Air To Air Gunnery - Theory and Application

Introduction

A2A gunnery is one of the most difficult of all fighter related flying skills, and one thing is for certain. Luck only goes so far! 'Spray and pray,' as some would have it, has a chance for success, but only a small one. The simple fact is that proficiency in A2A gunnery is founded on a bedrock of academic theory followed by the fine art of practice, practice, and more practice! While some folks have a better 'eye' for this than others, all of us can better our hit percentage if we understand what factors are in play as we close in on our target. So, without further ado, let's get right to those factors

Basic Theory

I know you all want to jump right into the part where we gun the bandit's brains out, but, sadly, we'll have to set that part aside for a time. The simple fact is that the more you understand gun employment theory, the better you are going to be at it. Sounds about right, you say. And it is…but this understanding comes at a price. And that price is your willingness to put a little study time into the various principles involved. My role in all of this is to take this academic mumbo-jumbo and make it as digestible as possible…and make it relevant to our sim at the same time.

We'll start off with some definitions. Most of these are terms that you may have run across at one time or another. The definitions that I'm going to use are intended to get the idea across without getting too deep into rocket science. Gun employment theory can get real complex, real fast…I don't want to do that, so I'll keep it as simple as I can.

Definitions

Machine Gun versus Cannon

As far as fighter aircraft go, these terms are roughly related to the caliber of the gun. Anything up to .50 caliber is a machine gun…anything over that is a cannon.

Caliber

The caliber of a gun is the size of the round as measured by its diameter. The units may be inches or millimeters. A .50 caliber is about one half inch in diameter. A 20mm is about one inch in diameter. A 37mm round is about one and one half inches in diameter. The following figures show the relative sizes

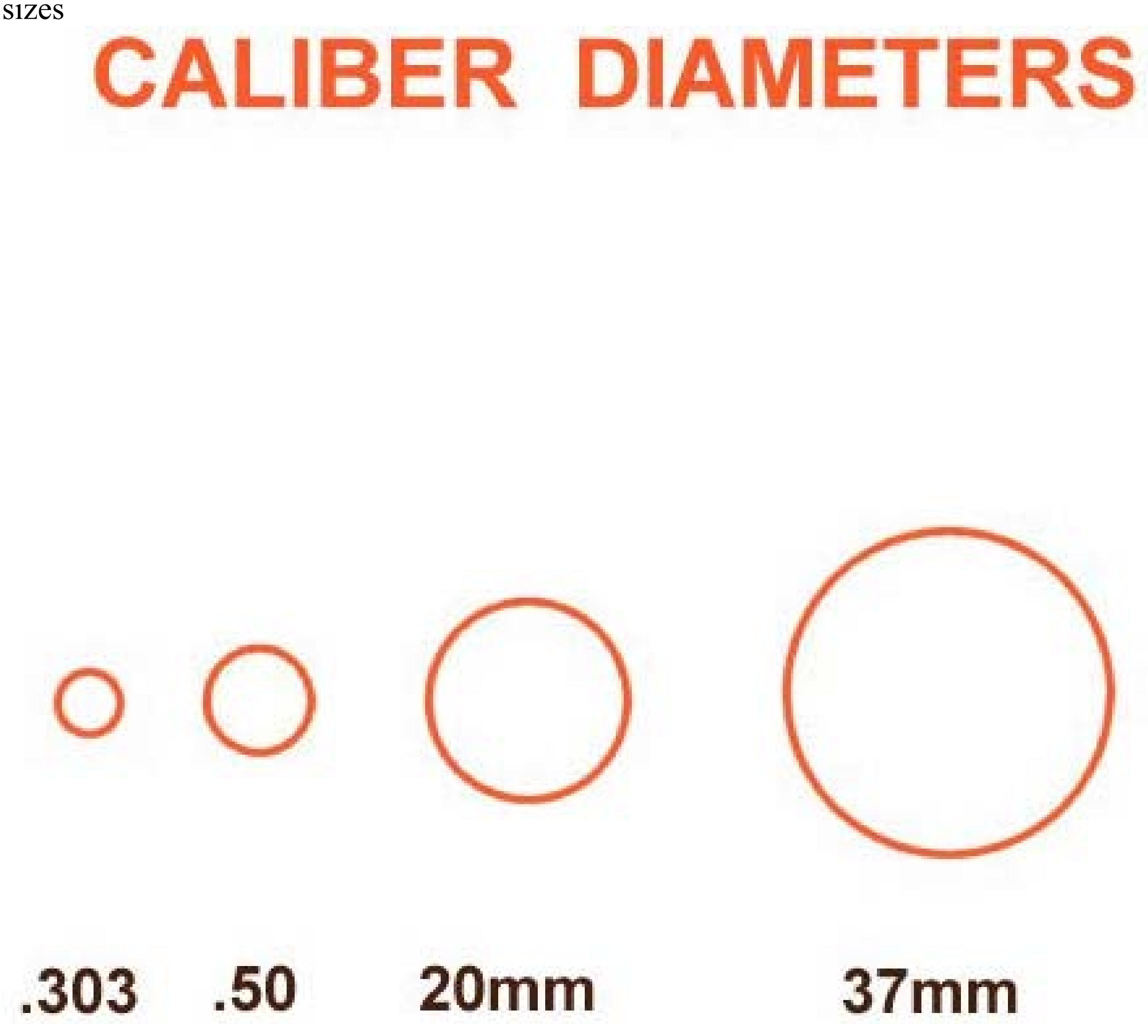

Figure 1 - Caliber Diameters

But diameter is only half the picture. As diameter increases, so does projectile length…and, consequently, projectile weight. The next figure makes this clear.

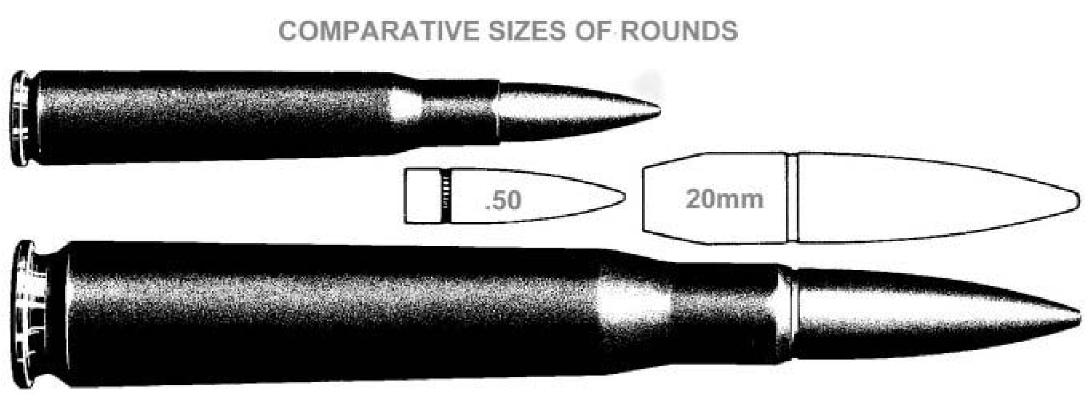

Figure 2 - Comparative Sizes of Rounds

Kill mechanism.

Projectile types include ball, armor piercing, incendiary, high explosive, and combinations of these.

Ball

A typical rifle round used in WW1 and early WW2.

Armor piercing

The round has a hardened steel core for penetration of aircraft structures.

Incendiary

The round contains a chemical that ignites upon impact. Good for setting fuel and hydraulics on fire.

High explosive

Similar to the incendiary round, except the chemical has more destructive power.

Combination

The above round types can be combined…HEI (high explosive, incendiary), API (armor piercing, incendiary) for extra hitting power.

Rate of fire

Also known as cyclic rate. This is the number of rounds fired in a given amount of time, usually rounds per minute (rpm).

Table 1 - American Aircraft Guns

Type	Operational Date	Bullet Weight (lbs)	Rate of Fire (rounds/min)	Weight of Fire (lbs/min)	Muzzle Velocity (ft/sec)	Lethality
Machine Guns						
.30-Cal M2	1929	.02	1,200	25	2,600	1.7
.50-Cal M2	1933	.10	800	81	2,810	6.4
Cannon						
20-mm M2	1941	.30	650	196	2,850	15.9
37-mm M4	1941	1.34	135	181	2,000	7.2
20-mm M3	1944	.30	800	241	2,750	18.2

Table 2 - German Aircraft Guns

Type	Operational Date	Bullet Weight (lbs)	Rate of Fire (rounds/min)	Weight of Fire (lbs/min)	Muzzle Velocity (ft/sec)	Lethality
Machine Guns						
MG 17	1934	.02	1,100	22	2,971	1.9
MG 81	1938	.02	1,500	30	2,396	1.7
MG 131	1938	.09	840	75.6	2,462	4.6
Cannon						
MG FF	1935	.29	520	150	2,265	7.7
MG 151/20	1937	.29	740	215	2,577	14.3
MK 103	1941	.83	420	348	2,824	27.8
MK 108	1942	.78	600	468	1,658	12.9

Table 3 - Great Britain Aircraft Guns

Type	Operational Date	Bullet Weight (lbs)	Rate of Fire (rounds/min)	Weight of Fire (lbs/min)	Muzzle Velocity (ft/sec)	Lethality
Machine Guns						
Browning .303		.02	1,140	23	2,742	1.7
Cannon						
Hispano Mk II		.33	650	198	2,889	16.5
Hispano MKV		.33	758	248	2,758	18.9

Table 4 - Russian Aircraft Guns

Type	Operational Date	Bullet Weight (lbs)	Rate of Fire (rounds/min)	Weight of Fire (lbs/min)	Muzzle Velocity (ft/sec)	Lethality
Machine Guns						
ShKAS		.02	1,800	36	2,709	2.6
UBK		.12	1,050	126	2,790	9.8
Cannon						
ShVAK		.24	800	192	2,462	11.6
NS-23		.50	550	275	2,265	14.1
VYa		.50	500	250	2,971	22.1

Muzzle velocity

The speed that the round leaves the barrel. Usually expressed in feet per second (fps) or meters per second (mps). After leaving the barrel, the projectile will decelerate as a function of its unique ballistic characteristics.

