same effect. Although the dispersion cone of shrapnel was still too wide, especially in surface-stabilized rockets, the latter had the advantage that they could be used against enemy bombers flying in close formation from distances two to three times greater than normally.

As a result of the consideration discussed above, in my capacity as Chief of Development, I advocated the following standpoint at that time:

For the purpose of bringing the largest possible explosive and incendiary charges to the target, rocket armaments were more efficient than automatic cannon, in the first place because of their considerably lower weight and in the second place because they were capable of achieving either salvo fire (smaller rockets) or a shrapnel effect (larger rockets). The poorer ballistic performance of the rockets as compared with cannon ammunition would have to be accepted as a necessary evil under the proviso that possible improvements were to be introduced as soon as possible. In the meantime the rockets made up for their defect by the sheaf of fire released by the salvo shots and the dispersion cone resulting from the shrapnel fire. Smaller-caliber rockets of the R-4/M model were planned for medium-range operations (up to 1968 ft) and were to be installed in the aircraft either alone or in combination with 30 mm automatic airborne cannon. Large-caliber rockets of the R-100/BS type (a medium-caliber 110.25-lb. rocket, the R-50/BS, was also to be developed) were to be installed ~~at~~ for use from longer distances, up to 6560 ft, provided that the long-shot effectiveness of their incendiary shrapnel charge should prove adequate to cause serious damage within a formation of bombers under attack, in other words if the rockets should prove more capable of bringing down enemy aircraft than the projectiles of the 55 mm automatic airborne cannon.

In addition to rocket armaments, the SG-500 with 50 mm ammunition -- a bundle of tubes designed to fire on the small shot principle -- was another possibility for ranges of approximately 3280 ft. The same weapons could also be used a vertical armaments with automatic firing mechanism.

It can be assumed that these conclusions would have been revised in favor of the 55 mm cannon at such time as a stabilization method permitting precision long-shots should have been devised and widely introduced. In the event of such a development, improved firing accuracy might have been expected even with semi-rigid weapons.

B. <u>The Single Precision Shot</u>

Even prior to the introduction of rocket armaments, the Development Department had initiated a project to investigate the problem of single precision shots from large-caliber airborne weapons. Experiments had been carried out with the MK-101 (muzzle velocity of mine projectile 2952 ft/second - see page 12 of this study) which was already available at that time; it had been tested as a rigidly mounted weapon and also as a so-called semi-fixed weapon, i.e. manually adjustable, installed in both cases in a twin-engine multiseater. The firing range used in the tests was 3280 ft. In the case of the semi-fixed weapon, the pilot flew a steady, direct course (ram-course) towards the target shown in his rigidly mounted automatic gunsight, while the airborne gunner adjusted the weapon, which could be moved within narrow limits, to compensate for any minor errors. The gunner took aim through a large-size telescopic sight (ram-course: target approach below the angle so that the target cannot escape). According to these experiments with the semi-rigid installation method, a 5.5-fold increase in hits could be expected in firing at air targets without making corrections. At that time, however, this procedure could not be applied to aerial combat, inasmuch as an aircraft attacking from a distance of 3280 feet would have presented too easy a target for the concentrated defensive fire of the enemy bomber unit. Nevertheless, the procedure could be utilized with such long-range guns as could be committed beyond the range of the enemy's defensive fire.

IX. The Significance of Airborne Cannon Installed in Close-Support Aircraft in Antitank Operations

A. Automatic Cannon

During the first half of the war, the airborne armaments of the close-support aircraft were intended merely to hold the enemy in check during the approach flights and to serve as an instrument of self-defense. The offensive weapons were the bombs. In the beginning, the units at the front were highly skeptical at the thought of shooting weapons as offensive instruments. In my opinion this was due primarily to the fact that a good many German close-support pilots had been recruited from among former bomber pilots, who were familiar with releasing bombs but had had no training in firing weapons; thus retraining was often necessary.

At that time, a number of the close-support squadrons on the Eastern front were equipped with cannon for use as an offensive weapon, and the suggestion had been made that these aircraft be committed together with bomb-releasing aircraft in attacks against large enemy armored units. For it had been observed repeatedly that the Russian tanks damaged by enemy bombardment on their own territory were towed away immediately to be repaired. Moreover, instances had been reported in which Russian soldiers had tried to make it appear that their tanks had been knocked out of action by simply abandoning them in the hope that there would be no further attack. Thus the motivation for utilizing airborne cannon in antitank operations was not only to increase firing accuracy but also to ensure total destruction. It might happen that a tank would have to be attacked repeatedly to make sure of its being destroyed. Total destruction was considered achieved when the tank went up in flames as a result of the hits it had received.

The close-support aircraft equipped with offensive cannon were at a disadvantage in that they could continue their attack long enough to be certain of destroying the enemy tank only if there was no antiaircraft artillery fire to interfere. Consequently they were of no use whatsoever against tanks equipped with antiaircraft artillery, since they would have offered far too good a target. Both aeronautical aspects and factors pertaining to the target identification process required that their approach flight be begun at approximately 1968 ft, with an angle of 10-20° and proceed as close as possible to the target before opening fire.

