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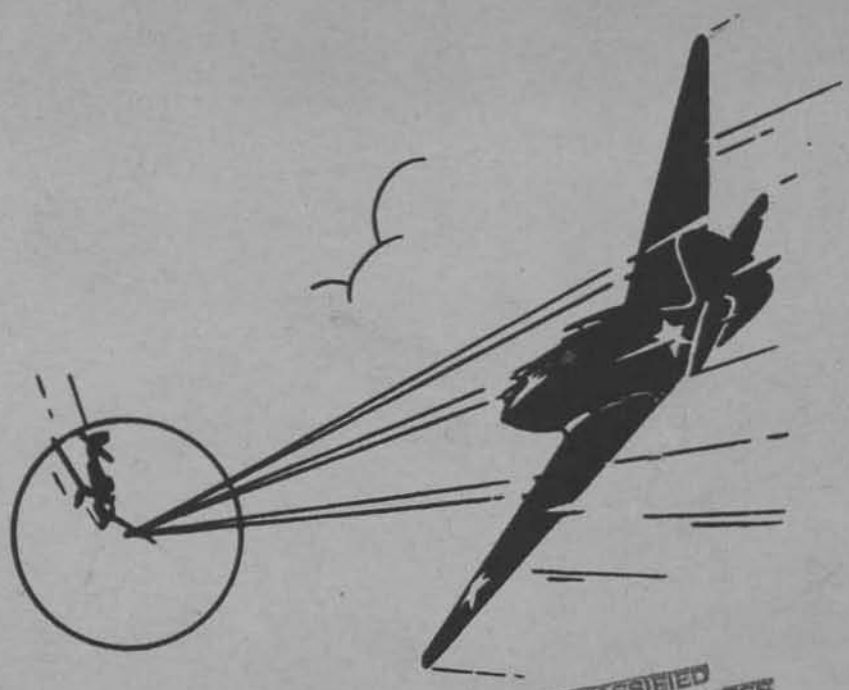
FIXED AERIAL GUNNERY

HOW TO MAKE YOUR BULLETS HIT



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June 15,1943

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U.S. Army Air Forces School of Applied Tactics, Eglin Field, Fla.

F I X E D A E R I A L G U N N E R Y

"How to Make Your Bullets Hit"

* * * * * * * * * *

1232

ARMY AIR FORCES SCHOOL OF APPLIED TACTICS
Department of Air Defense
Synthetic Training Section
Orlando, Florida.

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FIXED AERIAL GUNNERY

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FIXED GUNNERY SYNTHETIC TRAINING SCHEDULE

Sessions to consist of two periods each conducted on alternate days, or one period each conducted on consecutive days.

PERIOD	TIME	SUBJECT
1st	50 min.	Introductory Talk Movie Part I (Pgs. 1 to 22)
2nd	10 min. 40 min.	Recognition Quiz (Speeds) Part I (Pgs. 22 to 27) Discussion with practice on Deflection Training
3rd	10 min. 40 min.	Recognition Quiz (Wing Span) Part I (Pgs. 27 to 32) Discussion with practice on Range Trainer
4th	50 min.	Movie General Quiz Dual Projection Trainer
5th	25 min. 25 min.	Link BB Range Gunairstructor
6th	25 min. 25 min.	Link BB Range Gunairstructor

Movie should be shown a minimum of two times. It may be shown after the formal period is over and should be shown any time a student requests.

[redacted]

PART I

INTRODUCTION.

Your job as a fighter pilot is threefold:

1. Be able to fly your airplane instinctively.
2. Be able to leave your base, intercept your enemy, and return to your base.
3. Be able to successfully accomplish your mission - destruction of the enemy.

More than any other flier, you, as a single-seater fighter pilot, are required to be skilled in all three jobs. In the first place, you fly the "hottest" plane available and the nature of your assignments demands that you know how to get the best out of it. In the second place, you are a one-man crew - pilot, co-pilot, engineer, radioman, navigator and gunner. You must keep track of manifold pressures, wind-drift, radio operation and a hundred other things. Yet, you must be able to accomplish the purpose of your flight - the mission you have been assigned.

Finally, if you are to accomplish your mission you must have confidence in your own ability to shoot down enemy planes. You must hit and hit often. You have learned how to fly in formation and fight as a team. However, if you cannot shoot, your whole training is wasted. You must know when and how to fire your guns. For this, a thorough knowledge of recognition, sighting and range estimation is essential.

The purpose of this "refresher" course is to enable you to review the basic principles of fixed gunnery, and to provide you with an opportunity to prove those principles by actual practice on various synthetic gunnery training devices.

Fixed aerial gunnery is not exactly a simple subject. Yet, if any gunnery method is to work under split-second timing in the air, the process must be made simple. The job must be analyzed and reduced to a simple system. Then the simple routine must be practiced until its performance becomes automatic and instinctive, as readily and naturally performed as breathing.

This war will undoubtedly be won by conditioned reflexes, or by developing the habit of putting lead in the right place at the right time. Most pilots who have had victories in the past and present wars agree that there is no such thing as a "born" gunner who consistently shoots down the enemy by "feel". Only long, tiring hours of searching study and conscientious practice will prepare you for the duty you must perform in the combat area.

First, learn the principles laid down here. Your ability to execute them will depend only upon the extent to which you practice them. If you know all the information contained in these few pages, you will know enough about gunnery theory. Practice will be all you need. Properly combine the two, and you can become one of the best trained fighter pilots in the world.

THE WHO - WHERE - WHEN - S Y S T E M

Perhaps the best way to simplify a difficult job is to break it down into separate tasks and then get each one done in its proper order. Like most difficult jobs, fixed aerial gunnery can be scientifically analyzed and broken down into component parts. Furthermore, the analysis can be set to rhyme.

GUESS WHO	- WHO (Recognition)
FIGURE WHERE TO	- WHERE (Lead)
RECORD HOW FAR	-
THEN PUT IT "THAR"	- WHEN (Range)

WHO - Friend or Foe (Recognition)

This is the first question in any contact. Without the answer to this there can be no answer to WHERE or WHEN. The number of radii lead, or where to aim, can be determined only if you know the speed at which the target is flying. The size of the target as it appears in the ring gives an accurate estimation of the range. You will therefore be able to tell when to fire only if you know the target's wing span or fuselage length. Obviously, you must first identify a plane before its dimensions and speed can be determined. The art of recognition cannot be taught here but its importance cannot be over-

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emphasized. Aircraft recognition is indeed the basis of fixed gunnery.

WHERE do I aim? (Lead)

When you shoot at a moving target you must realize that your bullet does not reach the target instantaneously, but that it takes a certain definite time which depends on the range and the bullet's velocity. During this "time of flight" of the bullet, the target moves through a certain distance which depends on its speed. You must estimate this distance and shoot ahead of the target to allow for it. This correction is called target deflection or lead.

Lead is not a mysterious correction used only in aerial gunnery. It is an everyday occurrence which nearly everyone has observed or used unconsciously. A common example is a stationary passer throwing a football to a runner crossing in front of him on the football field. See Figure 1. He does not throw it at the runner, but always at some point in front of him in such a manner that the runner can catch the ball without changing his speed or direction.

Both a football and a bullet require a definite time to cover a given distance. This fact cannot be disregarded in gunnery or the result will be consistent missing of the target.

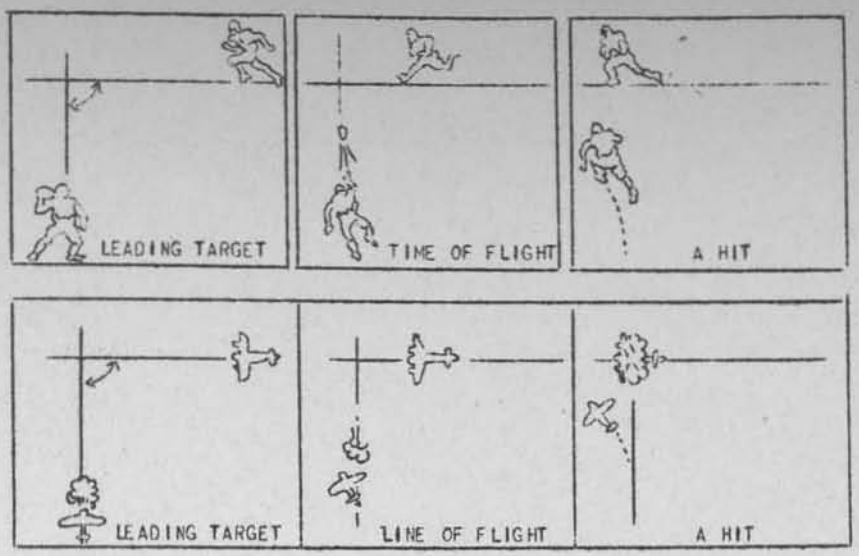

Figure 1

Calculation of Lead

It will be well to consider in more detail the problem of lead and to take the case of a fighter pilot attacking an enemy plane. Figure 2 shows a gunner firing his guns correctly at a target flying across directly in front of him.

Assume that the distance AB from the fighter plane to the target is 300 yards and that the velocity of the bullet is 2,700 feet per second.[1] It will take 1/3 of a second for the bullet to reach the target. If the enemy plane is traveling at a speed of 300 miles per hour, it will fly 49 yards during the time of

1) In the case of a gun firing forward, the speed of the plane must be added to the muzzle velocity of the bullet. For a range of 300 yards the amount of bullet slow-down due to air resistance is approximately equal to the speed of the fighter. Therefore, the average velocity over the range of 300 yards may be assumed to be 2,700 feet per second relative to the air for a bullet with a muzzle velocity of 2,700 feet per second.

