Theory of Ballistics to Study the Mystery of Ultra-Long Range Precision Shooting

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Summary

(a) In the modern definition of shooting distance, a distance of more than 1,000 meters can be regarded as ultra-telephoto range, which is a very long distance for most of the 7.62-meter range.

In the case of ammunition with a caliber of over 1,000 meters, the ballistic trajectory of a bullet flying over 1,000 meters has already been affected by various controllable or uncontrollable internal and external factors to such an extent that it is not like the case of mid-range of 300-600 meters, where the shooter can still hit the target by sheer luck and intentionally omitting the correction of the ballistic trajectory. Therefore, whether or not the shooter takes the above factors into consideration or tries to minimize their effects is the key to whether or not the first shot can be hit or whether or not a reasonable hit rate can be achieved at long range.

Secondly, the snipers of the National Army have been relying on the original fixed shooting table (or the pre-set range marking on the adjusting screw) and a large number of experience parameters accumulated through live firing, coupled with the fact that there are not many opportunities to shoot at long distances and ultra-long distances, which can trigger the snipers to be willing to study the theory of scientific ballistic reasoning in-depth is not a big motivation, which has led to the snipers of the National Army generally have a weak conception of the scientific conception of ballistics, and this has become a problem that needs to be solved urgently for the current ballistic research and application of the National Army.

After collecting relevant literature and professional books on ultra-range shooting from advanced countries in Europe and the United States, the author has divided the mystery of ultra-range shooting into two aspects: "Theoretical analysis of ammunitions" and "Scientific ballistic application steps". The main purpose is to help snipers in China to systematically examine and check the relevant factors, so as to ensure that they can still obtain the first shot or achieve a reasonable hit rate at an ultra-range.

The application of scientific ballistics is an important method that snipers must master in order to break the bottleneck of precision shooting at long distances. It is hoped that this study will encourage the National Army sniping troops to emphasize the practical benefits of scientific ballistic application, and try to correct the past practice of relying on empirical parameters (careful aiming) to one that is based on ballistic data.

（This is the way to make the best use of the weapon in hand (heavy sniper rifle) and the best use of the weapon in hand (sniper with ballistic thinking and technology) to create the advantage of long range of over 1000 meters.

Keywords: sniping, ballistics, long range shooting, heavy sniper rifles

I. Preamble

The snipers of the National Army have been relying on the factory fixed range table (or the pre-set range markings on the adjusting screw)and a lot of experimental parameters accumulated by live firing, coupled with the fact that there are not many opportunities to shoot at long distances above 600 meters or at ultra-long distances of 1,000 meters, there is not much incentive for the snipers to study the theory of scientific ballistic reasoning in-depth, which has led to the snipers of the National Army generally being weak in the application of the concept of scientific ballistic reasoning, and falling into the predicament of "Learning but Not Using" and "Using but Not Knowing". As a result, snipers in the National Army are generally weak in the application of scientific ballistics and fall into the predicament of learning without using and using without knowing. This phenomenon has limited the development of long-range sniping capability of various units, and it is an urgent problem to be solved in ballistic research and application in China.

Since ballistic trajectory is an unchanging law of physics that exists in everything in the universe, it is a science of comparing every penny and every cent, even if the sniper does not understand and consider or deliberately ignore the calculation of the real impact of the external environment on the ballistic trajectory, these factors will still play an adverse effect on every bullet after the sniper holds his breath and pulls the trigger. Therefore, this paper will focus on discussing the necessary knowledge, concepts, and methods of ballistics that are related to the snipers' practicality and can help to improve the ability and hit rate of long-range shooting, hoping to throw a brick to attract jade, and encouraging snipers in the whole army to make joint efforts to study and learn the intelligence and skills that should be necessary for their duties, so as to solve the dilemmas of the application of scientific ballistics that have been hindering them for many years.

What is ultra-long range shooting?

Although there are no precise definitions in the literature, as far as empirical constants are concerned, the definitions can be categorized as follows: 0-300 m for Close Range, 300-600 m for Medium Range, 600-1000 m for Long Range, and 1000 m and above for Extreme Long Range (ELR)The distance between 300-600 meters is Medium Range, 600-1000 meters is LR (Long Range), and 1000 meters and above is ELR (Extreme Long Range) The reason for this classification has a ballistic significance, which is explained in the following order:

1. **Close range (0-300 meters)** Modern rifles or snipers are designed to meet the needs of medium and long range shooting.

   The munitions used usually fly at supersonic speeds of 2.5 to 2.7 times the speed of sound, so 300 meters is a very high speed.

   The in-foot flight time is very short (usually between 0.4 and 0.5 seconds) and is not affected by external environmental factors.

   Even the wind, which has the greatest impact on trajectory, usually requires more than 10 miles to cause an off-target shot. In addition to this distance, the high accuracy of shot dispersion and small changes in ballistic elevation, so in terms of real-world needs, any target can be shot directly at the center point to achieve quick hits, in order to give full play to the low-extension characteristics of the ballistic range of direct-fire weapons, also known as direct-fire distance (PBR, Point Blank Range) but the actual effect still depends on the ability of the ballistic path or the size of the target. （However, the actual effectiveness depends on the ballistic capability or the size of the target (the lower the trajectory or the higher the target height, the longer the PBR) Taking the characteristics of the most common .308 (175-grain) SMK ammunition as an example, a field sniper's typical engagement target is a humanoid target that is 100 centimeters high on average and leaps in a kneeling or low stance, then the gauge is set at 300 meters, allowing direct fire at a target that is within 400 meters; however, from the perspective of a V.A. sniper's typical target is a head-shaped target that is 20 x 25 centimeters in size on average, then direct fire cannot be performed and must be directed at the individual sniper. However, if the typical target is a head-shaped target with an average size of 20X25 centimeters from the perspective of a V.A. sniper, it is not possible to shoot straight, and it is necessary to measure the range of the target and install a meter to achieve a precise hit. (Figure 1)

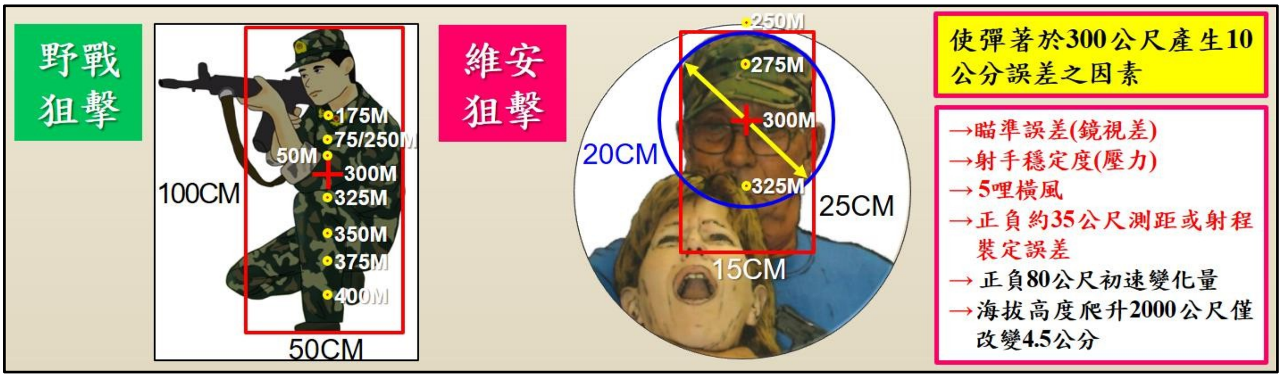

Figure 1 Depending on the mission and target, the effect of direct shooting at close range will be different.