The interest of the close-support pilots in airborne cannon was awakened at that time with the help of special experimental units from the development and testing agencies, assigned to temporary duty with the front units. Once the pilot had mastered the attack procedure and the technique of pin-point bombardment, and had studied carefully the weak points of the Russian tanks, the new weapon was assured of every prospect of success.

Since the supply of available 30 mm cannon of the MK-101 type was soon exhausted, and the new MK-103 did not become available until 1944, the demand for armor-piercing weapons had to be met from antiaircraft artillery and Army stores insofar as this was possible. The following automatic cannon and types of ammunition were used in antitank operations:

Model	Caliber mm	Weight of Weapon/lbs	Type of Ammunition	Muzzle Velocity ft/sec	Weight of Ammo /g
MK-101	30	397	armor-piercing shell	1648.8	350
MK-103	30	308.7	armor-piercing shell	1648.8	350
BK 37 mm+	37	613	armor-piercing shell	3837.6	380
BK 50 mm++	50	1096.4	armor-piercing grenade	2738.8	2060

\+ - Adapted from the 37 mm aircaircraft artillery cannon

++ - Adapted from the KWK-39 antitank cannon

The greater weight of the 37 mm and 50 mm BK models had no appreciable effect on their suitability for use in close-support aircraft. (See pages 40 and 41 of this study for information on the development of the 50 mm airborne cannon into the MK-214/A.)

We have already mentioned the fact that the armor-piercing grenade cartridge with a tungsten-core shell was not entirely satisfactory because of its high degree of penetration effectiveness could be brought to bear only against unprotected (i.e. by a screen) armor plating.

B. Rockets

The highly unsatisfactory supply situation as regarded weapons and solid-core ammunition led the Development Department to undertake extensive experiments with rockets asa new means of combatting tanks and to introduce the results of these experiments in a number of close-support units; this work was carried out with the support of the appropriate branch inspectorate, the Office of the General of the Close-Support Forces (General der Schlachtflieger). The method of firing was by salvo and the same attack procedure was used as with the automatic cannon.

The successive models listed below characterize the course taken by the development of rockets for antitank operations:

Model	Max Velocity ft/sec	Weight lbs	Warhead	Penetration Effectiveness	Remarks
Tank Terror	442.8	12.1	hollow charge	over 100 mm	An Army weapon with electrical firing mechanism
Tank Lightning I	1115.2	15.4	hollow charge	over 100 mm	An Army weapon with electrical firing mechanism
Tank Lightning II	1246.4	11.02	hollow charge	over 100 mm	R-4 propulsion with Tank Terror warhead
Tank Lightning III	1574.4	8.8	hollow charge	over 100 mm	R-4 propulsion with warhead of same caliber

The use of the hollow charge principle for the warheads guaranteed penetration effectiveness under all circumstances. The velocity, as shown in the table above, was increased with each successive model. Plans had been made to increase the maximum velocity even more in the Tank Lightning IV, a model still in the development stage.

C. Special Weapons

In order to obviate the necessity of having to fly directly into enemy defensive fire when attacking a tank covered by antiaircraft artillery, during the last year of the war it was planned to equip the close-support aircraft, too, with the same vertical armaments as the fighter aircraft had. The SG-500 (see page 56 of this study), with automatic firing mechanism, was selected for this purpose. After a number of initial difficulties in connection with the automatic firing mechanism had been overcome, experimental models with five and ten 50 mm tubes and armor-piercing explosive grenades were tried out in the air and found to be satisfactory. The goal of this line of development was to permit a close-support aircraft to exploit to the utmost the factor of surprise by attacking a tank in open terrain in a low-level approach and by destroying it from directly above at an altitude of approximately 32.8 ft. The frontal attack method was no longer used. In my opinion, this application of vertical armaments was of great tactical value and possessed great technological potential.

X. The Installation of Weapons in Day-Fighter, Night-Fighter, and Close-Support Aircraft

A. Standardization of Models to be Installed

The installation of airborne offensive armaments in the fighter and close-support aircraft was characterized by a high degree of standardization. With very few exceptions, the parts to be installed had been constructed and tested in accordance with "official specifications" (Amtsforderungen) by the developing firms of the former Ordnance Branch (Waffenabteilung) and had been manufactured and delivered in accordance with precisely formulated delivery specifications. In this way one could be certain that every single item met the standards set (for example, the degree of rigidity or flexibility in a gun mount needed to stabilize the dispersion pattern of the weapon). There were only a few plants of the aircraft industry which participated from time to time in developmental work on the equipment needed for the installation of airborne weapons. Nevertheless the aircraft firms had a certain amount of influence over the external designs and the dimensions, first through direct contact with the developing firms, and later through their representatives on a Development Commission (Entwicklungskommission) made up of experts from the industry and former Development Department personnel. The aircraft firms were prohibited from independently making any subsequent changes in this "government-owned" (reichseigen) equipment when it came time to install it.