Time of flight (TOF)

The time it takes the round after leaving the barrel to reach the target. Usually measured in seconds.

Dispersion

A target shooter will fire his rifle a number of times to establish a 'group.' The smaller the group, the more accurate the shooter is. For aircraft, a technician will fire the gun at a target and then count the projectile impacts and measure their pattern from the center aim point. Typically, this calculation will be expressed as a percentage of rounds fired within a certain area, usually a circle with the aim point at its center, and is called the gun dispersion. A typical gun dispersion results in about 80% of the rounds being grouped in a five-foot diameter circle at a range of 1000 feet.

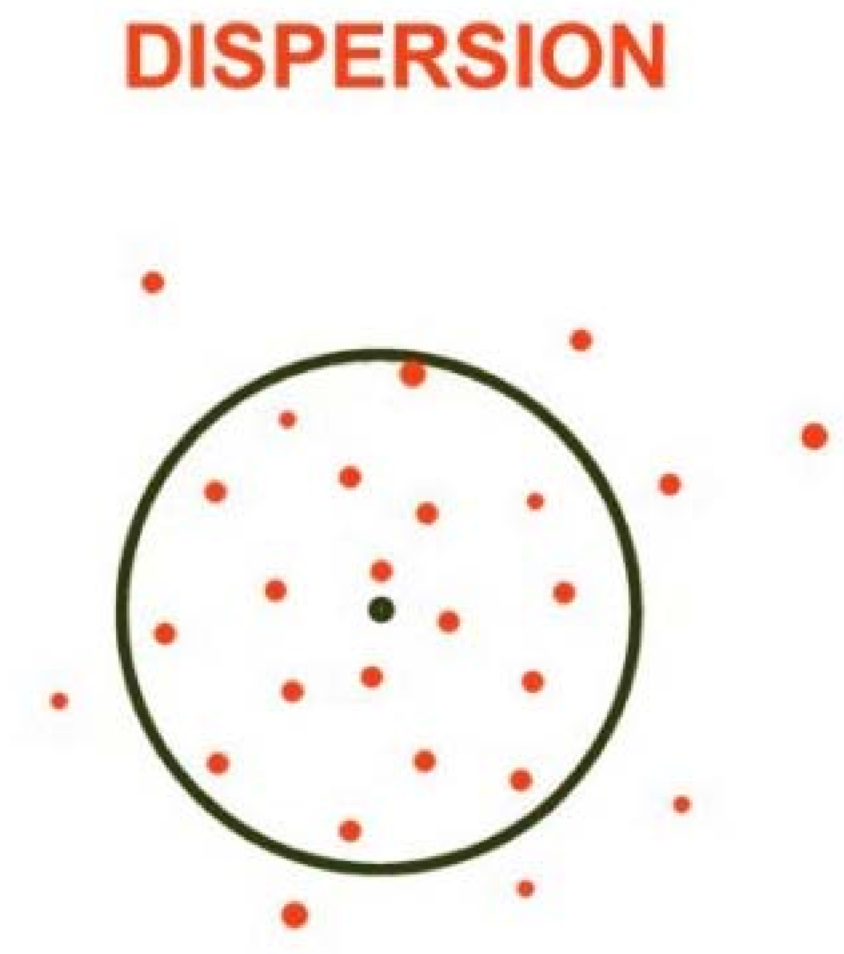

Figure 3 - Gun Dispersion

Weight of fire

A concept used to describe hitting power. Literally expressed as 'x' amount of weight in a given period of time. A good example is the Spitfire Mk I with its eight .303 caliber guns. Even though the guns have a small caliber, they have a relatively high rate of fire, and when all eight are fired in unison, the amount of lead being thrown is considerable.

Angle off

This refers to the relative headings of the fighter and its target. Angle off is simply the difference in the direction the two aircraft are pointing. If they are pointing in the same direction, the angle off is zero…if they are approaching head on, then the angle off is 180 degrees. Angle off is a measurement of heading.

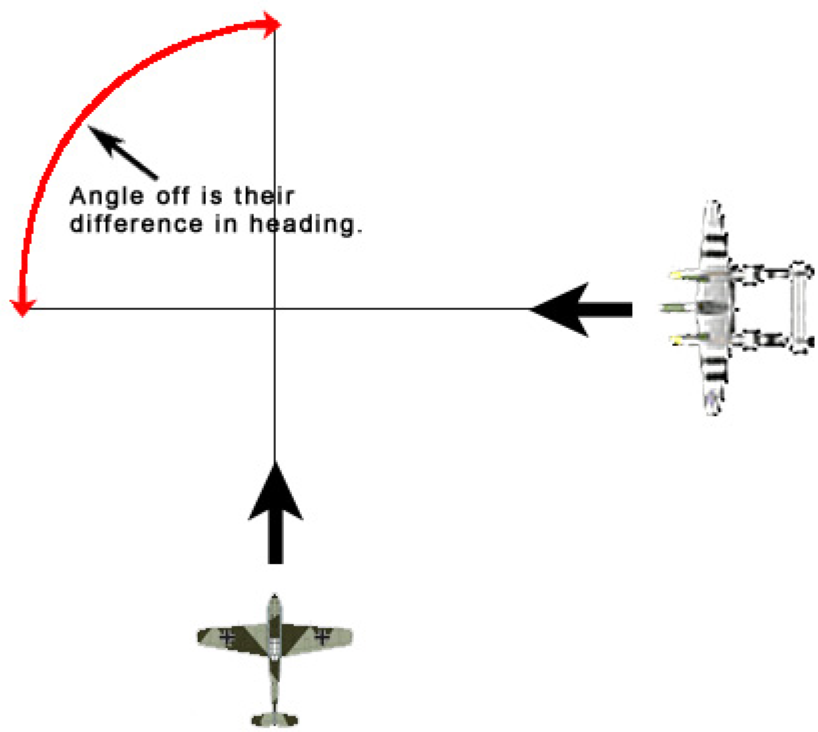

Figure 4 - Angle off

Aspect angle

This term is a measurement of position. The heading of the attacker relative to the target is irrelevant. Aspect angle refers to the attacker and is measured using the target as the reference. This measurement originates at the target's six o'clock. This is the zero aspect position. The twelve o'clock position off the target's nose is the 180-degree aspect position. From the six o'clock position to the twelve o'clock, aspect angles are referred to as either 'right' or 'left.' This is in reference to what side of the target you as the attacker are looking at. If you are looking at the target from its 3 o'clock position, you have a 90 Right aspect. And if you are looking at the target from its 7:30 position, you have a 45-Left aspect. Remember, your heading is not included in this term. Aspect angle is only a way of defining your position relative to the target.

Note: Aspect and angle off tend to be used in the same manner when we talk about gun attacks. This is a unique situation and occurs because we are usually thinking of the attacker being pointed at the target. When the attacker has his nose on the target, then his angle off and aspect are basically the same. In this discussion, I'll use the term 'angle off' with this in mind.

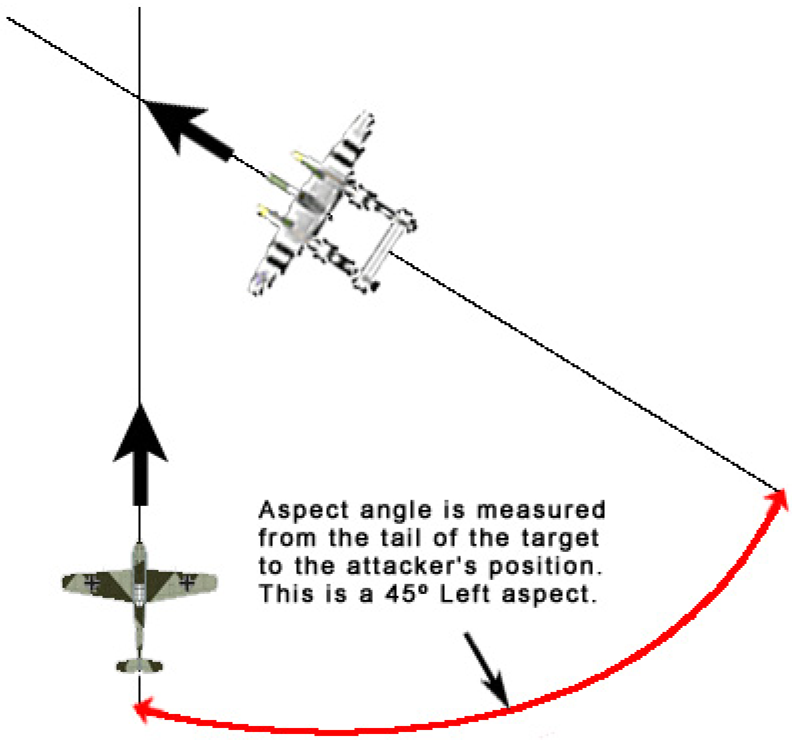

Figure 5 - Aspect angle

Target apparent size

We all recognize the significance of target size. Big targets are easier to hit than small ones!! Target apparent size refers to a single target and how it looks from various angles. If we shoot at a target from its dead six, we have a much smaller target size than if we were to fire at it from directly above. Planform is a term that refers to target apparent size. Planform is greatest when looking down on the target. The greater the planform, the better chance of hitting the target. Planform and aspect angle have much in common since they both refer to how the target appears from the shooter's perspective.