Source: Authors' own research (October 27, 2021)

2. **Mid-range (300-600 meters)** For most rifle and sniper ammunition, the magnitude of ballistic change begins to increase at this range, and the shooter must begin to pay attention to the control of ranging error and ballistic setting; otherwise, if the barrel cannot be given the correct angle of fire, the ballistic trajectory will not be able to obtain the appropriate fall compensation value.
   (BDC, Ballistic Drop Compensations) thus increasing the chance of off-targeting (the ballistic trajectory will be obviously high and low if the range is not set correctly) However, at this distance, the effects of external environmental factors such as temperature, atmospheric pressure, and relative humidity on the warhead are not yet apparent, and as long as the gauge is correctly set, in a windless environment, even if the shooter does not immediately correct the above environmental factors, the target can still be hit effectively in most cases. Therefore, 600 meters is usually the maximum distance snipers want to use in a standard environment with a fixed trajectory parameter for a shooting gauge. Finally, 500-600 meters is usually the upper limit of effective range for various applications that rely on precise ballistic parameters, such as moving target shooting, emergency corrective shooting, turning face shooting, and so on.
3. **Long Distance (600-1000 meters)** For most rifle and sniper ammunition, the ballistic trajectory at this distance is affected by Muzzle Velocity Variation (MVV), which includes standard deviation of muzzle velocity ([1]) and maximum dispersion ([2]) gravity, wind, temperature, atmospheric pressure, relative humidity and other

internal and external factors, which will become more obvious, and if not corrected in time, it may cause off-target. If it is not corrected in time, it may cause off-target. Moreover, at this distance, the influence on the ballistic trajectory due to the slight tilt angle control of the gun face and the influence of the barrel's pitch angle due to the terrain, as well as factors such as Spin Drift and Coriolis, etc., will also begin to increase (Figure 2) Take the simulated ballistic trajectory of the T93K1 sniper rifle with TC94 sniper ammunition (average muzzle velocity of 808 meters per second) as an example:

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[1] According to Bryan Litz's book Accuracy and Precision for Long Range Shooting, page 272, the standard deviation (SD) of muzzle velocity is defined as less than or equal to plus or minus 10 feet per second for hand-loaded precision ammunition; less than or equal to plus or minus 15 feet per second for factory-produced precision ammunition; and greater than plus or minus 20 feet per second for inferior ammunition. If the SD is less than or equal to plus/minus 15 feet per second, it is the quality of ammunition produced by factories; if it is greater than plus/minus 20 feet per second, it is the inferior quality of ammunition. In addition, it also summarizes that for most long range projectiles, if the initial velocity error can be controlled within plus/minus 10 feet per second, it is equivalent to an uncontrollable vertical dispersion of 0.5-1MOA (ballistic trajectory height difference) at 1,000 yards.

[2] Extreme Spread (ES, Extreme Spread) muzzle velocity is the main reference value to measure the stability or extreme performance of the ammunition, which is based on the 110 years of the National Army sniper fire. For example, the M33 .50 caliber ordinary bullet used by Type I snipers in hand competitions, the maximum spread of muzzle velocity as measured by the Department can reach 21 meters, and this uncontrollable factor will produce an uncontrollable change of ballistic trajectory height of about 60 centimeters over 1,000 meters. Therefore, Bryan Litz, a U.S. ballistics expert, suggests on page 188 of Applied Ballistics for Long Range Shooting that the maximum spread of muzzle velocity should not exceed 30 feet per second (i.e., about 9 meters) for long range shooting purposes. This shows that there is still room for improvement in the quality of sniper rifles and ammunition currently used in China compared to the standards of advanced countries.

(1) **In terms of muzzle velocity variation of plus or minus 6 meters per second (i.e., the upper limit of the definition of inferior ammunition quality):** at 600 meters it would be about 11 centimeters, at 800 meters about 24 centimeters, and at 1000 meters about 47 centimeters.

(2) **In terms of tilt angle effects:** 600 meters tilted 1 degree is about 7 centimeters, tilted 2 degrees is about 7 centimeters, and tilted 2 degrees is about 1 meter.

Shifted 14 centimeters, tilted 3 degrees about 21 centimeters off target; 800 meters tilted 1 degree about off-target

15 centimeters, tilt 2 degrees about 30 centimeters off target, the farther the distance the greater the effect of the tilt angle.

(3) **In terms of pitch angle effects, a** 10-degree pitch at 600 meters would result in a ballistic deflection of approximately 5 centimeters, 800 meters would result in a ballistic deflection of approximately 5 centimeters, and 800 meters would result in a ballistic deflection of approximately 5 centimeters.

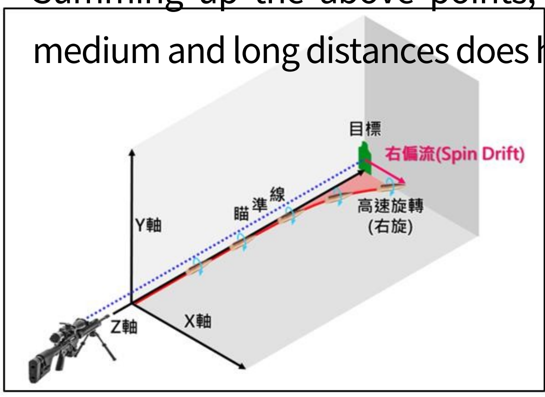
It is approximately 10 centimeters high at 10 degrees pitch and nearly 20 centimeters high at 1,000 meters.

(4) **In terms of warhead rotation offset:** approximately 8 centimeters to the right at 600 meters and 16 centimeters to the right at 800 meters, 1000 meters is approximately 32 centimeters to the right.

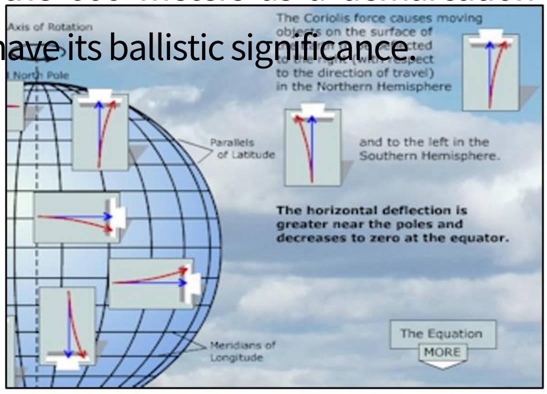
(5) **For the effect of the Coriolis force:** the horizontal offset affected by the Coriolis force, regardless of the direction of the muzzle.

Approximately 3.3 centimeters to the right at 800 meters, 6 centimeters to the right at 1000 meters, vertically offset, shooting east (west), approximately 7.5 centimeters high (low) at 800 meters, 15 centimeters high (low) at 1000 meters.

Summing up the above points, the 600 meters as a demarcation between medium and long distances does have its ballistic significance.



旋轉偏移：右旋之膛線賦予彈頭高速旋轉維持飛行穩定，同時也改變了空氣動力，使得彈頭必然產生右偏移(左旋膛線則左偏移)。一般而言，在相同距離上，其偏移量約為科氏力影響4-5倍。



科氏力影響：因地球自轉產生之慣性力使得原直線運動之彈道產生路徑偏移之現象，北半球無論槍口朝向何方射擊，影響均偏右；南半球則均偏左。通常需超過1000公尺才會產生明顯之影響。

Figure 2 Schematic diagram of the right-handed deflection of the bullet and the effect of the Kurtosis force in the northern hemisphere, with additional explanations.