B. Remote-Control Operation of Weapons

The operation of German airborne weapons in the aircraft was carried out electrically, or rather electropneumatically. This method had been developed systematically since the very earliest weapon models, so that there was already a good deal of practical experience to fall back on in connection with standardized control units with thoroughly tested component parts for later weapons and equipment. Electropneumatic units had to be used when a good deal of power was required, for example to set and cock a weapon.

Particularly characteristic of the German electrical control system were the electrical detonation of ammunition by means of fuse elements inside the weapon rather than the traditional firing-pin mechanism, and the development of ammunition with electrical fuse cap. This type of electrically detonated ammunition, originally developed for the control-operated 7.9 and 13 mm weapons, proved to be considerably more accurate and more reliable than the conventional firing-pin method; moreover, it was less sensitive to jarring. The electrical firing method also eliminated almost entirely the danger of premature detonation in the case of large-caliber weapons with the bolt unlocked.

By installing the wiring system accordingly, it was possible to fire the weapons located in the fuselage and wings singly, in groups, or all together. This was desirable inasmuch as an aircraft usually had weapons of different types, with varying firing speeds and varying amounts of ammunition (during the last years of the war, most aircraft carried both cannon and rockets). The level of the ammunition stock for each individual weapon was indicated by a round-counter (Schusszähler) on the instrument panel of the aircraft. Each counter had a visual signal which indicated whether the weapon in question was ready for firing or whether it had to be cocked by means of an electrical cocking contact. Fully automatic cocking apparatuses, capable of automatically correcting any jamming of the weapon which could be remedied by cocking, were designed with additional electrical components and appropriate wiring systems.

In order to meet these performance demands, it was inevitable that the weapon-controlling electrical systems installed in aircraft should be highly complex. Nevertheless they proved to be quite satisfactory in all theaters of operation. In spite of this fact, it is my opinion today that it was not really necessary to make quite such extensive use of the technical possibilities of electrical wiring. Even towards the end of the war, a number of simplifications were being undertaken in this field, with a view to saving costly labor and materials. But even these modifications by no means achieved the ultimate goal of reducing the wiring diagram pertaining to offensive airborne armaments to the very most simple form consistent with safe and effective operation on the part of the individuals involved.

C. The Mounting of Automatic Offensive Armaments

We have already mentioned that in Germany the mounts intended for fixed airborne offensive weapons were developed as standardized equipment, with no regard whatsoever for the various aircraft models in which they would later be installed. There were, of course, a few aircraft firms which, from time to time, attempted to ignore this principle when a given mount threatened to jeopardize their freedom in respect to design. In general, however, the validity of the standpoint that the development of gun mounts must be left up to armaments specialists found recognition in most quarters, once the coordination among the weapon, gun mount, and aircraft firms had brought about a lively exchange of opinions among the various designers. Later on, this spirit of cooperation was further fostered by a Weapons Installation Group (Waffeneinbaugruppe) proposed by the Development Department. This group, organized as a mobile unit made up of experienced engineer and ordnance mechanic (Waffenmonteur) personnel, was assigned to carry out preliminary tests in order to clarify any potential problems in connection with weapons installation in new aircraft models. Thus really serious difficulties were out of the question when it came time for the final testing of the weapons system, prior to declaring the aircraft ready for operation.

The following principles were basic guidelines for the development of all gun mounts:

1) The gun mount must have no appreciable unfavorable effect on the dispersion pattern of the weapon.

2) The recoil reaction of the weapon must be almost entirely absorbed by the gun mount.

The following requirements were set for the rigid and flexible mounts for large-caliber cannon:

1) Dispersion pattern of the unrigged weapon at 328 feet, with the mount firmly fastened to a rigid pedestal:

7 individual rounds = 300-300 mm

burst of fire comprising 7 rounds of fire = 300-300 mm

2) Absorption of recoil reaction by means of an adjustable buffer mounting or some similar device

3) In the case of mobile twin mounts, a mechanism permitting the adjustment of the gun or guns in respect to both height and lateral position

4) Inherently rigid connecting piece between the front and rear mountings in the interests of operational safety and durability

6 5) No need for special handling during installation in the aircraft, and no wear and tear on parts subject to stress.

D. Installation of Airborne Armaments

a. Day Fighter Aircraft

In the case of several German fighter aircraft, the installation of automatic airborne cannon deviated considerably [illegible], in addition [illegible] in that 20 [illegible] ammunition was also fired through the propeller. Thanks to the electrical detonation of the ammunition, this method could be applied with the MG-151/20 without incurring the least danger to men or materiel. In the case of this particular ammunition, the detonation process was activated by a contact transmitter attached to the engine and synchronized with the propeller revolutions. In addition, the percussion fuse was designed to ensure that the ammunition could not explode for quite a few feet after leaving the weapon; thus, if the synchronization should be defective, the worst that could happen was that the shells would hit the propeller as non-explosive solid projectiles.