Line of sight rate (LOS)

The LOS is the speed that the target is crossing your gun line. This value is zero in a head on or tail aspect, and is maximum when the target is at 90 degrees angle off.

The Gun Line

If you were to look through the barrel of the gun out to infinity, you would be looking along the gun line. The gun line establishes the initial vector of the round as it leaves the barrel (also known as the line of departure, the LOD). The gun line is an important part of the process of matching up the gun sight to the gun in an aircraft. It is the basis upon which all other calculations are made. If an aircraft has multiple guns, it has multiple gun lines.

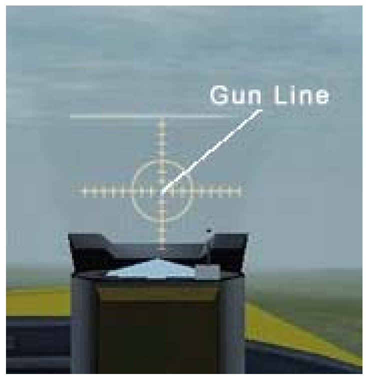

Figure 6 - Gun Line

In our aircraft the gun line can be represented by using the center of the Revi gun sight. This is 'fixed' position, meaning it doesn't move. You can think of it as being similar to the sight on the end of a rifle. It is one way of visualizing where the gun is aimed.

Gravity Drop

Once the round leaves the barrel, it becomes a falling object subject to the laws of gravity. A round will drop approximately 16 feet in its first second of flight.

Harmonization

In discussing harmonization, we will use the concepts of gun line, and gravity drop. Harmonization is the process of lining up the gun lines so that they intersect at some point in front of the aircraft. The TOF for the rounds to cover that distance will be computed and used to calculate a gravity drop value. That value will be added to the gun line. Then the gun(s) will be adjusted so that the resulting projectile path (including gravity drop) will intersect at the same point.

In fighters that have guns installed in the wings and nose, harmonization is much more of a factor to be considered. The basic idea is to adjust the guns so that all the gun lines converge at a predetermined distance. Why, you ask? Some might think it would be better to have the guns adjusted to spread out the gun lines...that way the pilot might have a better chance of hitting something. Now, there is a smidgen of logic to that idea, but only a smidgen. The better idea is to have the gun lines come together. That way the pilot has a highly concentrated area of fire that will deliver a killing blow to whatever it hits. Certainly, that area may be relatively small, but the issue is not the size of the projectile impact area. Instead, the issue is accuracy in aiming. We'll get to that eventually. For now, we just want to establish the idea that harmonization is the process of converging gun lines so that they intersect the sight line at a predetermined distance.

During WW2, harmonization was a hot topic among pilots. The debate raged back and forth over what range the guns should be harmonized at. Some liked a short range…short being in around 300 feet. Others wanted the range a bit further out…as much as 1000 feet. In many fighter units, the matter was left up to individual preference.

Figure 7 - Harmonization

Projectile Density

In simple terms, projectile density refers to how many bullets we can expect to have in a given amount of space at a particular point in front of our aircraft. We all immediately recognize that the denser the bullet pattern, the greater chance we have of hitting our target.

We have all seen the WW1 movies of the Red Baron blasting away at his opponent. Rat-tat-tat-tat! One, maybe two small caliber machine guns. A moderate rate of fire for the time. But nothing like the guns in a WWII fighter.

Let's try to interject a reality check to the matter of projectile density. What you want to take away from this part of the discussion is the understanding of how angle off and aspect angle affect your chances of hitting your target.

Let's fire a one second burst from our MG 17, 18 rounds. Now let's picture what the bullet stream looks like. For starters, it's 2,971 feet long…remember muzzle velocity. As the last round is coming out of the barrel, the first round is one half mile away! Spread those rounds out over that distance, and we end up with one round every 165 feet. Then we have to remember dispersion. The bullet stream is not a 'frozen rope.' Instead, it is a cone that is about 15-20 feet in diameter at 3000'.

One round every 165 feet! Not exactly the blizzard of fire that some might think. And then those rounds get spread around due to dispersion. That doesn't help things much. But there is one more parameter that we need to look at, and that is the relationship of the target's flight path to our bullet stream.

If we are at the target's dead six and are shooting at it, then many of the rounds have a chance of getting a hit. This is because the target remains in the general area of the bullet stream during the entire burst length. But what happens if the target is crossing the bullet stream? Whoa!! Our neat little picture of instant target obliteration takes a big hit (no pun intended!). Let's use a little math again to make the point. Let's have the target cross the bullet stream at 90 degrees. We'll say the target is doing 500 knots…that will give it a speed of about 850 feet per second. The target is a typical has a length of about 60 feet. How long does it take the target to cross the bullet stream? About one tenth of a second! We remember our rate of fire was 1,100rpm or about 18 rounds per second…so, in 1/10 of a second, only about 2 rounds have a chance of hitting the target. Now, we throw dispersion into the equation and our chances of hitting the target become even less.

It is very important to visualize the bullet stream as three-dimensional. In seeing the bullet stream in this manner, significance of target angle off and apparent size becomes all too clear. The faster the target moves through the bullet stream, the less chance it has to be hit. If we as the shooter can do something to keep the target in the bullet stream longer, then we increase our chances of success. This is an aiming problem, and we'll call that problem 'the lead angle solution.'

<u>The Lead Angle Problem</u>

Now that you have a good understanding of the definitions we will be using we will start to a look at some of the problems we face when trying to shot down an enemy plane, starting with the Lead Angle Problem.

There are two variables to solve for when we look at the lead angle problem. First, let's identify the problem. We are in a gun platform that is moving. We are trying to hit a target that is also moving. We intend to shoot rounds at the target…this will take a certain amount of time (TOF) and this in turn will result in some gravity drop.

The problem then is to fire our gun having taken into consideration two things…lead for target motion, and gravity drop. The next figure is a common illustration of the lead angle problem found in many sim manuals. Both the attacker and target are flying straight. The situation is similar to a skeet shooting problem. We'll use this figure to discuss the problems in computing lead for target motion and gravity drop.

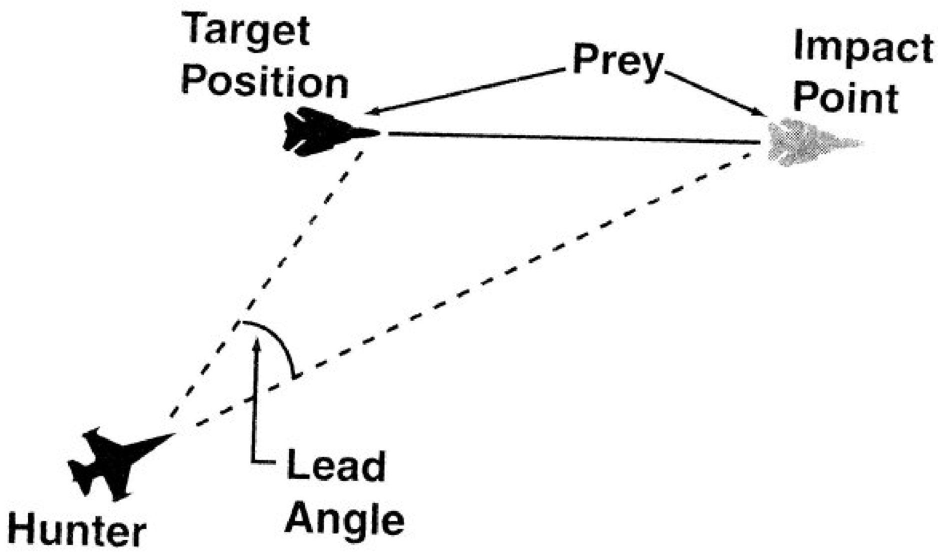

Figure 8 - Lead Angle

Computing the lead angle

In a gun attack, the firing geometry can range from a pure tail chase to a head on set up. Clearly, the lead for target motion is greatest when the target angle off is 90 degrees and is essentially zero when the angle off is zero or 180 degrees.

Computing gravity drop

We have already shown that the gravity drop value is a function of TOF. Many of the assumptions mentioned above also have a negative impact on the gravity drop calculation. Incorrect closure, range, and altitude values all result in errors…while the gravity drop part of the total lead angle is usually much smaller than the lead angle part, the value is still significant to the overall gunnery solution.

Gunsight types

Before we move on lets take a look at some types of gunsights… At this time, I must emphasize one thing to the max!!

The air to air gunnery problem is always the same. The only thing that changes is the way we look at it through our HUD. All gun sights try to do one thing…show the pilot where he should aim. While gun sights may look different and may operate with different inputs and assumptions, the bottom line is that they are

designed to allow the pilot to point his gun line in the correct direction. For a given situation, there is only <u>one</u> aiming solution.