Source: Authors' own research (September 16, 2021)

4. **Extremely Long Range (1000 meters or more)** For most sniper rounds, the warhead travels over
1000 meters, the ballistic trajectory itself to a variety of controllable or uncontrollable internal and external influences, such as the tilt angle of the gun surface and barrel pitch angle during shooting, the shooter's own ability to shoot (aiming error and shooting stability) the distance and range setting error, the wind measurement and wind deflection correction error; the accuracy of the gun and ammo dispersion, the muzzle velocity variance; the bullet head due to the high speed of rotation generated by the right deviation.
(also known as right-deviation flow) ballistic changes due to varying air densities and flight resistance (including altitude, atmospheric pressure, temperature, and relative humidity); unpredictable wind speeds and directions; and even the effects of geography.

Factors such as the effects of the rotation of the ball, such as the Coriolis force, have reached the level of a tiny fraction of a millimeter or a thousand percent, and it is no longer the case that at 300-600 meters, a shooter who leaves things to chance and deliberately ignores ballistic corrections will still be able to hit the target with good luck. Therefore, there are many ballistic considerations before firing at long distances, and if the shooter fails to take these factors into account or try to minimize their effects, the result will be extremely unfavorable to the accuracy at long distances. In addition, for common military ammunition (.308 Win, .300 Win Mag., .338 Lapua Mag., and .50 BMG, etc.) the residual velocity of the warhead will be less than 408 meters per second (for speed of sound) or 340 meters per second (for speed of sound) before and after 1,000 meters, which will result in the accuracy of the output parameter of the trajectory simulation and the flight stability of the warhead. The accuracy of the ballistic simulation output parameters and the flight stability of the warhead are greatly reduced, which makes it more difficult to execute a precise shot. The residual velocity of the warhead is lower than 408 meters per second, which is the distance at which it enters the speed of sound, and this is also the distance that American ballistician Bryan Litz wants to redefine as the standard for modern long-range sniping, so that different ammunitions will produce different definitions of long-range.

Current Ultra Long Range Shooting Records and Explanations

With the advancement of technology, ammunition and weaponry, modern long-range shooting has completely exceeded the traditional definition, and the American sharpshooters of the Civil War are absolutely unimaginable, as they once set a record of 600 yards!

For modern snipers, the "long range" record has become a "short to medium range" which everyone can hit every shot. As mentioned in the previous section, the modern definition of "long range" is 600 to 1,000 meters, and only snipers who shoot beyond 1,000 meters can be called "ultra long range".

世界前十大「超遠距離」狙擊紀錄排名

使用槍型	使用彈藥	射擊發數	狙擊手國籍	時間(月,年)	發生地(國家)	狙擊距離(排名與人名)
McMillan Tac-50	Hornady A-MAX .50	查無	加拿大	May. 17	伊拉克	3,450m 1 匿名
Barrett M82A1	NM140F2 Grade A.	查無	澳洲	Apr. 12	阿富汗	2,815m 2 匿名
AI L115A3	.338 Lapua Magnum	Tgt1: 3 rds Tgt2: 1 rd	英國	Nov. 09	阿富汗	2,475 m 3 Craig Harrison
McMillan Tac-50	Hornady A-MAX .50	3	加拿大	Mar. 02	阿富汗	2,430 m 4 Rob furlong
McMillan Tac-50	Hornady A-MAX .50	查無	加拿大	Mar. 02	阿富汗	2,310 m 5 Arron Perry
Barrett M82A1	Raufoss NM140 MP	查無	美國	Oct. 04	伊拉克	2,300 m 6 Brian Kremer
Browning M2 MG	.50 BMG	2	美國	Feb. 67	越南	2,286 m 7 Carlos Hathcock
Denel NTW-14.5	14.5X114m	查無	南非	Aug. 13	剛果民族共和國	2,125 m 8 匿名
Barrett M82A1	.50 BMG	查無	美國	Jan. 08	阿富汗	2,092 m 9 Nicholas Ranstad
McMillan Tac-338	.338 Lapua Magnum	1	美國	Aug. 08	伊拉克	1,920 m 10 Chris Kyle
AI L115A3	.338 Lapua Magnum	查無	英國	Aug. 09	阿富汗	1,853 m 11 Christopher Reynolds

資料更新時間：2021年9月

Only those shooting records beyond 2000 yards can be ranked among the world's top ten long range shooting records. (Figure 3)

Figure 3 Ranking of the World's Top 10 "Ultra Long Range" Sniping Records

Source: author's own moderation, reference The Longest Sniper Kills in History/Statista/Defense spending and arms trade/2017.(moderation date September 16, 2021)

From the information compiled by the authors above, several special phenomena can be observed:

In the top ten ranking, the record ratio of bolt action sniper gun to semi-automatic sniper gun is 6 to 4.[3] It can be seen that semi-automatic sniper gun can reduce the effect of environmental factors (such as wind changes)between two shots with a faster rate of fire, which can really make up for the lack of accuracy in the design, and achieve the purpose of ultra long-range shooting.

Seven of the top ten records are for .50-inch machine gun cartridges designed by Branning 100 years ago.

(.50 Cal BMG) 12.7x99mm ammunition, demonstrating the superior ballistic performance and continued development potential of this caliber of ammunition. Three of the records were set by Hornady's A-MAX precision ammunition, which took 1st, 4th, and 5th place. The warhead features an extremely low drag design

(VLD, Very-Low-Drag) with a drag coefficient ratio of 0.811 to the G7 standard warhead (i7)[4] has a very high ballistic coefficient (the original manufacturer claimed a G1 ballistic coefficient of 1.050; Applied Ballistics measured 0.991) This phenomenon shows that although the ballistic coefficient is not directly representative of the accuracy of the good or bad, but it can ensure that the warhead has a slower rate of initial velocity decline, so that the flight speed is reduced to the speed of sound, the warhead into the unstable flight of the critical distance farther, and effectively extend the shooter's distance to the battle. Higher ballistic coefficient also means that the warhead has less wind resistance, and can maintain higher velocity and kinetic energy when traveling to the same distance, with smaller ballistic drop and wind deflection correction values, resulting in a higher hit rate, and is therefore suitable to be used as a super long-range projectile.

Third, among the top ten, two records were set by .338 Lapua Mag ammunition (specification 8.6X70mm), which is a newcomer in the current ultra long-range firing ammunition (observe that the eleventh place is also set by .338 Lapua Mag ammunition)

Although .338 Lapua Mag ammunition has been developed and promoted by Finnish Lapua ammunition manufacturer for more than 30 years, due to its excellent characteristics of low trajectory extension, high accuracy, and high residual kinetic energy after over 1,000 meters, it has been widely used by European and American military, police, and precision shooting competitions in recent years, and it has become a new choice for the advanced countries in the pursuit of the balance between lightweight and flexible and long range precision. It has become a new choice for advanced countries to balance the conflicting needs of light weight and agility with long range accuracy.

Among the top ten records, nine of them were set by advanced sniper guns or precision rifles, with the only exception of the longest distance record of 2286 meters set by Carlos Hathcock, a well-known sniper of the U.S. Army Marine Corps during the Vietnam War, who used a Browning M2 heavy machine gun with a self-modified sniper's scope in semi-automatic mode of fire (Figure 4). Record was held until 2002 when Canadian sniper Arron Perry surpassed it with a kill distance of 2310 meters. Up to now, after more than half a century of competition among snipers from different countries, the record still remains in the top ten, which shows the novelty of Carlos Hiscock's idea and his ballistic calculation and shooting skills that are far beyond the ordinary people, which is the best example of the "boldness and carefulness" of snipers.

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[3] The McMillan Tac-50 or Tac-338 are hand tethered sniper rifles, while the Barrett M82A1 is a semi-automatic sniper rifle. The 7th record was set by a South African sniper with the NTW14.5 anti-material sniper rifle produced by Denel Defense Enterprises, which is a hand-bolted design, and according to the official data, the accuracy of the 1000-meter rifle can reach the standard of 2MOA.