In addition, large-caliber cannon were often mounted at the base of the wings and further along the wings, and in the nose of twin-engine aircraft, where -- without benefit of fire control -- their full firing speed could be brought to bear. The suggestion was made that, when several weapons were installed at wide intervals along the wings, they should be so adjusted that the fire cones from each individual pair crossed one another at different ranges, so that the main area of aerial combat could be covered with evenly distributed fire (for example, 984 feet for the outer pair of weapons and 492-656 feet for the inner pair). Equal care was taken in adjusting weapons mounted lower down, i.e. at any point below the line of sight, which runs approximately along the longitudinal axis of the fuselage. If the angle of incidence was favorable, the trajectory crossed the line of sight twice, once with its ascending branch (quite near) and once with its descending branch (at some distance away), thus providing two correlated points of low-angle fire for useful reference in adjusting for height. (I have no information as to which methods of adjustment were in use at the front during the last phase of the war.)

The last developmental phase in the field of fighter airborne armaments was concerned almost exclusively with 30 mm weapons (automatic and special cannon) and with the R-4/M rockets. The offensive armaments of the twin-engine jet fighter, the Me-262, consisted of six 30 mm MK-108's with forty-eight R-4/M rockets (total weight of the weapon when installed, 11,718.9 lbs.). At the beginning of 1945, however, in the face of strenuous objections on the part of armaments experts, it was decided that these highly effective offensive weapons were to be replaced by a rigidly mounted 50 mm MK-214/A for purposes of long-range combat.

The maximum permissible weight for weapons to be carried by a jet aircraft with power unit varied between 441 and 551.2 lbs. Weapons any heavier than this were rejected on the grounds that they jeopardized the aircraft's flight performance. The limit of 551.2 lbs. was already reached by the installation of two MK-108's with thirty to fifty rounds per barrel or with up to sixty

R-4/M rockets. Thirty rounds of ammunition per weapon was the minimum ammunition supply required for a fighter aircraft.

Similar armaments projects were carried out for the single-engine jet fighter, the Me-162 ("people's fighter" (Volksjäger)) and for the rocket aircraft Me-163 (Adder (Natter) and Julia). From the very beginning, the equipment of the Me-163 proved to be inadequate. The situation was somewhat better in the case of the Adder and the Julia. The Adder had been designed as an expendable weapons carrier (manned antiaircraft artillery rocket) which could be employed only once. After combat, the pilot and power unit were to be landed by parachute, while the fuselage and armaments unit would be simply abandoned. There were provisional plans to equip the Adder and the Julia with two 30 mm MK-108's as well, but this was merely an interim solution and the plans were to be dropped as soon as the R-4/M rockets should become available. The final stage of the Adder project called for armaments consisting of approximately thirty R-4/M rockets, to be lined up in grid arrangement in the nose of the fuselage. They were to be fired at intervals of 20 milliseconds by a relay switch activated by a single release mechanism. In this way there was no danger that rockets lying next to one another would be influenced in any way by the unfolding of the tail unit. As a possible alternate solution, test installations were undertaken with about forty to fifty of the spin-stabilized Rz-73 rockets (see page 46 of this study) used by the antiaircraft artillery forces with their rocket projector equipment. This was done over the objections of the Development Department (a symptom of impending collapse!). The alternate solution proposed for the Julia, which -- unlike the Adder -- was to be brought down on landing skids, called for a battery of forty-nine 30 mm tubes (SG-119) to be fired as small shot, instead of the originally planned two MK-108's. Whether or not the Adder and Julia projects were correctly planned by the aircraft designers remained an open question until Germany's capitulation. The two models had not yet been tried out; thus there were no test results available. The degree of firing accuracy prophesied for the Adder did not seem to be particularly favorable in view of the conditions under which it was to be employed and made it quite clear that in the case of such a specialized aircraft with relatively short flight endurance and relatively high speed, special methods of locating and tracking the enemy target are bound to be determining factors in its successful employment.

The recoilless weapon tubes gathered into bundles as a special weapon were used not only as supplemental vertically-mounted weapons, as we have already mentioned, but were also installed frontally in the fighter aircraft as standard weapons. In addition to the use of the SG-119 in the Julia project, an alternate proposal concerning the armament of the He-162 made use of the possibility of installing two

SO-117 round billets in the nose of the fuselage and of suspending two SO-118 tubular drums, in streamlined casings, from the wings as drop ammunition. By the end of the war, experiments had just been completed on a release mechanism, based on a photoelectric cell, designed to fire automatically the vertically-mounted special cannon. The system achieved a release accuracy of ± ms (??) and a 100% armament error of 400 mm in altitude and depth, at a firing range of 328 feet.