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flight of the bullet. Hence the target will fly from B to C while the bullet goes from A to C.

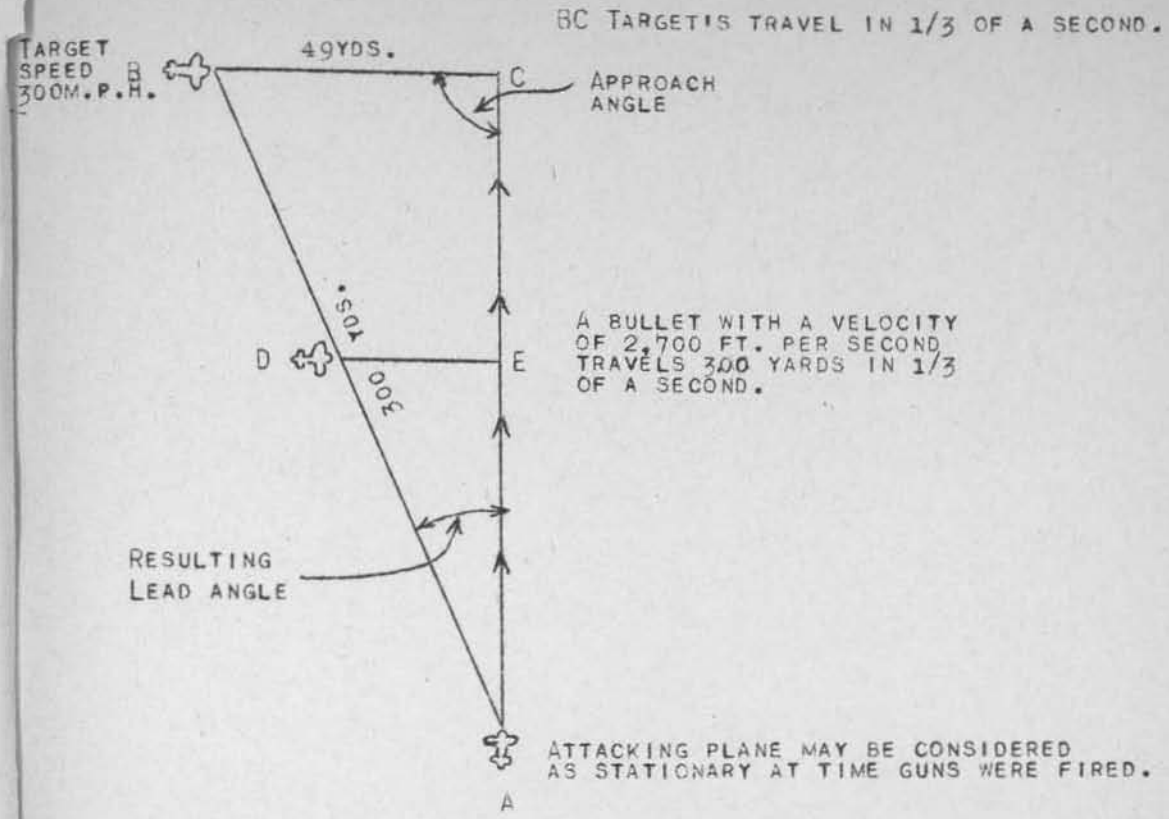

Figure 2

Now, if the target plane were only 150 yards away, that is at D, and traveling at the same speed, the bullet would take 1/6 of a second in flight from A to E, and the target would fly from D to E requiring a 24½ yard lead. It is important to note that in each case the angular lead (angle of deflection) is the same and independent of the range. Note in Figure 3 that if we double or halve (or otherwise proportionately increase or decrease) the time of travel of both bullet and target, the lead angles do <u>not</u> change.

FIG. 2

RELATION OF LEAD - ANGLE TO RANGE

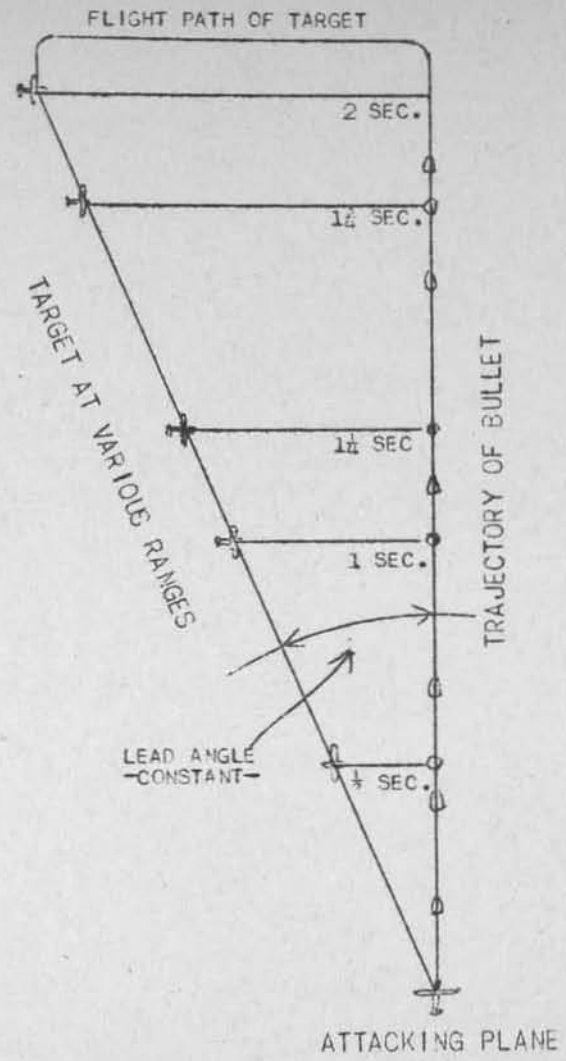

Figure 3

This simple fact gives us the great advantage of having the angle of lead which we give a target remain the same regardless of the range. For this reason you will never hear mentioned the length of lead. All leads will be measured in angles and expressed in sight radii.[1] Thus (1) the speed

1) Radius of Army sight subtends on angle of thirty-five (35) mils.

of the target and (2) the approach angle[1] from which you fire at it are the only two variables which must be considered in computing lead.

(1) Target Speed

Lead is the amount the gunner shoots ahead of the target in order to allow for the distance it moves during the time of flight of the bullet. The distance the target moves obviously depends upon its speed. Change the speed, or the distance which the target travels in a given length of time and the lead angle must change. Decrease the target's speed and the angle decreases. Increase it and the angle increases. Figure 4 illustrated the differences of lead angle for three different speeds. It is very important to realize that for a given target speed range has no effect on lead. Lead as applied to aerial gunnery is angular.

1) Approach-angle is the angle between the line of sight (path of bullet) and the target's line of flight.

FIG. 4

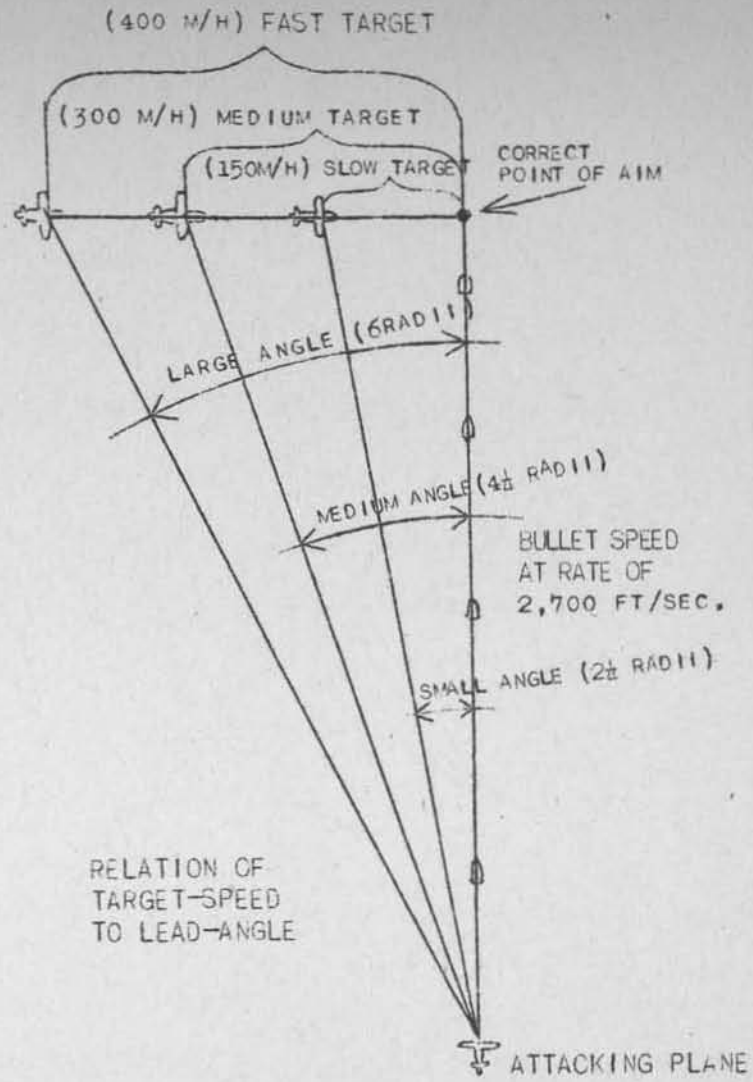

Figure 4

(2) Approach Angle

The angle between the path of the bullet and the flight path of the target (the approach angle) also has a bearing on the lead angle. While this is an unfortunate complication, a clear understanding of the problem is all that is necessary in order to arrive at a solution.