[4] Very low drag coefficient (VLD, Very-Low-Drag) ammunition, usually refers to the experimental warhead and G7 standard warhead air resistance ratio of less than 0.88 of the ammunition, its ability to meet most of the needs of long-range shooting can also have a better performance of ultra-range ballistic, such as the domestic special services units use the Falconeye.50 precision ammunition with a drag coefficient of 0.859 also belongs to the Falconeye.50 precision ammunition with a drag coefficient of 0.859 used by domestic special forces is also a good example.

Picture 4 Carlos Hescak uses a Branning M2 heavy machine gun with a sniper's scope to shoot from a long distance.

Source: Bryan, 〈In Memoriam: Legendary USMC Sniper Carlos Hathcock II〉 http: //guide.sportsmansguide.com.(May 20, 2016)(retrieval date September 16, 2021) (day)

In addition, there are two other phenomena that cannot be easily seen from the sketch. The first one is that most of the long range shooting records happened in high altitude areas, mainly because the air density is less at high altitude, which helps to extend the effective range. The second is that most of the long range shooting records are not first shot hits, but rather 2-3 shots to hit the target, so there is no need to over-interpret these world records in a deified manner. [5]Take the KO2M (King of 2 Miles) standard organized by the NRA every year as an example, which stipulates that participants are limited to a different number of rounds at different distances, but they must hit at least one round before they can shoot at the next target or advance to the next stage. Taking the 2017 competition standard as an example, in the first stage, starting at 1416 meters (target 94X58 centimeters) 5 shots are given, but the next three targets at 1567 meters (94X58 centimeters) 1727 meters (94X76 centimeters) and 1819 meters (94X76 centimeters), only 3 shots are given. Stage 2, first target at 2438 meters.

(104X84 centimeters) Second Target Distance 2768 meters (137X107 centimeters) Final Target Distance

For the first time, a 5-round chance will be given for a shot to 3078 meters (152x122 centimeters)If you have successfully marched and shot to the top of the

For example, for the 14 shooters who shot at the longest distance of 1819 meters in the first stage, even though all the participants used extremely high precision firearms (usually with 0.5MOA accuracy)[6] and manually loaded precision ammunition with extremely low resistance design (mostly .338, .375, .408, .416, .50 inches in calibers, (e.g., Fig. 5), and supplemented with professional teams to assist with trajectory observation and wind deflection correction, (e.g., Fig. 6), for the longest distance of 1819 meters, there was no significant difference between the 14 shooters who shot at the longest distance of 1819 meters. (Figure 6) However, for the far away 1819 meters, it is not possible to make any correction for the wind deflection.

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[5] The 10th place record was set by American sniper Chris Kyle in Iraq, which is also the highest in his military career.

The record shot (2,100 yards, or 1,920 meters)[redacted] his autobiography, American Sniper, pp. 326-327: "Maybe it's because I pulled the trigger to the right to correct for wind deflection; maybe it's because gravity shifted the bullet to hit the target accurately; or maybe it's just because I'm the luckiest son of a bitch in Iraq...at 2,100 yards. I'm still amazed by that shot. It was a lucky shot, otherwise I wouldn't have been able to hit him with one shot.One of the few long-range hits with a first shot.

[6] MOA (Minute of Angle) known in Chinese as jiao cents, is a unit of angle, with 1 minute of angle equal to 1/60th of a degree (i.e. 0.0166 degrees) Calculated in imperial units, the angle radial extension to 100 yards formed by the pinched angle (chord length) of 1.047 inches wide, converted to metric units that is, 100 meters formed by the clip

The angle (chord length) is 2.9 centimeters wide, so when a firearm is described as having a 1-cent accuracy, it means that the average dispersion of the firearm at 100 meters can be smaller than A 2.9 centimeter diameter circle. 2 angular minutes is 5.8 centimeters, and so on. Because of its small angular size, it is used by the military to measure the accuracy of firearms or to adjust scopes to correct for wind deflection and angle of fire.

For targets, the average hit rate was about 48%, with only 6 first shots. (Of the 10 shooters who made it to the second stage, the average hit rate on the longer 2,667-meter target was only 10%, and none of them had a first shot) It can be seen that shooting at long distances is not as easy as one might think, and that the distances specified in any of the above competitions are beyond the maximum effective range of most common military sniper ammunition (i.e., the velocity of the projectile has entered the range of the

speed of sound penetration or has been lower than the speed of sound, as will be explained in more detail later in the article) Therefore, under the circumstance of insufficient ammunition capability, accuracy, environment mastery and resources, it is as difficult as climbing up to the top ten in the world to complete the sniping of "humanoid" targets at ultra-long distance by two sniping team members independently in the battlefield and hope to enter the world's top ten rankings.

Figure 5 Commonly Used Ammunition for KO2M Competition in the USA
Source: Applied Ballistics Inc. Youtube professional channel 〈Derek Rodgers KO2M Final Run 2017- 2 Mile 〉(Retrieved October 1, 2021)

Figure 6 Team led by AB Ballistic Consultants, Inc. won the 2017 KO2M Championship.
Source: Applied Ballistics Inc. Youtube professional channel 〈Derek Rodgers KO2M Final

Run 2017- 2 Mile 」(Retrieved September 23, 2021)

The Secret of Ultra Long Range Shooting

After collecting relevant literature and professional books on ultra long-range shooting from advanced countries in Europe and the United States, the author has divided the mystery of ultra long-range shooting into two directions: "Theoretical Analysis of Ammunition Capability" and "Steps of Scientific Ballistic Application", with the purpose of assisting snipers in China to systematically examine and check the relevant factors, so as to ensure that they can still obtain the first shot or achieve a reasonable hit rate at an ultra- long range. The following is a description of each of these factors:

I. In terms of the theoretical analysis of ammunition capacity

(a) Can the existing internal and external conditions such as firearms accuracy (or shooter's shooting ability) standard deviation of muzzle velocity and maximum dispersion, range and range setting error, wind measurement and wind deflection correction error satisfy the expected hitting effect of the weapon system when shooting at a certain size of target at a very long distance? Take the U.S. Army's WEZ (Weapon Employment Zone) analysis method as an example, after simulation by the system, it can be seen that when using a 7.62mm M110 semi-automatic precision rifle to shoot at an E-Type standard humanoid target (50x101 centimeters) at a range of 1000 meters, it will be able to achieve the expected hitting effect in terms of 1 MOA accuracy, standard deviation of muzzle velocity of plus or minus 15 feet per second (i.e., 4.5 meters), range error, and standard deviation of muzzle velocity. (i.e., 4.5 meters) range error of plus/minus

Under the same conditions, if the M2010 bolt action sniper with the same accuracy of 1MOA is used with the .300 Win Mag Magna Range Extender, the theoretical hit rate can be increased to 63%. If the M107 semi-automatic sniper rifle is used instead, with MK211 MOD 0 sniper ammunition, although the short recoil principle of the barrel reduces the accuracy to 1.5MOA, due to the high ballistic coefficient and sufficient ballistic flight, the theoretical hit rate can reach 90%. [7]Therefore, the sniper's ability to objectively analyze the size of the theoretical hit rate based on the five factors of "man, gun, scope, bullet, and ring" is the sniper's primary consideration when executing ultra long-range shooting.