In my opinion, the equipping of the fighter aircraft with supplementary vertical armaments of this kind would have resulted in a new offensive weapon for close combat operations, a weapon whose value should not have been underestimated; in combination with the frontal weapons, they could have increased offensive fire by shooting from below as the fighter flew under its target. The extra weight involved was only 176.4 lbs (for the most promising weapon, the SG-500, with mine ammunition containing 0.77 lb of explosive and with ten tubes), which -- at that time -- ought not to have played any role in the permissible weight of a fighter aircraft, in view of the additional value the weapon represented. There was, however, one qualification in connection with the use of the photoelectric cell; the prescribed distance from the target, for which the angle of incidence of the tubes had been computed on the basis of detonation lag and time of trajectory flight, had to be maintained with a margin for error of no more than 164 feet.

b. Night-Fighter Aircraft

In night fighter operations, armaments mounted for oblique-angle firing had been utilised previously with considerable success in combination with the standard frontal armaments, which consisted of four to six large-caliber automatic cannon. The oblique-angle armaments were introduced when it turned out that the airborne radio operators were achieving highly successful hits with mobile weapons. These hits were delivered at a slant from below and took full advantage of the suprise factor in that they were directed from a position which was not normally covered by the search radar of the enemy bombers, a position from which it was impossible for their frontal weapons to operate.

During an attack with oblique-angle armaments, the night fighter aircraft maintained the same course and the same speed as the bomber under attack. In the beginning, the oblique-angle armaments consisted of two MG-151/20 or MG-FF/M and later, of two 30 mm MK-108 cannon, which were mounted behind the control cabin of the twin-engine aircraft at an oblique angle of 75^{0}, pointing towards the front and upwards. The oblique-angle weapons were fired by the pilot, who took aim by means of a reflector sight which was mounted on a hinged plate and which could be swiveled about at the same angle.

Because of its extreme effectiveness (small shot and increased explosive effect), the SG-500 special weapon which we have already described was particularly well-suited for employment as an oblique-angle armament in the night fighter aircraft.

There was, however, one serious limitation; because of the restricted number of rounds carried by the SG-500, it could be used only once during a mission. It was a matter of principle that the automatic cannon mounted in the night fighter aircraft should carry such an abundant supply of ammunition that they could be used during several air fights in a single mission.

Whenever possible, the frontal weapons, consisting of four to six cannon, were installed in the turrets of the twin-engine night fighter aircraft. No plans were made to utilize rockets in night fighter operations, since it was assumed that their flare would have blinded the pilots. In addition, the fighter's own position would have been endangered by the firing of rockets. For this reason, the automatic cannon carried by the night fighter aircraft had to be equipped with long flash hiders and utilized night or dark tracer ammunition instead of the normal tracer ammunition used in the day fighters.

c. Close-Support Aircraft

The airborne weapons for the close-support aircraft were designed as a standard armament unit for installation under the fuselage of the aircraft. A unit of this kind contained the entire armament system. It could be mounted and removed with equal ease. Once its position on the fuselage had been adjusted, the exact point was marked with dowel pins. Thus the unit could be remounted immediately and was ready for action as soon as the wires had been connected. Consequently, the close-support aircraft could be used either as a weapons carrier or as a bomb carrier, depending upon the type of mission in which it was to be employed. The intense recoil reaction of the cannon was muffled to a degree tolerable to the stability of the fuselage by means of muzzle brakes, in which the muzzle gases were absorbed and deflected. The muzzle brakes were designed in such a way that the gases could escape to the side. This also eliminated the secondary danger, i.e. that the skin of the airframe might be damaged by the escaping gas. The most conspicuous innovation in this method of installation (in the Hs-129, for example) was the wedge-shaped casing under the fuselage, which played a significant role in keeping the aircraft steady during bumpy weather and in increasing the aiming accuracy while firing. In the later close-support aircraft (i.e. in the most common model, the Ju-87), both 37 mm cannon were installed in the wings.

The bomb-weapons, also called "watering cans", represented still another type of armament unit. These were bomb-shaped cylinders containing either three 79 mm twin-barrelled MG-81's with 250 rounds of ammunition each or one MG-151/20. The barrels were set at a downward angle of about 10°. The "watering cans" served as a supplemental weapon for the combatting of ground targets. When necessary, several of them could be suspended in the bomb release clips or from the wings. They, too, could be made ready for firing without delay simply by plugging in the wires which connected them to the electrical remote-control network.

The rockets designed for use against tanks were stored in ~~landing~~ launching rails installed underneath the wings. As has already been pointed out, they were fired in salvos in order to increase the overall chances of a successful hit. Until the automatic rocket launcher was devised, rocket development for the fighter and close-support aircraft tended to favor the arrangement of the rocket tubes in bundles rather than in grids, primarily for reasons of aerodynamic design, since the bundles could be "integrated" into the aircraft fuselage (as in the case of the Adder, see page 87 of this study), installed at the base of the wings (as was the case later on with the automatic launching device) or encased in a pear-shaped mantle suspended from the wings as drop ammunition.

As a general rule, in connection with the installation of frontal armaments in close-support aircraft, it was discovered that it was more advantageous to fire downwards at an angle of about 10°, exactly at flight level. The approach run was easier for the pilot, the potential duration of fire during the run was increased (since the firing range decreased steadily towards the end of the run), and the danger of touching down on the ground was far less acute.

In addition to rocket armaments, which I regarded at that time as well worth further developmental work, I considered the vertical installation of the SG-500, with ten recoilless tubes and automatic firing mechanism (described on page 79 of thus study) to be extremely promising for antitank operations, especially in view of the fact that at that time enemy tanks were beginning to carry antiaircraft artillery.