In the case illustrated in Figure 1, it should be observed

that the target is traveling at right angles to the gunner's line of sight. This is called a full deflection shot. An approach angle of 90 degrees is, therefore, a full deflection shot. It should be obvious that if the target were coming directly toward or going directly away from the fighter plane (flying along AC), no angular leed would be necessary. It would then be a "no deflection" shot, and the approach angle would be 0 degrees.

If the target is approaching (or departing) at a 45 degree angle to the line of sight (45 degree approach angle), we may determine the correct lead by the aid of figure 5.

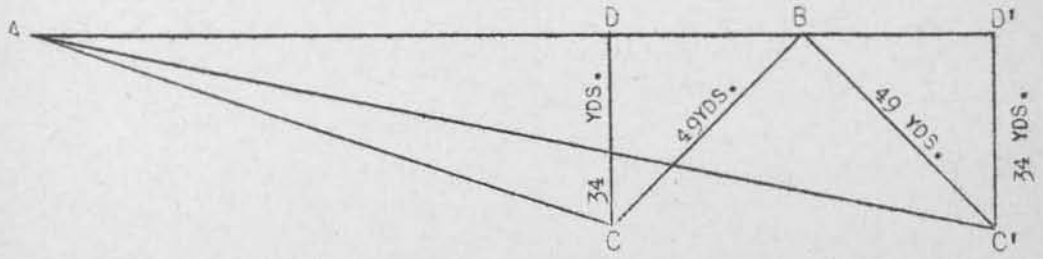

Figure 5.

As before, while the bullet goes from A to C (A to C') the target goes 49 yards from B to C (B to C') but the lead apparent to the gunner is the line CD (C' D'). This may be determined by solving the triangle BDC. This is a 45-45 right triangle whose hypotenuse is known. Instead of leading the target 49 yards as we did in the 90 degree approach angle,

we lead it about 70 percent of 49 yards or 34 yards in this case. (In the 45-45 triangle a leg is always about 70 percent of the hypotenuse.)

If the target were departing at 45 degrees, the correct lead would be D'C'. The difference in the ranges AB, AC and AC' can, for all practical purposes, be overlooked because of their small size as compared with the bullet velocity.

From the foregoing we can see that we must allow for a full deflection shot (100 percent lead) when the approach angle is 90 degrees and no lead when the approach angle is 0 degrees. A 30 degree approach angle will similarly be found to require a 50 percent lead. It should be noted that the greatest change in lead takes place as the approach angle changes from 0 to 45 degrees.

In summary:

Approach angle	0	30	45	60	90	degrees
Lead	0	50	70	85	100	percent

The matter can be clarified by pointing out that for a given range[1] the number of <u>yards</u> (actual lead) that you must

1) Range here is ssumed to be distance from attacking plane to correct point of aim or collision point.

lead the target remains constant, no matter from what angle the bullet comes. This is because it takes the bullet the same length of time to cover the distance to the target, regardless of the approach angle, and during that time the target will travel forward the same number of yards, regardless of what direction the bullet may be coming from. Figure 6 illustrates the point.

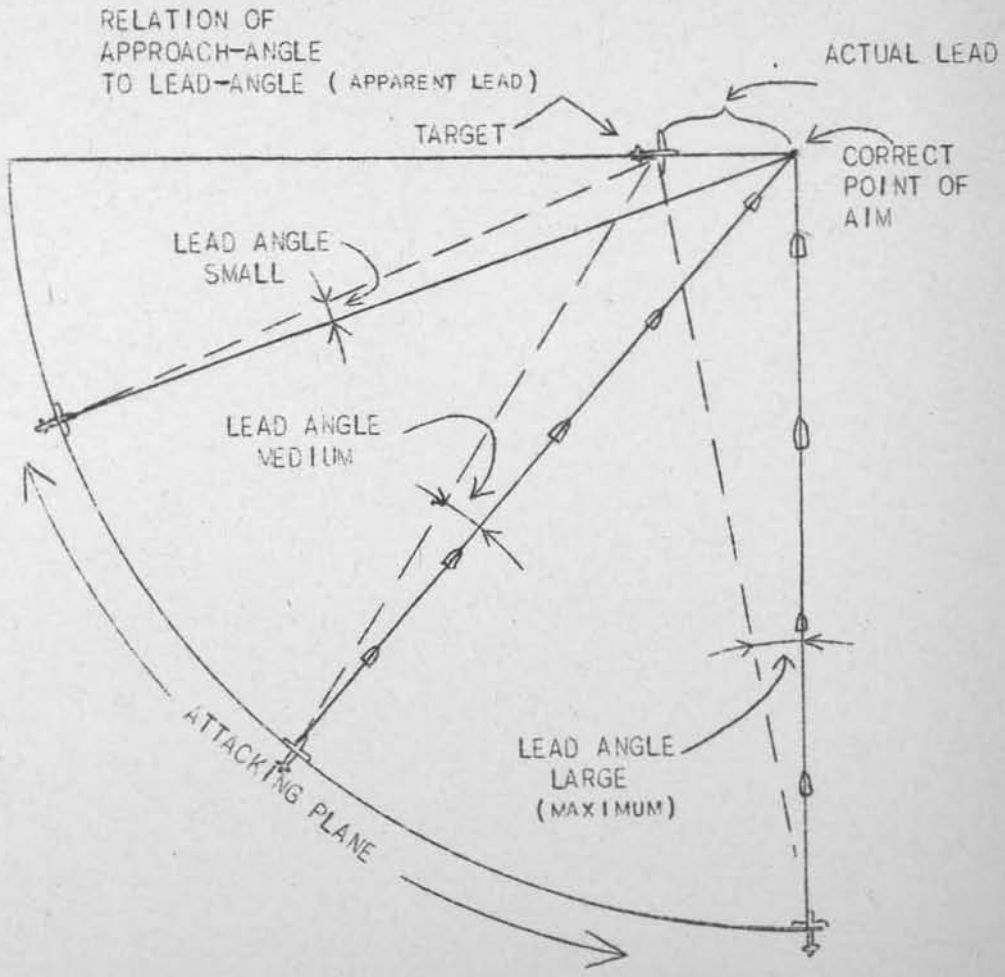

Figure 6.

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Figure 7, however, shows that even though the actual lead in yards remains the same, nevertheless, the lead angle (apparent lead) is less from fighter (A) than from fighter (B), because while the actual lead distance is seen from broadside in the first case, it is seen from a foreshortened angle in the second case.

RELATION OF LEAD IN FEET TO LEAD IN RINGS

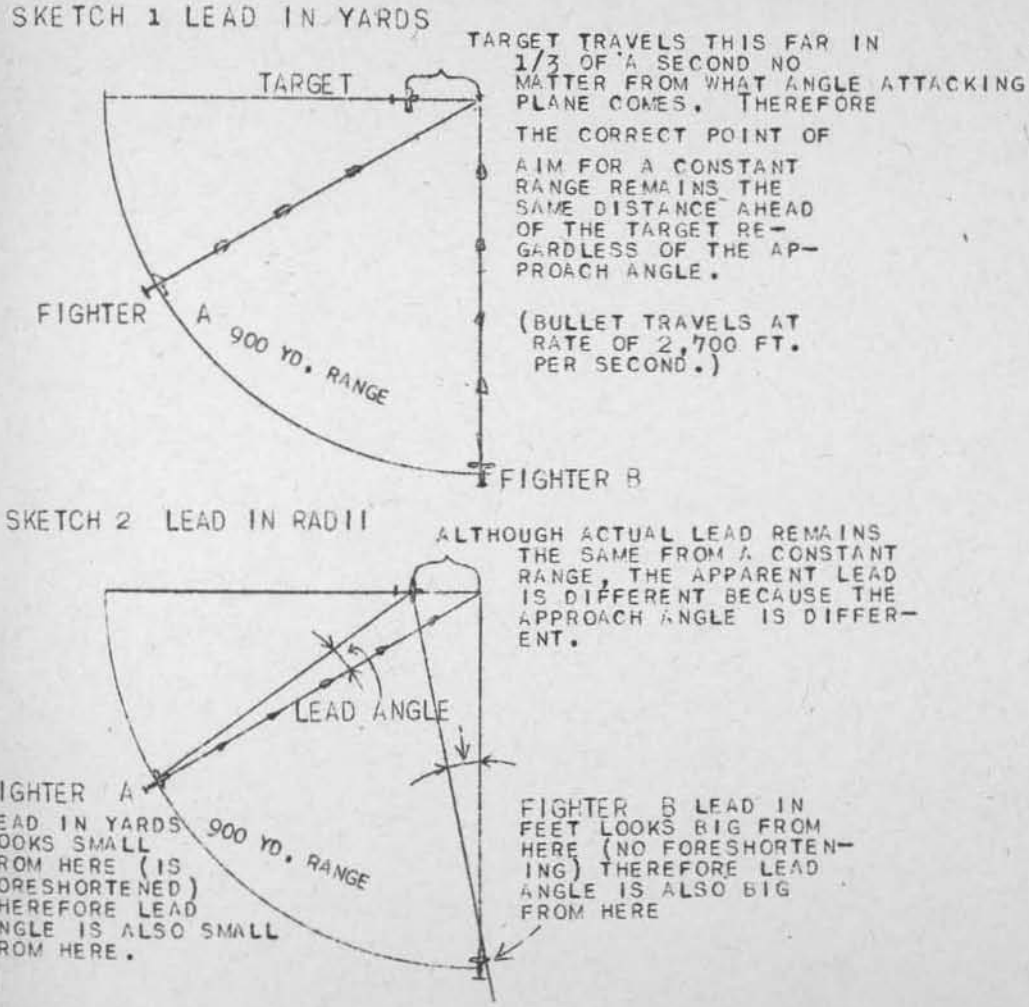


Figure 7

Actual lead, then, is identical for any approach angle, but apparent lead equals maximum lead times the sine of the approach angle.