(b) At the distance of the intended shot, is the speed of the warhead below the average speed of sound of 340 meters per second? Because when the warhead flying in the air from supersonic flight into subsonic speed, the center of pressure and the Magellanic force are changed and far away from the center of gravity, so that the warhead in motion and twist (Nutation and Twist) phenomenon aggravated, (as shown in Figure 7) the bullet axis can not be stably maintained in the tangent to the trajectory, the result of the yaw angle increases the air resistance increases, which in turn affects the stability of the flight of the bullet and the hit rate, and even cause severe even cause rolling and cross-bombing phenomenon. (Figure 8)

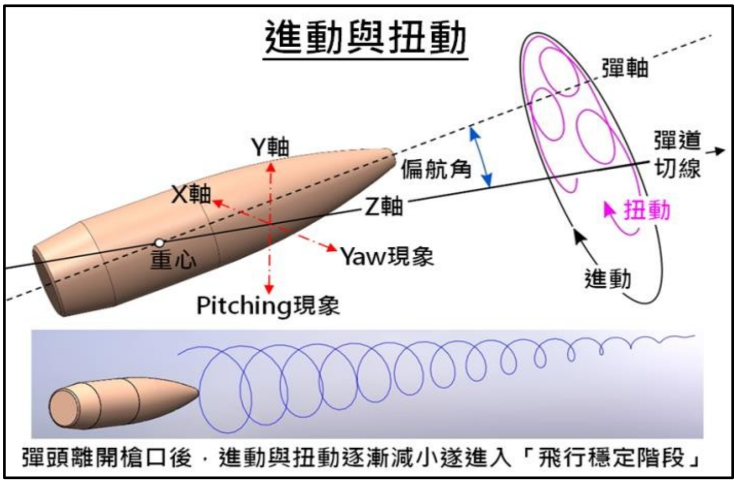

Figure 7 Schematic diagram of the "advance and twist" phenomenon of the warhead flight (Author's own adjustments)

Source: Jin-Kai Kuo, Sniper Ballistics, Third Edition (Kaohsiung, Taiwan, Army Infantry Training Command, R.O.C. 110) p14. (Date of retrieval September 16, 2021)

[7] TC 3-22.10, Sniper (U.S.A., Headquarters Department of the Army, 2017),P2-20~2-23 & K-2~K-3.

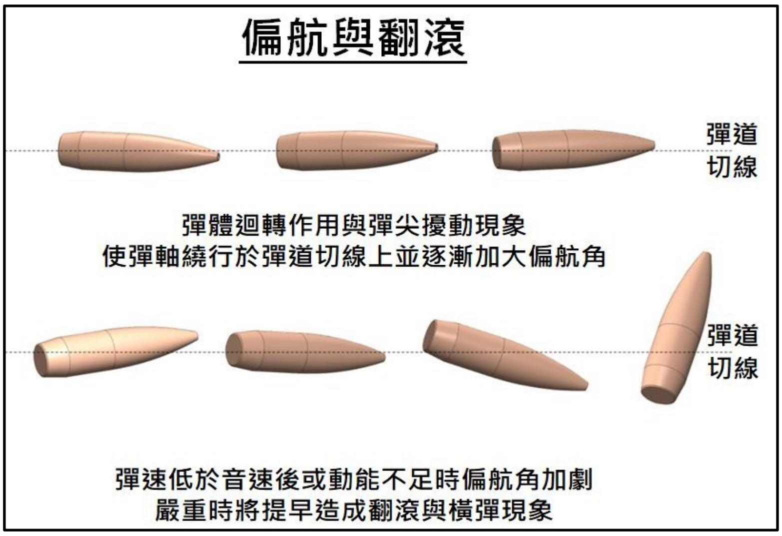

Fig. 8 Schematic diagram of the "yaw and roll" phenomenon of the warhead flight (Adapted by the authors).

Source: Jin-Kai Kuo, Sniper Ballistics, Third Edition (Kaohsiung, Taiwan, Army Infantry Training Command, R.O.C. 110), p14. (Date of retrieval September 16, 2021)

Therefore, the distance at which the warhead enters subsonic flight can be used as a reference for the "Maximum Effective Range" of military weapons, i.e., even if the weapon exceeds this range, even if the killing power is sufficient, the hit rate will be reduced significantly, and there is no longer any need to explore the effective range. Using the built-in Elite Ballistics function of the Kestrel 5700 to simulate the various commonly used ammunition of the National Army, the relevant parameters of the[8] are as follows under the average standard atmospheric environment (i.e., density height of 750 meters) that is more suitable for the modification of the shooting table of the People's Republic of China: The national TC74 semi-steel-core bullet (bullet weight of 62 grains, average muzzle velocity of 880 meters per second) is about 675 meters below the speed of subsonic, The TC94 sniper round (175 grains, average muzzle velocity 808 meters per second) is about 950 meters, the M33 regular round (661 grains) is about 675 meters, and the TC94 sniper round is about 950 meters.

(average muzzle velocity 860 meters per second) about 1,350 meters, and the U.S.-made Falconeye is about 1,500 meters.

The precision round (762 grains, average muzzle velocity 860 meters per second) falls at approximately 2080 meters. In addition, to supplement the U.S. Army's commonly used long range ammunition, in the average standard atmospheric environment more suitable for the U.S. Army's firing tables (density height of about 50 meters), the relevant parameters are as follows: .300 Win Mag size MK481 ammunition (250 grains, average muzzle velocity of 869 meters per second) falls below the speed of sound at about 1290 meters, .338 Lapua Mag size SMK/ Scenar ammunition (250 grains, average muzzle velocity of 899 meters per second) falls at about 2080 meters, and .338 Lapua Mag size SMK/ Scenar ammunition (250 grains, average muzzle velocity of 762 grains, 899 meters per second) falls at about 2080 meters. Scenar ammunition in the .338 Lapua Mag specification (250 grains, average muzzle velocity 899 meters per second) is capable of velocities up to approximately 1,350 meters, 12.7x99 centimeters.

MK211 (A606) ammunition (bullet weight 671 grains, average muzzle velocity 883 meters per second)

The range of a sniper can be up to about 1550 meters. Therefore, can a sniper effectively shoot at a distance of more than 1,000 meters? It is important to know whether the speed of the bullet at the distance to be shot is below the speed of subsonic, and this is one of the most important factors to be assessed before the shot is fired.

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8 Density Altitude (DA, Density Altitude) This refers to the density of the air at the location, which is equivalent to the density of the relative air at a given altitude in a standard atmospheric environment. It can be calculated from temperature, atmospheric pressure and humidity or read directly by a Kestrel 4000 or above. The higher the density altitude, the lower the air density and the higher the trajectory. Knowing the density altitude can shorten the time of inputting environmental parameters into the ballistic calculation software or simplify the traditional manual calculation procedure, which is an important reference index for environmental factors affecting the ballistic trajectory.

(c) Is the velocity of the warhead at the long range to be fired already below Mach 1.2, i.e. 408 meters per second? The reason is that Bryan Litz, a U.S. applied ballistician, has found that the impact of a bullet entering the subsonic velocity usually begins to occur when the speed of the bullet is lower than Mach 1.2, i.e., at a range of 408 meters per second, which is also known as the Transonic Range, as shown in Figure IX. With the current common ammunition used by the National Army, under the average standard atmospheric environment which is more suitable for our country's firing table, the velocity of the bullet will be lower than 1.2 Mach (Mach), i.e. 408 meters per second.