With that firmly in mind, we'll move on to the various gun sight types. In each category, we'll look at two issues…basic operating principle and system implementation. We'll start with the fixed sight.

The Fixed Sight

The first question that comes to some folk's minds is what does the word 'fixed' mean. Simply put, it refers to a sighting reference that does not move. There are several types. Up to the beginning of WW2, the most common was the 'ring and bead' sight. Note the ring and bead sight mounted on this MG 17.

Figure 9 - MG 17 Ring and Bead sight

Basic operating principle

This type of sight was used in the same way a shooter aims a rifle. A rifle has two sights…a rear notched sight and a front blade sight. The idea is to aim the rifle with the top of the blade aligned in the notch. This aligns the shooter's eye to the barrel gun line. The shooter then takes that 'sight picture' and aims it at the target. The next drawing shows a typical rifle sight-aiming picture.

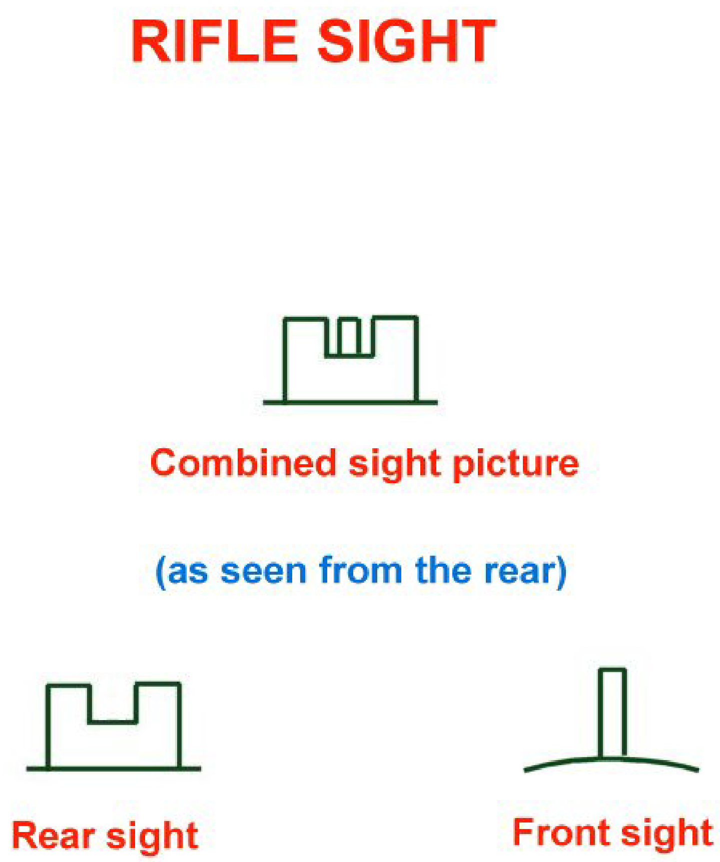

Figure 10 - Rifle Sight

The ring and bead sight works the same way. The ring represents the rear rifle sight, and the bead represents the front blade sight. When the pilot aligns the center of the ring with the bead, he is looking down the sight line. Let’s recall our discussion of harmonization. The gun line is adjusted to cross the sight line at some predetermined point in front of the aircraft. The operating principle then is simple…line up the target using the ring and bead and shoot, as the following picture demonstrates.

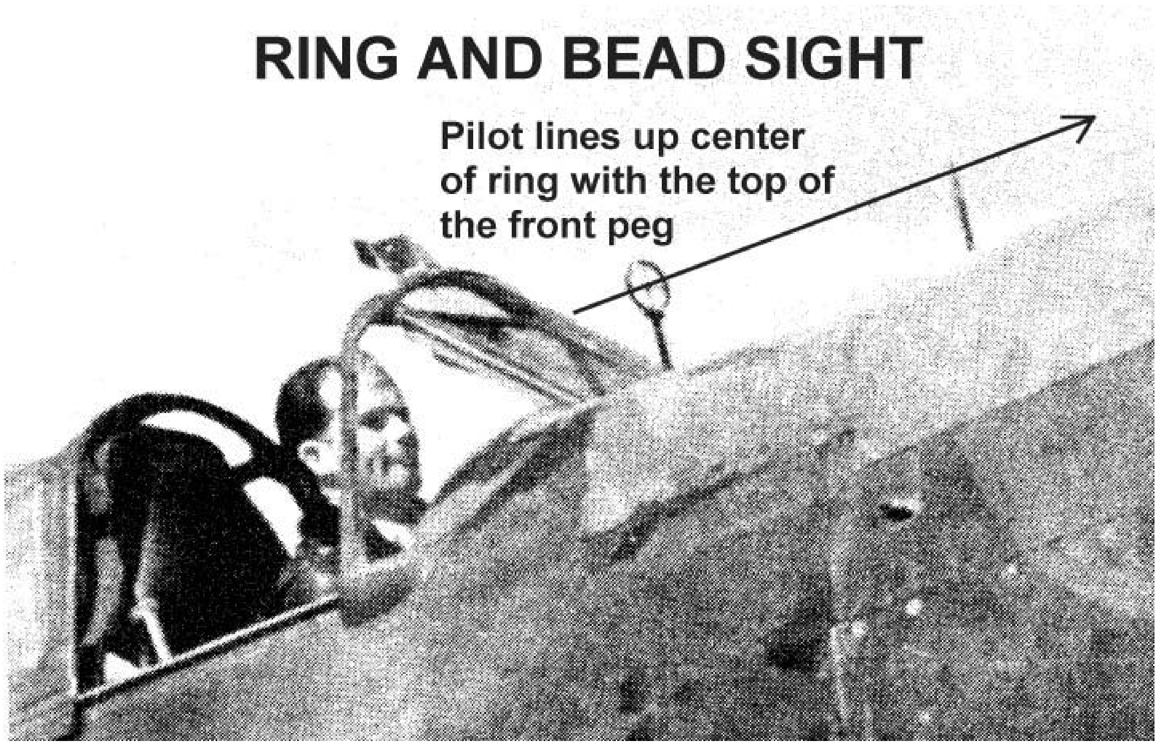

Figure 11- P40 Ring and Bead Sight

What could be more basic? As long as the pilot was still sitting on the ground and was shooting at something else on the ground, then this gun sight was pretty easy to use!! Put the airplane in the air and shooting at any kind of target…now that was something else entirely!

The 'ring' part of the sight often had one or two circles. The diameter of these circles could be used to estimate target range. This is done by using a technique known as 'stadiametric ranging.' This concept is a central part of many past and current gun sight designs. In the discussions to come, we will look at reticules and the principle in their operation, so a clear understanding of this is a good thing to have!

Stadiametric ranging

Stadiametric ranging uses the relationship of small angles and the arcs they subtend over a given distance. Whew!! I hope you are still with me!! Here is the basic idea.

We all are familiar with how we use clock code to define a position around our aircraft. Each one-hour of the clock represents an angle of 30 degrees. We can use angles to estimate range, as well as position. We begin by focusing on a very small angle…one degree. The next figure will show how this small angle can be used to compute range. The point of origin for this angle will be our gun sight, and the lines of the angle will be projected along the sight line. Sometimes a picture is easier to understand.

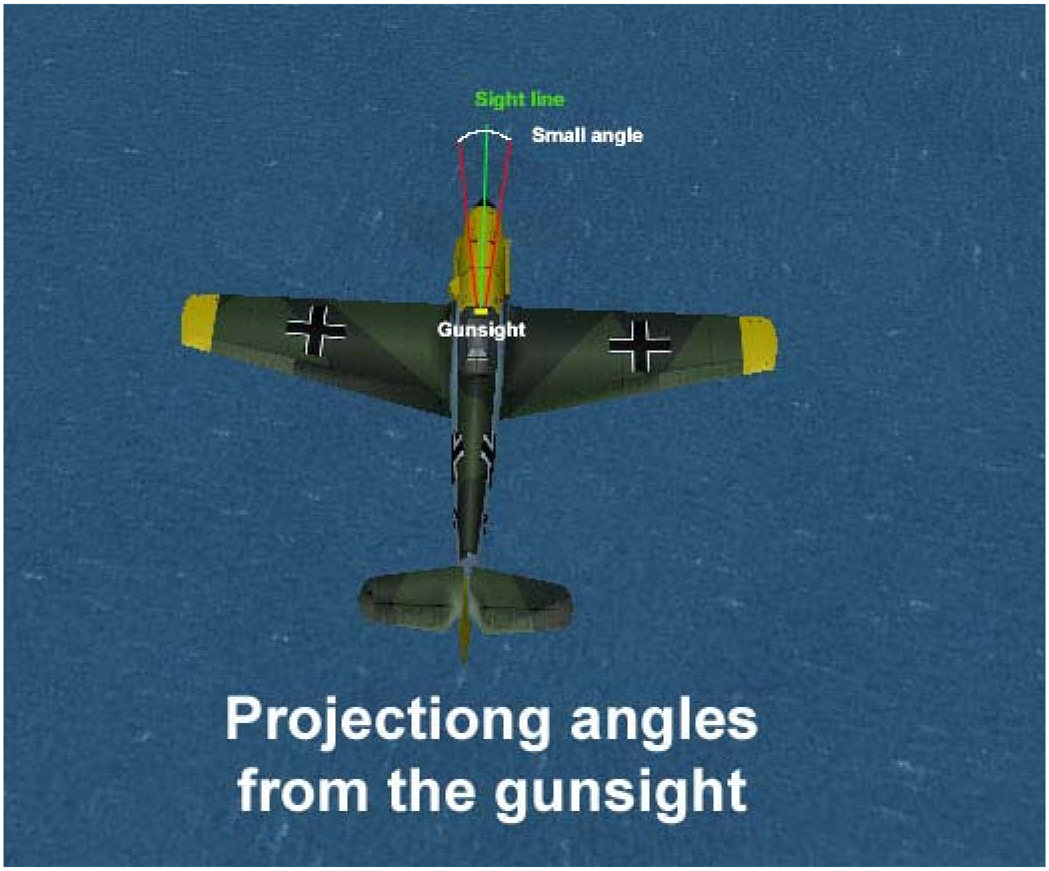

Figure 12 - Projecting Angles From The Gunsight

Now, we go to the math part. The distance between the two lines of the angle is known as the arc that the angle subtends. Fighter pilot instructors will say it this way; "The angle ‘x’ subtends an arc of ‘y’ feet at a distance of ‘z’ feet." Notice the unit of measurement for distance is feet. The unit of measurement for angles is NOT degrees…it is a value known as a ‘mil.’ There are about 17 mils in one degree…so a mil is just a very small angle. This is the definition of a mil:

A mil is an angle that subtends one foot at 1000 feet range. The arc size versus range relationship is linear, therefore, one mil = one foot at 1000 feet, two feet at 2000 feet range, and so on. Similarly, if one mil = one foot at 1000 feet, then 10 mils equals 10 feet at 1000 feet range, 20 feet at 2000 feet range and so on.

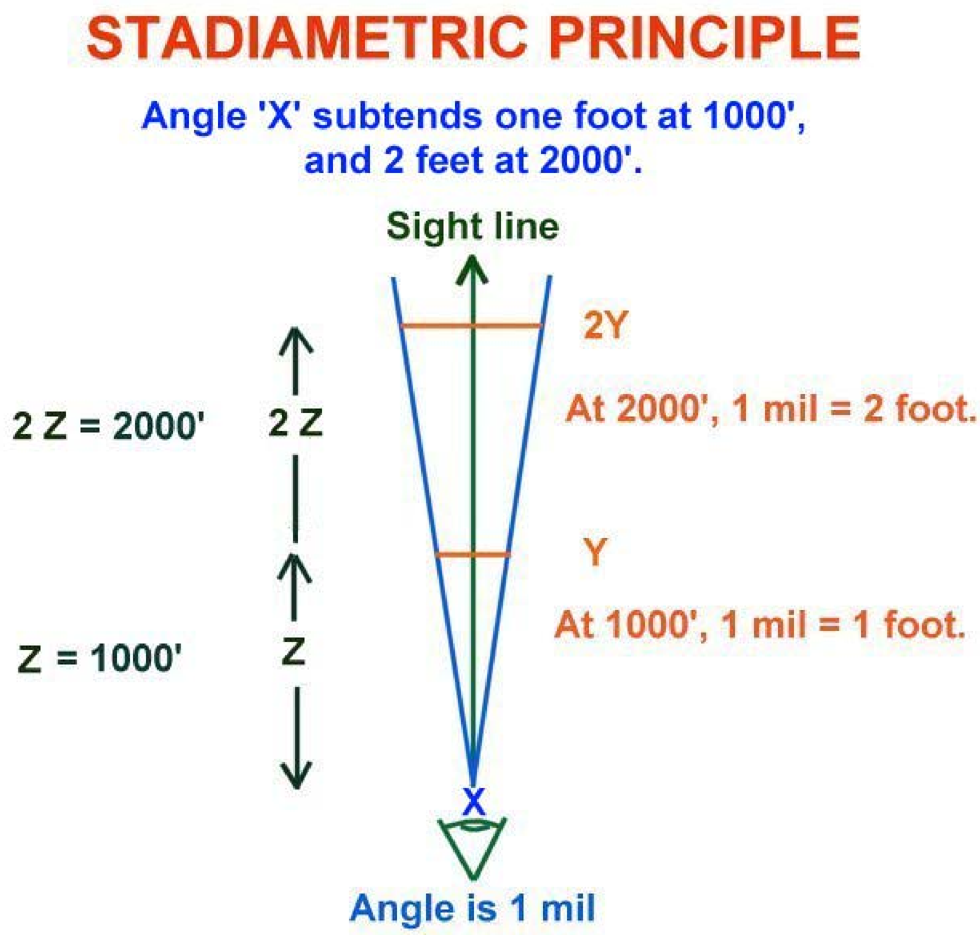

Figure 13 - Stadiametric Principle

Let's show a practical example of this concept. Go out to your car and then pace off exactly 50 feet and mark that spot. Now, get a piece of glass and look through it at your car. Draw a line on the glass equal to how long your car appears. Next, draw a circle on that piece of glass with a diameter equal to that line. You now have a tool to find out how far 50 feet is using your car as a reference. Just walk towards your car looking through the glass. When the car length matches the diameter of the circle, you are at 50 feet!!

Now we take this idea and apply it to a gun sight. Let's draw a circle on a piece of glass and say its diameter is a certain number of mils wide. If we were to hold that circle up in front of our eye and look through it, then the circle could be used to show what a certain distance looks like at a given range. For example, if we said that the circle had a diameter of 50 mils, then the circle would span a distance of 50 feet at 1000 feet range.

You know where I'm going with this…right?!! Now, we'll think of that circle as our gun sight reticule. We know the mil value of the gun sight reticule…50 mils in this example. The two remaining variables are range and arc distance. Let's change the name 'arc distance' to 'wingspan.. We now have a simple mathematical situation where we can solve the problem of determining target range. Here's how. Pick a target…say a Spitfire MK I. Its wingspan is a known value…approximately 50 feet.

Let's put ourselves at the Spits six and compare its wingspan to our 50 mil reticle. Picture in your mind the wingtips just touching the edges of the reticle. The range computation is "The 50 foot wingspan is 50 mils in size…therefore the range is 1000 feet." Now, let's pull the power back and increase our distance behind the Spit. When we look at the Spit in the reticle now, its wingspan looks to be about one fourth of the reticle diameter, or about 12 mils. What is the new range? Divide the observed wingspan size in mils into the known wingspan size in feet…forget about the decimal points!! 12 into 50 equals about 4…so the range is about 4000 feet. The next figure explains the process.

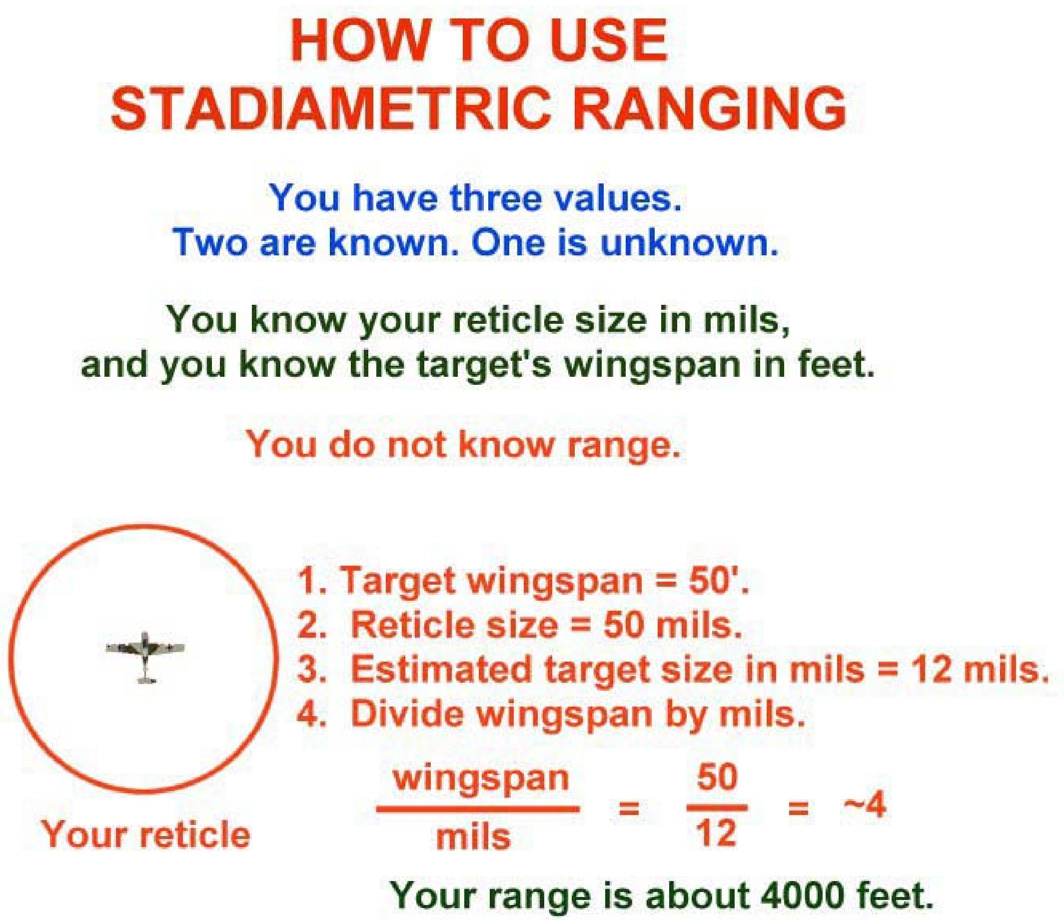

Figure 14 - How to use Standiametric Ranging

Some might ask why am I going through all this hoopla. The answer is simple. Effective use of the gun requires a pilot to estimate range quickly and correctly. Gun sight reticle displays are made to be a certain size to help the pilot accomplish this.