The correct approach angle is determined by two angles: the turn angle, measured in a horizontal plane; and the climb (dive) angle, measured in a vertical plane. Neither of these angles alone is the approach angle. The approach angle is measured in a slant plane and is always greater than either of the two separate angles. For instance, if the turn angle is 50 degrees and the climb dive angle is 30 degrees, the approach angle is almost 50 degrees. The approach angle equals the turn angle only if the climb dive angle is zero and it equals the climb-dive angle only if the turn angle is zero. However, for all practical purposes the approach angle may be assumed to equal the turn or climb-dive angle if the other angle is less than 20 degrees. Figure 8 shows the picture.

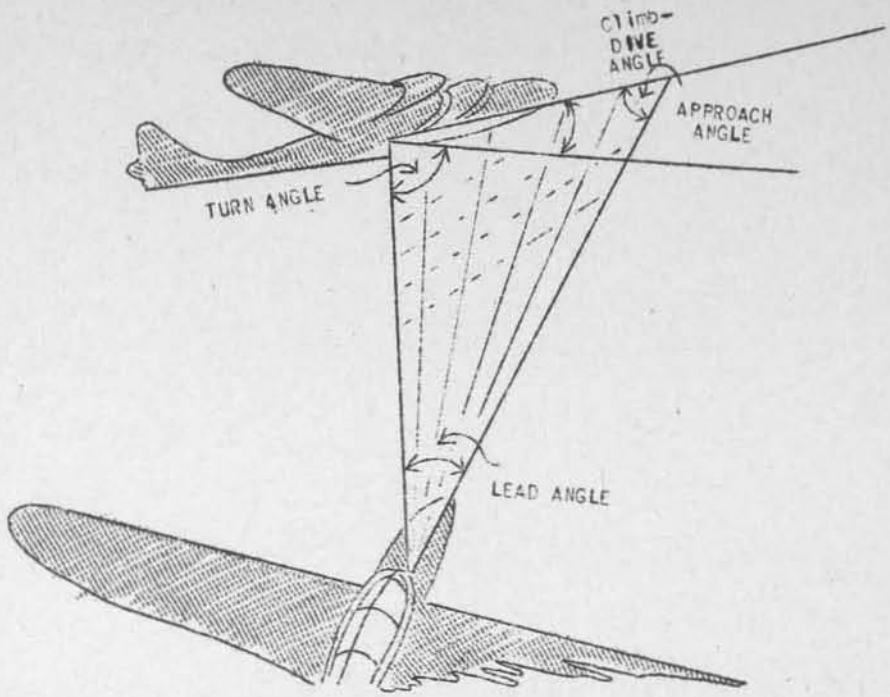


Figure 8

Thus we see that for any given target speed and approach-angle it is possible to ascertain the correct lead angle. But it is also obvious that the determination of the correct lead-angle must be made so simple as to be virtually instantaneous.

This has been achieved in two ways -- (1) by use of the gun sight, and (2) by means of convenient rules-of-thumb.

However, if you do not fully understand everything you have read so far, go no further. Go back and RE-READ. Only

by fully comprehending the above basic principles will what follows make sense to you. Remember in this game, while you fool no one but yourself, you can also cause a lot of other people to get hurt by not knowing your stuff. If you cannot honestly face yourself and say you know what it all means--Don't read on ---

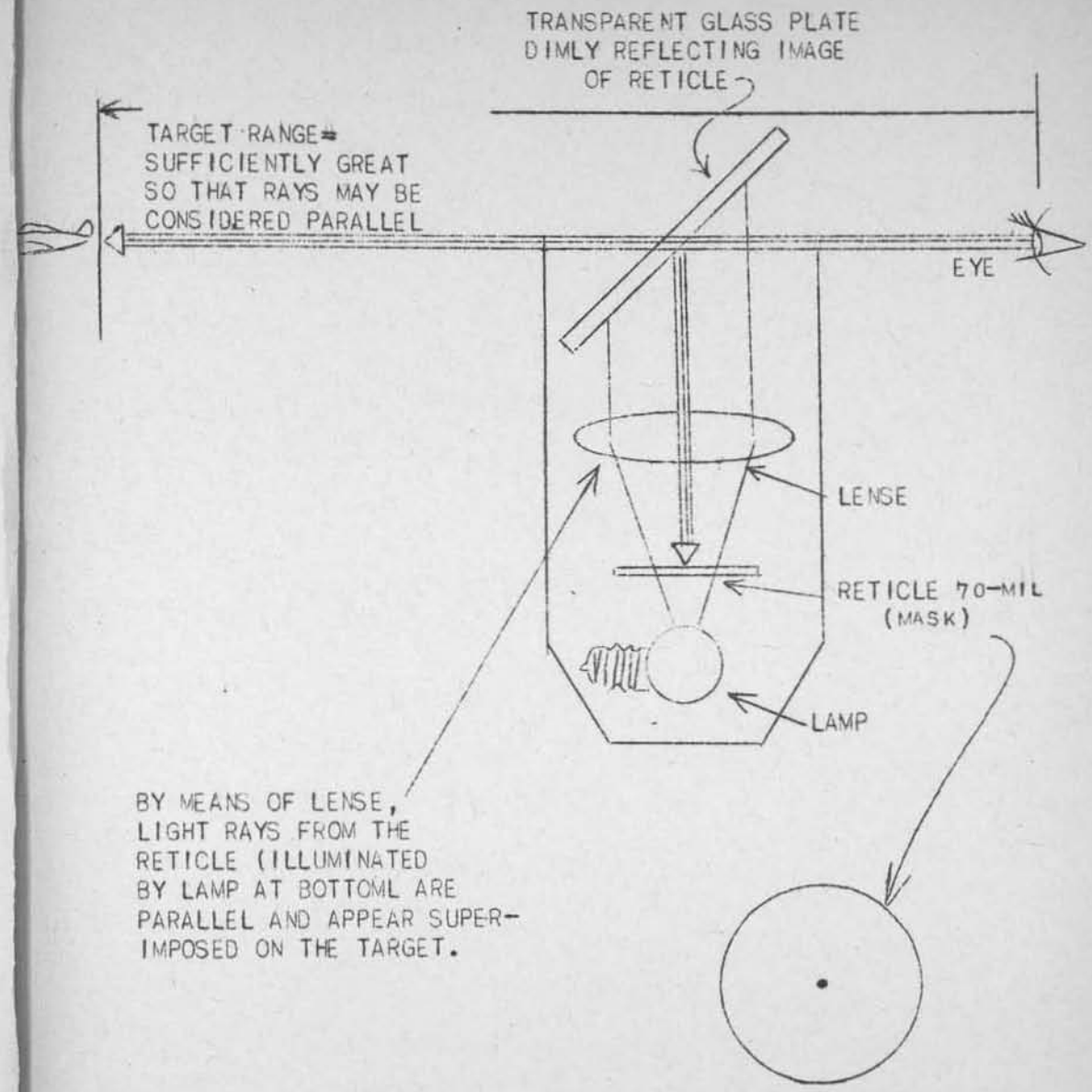
THE REFLECTOR GUN SIGHT

Description

The first short cut you have in estimating the correct lead angle is your gunsight. In order to use it correctly, you should understand how it is constructed.

The optical system of a reflector sight consists of a light source, a reticle, a projection lens system, and a reflecting plate. The bulb contains two incandescent filaments and the intensity of its illumination may be adjusted by a rheostat to fit existent light conditions. The reticle is an opaque plate on which the form of a ring and bead has been etched. When the bulb's light rays hit the reticle, the ring is projected, through the lens system, onto the reflector plate, through which the target is also visible. The reflector plate, made of special triplex glass, is interposed on the line of sight at 45 degrees. (See figure 9)

THE REFLECTOR SIGHT



THUS THE TARGET AND RETICLE
ARE IN YOUR FOCUS SIMULTANEOUSLY.

Figure 9

By this arrangement the lens system picks up the light rays diverging from points on the reticle and projects them as parallel bundles of rays. These rays are interrupted by the inclined reflector plate, where the image is viewed by the eye. The image then appears to be always in the same direction from the observer and in focus with the target.

As a result, the sight ring seems to be a large ring seen at a great distance superimposed on the target plane. As long as the ring can be seen, correct alignment of eye, bead, and peep is assured. If the gunner moves his head from side to side or back and forth, the size and position of the target plane do not change relative to the size and position of the ring. For the position and size of the target to change in the ring there must be relative movement between the firing and target planes.

In the ring and bead sight, because the size of the ring has been calculated according to the distance the pilot's eye is from the ring sight, it is essential that he place his eye at this exact distance, otherwise the basic allowance given by the ring will vary. For instance, if the distance of the sight from the pilot's eye is eight inches, a movement of two inches toward, or away from, the sight will give an error of 25 feet at 400 yards. This is not so with the reflector sight, which automatically compensates for any distance the pilot may place his head from the sight.