XI. Defensive Airborne Armaments for Bomber Aircraft

A. The Requirements Established - but Never Met - for Sufficiently Strong and Standardized Defensive Armaments

At no time during the war did Germany have at her disposal bomber aircraft with an airborne arsenal comparable to that of the Flying Fortresses. We have already indicated that the installation of defensive airborhe armaments in nearly every new aircraft model, but especially in the bombers, represented a difficult and thankless job for the engineer personnel concerned, since the tacticians called for the highest possible flight performance and regarded airborne armaments as of no more than secondary importance. And with the exception of one or two projects which were never completed, this principle was adhered to until the end of the war. In Germany's last jet bomber project (the Ju-287 quadruple-jet bomber), for example, defensive armaments consisting of a tail gun mount holding two 30 mm

MG-213's with a firing field of $\pm 15^\circ$ to either side and $\pm 15^\circ$ upwards, in combination with a single MK-108, which was mounted on a so-called keyhole mount in the floor of the fuselage and which was completely useless from the standpoints of both aiming and operating accuracy, were considered to be perfectly adequate. During the early developmental stages, it was assumed that ~~every~~ enemy fighter aircraft would be able to approach a jet bomber at best only very slowly and from the rear at an acute angle; in the awareness of their momentary superiority, the designers forgot that there was no reason why the enemy should not be able to build much faster fighters on the basis of the same technological principles.

In the beginning, the standard air armament of a bomber consisted of three gun stations; one at the top of the fuselage, one in the nose, and one in the belly of the aircraft. Every effort was made to give the gun mounts used in these stations as large an angle of traverse as possible and thus to achieve an overall range as complete as possible and as nearly free of blind angles as possible -- in other words, a field in which the areas covered by the individual guns overlapped at fairly short intervals, i.e. less than 32.8 ft. All the gun stations lay inside the crew compartment, for the original specifications had taken into account the fact that mutual assistance might be required in the operation of the weapons. It was only as the war progressed that bomber aircraft were developed which carried a tail gun mount as well. This had proved to be necessary because it had turned out that enemy fighters were able to come up into shooting range in the dead angle formed by the bomber's tail assembly. As a stop-gap solution, the bombers were equipped with a rigidly mounted tail gun aimed towards the rear. The tail gun was operated by the same remote-control system used for all rigidly mounted cannon and could be fired by the pilot, who took aim by means of a reflector telescope.

For a time, antiaircraft mines were used as drop ammunition, but this practise was soon abandoned inasmuch as the mines themselves might explode if hit by an enemy shell. The mines consisted of approximately twenty 37 mm grenades stored in a bomb release bay. Each grenade had a small parachute affixed to it and was fitted with a jerk igniter which was activated by the opening of the parachute. The burning time of the fuses varied. Operation of the antiaircraft mine bays by the gunner assigned to the top station proved to be most favorable.

B. Defensive Airborne Armaments of the Bomber Models Ju-288, Fw-191, and Hs-130

In the opinion of the author, the Ju-288, the Fw-191, and the Hs-130 -- all developed at about the same time -- were the only bombers whose airborne armaments xxxxx were strong enough to break the enemy's resistance and thus to permit the aircraft to reach their assigned targets safely. After the decision was finally made in favor of the Ju-288, the effects of the war and the reassignment of Germany's last bomber units to home air defense operations made it necessary to drop it from the program. The Ju-280 was to have four remote-controlled gun stations, one in the nose, one at the top of the fuselage, one in the belly, and one in the tail. Ultimately, each station was to be equipped with two MG-213's; in the interim, before the MG-213 should be introduced, with two MG-151/20's. There was room for two additional gun stations in the wings. The gunsight mounts for these armaments were located in a control cabin, which was to be built later on as a pressurized cabin. There were three periscope sights with fixed eyepieces, and the problem of free optical view for the gunners had also been solved satisfactorily. There were two pear-shaped windows in the lower half of the two side walls for the use of the gunner assigned to the belly station. The tail mounts in the upper part of the dome were controlled from the station at the top of the fuselage, those in the lower part from the station in the belly. The switchover was accomplished automatically.

C. <u>The Development of Gun Mounts for the Defensive Armaments</u>

During the course of the war years, a total of approximately 150 gun mounts were introduced, a number which seems at first glance to be disproportionately high. This was due in part to the willing understanding which the aircraft firms encountered for their proposals of new designs.