OK!! Enough of that stadiametric stuff. Let's get back to our review of fixed sights.

One problem that pilots had with using the ring and bead sight was that the pilot's head had to be held perfectly still when lining up the ring and bead. This was hard to do while maneuvering. A solution to this problem was the telescopic sight. This sight was essentially a tube with the ring on one end and the bead on the other. By leaning forward and looking through the tube, the pilot was lining up the ring and bead with his head in the proper position.

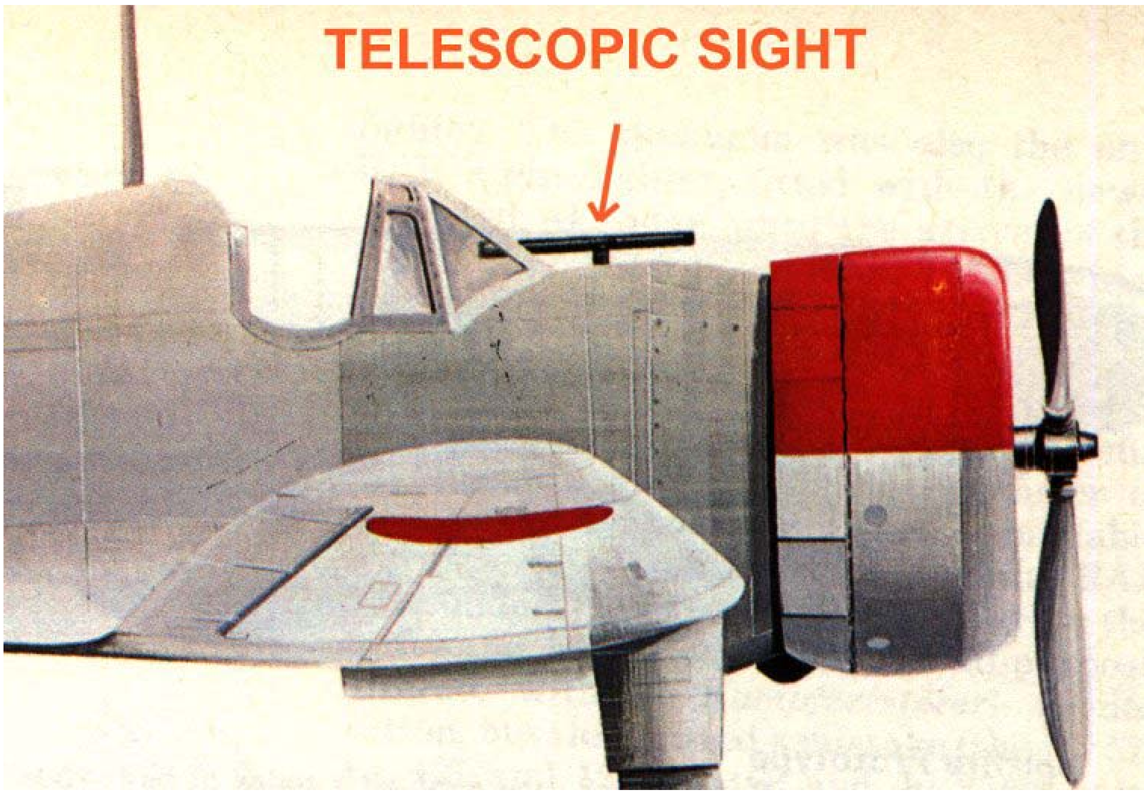

Figure 15 - Telescopic Sight

The technique in using the telescopic sight was identical to the ring and bead sight. The pilot had to maneuver behind his target. Then looking through the telescope to see the ring image, he would make the final pitch and roll corrections to superimpose the ring over the target (this must have been a lot of fun in a hard maneuvering fight…I don't know how those guys did it!!). But technology marches on, and by the time WW2 had begun, the ring and bead sight was being replaced with the 'reflector sight'. The next picture shows a Revi reflector sight.

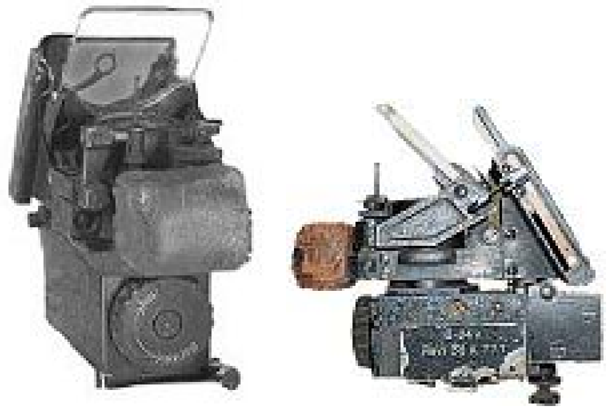

Figure 16 - Reflector Sight

The reflector sight was just a ‘high tech’ ring and bead sight. The reflected image was focused at infinity, and represented the gun line. The main advantage of the reflector sight was that it was always ‘in alignment.’ This allowed a small freedom of movement of the pilot’s head, whereas when using the ring and bead sight, the pilot had to hold his head perfectly still when aligning the sight with the target.

The reflector sight got its name from the fact that the gun sight image was reflected off a pane of glass towards the pilot’s eyes. This pane of glass was called the ‘combining glass’ because it ‘combined’ a light image formed by a gizmo under the front glare shield. The combining glass looks like a small HUD. The only difference between a combining glass and a HUD is that the HUD contains more info than just a gun sight reticle.

That covers the operating principles of the various types of fixed sights. Next, a few words about how the fixed sight was meant to be used.

Fixed Sight Implementation

From WW1 onwards, everyone agreed that there were two types of air-to-air gunnery attacks…low angle off and high angle off. The low angle off attack was by far the easiest for the average pilot to learn. This type of attack had the highest probability of success in that it maximized the desired aspects of fixed sight gunnery. Those desired aspects were minimum required lead angle and maximum exposure of the target to the line of fire.

This preference for a low angle off attack had a direct impact on fighter tactics. The concept of Basic Fighter Maneuvers (BFM) was developed, and the primary purpose of offensive BFM was to maneuver to the target’s six o’clock…or prevent the bandit from getting in your six o’clock in the case of defensive BFM. If you have ever wondered why traditional BFM references all seem to be oriented to maneuvering behind the target, this desire for a low angle off gun attack is the reason why.

The next point in general agreement was that the fixed sight became increasingly less useful as range increased regardless of the angle off. The solution was to emphasize short firing ranges. The gun sights were designed to allow the pilot to estimate range using the size of the gun sight reticle (stadiametric ranging), and the guns were installed in the aircraft to focus their lines of fire in a concentrated manner at a desired short range (harmonization).

The result was that the desired attack was a low angle off, one G firing situation. This worked very well against a target that didn't see you coming, and, historically, most kills were of this type. But, once the target started maneuvering, then all bets were off. The next figure shows a H75 at relatively high angle off. This situation will require a fair amount of lead…called 'deflection shooting' during WW2. It took a skilled pilot to use a fixed sight effectively in gun attacks of this type.

Figure 17 - High angle off

Putting rounds on target

Plane of Symmetry

The plane of symmetry is another one of those terms that we use when we try to explain what we're looking at when we use a gunsight. 99% of understanding and using a gunsight is in the understanding of what the gunsight display means with reference to the bullet stream. We have to establish a common frame of reference to do this. The plane of symmetry is a good place to start. The plane of symmetry is the vertical plane extending along the longitudinal axis and perpendicular to the rudder. It looks like this.