(i.e., density height of 750 meters) the penetration distance of the Chinese-made TC74 semi-steel-core round (62-grain bullet weight, average muzzle velocity of 880 meters per second) falls about 565 meters, the Chinese-made TC94 sniper round (175-grain bullet weight, average muzzle velocity of 808 meters per second) falls about 770 meters, the U.S.-made M33 regular round (661-grain bullet weight, average muzzle velocity of 860 meters per second) falls about 1,120 meters, and the U.S.-made Falconeye precision round (762-grain bullet weight, average muzzle velocity of 860 meters per second) falls about 1,720 meters. The US-made M33 regular bullet (661 grains, average muzzle velocity 860 meters per second) falls at about 1120 meters, and the US-made Falconeye precision bullet (762 grains, average muzzle velocity 860 meters per second) falls at about 1720 meters. Therefore, when the above ammunition enters the range where the speed of sound is penetrated, snipers should pay attention to the actual hit rate even if the environmental factors have little influence.

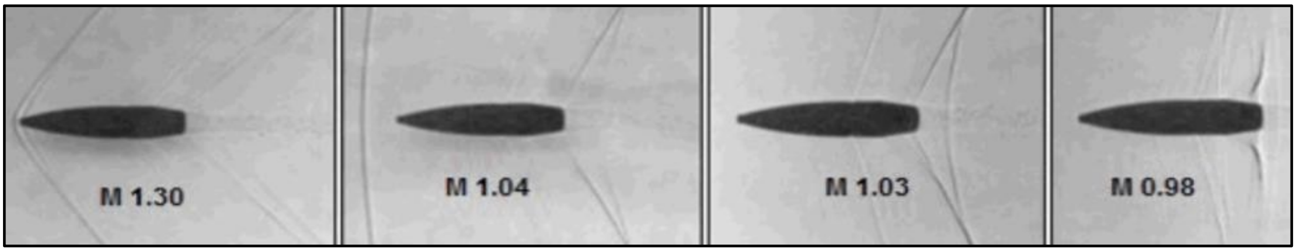

Figure 9 The impact of a warhead entering subsonic velocity occurs at velocities below Mach 1.2 (408 meters per second).

Source: http: //www.bulletin.accurateshooter.com/2014/09/practical-thoughts-about-transsonic-bullet-stability-and-accuracy/ (accessed September 16, 2021)

September 16, 2021)

II. In terms of scientific ballistic application steps

(i) Method of measurement (acquisition) of ballistic coefficients:

Ballistic coefficient (BC, Ballistic coefficient) is one of the important data input into the ballistic calculator for snipers who want to obtain accurate shooting parameters, the size of its value also directly determines the ballistic performance of the warhead outside the ballistic trajectory. Its meaning is that it is a coefficient to measure the actual air resistance of a warhead during flight, or the ability of a particular warhead to overcome air resistance, the higher its value, the better its ability. It is calculated by dividing the Sectional Density by the Form Factor, which is measured in pounds per square inch (lbf/in^2) but is usually omitted. (Figure 10)

彈道係數計算公式

$$\text{彈道係數(lbf/in}^2\text{)} = \frac{\text{截面密度(lbf/in}^2\text{)}}{\text{阻力係數}} = \frac{\text{彈頭重(格令)/7000}}{\text{(彈徑-英吋)}^2 \text{X阻力係數}}$$

資料來源：Bryan Litz,《Applied Ballistics for Long Range Shooting》,P16.

Figure 10 Ballistic coefficient formula (author's own adjustments)

Source: Jin-Kai Kuo, Sniper Ballistics, Third Edition (Kaohsiung, Taiwan, Army Infantry Training Command, R.O.C. 110) p6. (Date of retrieval: September 16, 2021)

However, the denominator of the above formula, the drag coefficient, is derived from "the air resistance of the bullet actually traveling in the air divided by the air resistance of a G1 or G7 standard bullet". In addition, the air resistance of the bullet flying in the air will change continuously with the change of speed, and when different environmental factors such as altitude, atmospheric pressure, temperature, relative humidity and so on affect the change of speed of the bullet, the result of the ballistic coefficient **will** also change immediately, so the **ballistic coefficient will be a little different at different ranges and is not a fixed value.**(As shown in Figure 11)

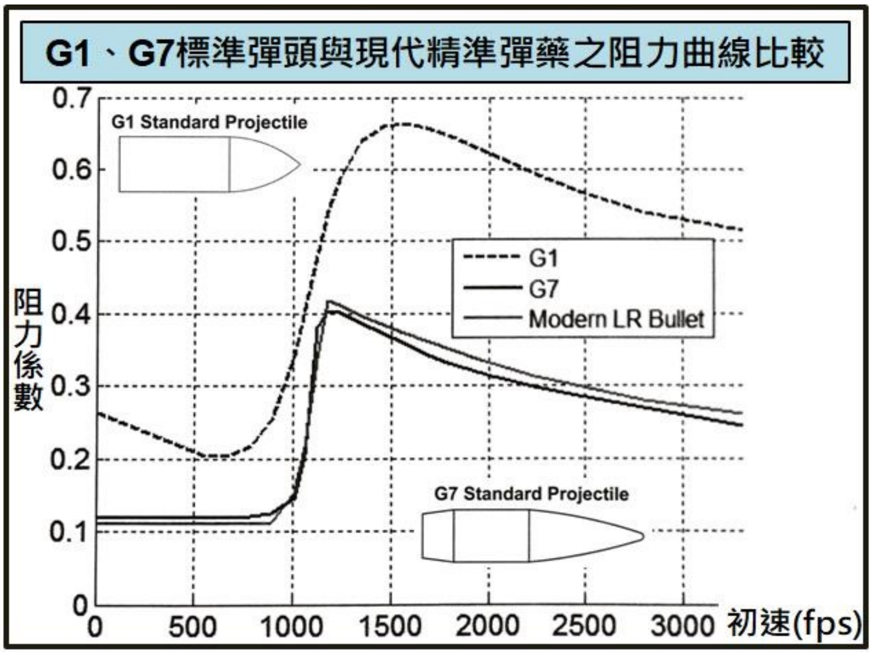

Figure 11 Comparison of resistance curves of G1, G7 standard warheads and modern precision ammunition

Source: Bryan Litz, Applied Ballistics for Long Range Shooting, P23. (retrieved September 16, 2021)

Taking the Sierra .308 MatchKing (175-grain warhead), which most closely resembles the ballistic characteristics of the

Chinese-made TC94 sniper round in the book "Ballistic Performance of Rifle Bullet- 3rd Edition" written by American applied ballistician Bryan Litz, as an example, the round has been measured by live fire.
After calculating the ballistic coefficients of the actual air resistance of the warheads at different velocities (3000 ft/s down to 1500 ft/s), it was found that, when compared to the G1 standard warheads.

The change is up to 13.3%, while the change is less than 3.3% when comparing with the G7 standard warhead. [9]**Therefore, it is recommended to use G7 ballistic coefficients for ballistic simulation when firing at long range, as the corrected value will be more accurate than the G1 ballistic coefficient input.** In addition, the ballistic coefficients provided by general ammunition manufacturers are rarely obtained through extensive live-fire testing, and usually only represent ballistic coefficients at a single distance (e.g., at the muzzle of a gun, at a distance where the bullet's speed is reduced to 2.2 Mach, i.e., 748 meters per second, or at a distance of 200 yards) which is comparable to the above mentioned values of the U.S. ballistician, Bryan Litz, who used at least 200 rounds of live fire to track the projectile with the aid of a radar wave velocity meter (Labradar). When compared to the above mentioned American ballistician Bryan Litz, who used at least 200 rounds of live ammunition to track the speed of the bullet throughout the entire flight by means of a Labradar, and then calculated the average value that is most suitable for inputting into the ballistic calculator, the error can be as high as plus or minus 10 percent. Moreover, for marketing purposes, some ammunition manufacturers may even exaggerate the values by deliberately displaying the highest value in the ballistic coefficient variation (A Peak B C) so special attention must be paid to the use of this product.[10]

(ii) Method of muzzle velocity measurement (acquisition):

Muzzle Velocity (MV) is as important as the ballistic coefficient, not only is it one of the most important inputs into the ballistic calculator, but the magnitude of its value also directly determines the external ballistic performance of the cartridge. However, Muzzle Velocity is closely related to the amount of ammunition fired, the form, the burning rate, the ambient temperature, the ammunition temperature, the weight and loading depth of the cartridge, the length and tangle of the barrel, the level of maintenance and even the degree of wear of the bore wall...and many other factors. As far as the current national situation is concerned, except for the environmental temperature, ammunition temperature, maintenance standard and the degree of bore wear that can be avoided or controlled by the shooter, the rest of the factors are beyond the shooter's direct control.