or modifications of the old designs on the part of the official Development Department, in part to the comparatively high number of new Airborne weapons introduced in Germany, and finally to the technological advances made in the field of gun-mount design. The attempts made by the Ordnance Branch to get along with a smaller number of gun-mounts for a given period of time, in the interests of relieving somewhat the industries charged with their development, of establishing a simplified -- and therefore more easily realizable -- production schedule, and of simplifying the supply problem, usually came to grief as a result of the high degree of freedom accorded the aircraft designers. In the case of the He-177 bomber, for instance, for reasons of weight (limited by the engine) the armament specifications called for remote-controlled gun-mounts with only one 13 mm MG-131 for each of the three gun stations (top of the fuselage, nose, and belly). These specifications were fulfilled exactly, and the aircraft was put into action, although at that time it must have been obvious that its armaments were inadequate and that the single mounts would have to be replaced by twin-barrelled mounts. A further difficulty was represented by the parallel contracts for new aircraft models, which were a common practice until the Gun Mount xxl Development and Installation Commission (Lafettenentwicklungs- und Einbaukommission) began to make its influence felt. Even prior to that time it was usually possible to push through the same specifications in respect to type and number of gun stations even in the case of parallel aircraft development projects, although it did happen occasionally that various details in the gun mounts concerned -- such as the overall height of the cartridge boxes or the position of the remote-control system -- were subjected to criticism and modifications ordered by each of the parallel projects. The specialized adaptation of these modified armaments systems to a number of different aircraft models, as well as the construction of the necessary experimental models, their testing and their ultimate approval for series production, tied up a good deal of the available development capacity -- something which could have been avoided by a program of systematic standardization, for example if the airframes could have been designed from the very beginning with a standard armament unit and standard equipment in mind. It was the task of the Gun Mount Development and Installation Commission, made up of representatives from the Development Department and from industry, to reduce developmental work in the gun mount field to a reasonable minimum, to adapt the variants already in existence into standard models, and to persuade the aircraft firms to utilize the standard equipment in all cases (for reasons which should be clear from the above, one of the most influential directors of the aircraft industry was named chairman of the Commission, whose work, incidentally, was very successful).

In order to clarify any problems pertaining to the operation and the placing of new gun mounts or gunsight mounts to be developed, the Development Department required construction models of each new instrument as the first step in the development process.

These wooden mockups were to be built so exactly that the functioning of the future equipment could be studied in every detail. All interested parties, including the aircraft industry in particular, were given an opportunity to voice their opinions of the models. These inspection sessions usually went off without anyone's having any serious objections to the model, so that it was normally just a matter of presenting a model of a fully operable gun mount or gunsight mount for approval. Experimental aircraft, i.e. stock aircraft which had proved especially well-suited to the accomplishment of air tests of the various types of equipment, as well as workshops at the testing stations had been placed at the disposal of the firms charged with development projects for the air armament program. In this way, the industry was able to carry out air tests with its various designs under the supervision of its own personnel and, on the basis of their views and experience, to evaluate the requirements which a given piece of equipment would have to meet under actual employment conditions. The fact that the weapon and gun mount industries, insofar as they were not identical, worked together very closely in respect to the fundamental functional requirements of the weapons to be installed on the gun mounts was an incalculable advantage.

Reliable functioning, without increased power consumption, at -60° and at speeds three times the ground acceleration were accepted basic requirements for all weapon and gunsight mounts (see pages 82 and 83 of this study). The angle of vision in glassed-in domes, etc. was specified as 65°. In the production of plexiglass, for example, a margin of error of 5' in vertical vision was permitted. Because of the additional deflection error caused by curved focusing screens, a maximum radius of curvature of 300 mm was permitted.

D. Control Systems and Remote-Control Systems

In Germany, the heavy, machine-driven manual gun mounts utilized electrohydraulic power. The method most commonly used was the Thoma-drive (frequently applied in the civilian field of mechanical engineering) combined with a Leonard aggregate. Gun mounts of this type were designed for a maximum angular velocity of 60°/second and a minimum angular velocity of 2°/second. The mounts were operated by means of stick control in accordance with the principle of angular velocity control, whereby the extent and direction of movement of the stick determined the angular velocity and the direction in which the mount moved. The gun mounts of this kind (the most common was the electrohydraulic rotating turret for one MG-151) proved to be eminently satisfactory during commitment in operations at the front.

Smaller gun mounts, designed for the 13 mm MG-131, were operated by electric motors.

The first remote-control system to be ready for use was the electro-mechanical torque amplifier for the rotating turret used with the Me-210 and Me-410. This control system worked on the principle of target speed control. The gunner adjusted both gun-sight and weapon by means of a phantom lever, and the direction of the lever and the weapon were the same in every position. This first remote control system had a disadvantage in that the movement was transmitted from the gun-sight to the weapon mount by means of rigid shafts, resulting in installation difficulties when the gap to be bridged was fairly large. The rigid shafts were necessary, however, since the introduction of additional joints would have led to a decrease in aiming accuracy. As far as I am informed, the degree of aiming accuracy achieved was 4 minutes, and the maximum rotation speed was 60°/second.

The electrically controlled gun-mounts coupled with periscope sights worked in part on the principle of angular velocity control, with a maximum angular velocity of 60°/second, and in part on the principle of target speed control, with a maximum rotation speed of 36°/second to either side and 18°/second upwards. In both cases, the system was operated by means of control sticks whose direction corresponded to the direction of the adjustment. Comparative tests performed with these experimental models had revealed that it took only half as much time to fix an aim on an attacking enemy fighter with the periscope sight coupled with the system based on target speed control as with the periscope sight coupled with the angular-velocity based system. The latter sight required an average of five seconds in an area covering approximately 120°, whereas the former took only 2.7 seconds when the attack was limited to the area of immediate danger.