With the ring and bead sight the pilot must align the bead of the fore sight with the inner ring of the back sight and both with his eye for every type of shot, otherwise his "line of sight" will be incorrect. For instance, if the eye is 1/8" out of line it will give an error of 20 feet at 400. Again, this is not so with the reflector sight which, so long as it's image is visible, automatically compensates for the position of the pilot's head.

The eye, like a camera, has to be in focus to see the object clearly, hence if the target is in focus the sights must be out of focus and are not seen distinctly. Not so with the reflector sight, which gives the pilot the vision of the dot and ring's image being superimposed on the target.

Speed-rating the sight

The standard Army 70-mil diameter sight has a radius angle from the bead to the circle of 35 mils. Mils, like degrees, measure the size of an angle. A mil is the angle subtended by approximately one foot (.98175 ft.) at 1,000 ft. The distance from the bead to the ring on the sight as seen by the eye, therefore, measures a distance of 35 feet at a 1,000 range. This is illustrated in figure 10.

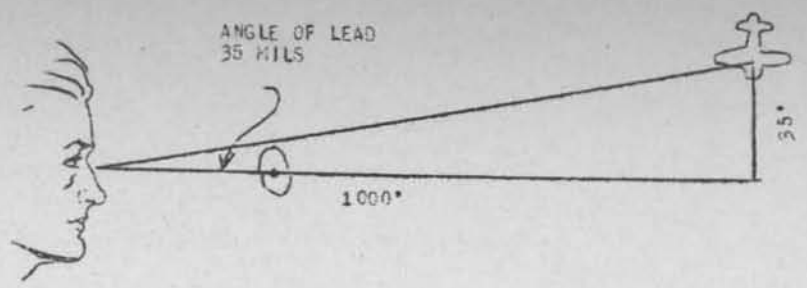


Figure 10

It is possible to use this principle in handling the problem of speed. As previously shown, the amount of lead necessary in any given case clearly depends upon the velocity of the bullet and speed of the target. By studying the velocities of .50 caliber M2 ammunition in a BAM gun, we find that a good average is 2,700 feet per second, over the first 1,000 feet. This means that such a bullet travels the first 1,000 feet in a .37 seconds. Now, by determining how fast a target must travel across the sight radius, a distance of 35 feet, to be struck by such a bullet, we can determine the speed-rating of the sight for that particular ammunition. Figure 11 will illustrate this:

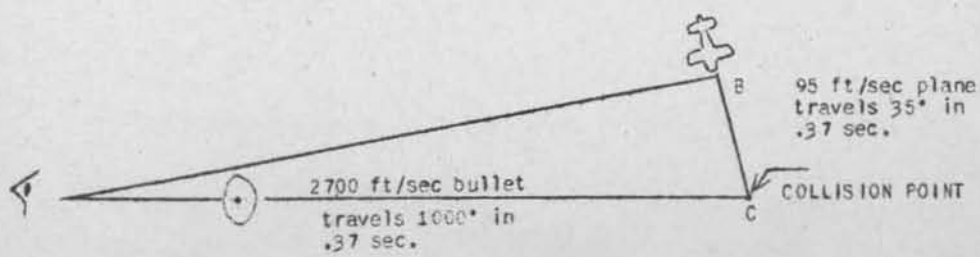


Figure 11

If we assume that the gunner is at A shooting along AC and an aircraft at B is flying toward C, it may be seen that at the end of .37 seconds the bullet will be at C, assuming that it maintains its average velocity of 2,700 feet per second. The aircraft will also be at C if it travels at the rate of 35 feet in .37 seconds, or at the rate of 98 feet in 1 second. Hence C will be the point of aim for the gunner in order to hit the aircraft under the conditions stated. Using the ring will, therefore, lead the target by a proper amount; that is, if the target is put on the ring it will result in a collision course between the bullet and the aircraft.

Since 1.47 feet per second equals 1 mile per hour, 95 feet per second is equivalent to 65 miles per hour which is the speed-rating of the sight. It is important for the pilot to be competent at rating the speed of his sight, due to the variances which may occur in issue reticles, or changes in velocity of future ammunition, or because special combat conditions or equipment installations make revision of the reticle desirable.

The following table shows the speed-rating for the 70-mil sight for bullet speeds from 2,000' to 3,000' per second:

70 Mil Ring

Bullet Velockty	M. P. H. Value
2,000	48
2,100	50
2,200	53
2,300	55
2,400	57
2,500	60
2,600	62
2,700	65
2,800	67
2,900	69
3,000	72

With a full understanding of the gun-sight, you are now ready to start the important business of applying the rule of thumb which will translate target speed into radii lead.

The One-Seventh Rule

On a right-angle approach to the target the ratio between target speed in miles per hour and lead in mils is almost the ratio of 2 to 1. This is true because, as we have seen, the radius of the 70-mil sight is equivalent to a speed of 65 per hour, or a ratio of 65 to 35.

Since you are estimating the correct lead angle by means of your gun-sight, you are not so much interested in the number of mils lead as you are the number of radii lead. Your 70-mil ring is the most convenient and reliable device you have for estimating the correct lead on a target and, although it is not the best sight for its purpose, you might as well

get the best out of it. Here's how it's done.

Because of the inaccuracies of aiming, of estimating the target speed, and of estimating the angle of attack, the 70-mil sight will be considered for all practical purposes as having a 70 mile per hour radius.

THIS MEANS, ONE RADII OF THE 70 MIL SIGHT IS THE PROPER LEAD FOR AN AIRPLANE TRAVELING AT 70 MPH AT RIGHT ANGLES.

Inasmuch as your knowledge of the target's speed is essentially a guess, you are apt to be as nearly correct estimating speeds easily divisible by the speed rating of your gun-sight (70 m.p.h.) as otherwise.

A recommended list is as follows:

Target Speed M.P.H.	Lead Angle No. of Radii	
420	6	
385	5.5	
350	5	
315	4.5	Rule of Thumb
280	4	
245	3.5	Drop the zero
210	3	from target
175	2.5	speed and divide
140	2	by 7.
105	1.5	
70	1	

This provides a variety of speeds sufficiently broad to deal with almost any situation within the limits of one's ability to estimate speed accurately. By knowing this rule-of-

thumb you will find it possible rapidly to determine radii lead for any type of plane.

How to Get Full Deflection Lead

Example: For a M/B Type 1 (Betty)

Mitsubishi Type 1 has maximum level-flight speed = 280 miles per hour. Therefore correct lead for full deflection shot = $\frac{28}{7}$ = 4 Rings (Radii)

Rule of Thumb

Drop the zero from the target's speed and divide by 7.

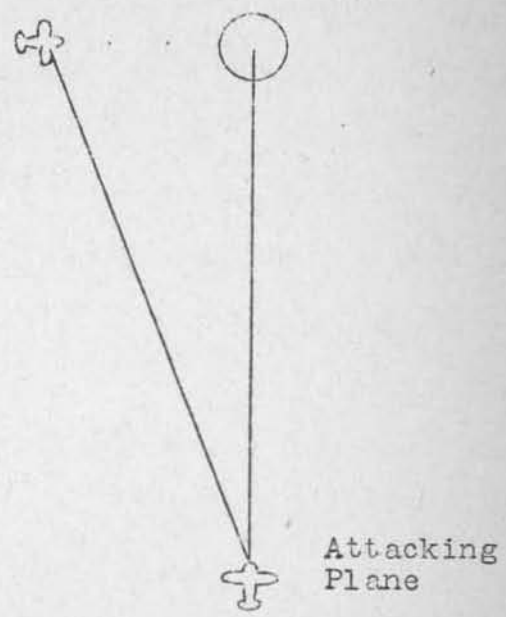


Figure 12

However, even such a simple matter as dividing by 7 can be a major problem under combat conditions. It is possible to make a still greater simplification in the matter of correlating miles per hour speed with number of radii lead...a simplification which eliminates all the "aerial arithmetic".

Inasmuch as each aircraft has a specific maximum level-flight speed it is possible for you to calculate and memorize the number of radii lead required on each plane in a 90 degree attack. For your convenience, the number of radii lead for

full deflection shots at a majority of enemy planes has been computed to the nearest half radii and listed in tabular form at the end of this chapter.

Fortunately, in most theaters of combat it appears that only a limited number of types of enemy aircraft are encountered. From both an operational and maintenance point of view it is desirable to keep planes of similar make and type together.

As a rule, no more than four or five types of enemy aircraft will be operating within an area of several thousand miles. A pilot going into a new theater of operation can, therefore, generally know just what type of aircraft will form the opposition.

Thus, in its simplest form, the answer to our full deflection lead becomes nothing but a matter of learning four or five simple "leads", without reference to arithmetic.

But remember this number of radii lead is calculated for maximum (level) flight speed only. It's just a working bssis. Increase the target's speed 50% and you must increase the radii lead by 50%. Decrease it by 30% and you must decrease the radii lead by 30%. In other words, the relationship between changes of speed and changes of radii-lead is directly proportional. This makes the matter so simple that if you know the basic lead figure you already have half the battle won.

Rule-of-Thumb for Approach Angle.

As the approach-angle changes from broadside to tail there

is a corresponding reduction of radii lead. For all practical purposes this change may be grouped in four catagories: 90° - 60°; 60° - 30°; 30° - 15°; 15° - 0°. Experience has proven that this is completely satisfactory and that the angles are easy both to judge and to remember. Figure 13 clearly illustrates the approach angles and the corresponding deflections. Note that in every case the decrease in radii lead is given as a fraction of full deflection.