Generally, in order to obtain the muzzle velocity, it can be measured by a Chronograph, but it should be noted that the speed measured by the traditional tachymeter with optical triangular screen (such as Chrony, Oehler, CED, etc.) is not the actual muzzle velocity, but the Bullet Speed measured by the distance of the tachymeter together with the ambient temperature, so it is necessary to consider the distance of the tachymeter and enter the correct ballistic coefficient through the ballistic calculation software (machine) to reverse the calculation. Therefore, it is necessary to consider the distance where the velocity meter is located and enter the correct ballistic coefficients through the ballistic calculation software (machine) to obtain the reverse calculation or, you can also refer to the American applied ballistics expert Bryan Litz 〈Velocity Decay between Muzzle and Chronograph〉 in the article provided by the "muzzle velocity per ft. recession curves" for conversion. When using the Velocity Decay Curve (Figure 12), simply place the G7 ballistic coefficient of the ammunition being used against the muzzle velocity curve, find the rate of muzzle velocity decay per ft. through the matrix, multiply this by the distance from the muzzle to the tachymeter to obtain the amount of muzzle velocity decay, and then add this back to the originally measured velocity to obtain a closer muzzle velocity. Although this compensation value is very small, if it is not compensated in time, the point of impact may be too high due to excessive correction when shooting at long range.

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[9] The ballistic coefficients provided in the book are averaged over a range of velocities from 3000 feet per second to 1500 feet per second using live-fire tests. The book also contains a large number of bullet sizes, specifications, G1/G7 ballistic coefficient variation curves and optimum values, and recommended barrel windings for a wide range of common ammunition, which are of great practical value.

[10] Source: Interviewed by Emil Praslick III, one of the leading wind experts in the U.S., Gavintoobe Youtube channel, "In-Depth ELR Discussion".

with Emil Praslick

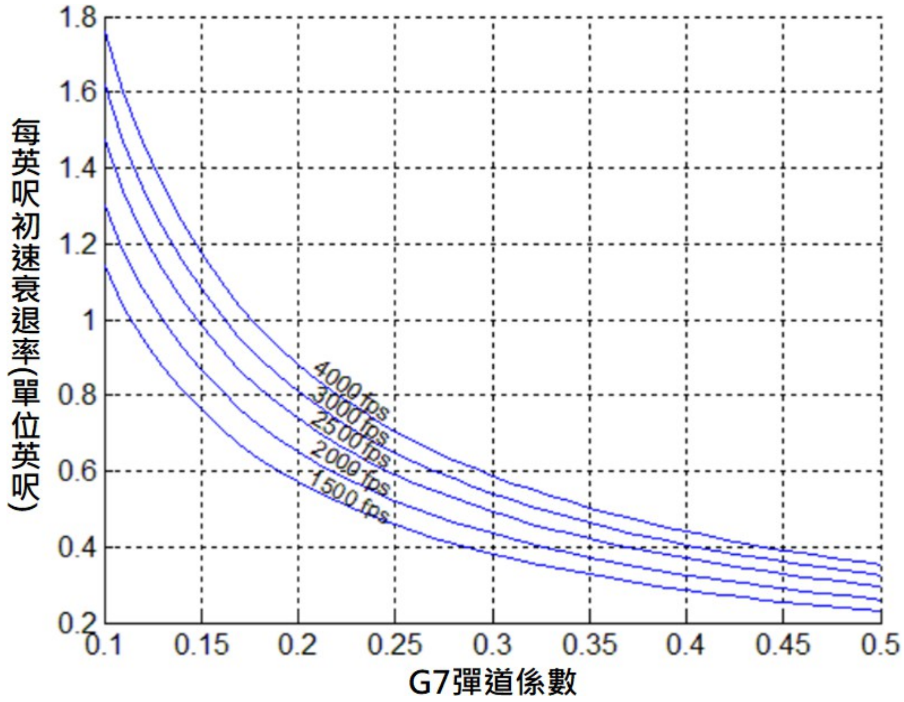

Figure 12 Bryan Litz Muzzle Velocity Recession Curve per Foot

Source: Bryan Litz, Velocity Decay between Muzzle and Chronograph (U.S.A., Applied Ballistics, LLC, 2021), P1. (accessed September 16, 2021)

In addition, it should be noted that the gun and the instrument must be completely perpendicular or the two optical gates of the tachymeter must be parallel to each other...etc., to avoid the wrong angle of incidence or the change of the distance between the optical gates to avoid the error of speed measurement (generally speaking, the larger the distance between the two optical gates, the smaller the error, so you can pay special attention to it when purchasing) However, if a high level tachymeter, such as a muzzle electro-magnetic or radar wave detection tachymeter, can be used, the muzzle velocity can be directly measured closer to the muzzle velocity(Fig. 13)If there is no tachymeter available, you can first refer to the muzzle velocity provided by the original manufacturer, and then utilize some of the ballistic calculation software (machine) such as the Truing Muzzle Velocity/ Calculating Muzzle Velocity function built in the Kestrel 5700 Wind Sounder[11] to perform a backward calculation. The ballistic coefficient of the ammunition must be obtained in order to avoid making additional mistakes. For example, the U.S. Army Sniper Training Instruction 2017 (TC 3-22.10), Annex, page B-3, states, "If the muzzle velocity entered into the ballistic calculator differs from the actual muzzle velocity by 5 feet per second (5 fps), the calculated ballistic trajectory is the same as the result of entering a 1% error in the ballistic coefficient. Therefore, it is recommended that each unit sniper team, while actively developing and upgrading the quality of snipers' equipment, should also try to obtain an accurate and reliable tachymeter, so that the average muzzle velocity obtained from the actual test can be used as the basis for ballistic calculations to improve the hit rate of long-range shooting.

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[11] Built into the Kestrel 5700 Elite Weather Station is a feature that allows all firearms (especially ballistic coefficients) and environmental parameters to be entered correctly.

By feeding back the difference between the actual trajectory and the simulated value, it can back calculate the muzzle velocity to match the actual muzzle velocity. Usually, it is recommended to use the bullet speed to enter 1.2 Mach.

(i.e. entering the speed of sound, about 408 meters per second) 90-100% of the distance as the base calibration distance (for example, the T93K1 sniper rifle with TC94 sniper rounds, it enters 1.2 Mach at 714 meters, so it is recommended to implement the calibration distance between 640-714 meters) The system will automatically correct the muzzle velocity after the data feedback of the baseline calibration distance is completed. It is then recommended to verify the ballistics with 1/2 baseline calibration distance, and if the simulated value is in line with the actual requirement, the Cal MV calibration will be completed.