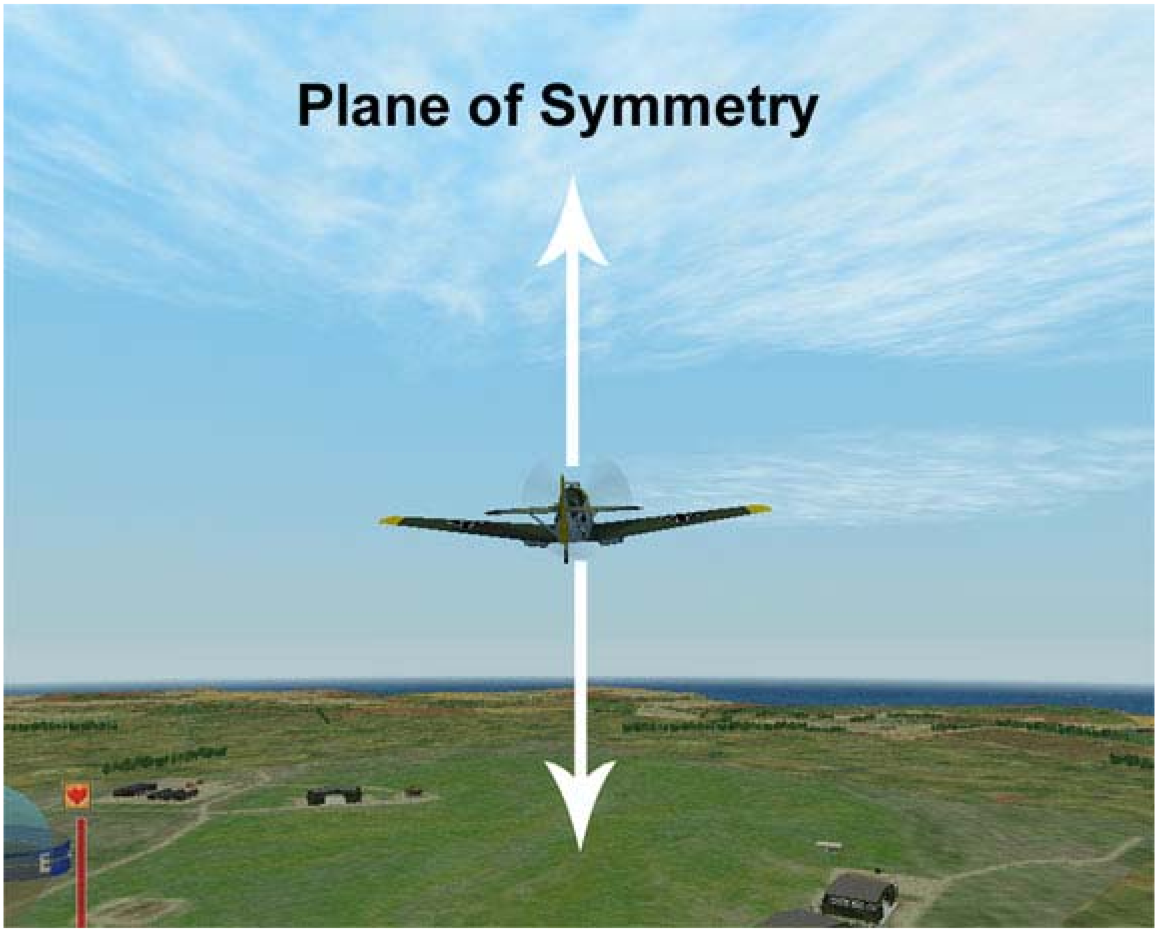

Figure 19 – Plane of Symmetry

A common way of visualizing the plane of symmetry is to use a line coming out of the top of our canopy that is perpendicular to the wings and fuselage. You can also think of the plane of symmetry as your lift line. Some like to use the vertical stabilizer to represent the lift line…that's OK as long as the thing is vertical, and not canted off to one side or the other. The significance of this concept to gun employment is that the gun line lies in this plane, and that the bullet stream begins in this plane.

<u>Plane of Motion</u>

The plane of motion is the direction our aircraft is going. You may ask if the plane of motion and the plane of symmetry are the same. The answer can be yes…or no. The issue is gravity. Anytime that gravity is exactly in alignment with the plane of symmetry (wings level, inverted or upright), the two planes are the same. But add a little bank, and gravity now becomes a force that takes the plane of motion away from the plane of symmetry. Why? Because our aircraft is affected by gravity, and the gravity force (or vector) has to be added to our lift line to get our actual plane of motion. It looks like this.

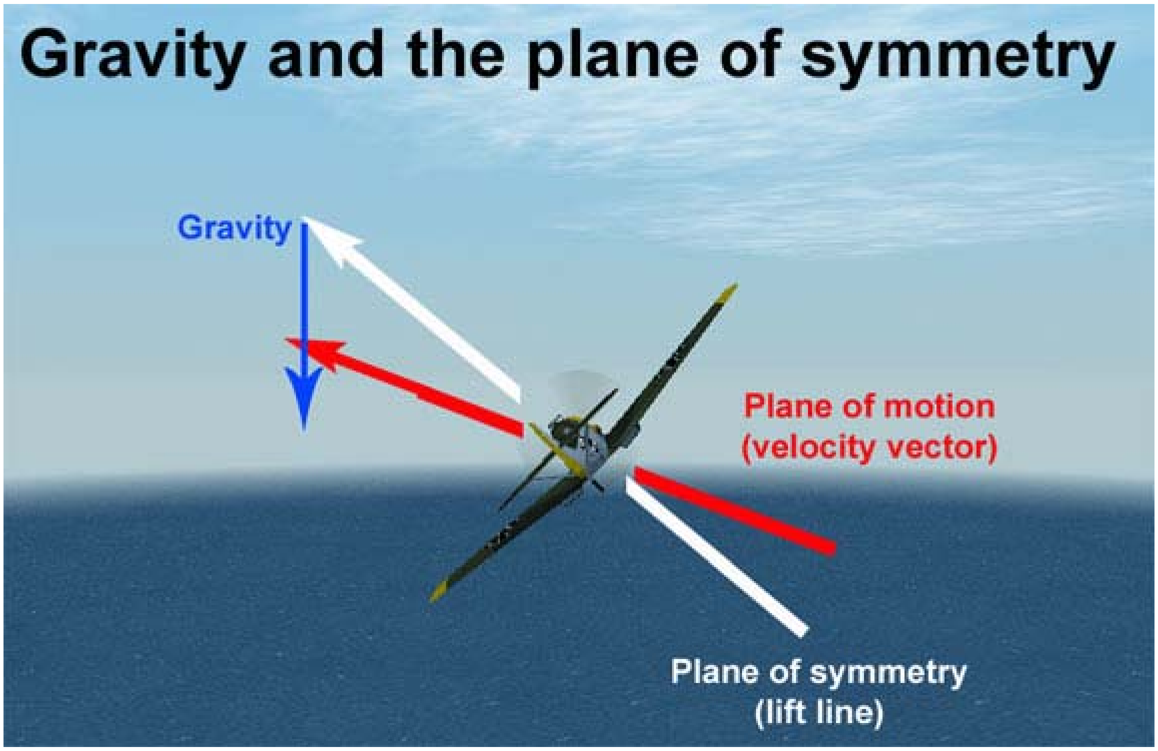

Figure 20 – Gravity and the plane of symmetry

Let's shift our attention to the gun line. As we turn our aircraft, our gun line follows our nose across the sky. If our gun line was a pen, it would draw a line that would represent our actual plane of motion. As seen through the HUD, it would look like this.

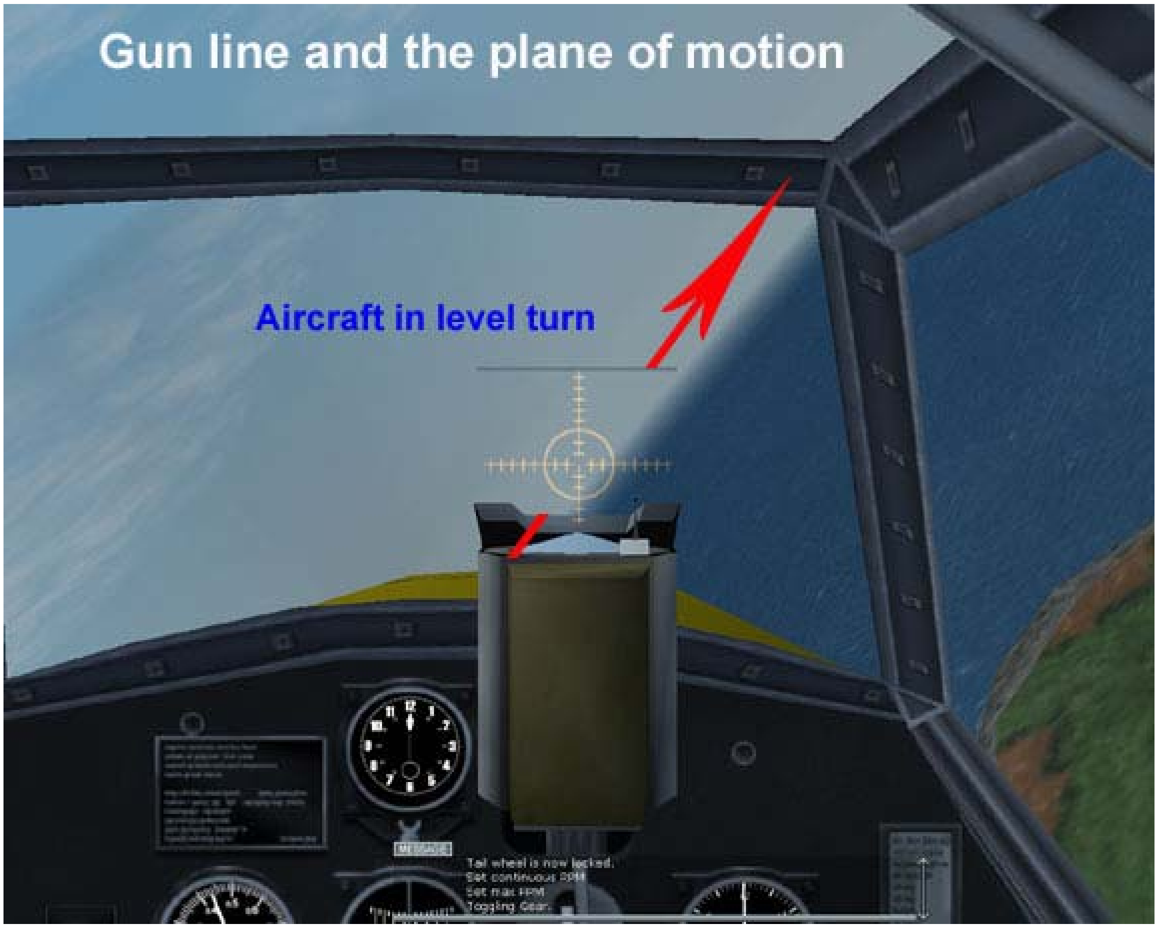

Figure 21 – Gun line and plane of motion

Now let's bring gravity drop back into the discussion…this time we'll apply it to the bullet stream. Gravity starts acting upon the round as soon as it comes out of the barrel…the further the round flies, the further it drops. Looking at Figure 4 again, I'll add a nominal gravity drop value to the end of the bullet stream. By connecting the two lines, we get a simplified representation of the bullet stream.