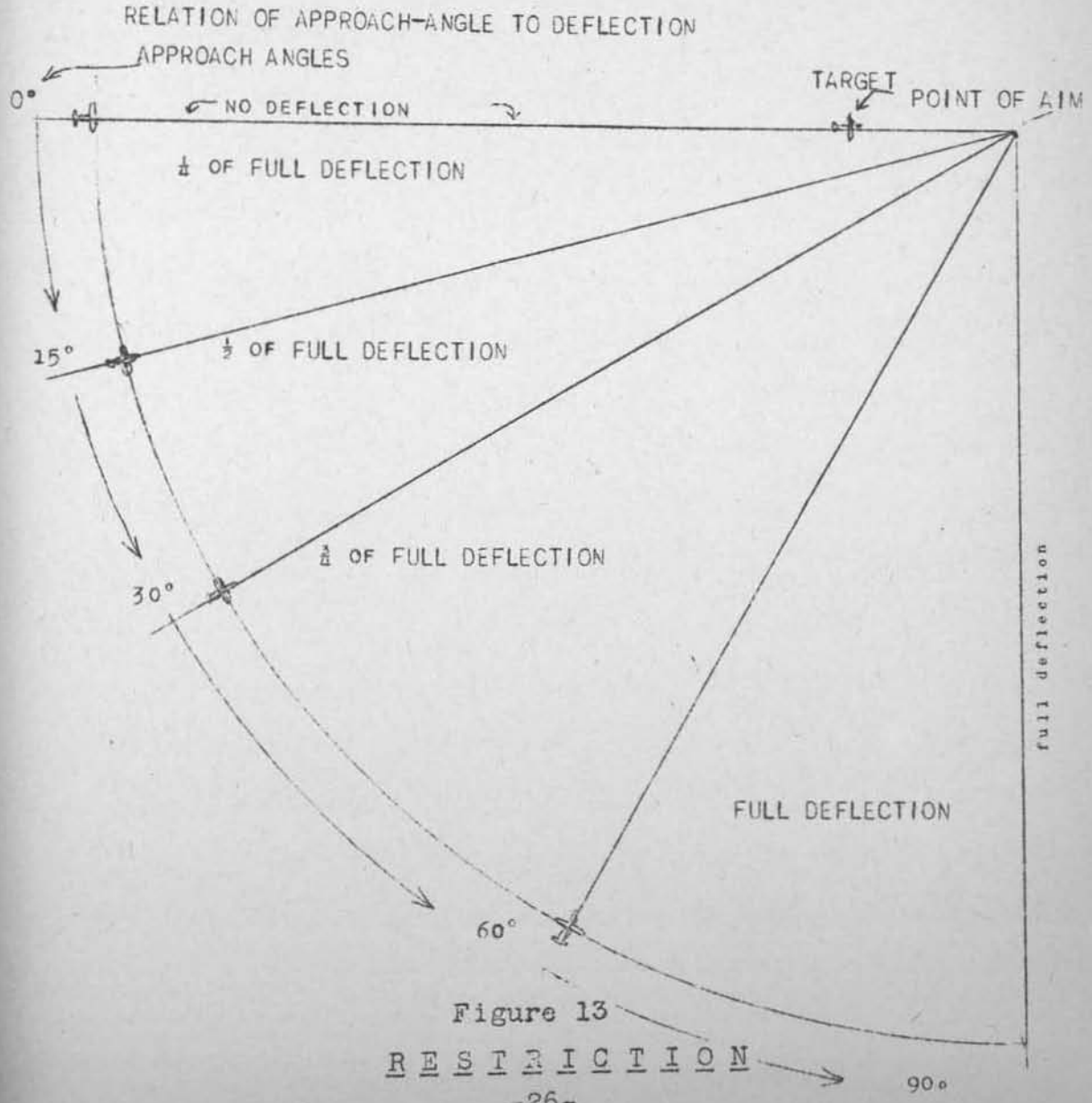


Figure 13

The rule of thumb we will adopt, then, is for 90 to 60 degree approach angle, allow full deflection; for 60 degrees to 30 degrees, allow 3/4 full deflection; for 30 to 15 degrees, 1/2 full deflection; 15 to 0 degrees, 1/4 full deflection.

WHEN.....Am I at the Correct Firing Range

So far, you have the answers to the questions:

WHO...friend or foe -- and type of foe (purely a recognition problem), and ---

WHERE...do I aim.....answered by knowledge of the rings lead-factor (a completely instantaneous affair with an equally instantaneous correction for approach-angle)

It should be emphasized that the answers to both WHO and WHERE can almost invariably be had when the target is still far away. This leaves ample time for cool and deliberate decision and for answering that final important question.....WHEN..

This could be a controversial subject were it not for one incontestible fact --------- experience. Actual combat results have for some time been proving and reproving that the best "get your man" range for opening fire is 300 yards.

As you close on your target to 300 yards, your guns are most effective; i. e., at any given instant you have the greatest number of bullets concentrated within the most efficient area along the sight line and consequently stand the best chance of hitting effectively.

While target range estimation can be an extremely simple affair it has long been one of the student fighter pilot's worst headaches.

The 70-mil reflector sight has, however, been designed so that the ring will quickly and accurately indicate the range of any aircraft of known size. In effect, the sight is a simple and useful range-finder.

We have already seen that the MIL is the unit of measurement which has been adopted and that a one-foot ruler held up 1,000 feet (333 yards) away gives us an angle of 1 MIL. Thus, an airplane with a wingspread of 35 feet at 333 yards' range will fill 35 mils or 1 radius in our sight; a 70 foot wing, 70 mils or 2 radii; a 100 foot wingspread will fill 100 mils, or about 3 radii, etc.

Here we have another fortunate circumstance. If 300 yards is the best range at which to open fire and 333 yards is a range which can be accurately measured by your ring sight, the two can, for all practical purposes, be considered one and the same.

Consequently, if we know the wingspan and fuselage length of any given target, it is an easy matter to tell when it is at 300 yard range. Just wait until the target fills the same number of mils in the sight-ring as you know it measures in size (feet), then open fire. You are at firing range when you press the trigger.

Although a target traveling at a 45 degree angle to your line of flight will appear foreshortened in both fuselage and wingspan, the tendency to shoot too soon will normally compensate for the apparent decrease in the size of the ship in the ring sight. Actually, a target viewed at a 45 degree angle will appear only about 3/4 of its actual size and fire may, therefore, be opened a split-second sooner than otherwise.

Remember that either wingspan or fuselage length can be used to estimate range. Just use whichever one is the most nearly full-view to you.

When you first learned to drive a car you probably found it difficult to estimate whether or not it would fit between two obstacles on the road. Similarly in flying, one of the most difficult tasks for you is going to be to wait until you are at 1,000 foot range before opening fire. Firing while still out of range is usually the student fighter-pilot's first mistake and the one he hangs onto the most tenaciously.

Thus we see that once we have recognized our target and pigeonholed it as to characteristics, we have been able to apply our 1/7 rule (or know the rings-lead) and approach angle correction to deflection and our gunsight to get range.

The WHO-WHERE-WHEN system now becomes simply a constant challenge that requires nothing but practice, practice, and some more practice.

WHO - WHERE - WHEN.....WHO - WHERE - WHEN .....
Think of it every time you see a plane in the air, a model on the ceiling, a picture in a magazine, a movie, a classroom, your own room. Think further of the answers, too. Learn to recognize every plane. Know its speed, its size, its lead.

* * * * * * * * * *

GERMAN AIRCRAFT

FIGHTERS	Wing Span	Fuselage Length	Max. Level-Flight Speed	Radii Lead
Fock Wulf FW 190	40'	29'	390	5.5
Messerschmit Me 109E	33'	29'	350	5
Messerschmit Me 109F	33'	30'	390	5.5
Messerschmit Me 109G	33'	30'	400	6
Messerschmit Me 110	53'	40'	360	5
Messerschmit Me 210	53'	36'	360	5
Junkers Ju 88 C5	66'	47'	350	5
BOMBERS & DIVE BOMBERS				
Dornier Do 17	59'	53'	310	4.5
Dornier Do 217	63'	57'	320	4.5
Focke Wulf FW 200 K	108'	78'	260	4
Heinkel He 111 HaE	74'	54'	250	3.5
Heinkel He 177	103'	64'	200	3
Henschel Hs 129	45'	33'	250 (est)	3.5
Junkers Ju 86P (approx.Dimen.)	77'	53'	280	4
Junkers Ju 87B	45'	37'	250	3.5
Junkers Ju 87D	45'	37'	250	3.5
Junkers Ju 88 A6	66'	47'	290	4
Junkers Ju 288	60'	47'	---	-
COOP. RECONN. & TRANSP.				
Focke Wulf FW 189	60'	39'	220	3
Junkers Ju 52	96'	62'	160	2.5
Junkers Ju 90	115	86'	210	3
NAVAL				
Arado Ar 196	41'	36'	190	3
Blohm & Voss BV 138	89'	65'	170	2.2
Dornier Do 26	99'	81'	210	3
Heinkel He 115	76'	57'	210	3
GLIDERS				
DFS 230	72'	37'	100(cru)	1.5
Gotha Go 242	79'	53'	149(Max)	2