When the war came to an end, experiments dealing with the best possible design for a remote-control system had not yet been brought to a conclusion, due to the fact that they had been relegated to the background as not of urgent significance. Approximately ten different remote-control systems had been developed for detailed testing.

XII. Summary and Future Prospects

In order to summarize the main characteristics of the developmental work in progress at war's end, it can best be divided into two categories:

1) short-term development

2) long-term development

Re 1), above:

Short-term development was devoted to equipment which showed promise of perfecting the airborne armaments of the fighter aircraft and of the close-support aircraft and, thus, of lending their struggle against the enemy bomber and tank invasions greater strength.

a. Day Fighter Aircraft

The purpose of armaments development was to place the day fighter aircraft in the technological position to fulfill the following missions in connection with the enemy bomber units:

1) to disperse the bomber formation

2) to destroy the majority of the individual bombers in single combat.

An airborne arsenal of long-range offensive weapons, capable of adequate effectiveness even outside the range of a bomber unit's defensive fire, was required to fulfill the first of the two missions listed above. This meant that the mass action of the fighter's armaments had to be effective over a range of more than 3,280 ft., or even better, 3,936 ft. It was for this reason that plans were made for an increased use of the fire salvo method, with rockets based on the R-4/M (but with increased effectiveness and increased maximum velocity) in combination with the 30 mm MG-213, as well as for the introduction of the rapid-firing light 55 mm airborne cannon and the 210 mm incendiary shrapnel rocket. The gunsight to be used in all cases was the automatic reflector sight, EZ-42, with fully automatic range meter, which would relieve the pilot of any need for mental calculations[1].

As far as fulfillment of the second mission is concerned, in my opinion the stage of development already achieved in the armament strength of the Me-262 (six 30 mm MK-108 cannon with forty-eight R-4/M rockets -- later on, instead of the MK-108's, the 30 mm MG-213, with a firing speed of 1,100 rounds per minute) fully met the requirements for combat with a single bomber. For single-engine jet fighters with an armament weight limitation of approximately 551 lbs., there was the more favorable alternate armament consisting of two automatic rocket launchers, each with thirty

1 - For the 210 mm incendiary shrapnel rocket, which was to be fired from a range of 4,920-6,560 ft., the gunsight was coupled with an automatic firing mechanism.

R-4/M rockets instead of the two 30 mm MK-108 cannon. As additional fighter armament, there was also the vertically mounted SG-500 special weapon, consisting of at least five -- even better, ten -- 50 mm tubes with mine ammunition and with a firing mechanism based on the photo-electric cell, which gave the fighter pilot the chance at a second attack after his run with the frontal weapons, since he could fly underneath the target and fire once more from a range of 164-328 ft.

The question of whether or not the plan to attack enemy bomber units with super-speed specialized aircraft (rocket fighters) of the Adder and Julia types had any prospect of success (unless, of course, the enemy bomber was simply to be rammed) cannot be answered, since there had been no opportunity to gather any experience on this method of attack.

b. Night Fighter Aircraft

It was extremely desirable that a blind firing method with automatic gunsight and fully automatic range indicator be devised for dark night fighter operations.

c. Close-Support Aircraft

In view of the anticipated increase in the strength of the antiaircraft artillery forces assigned to cover the Russian tank units, plans were made to improve the ballistic performance of the rockets making up the standard frontal armaments of the close-support airzraft and to supplement these frontal weapons by the introduction of vertically mounted recoilless SG-500 tubes with armor-piercing ammunition and automatic electrical release mechanism. With the help of these weapons, it was hoped that the aircraft would be able to take full advantage of the factor of surprise and destroy the tanks as they flew over them at an altitude of about 32.8 ft.

Re 2), above

a. Day Fighter Aircraft

Long-term offensive armaments development was dedicated to the goal of increasing the combat range to approximately 6,560 ft, in other words of making it so long that enemy bomber units could be attacked effectively from points lying outside the range of their defensive fire.

One possibility in this connection was the heavy 55 mm airborne cannon (muzzle velocity 3,280 ft/second, 0.99 lbs. explosive charge), which was designed for installation in twin-engine fighter aircraft carrying a several-man crew. During the last year of the war, however, there was no opportunity to take up the problem of designing a suitable mount for this weapon. It was planned to use either the semi-fixed firing method, whereby the pilot flies directly at the target and the gunner makes whatever minor aiming adjustments may be necessary in the gun, which is mobile within very restricted limits, with the help of a magnifying telescopic sight, the fixed installation method with stabilization of the weapon, or the semi-fixed firing method in combination with a stabilized platform on which the weapon could be raised or lowered.

b. Bomber Aircraft

The further development of airborne defensive armaments for bomber aircraft was determined by an innovation in aircraft design, i.e. the introduction of the pressurized cabin. The use of remote-controlled gun stations coupled with periscopic gunsights, as planned for the Ju-288, was to be a guideline for future development. The gun stations were to be equipped primarily with 30 mm MG-213's, in double and triple-barrelled models.