Figure 22 – Simplified bullet stream

This is what it would look like from the cockpit. But this is a two dimensional view of the situation. To get a three dimensional view, we need to take a 'God's eye' view from above. The next figure is a very exaggerated view of the situation. For the sake of illustration, we'll say our gun fires five rounds as we turn. We open fire at position A and cease fire at position B. The five lines represent the paths of rounds 1 through 5. Please note the lines are straight. Rounds fired in a turn DO NOT curve or bend because we are in a turn. They fly straight and true as this figure shows.

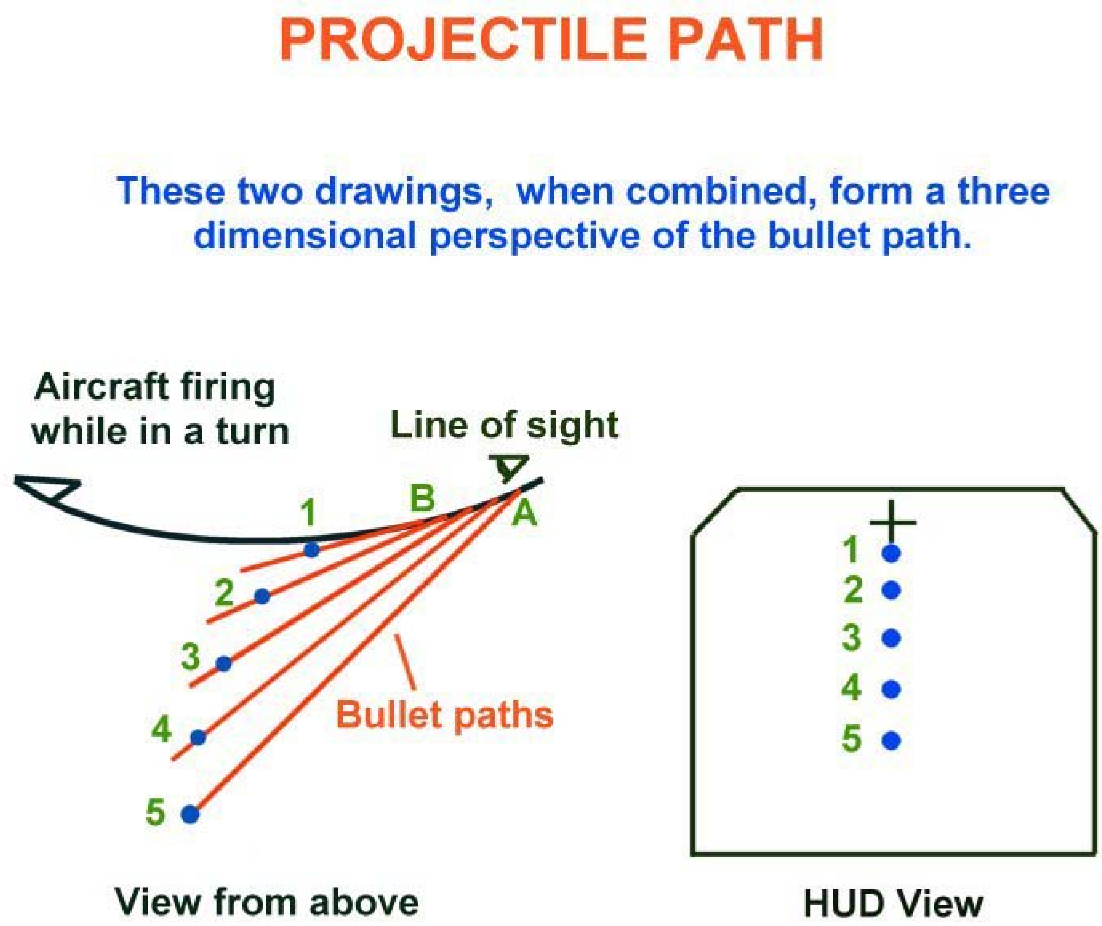

Figure 23– Projectile path

But gravity does alter their flight path. That is why the HUD view shows a slight 'drop' if we could visually see the bullet stream. And we can. Our sims always show the bullet stream as a tracer path…by firing a long burst in a hard turn, you can easily see the effect of gravity on the bullet stream. Just keep in mind that the HUD view can be misleading since it is a two-dimensional picture. Take Figure 6 and file it away for safekeeping. You'll need it as we get into the next section.

As a final comment, please recognize that the 'spread out' nature of the bullet stream is caused by the shooter's turn rate, i.e. G load. As turn rate increases, the bullet stream 'thins out.'

Why do I need to know this?

First, we talked about the plane of symmetry…then we went on to mention the plane of motion…and we finished up with words about the bullet stream. What's the big deal? Here is the very simple answer. You can fire at a target and know that you have a good probability that many of your rounds will hit the target…or you can fire knowing that only a small number of rounds have a probability of doing so. To get yourself into the first group, you need to maneuver to get your bullet stream plane of motion into the target's plane of motion. We call this a 'tracking' shot.

Figure 24– Aligning the Bullet Stream with the Target's Plane of Motion

If you are in the second group, and your bullet stream plane of motion intersects but does not lay in the plane of motion of the target (and sometimes, this is the only shot that you get), then your probability of getting a hit is much less. This is called a 'snap' shot.

Figure 25– Bullet stream vs. Target flight path

The Big Three

The two main components of a successful gun attack are getting in range and flying in the plane of motion of the target. We'll keep these in mind as we talk about how to us the sights. The questions you want answers to are:

- How do I know when I am in range?
- How do I know when I am in plane?
- When do I open fire?

Tracking Shot

Determining Target Range

We've hit the concept of stadiametric ranging pretty hard so far. This will be your method of determining range, but there is one little problem. We do not know what our reticle or ring diameter is in mils, and if we do not know this, then computing target range is going to be inexact at best. As a substitute, try this. For a fighter sized target, do not open fire until the targets wingspan at least the size of the reticle diameter.

There are two main problems to solve in this type of gun attack…getting into the target's plane of motion and predicting the correct lead angle (the open fire point).

Determining Target Plane Of Motion

We do this by first considering the amount of G that we are going to use to track the target…low G or high G. In either case, there are target, HUD, and gunsight cues to help you.

Look first at the target. Imagine a line extending from the target's tail, through his nose, and out to the front. Think of this line as the target's flight path…his plane of motion. You want to get your bullet stream on this line. Now visualize a line extending through the target's wing. Call this the target's wingline. We'll use this line to represent target bank angle.

Pulling your pipper out in front of the target is not all that hard. Keeping it there is another matter. Here are the cockpit cues to make this a little easier. The key to success lies in your ability to match the target's angle of bank. We do that by aligning our wingline with the target wingline.

For low G situations, use your tab at the 3 and 9 o'clock position on the sight reticle. You can also use the top of the HUD to approximate your wingline. You want to align these references with the target's wingline.

For high G situations, use the 6/12 o'clock tabs or use the top of the HUD making sure it is perpendicular to the target's fuselage line. You can also use the sides of the HUD to line up with the target's fuselage.

Determining The Open Fire Point

The major difficulty in tracking with a fixed sight is getting the lead for target motion right. Since the primary variables of range, closure, and angle off are infinite in number, all we can do is employ an educated guess. By this time it is clear that the amount of required lead is reduced if we can minimize range and angle off. We should try to do that.

Next place the gun line in front of the target and varying your G to allow the target to move towards the approximate lead point. One technique is to start out with a little more lead than necessary…then relax G slightly to move the target 'forward' towards the gun line. As the target nears your lead point, squeeze and hold the trigger down. Maintain your attitude steady and allow the target to continue to move forward slightly. By letting your aim point drift to the target, you are allowing for small errors in your lead estimation.

Don't worry if you don't get this the first time you try because it is something that only come with practice.

Snap Shot

A 'snap shot' is when the shooter fires without attempting to track the target. It is similar to skeet shooting in that the shooter fires a burst across the target's flight path. This results in fewer rounds having a chance to hit the target. Because of this, the snap shot has a lower probability of getting a kill than does a tracking shot. But a snap shot is better than no shot at all…and in an intense, swirling knife fight, it may be the only shot you get.

Determining Target Range

The dynamic nature of the snap shot situation means that the target will not be in the HUD area prior to your pulling the trigger. Consequently, you will not be able to use the reticle to range with. Instead, you will have to estimate target relative size, always keeping in mind that the objective is to take a close range shot.

Determining Target Plane Of Motion

There is absolutely no requirement for you to be wings level relative to the target's flight path.

Determining The Open Fire Point

While no two situations are the same, practice and experimentation will lead you to good results.

CONCLUSION

This has been long and involved, but I hope you understand gunsights better now than you did before. Nothing has changed since the Red Baron took to the air. Get in close, steady your aim, and fire a good burst.