JAPANESE AIRCRAFT

FIGHTERS	Wing Span	Fuselage Length	Max Level-Flight Speed	Radii Lead
Type 97 SSF Nate	36'	24'	280	4
Type O MKI SSF Zeke	39'	29'	350	5
Type O MK2 SSF Hap	36'	28'	310	4.5
Type 1 SSF Oscar	36'	28'	320	4.5
DIVE BOMBER				
Type 99 D/B Val	48'	33'	240	3.5
TORPEDO BOMBER				
Type 97' T/B Kate	52'	34'	230	3.5
BOMBERS				
Type 96 M/B Nell	82'	54'	230	3.5
Type 97 M/B Sally	72'	52'	230	3.5
Type 1 M/B Betty	80'	64'	290	4
FLOAT PLANES AND FLYING BOATS				
Type 95 F/P Dave	36'	28'	170	2.2
Type O F/P Pete	37'	31'	220	3
Type 97 F/B Mavis	131'	82'	160	2.5
Type O F/P Rufe	39'	35'	300	4.5

ITALIAN AIRCRAFT

Fiat CR 42	32'	27'	270	4
Fiat G 50	36'	26'	290	4
Macchi MG 200	35'	27'	300	4.5
Macchi MC 202	35'	30'	330	4.5
Reggianne Re 2000	37'	26'	320	4.5
Reggianne Re 2001	37'	29'	360	5
BOMBERS				
Cantieri Cant Z 1007 bis	81'	61'	280	4
Fiat BR 20	71'	53'	270	4
Savoia Maschetti SM 79	69'	53'	300	4.5
Savoia Maschetti SM 84	69'	59'	300 (est)	4.5

FIXED GUNNERY
SYNTHETIC TRAINING SYLLABUS

Part II

ARMY AIR FORCES SCHOOL OF APPLIED TACTICS
Department of Air Defense
Synthetic Training Section
Orlando, Florida

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MAKING IT "INSTINCTIVE

The necessity of making whatever we do in aerial gunnery a matter of "instinctive" action---automatic reaction is beyond dispute. Despite the simplicity of the WHO - WHERE - WHEN system, things are still going to happen so fast when you get up there that there will be no spare time for "thinking" things out.

The question WHO must immediately be answered because there may be several WHO's at the same time. WHERE must also be instantly answered because there must still be time to ask "WHEN", and to get calmly and previsely set for the actual performance.

Basically there is much in common between fixed aerial gunnery and coming in for a landing, playing a game of tennis, swimming, or riding. A certain rhythm is essential. If your landing approach is poor, if you have to play with your flaps, overwork your throttle, vassilate your speed, you're a good man if you can still consistently make a good landing.

Watch a professional athlete, a golfer, tennis champ or oarsman...for that matter, a professional at anything. The one thing that sets him head and shoulders above others is his "rhythm". There's a steady, well-planned timing to every move he makes. His every motion has been started...and many may have been finished...before we have even had time to consider what should be done next. "It's all so lovely and easy".

But don't believe it was easy to get. Hours, months, more often years, of practice are hidden in those "simple" motions.

unused time profitable but it also enables you to get that much more out of your in-the-air training.

Not only is the WHO, WHERE, WHEN system already a major simplification of the fixed gunnery problem but six specific synthetic aids have been developed to simplify the learning and practice of it.

These consist of:

1. Recognition, range and point-of-aim cards
2. The stationary deflection trainer
3. The range estimator
4. Dual Projection Trainer
5. Link BB Range
6. The Gunairstructor

This is the order in which they fit into your picture and here is the way you can get the most out of them.

1. RECOGNITION, RANGE AND POINT-OF-AIM CARDS:

Consisting of a large and constantly growing collection of clearcut illustrations of virtually every type of aircraft, these cards give you an opportunity studiously to observe and to learn the fundamentals of the "WWW" system.

Each card illustrates the appearance and gives the size, shape, cruising and maximum speeds of different aircraft. Accompanying the cards is a celluloid overlay inscribed with a mil-ring corresponding to the 70 mil sight of your plane. Placing

the overlay on the card you can learn to determine whether or not the plane is in range by observing how many mils it fills in the sight. By knowing its speed and applying the 1/7th rule you can estimate the correct point of aim.

Holding the card up to the light immediately makes it possible to compare your estimates with the actually correct point of aim and range by virtue of the dot and figures printed on the reverse side of the card in exactly the correct relationship to the target.

Get your hands on as many of these cards as you can. Go over them again and again. Don't just look at them. Learn to see them too. Most of us go thru life doing mostly the former, very little of the latter. Trouble is, life won't be long enough for the fithter pilot who goes on that basis. Borrow cards from the ground school, from your flight group, from anybody who has them. But, just remember, they need them too, so keep 'em moving.

Go thru the routine with each one. WHO? WHERE? WHEN? You will find the answer to WHO greatly facilitated by your making an actual drawing of each type of plane. If you can't draw freehand, then make a tracing. The mere physical action of putting down every line compels you to see every feature. In the first plane you draw you will discover half a dozen things you never knew about it before. The bigger the picture

you copy the better. Better still, copy both large and small pictures. Get used to seeing the target as you actually will... too darned small.

Apply the proper radii lead to every view. Do it so many times that you can hit it on the nose without second thought. In the middle of looking at one card catch yourself by a rapid-fire "shot" at another. Be tough on yourself. Wash yourself out so many times you want to give up. If you can't lick the cards, you'll never lick the real thing.

Look carefully at the ring in the over-lay-sight. Get so that you can instantly read it by diameter and radii. Push the target off to the top, the bottom, the sides.....and still call off the range. Don't always just place it in the center and give yourself a "sitter".

Pile up the cards and use a blotter to cover the statistics in the top center. Call off the names, and sizes and speeds as fast as you can turn them over. Pick your spot, judge your range. Give them the WHO-WHEN-WHERE works.

2. THE STATIONARY DEFLECTION TRAINER

This is a valuable device, particularly as an adjunct to the cards. It affords a first opportunity actively to apply a good deal of the more or less static information which you have just been getting from the cards. Where previously you

were looking at a flat plane thru a flat gunsight, now you see a three dimensional model thru a three dimensional 70-mil reflector sight.

The machine is so designed that the target's speed can be set and its attitude can constantly be changed in azimuth and elevation. For every given speed and angle there is an automatic deflection-computer. When you pull the trigger a spot of light will strike at the point where your bullets would have gone in relation to the target if it had actually been moving at the speed and in the direction indicated.

Again apply the "WWW" system. Recognize the plane, the wingspread and the fuselage-length. Note the speed. Apply the 1/7 rule or what you know to be the proper radii lead. Allow for approach-angle and then "let him have it!"

Do not fail to notice that one of your first tendencies will be to allow <u>in</u>sufficient lead. This is due partly to the fact that you may find it difficult to believe that the amount of lead must be so great. Recognize the difficulty and automatically you have half licked it. Practice will do the rest.

At first, put the target in a number of successive stationary attitudes. Then, as you improve get someone gradually to change the target's attitudes and see how well you can "follow thru".

DON'T PLAY WITH IT AS A GUESSING MACHINE. Here's your chance every time, wrong or right, to look long and see well just what you are doing and why you are, or are not, getting results. You'll never get a chance like that in the air. Particularly notice the opportunity to estimate your approach angle, and to apply quarterly decreasing amounts of radii lead.

Inasmuch as time is so essential in fixed gunnery, gradually learn to speed up your ability. But don't rush it at first. Go slowly, study and think. Analyze your good shots as well as your poor ones. After several hours of practice (logged over a number of days) start limiting yourself to a certain amount of time per answer. See what you can do with 20 shots in 5 minutes...then in 3 minutes...finally in 2 minutes. If you're not doing so well go back to the slow plodding; log more time; then gradually start speeding up again.

Get so good at using the device that you can even do it in reverse. As mentioned, there is provision in the design of the machine whereby the speed of the target may be varied, thus automatically varying the deflection reading which the device puts out. Get someone to vary the speed by moving the necessary adjustment. Then only by your knowledge of where the correct point of aim is located for a certain target speed, by looking thru your sight give directions until the target speed adjustment is back in the correct place for the lead you have selected. Your accuracy may readily be chacked on the speed-

scale.

In other words, get so sure of yourself that you can work problems backwards, knowing the aircraft's size and speed and consequently its radii lead so well that you can properly calibrate the air-speed adjustment instead of it calibrating the lead. It's the same as the flight surgeon asking you to line up the two sticks in the depth-perception test.

When you have gotten so that you can thus read the Stationary Deflection Trainer "backward", you are certainly ready for the next step...

- -

*NOTE: Those with gambling proclivities BEWARE!!! This machine is particularly "HOT". It's too easy to get talked into a 20-shot, 3, 2, or 1 minute bet on the most hits. It won't do your shooting any good---not much!

- -

3. THE RANGE ESTIMATOR:

The WHEN part of the system is the last question requiring individual attention. As already seen, here is where your mil-ringed sight really comes into its own--as a range finding device.

To provide you an opportunity to practice reading range directly from an actual sight, the "range estimator" has been created. This simple device consists of a 70-mil training sight mounted on a platform above a scale-model aircraft, the model being hidden from view except through mirrors mounted on

a track in front of the sight. By moving the mirrors back and forth along the track the apparent size of the aircraft changes in the sight. The change is directly calibrated on a tape. The model may also be rotated to present itself at different angles to the sight.

Again, much the same self-instructional technique should be employed as with the deflection trainer. Move the model back and forth, through every possible range and angle.

Observe that though the range is maintained constant the number of mils which the plane fills in the sight decreases by about 1/4 when it is at a 45 degree angle.

Get so good that you can call off the range instantly, no matter where the target is in the sight. In the air there is no time to count mils in the center of the sight, (where it is easiest) let alone at the edges. Keep your hand in at deflection by first applying the correct lead, then reading the range whenever the target is in the sight.

A convenient trick for counting mils when the target is off-center in the sight is simply mentally and visually to drop down or run up vertical lines from the tops of the ship until they cross the horizontal line thru the middle of your sight. Having practiced until you are "perfect" at reading mils along this line it thus becomes as easy to read range in a corner of the sight as in the center...and you are ready for another forward step.

4. DUAL PROJECTION TRAINER

The Dual Projection Trainer is designed to teach Flexible Gunnery. You may wonder why fighter pilots who are interested primarily in Fixed Gunnery are concerned with a flexible gunnery trainer. Eventually, we hope to adapt this device to the teaching of fixed gunnery. In the mean time, you should be familiar with the device for several reasons.

1. The trainer enables you to see your attack from the enemy's viewpoint. You are the deck gunner defending a bomber, traveling at the rate of 240 miles an hour, from enemy planes attacking you from various angles. You are provided with the means of analyzing these attacks from a vulnerability standpoint. You can see which attacks offer a difficult target and those which present an easy or "sitting duck" shot.

2. You will notice the trainer provides an excellent means of teaching recognition under closely simulated combat conditions.

3. On a majority of the attacks the attacking plane comes in very fast. The trainer demonstrates the necessity of using ample lead in order to hit a rapidly moving target.

4. The attacks are flown by models. Since each attack is based upon the latest available intelligence reports from combat theatres they offer an excellent opportunity to study approaches and breakaways from a tactical standpoint.

5. Since the Army Air Corps has ordered 1,100 Dual Projection Trainers, you may at some future time come in contact with

the trainer. Here you have an opportunity of getting at least a speaking acquaintance with the machine and to observe its capabilities and limitations as a gunnery trainer.

When using the trainer you sit behind a mock-up machine gun and face a motion picture screen. Behind and above you are two (2) 16 mm motion picture projectors which are synchronized by means of a flexible shaft. One projector fills the screen with pictures of what you would see if you were actually looking out of the top turret on a bomber. You see clouds, landscapes, portions of your own plane and attacking enemy planes, maneuvering, approaching and breaking away just as they do in combat. You estimate the range of the attacking enemy planes and open fire when you think you are within range. If the target is within range you hear the sound of your own guns. If it was out of range you hear the sound of a gong. Engine noise and noise of your own gun's firing are simulated.

5. LINK BB RANGE:

The Link BB Range provides you with a means of mastering the art of deflection shooting. In order to align your sights on the moving target you must apply the same coordination between hands, feet, and eye that you would if you were flying a P-40, a P-39, or any other fighter plane on a combat mission. At the same time, the equipment is kept small and compact, so that all firing can be kept under the supervision of competent instructors. This is accomplished by the use of

four (4) C-3 Link Trainers, a model of an enemy plane which is carried around on a double U track by an electric train, and machine guns mounted on the Link Trainers that fire BB's at the same rate that an actual machine gun fires bullets. The BB machine guns are mounted as fixed guns, one on each Link. In the front of the dash board of the Link is mounted a standard 70-mil reflector gun sight.

The machine gun and the gun sight are harmonized so that the line of sight and the line of fire converge at a simulated range of 300 yards. As the Link is controlled in the same manner as an airplane, you must get your control manipulation down pat before you can fire on the moving target with any degree of accuracy.

All parts of the BB gunnery range are scaled down in size. The size of the target, the speed at which the target travels around the track, the firing range, and the velocity of the BB's are all reduced to a scale of 1-30. The speed at which the train carries the target around the track for a simulated speed of 400 miles an hour is 19 feet per second. For such speeds the track has to be banked sharply inward and the curves made not sharper than a seven (7) foot radius. The track is 170 feet long, made of iron rails, and is laid out on a platform 30 feet by 50 feet, five feet above the floor. The track is laid in an oval shape with a sharp U on the side facing the Links. The nearest point from the Links to the track is fifteen feet (representing 150 yards at a 1-30 scale) and the

farthest point is 60 feet (representing 600 yards at 1-30 scale). Thus, the target, as it is carried around the track, is within a range of (simulated) 150 yards to 600 yards of all of the links. Due to the shape of the track you are given shots at approach angles varying from a head-on or tail shot to a full 90 degree deflection shot.

6. THE GUNAIRSTRUCTOR:

Here's where the action begins. Whereas so far your activity has been of rather a stationary, objective nature, with each factor considered conveniently individually, the world is about to start seemingly revolving around you. You are now going to be called upon to apply collectively and by active physical manipulation and coordination all that you have heretofore been learning by mental analysis and semi-passive observation.

As a synthetic device the Gunairstructor is particularly difficult to describe; perhaps, because it is so "unsynthetic" in the realism with which it produces actual conditions. Proof of this is that the best way to tell someone how to "fly" it is to advise that they go about the job just as though they were in an airplane.

Climb into the cockpit and you will find the same old stick and rudder pedals, the throttle, trigger, and reflector-gunsight. Looking thru the windshield out from under the hood there is the skyscape (land, sea, and sky) just as it looks to

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you from about 10,000 feet aloft. As you manipulate and coordinate your controls you can climb, glide, dive, bank, turn, slip, skid, or otherwise make your plane perform just as it would in the air.

The roar of your engine drowns all but the crack of your guns when you fire. As you dive the engine picks up speed and whines; climbing it slows down, begins to labor. Your nose drops in turns, (or when the throttle is closed), must be held up with back-stick pressure. Crossing controls causes slipping or skidding. Rough control manipulation gets rough results; coordinate smoothly, and you're "riding the air".

However, this is not as easy as might first appear, for you are not alone in the sky. Also present is an enemy plane flown by the Gunairstructor Operator, who is capable of making it perform in any way he chooses (just like an enemy pilot with his plane), regardless of what you in the pursuing fighter may be doing. Right, left, up, down, in and out of range, tail shots and deflection shots, the target can give you all of them either in as rapid or as slow succession as desired. Any flying relationship between target and pursuing fighter (your plane) can be continued as long as you like. In fact, at any given instant, everything can be "frozen" and you can stop and analyze every element of the situation as long as you like.

Furthermore, and of perhaps greater importance, when you fire you can now instantly tell whether you hit or missed. Hit the target, and immediately it flashes red.

But of greatest importance is that you can now also tell why you hit or missed. At the operator's discretion a light, indicating the correct point of aim for any given maneuver of the target, can be projected onto the screen whenever you pull the trigger. Thus you can instantly compare the position of the light in relation to the target with the relationship of the "pipper" in your sight and the target. If your pipper and the light spot coincide, you are on the mark. Too much or too little deflection are immediately obvious by observing whether your pipper is ahead of or behind the dot.

Proper use of your trigger is an added problem you will find in the Gunairstructor. Most people find it just as difficult to coordinate the trigger with their other controls as they once found it difficult to handle the throttle when they were first learning to fly. "Trigger shyness" is one extreme. Firing in too-short burst may save ammunition but it too frequently saves the target as well. Firing too much is the opposite dangerous extreme. Learn to use the trigger with decision. Don't miss many good shots waiting for a "sitter". Fire when your sights are "on". And DON'T forget to stop shooting when you are "off".

When you have finished a period observe how many rounds you have fired and get to know how to make limited ammunition do the most good. The knowledge may someday get you home. In the past trigger coordination has always been each pilot's own secret... and he has been stuck with it. In his single-seater fighter

no one but himself knew how, when, or where he fired. In the Gunairstructor your instructor can help you develop the right technique. Like most valuable things, it is not easy to acquire. Give it plenty of thought and practice.

Just as in the air, your target can be brought and held in the sights only by proper manipulation of your controls. Just as in the air, things can happen at a split-second pace. Fortunately they can also be made to occur in slow motion..even stop-motion.

Carrying your training ever closer to the air stage of gunnery operations, it is important to recognize the effect on your shooting ability of the noise in the Gunairstructor. While noise and airplanes have automatically gone together since the beginning of flying, you will now find it difficult to apply, under the simulated engine conditions, the simple principles which you have quietly been learning with cards, the Deflection Trainer and the Range Estimator. You will find much more concentration required, much more necessity to "Know your stuff".

It is common knowledge that there exists considerable "interference of the senses" and that sound is not the most neglible element. Interfering considerably with one's ability to concentrate, it demands that your knowledge of the subject be even more "instinctive" than would otherwise be necessary.

Thus, in the Gunairstructor you have the final stage of your WHO-WHERE-WHEN ground training. The only thing more like flying is flying itself. And the purpose of every one of your

Gunairstructor "flights" is to give you more WHO-WHERE-WHEN practice, to give it to you under conditions more and more simulating the real thing, more planes to recognize, more deflection shots, more changes of attitude, more trigger coordination, more control coordination, more use of the gunsight, less and less time to arrive at decisions, more and more ability to do it "instinctively".

Simple as the system is, the only way anyone can master it is by continual repetition, practice, repetition. Each stage of your training is designed to give you an increasing amount of active practice.

First comes the "fundamental" written stage to give you an understanding of the broad picture and the basic formula.

Secondly, you practice slowly, methodically, in two dimensions, with the Recognition, Range and Deflection Cards.

Thirdly, you start working in three dimensions, with an actual gunsight, on the Stationary Deflection Trainer.

Fourthly, you learn on the Range Estimator to pick your range....to hold fire until it counts.

Fifthly, you step into the Gunairstructor cockpit, take over controls, are required to fly as well as to shoot. You must translate gunnery problems into manipulations. You see things as they will actually look. You learn to make split-second correct decisions because you get so much practice that you can make them instinctively. WHO, WHERE, and WHEN come-alive.

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