Figure 13 Muzzle Electromagnetic (MagnetoSpeed) and LabRadar Tachometers
Source: http: //www.3gsports.de〈MagnetoSpeed V3 Chronograph〉 and http: //www.ocabj.ne〈t LabRadar Chronograph Review〉 (Retrieved 2021 (September 16, 2011)

(iii) Scope capability and installation check:

"Man, gun, mirror, bullet and ring" are the core elements for snipers to carry out long-distance accurate shooting, and whether they can be integrated is crucial to the success or failure of the sniping mission. After deducting the "external environmental factors", the aiming factors generated by the "human and the mirror" have the greatest influence on the accuracy. Therefore, if snipers are unable to understand and eliminate the adverse effects of the optical scope's innate design on shooting accuracy, they will not be able to effectively implement trajectory modification, parameter verification and collection, which will significantly reduce the effectiveness of the ballistic application in long-distance shooting. The factors of the scope and their effects on long-range shooting are described as follows:

1. Magnification/Scope Power:

This is the magnification of an image through an optical lens, e.g., a 10-meter object on a 100-meter scale (1 meter).

(bit)[12] , when viewed through a 10x lens, is equivalent to viewing the object with the naked eye at 10 meters.

The higher the magnification, the better the ability to observe and acquire the target and enhance the ability to construct a correct aiming picture. The higher the magnification, the better it is for target observation and acquisition, and enhances the ability to construct a correct sight picture. Generally, in order to satisfy the sniper's need to shoot at long distance, it is recommended to use a sniper's scope with a maximum magnification of at least 25~30 times, and the one with variable magnification is preferred. For example, 5-25X56 or 5-30X56. However, the magnification will directly or indirectly produce many negative effects, so special attention must be paid when using. They are summarized as follows:

(1) Narrowing the Field of View reduces the shooter's ability to monitor the battlefield environment.

(2) It is easy for the shooter to focus too much on the target features or movement when aiming, instead of focusing on maintaining the relationship between the cross hairs and the sight picture, resulting in aiming errors.

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[12] Meters, also known as milli-radians, are used to indicate a specific height or width at a certain distance. 1 meter is equivalent to 0.05729 degrees at 100 meters, and 1 degree is equivalent to 3.438 MOA (since a circle is 360 degrees, 1 degree is equivalent to 60 MOA) Meters are used in the same way as MOA, to indicate a specific height or width at a certain distance. 1 meter is equivalent to 0.1 meter of height (width) at 100 meters, and 1 meter at 1000 meters. Because of the ease of conversion, military scopes or binoculars are often engraved in meters to facilitate the shooter's estimation of the distance to the target.

(3) When the shooter's breathing and heartbeat are rapid, the cross wire shakes and trembles more obviously, which will easily increase the shooting pressure, resulting in hesitation or rapid buckling.
(4) Reduced light intake reduces overall brightness and makes images more hazy when used in low-light environments.
(5) The Eye Relief is shortened, making it easier to find and aim the cheek pads.
(6) If the eye distance is too close and the gun is not stable enough, the eye will be easily hit by the goggle due to recoil. (Scope Bite)
(7) The effect of Optical Parallax is greater, and if the shooter fails to make immediate adjustments to eliminate it, or if the cheekpiece is not consistent enough, it will increase the aiming error.
(8) The effect of thermal turbulence is more pronounced, increasing the interference with the shooter's aim.

2. Exit Pupil Diameter (Exit Pupil)

The size of the beam that passes through the optical lens and reaches the shooter's eye is obtained by dividing the size of the receiving lens diameter by the magnification. Therefore, if the size of the objective lens is the same, the larger the magnification, the smaller the exit pupil diameter; conversely, the opposite is true. Theoretically, its size must be larger than or at least equal to the pupil of the human eye to ensure that the light from the objective lens can fully enter the pupil, obtaining a bright and clear image and avoiding vignetting or aiming deviations. (Figure 14) Physiologically, the size of the pupil of the human eye adjusts naturally with the brightness of the environment, and usually shrinks to 2-3 centimeters under strong sunlight,
In the dark at night, it automatically zooms in to about 5.5-7 cm (depending on age, usually 20 years old).
(This can be enlarged to about 7mm for a young person and 5.5mm for a 65 year old) Therefore, the original
Variable-magnification scopes with the pupil size deliberately controlled between 2-7 centimeters can satisfy the basic needs of day and night scopes, while fixed magnification of 4-5 centimeters

is preferred, such as the 4.25 centimeter pupil diameter of the TS95 10x scopes made by China. Usually, snipers will adjust the magnification to the highest level in order to have a clear view of the target when shooting from a long distance, and at the same time, the pupil diameter will be reduced, which greatly increases the difficulty of constructing a clear sight picture.

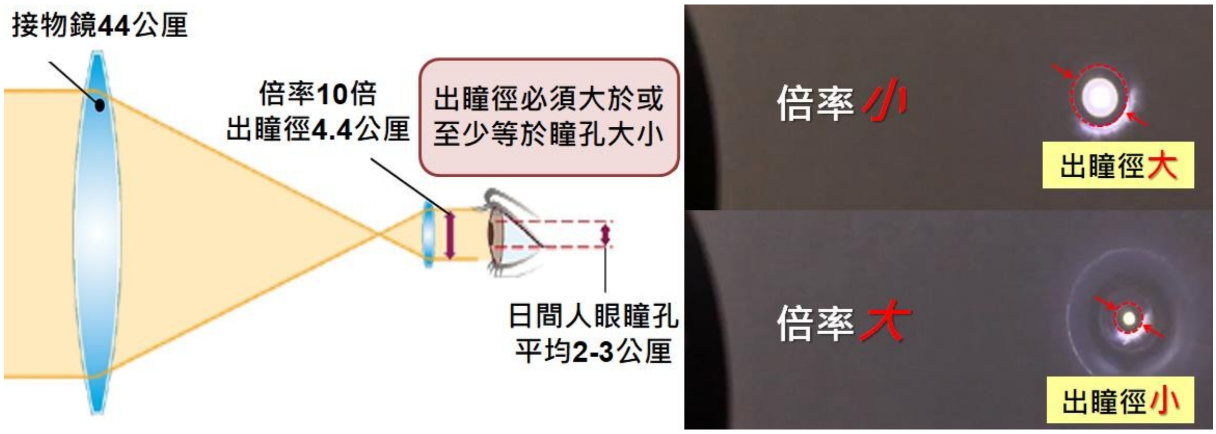
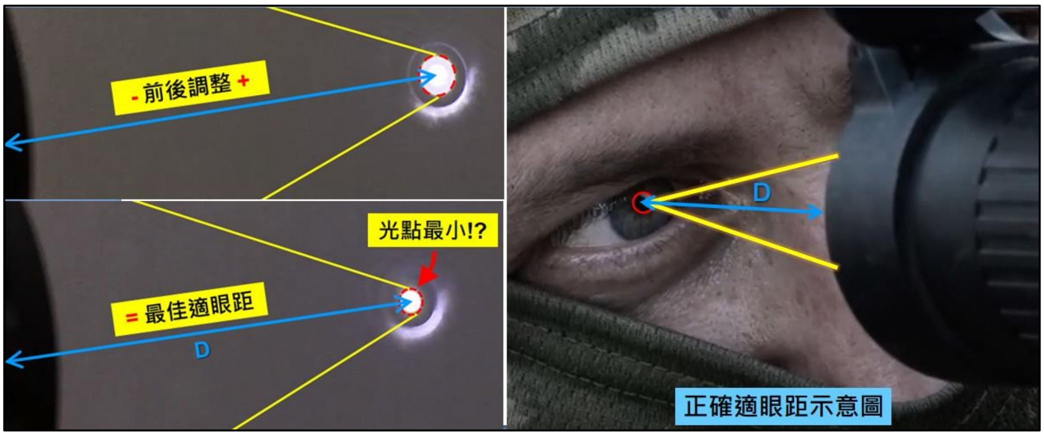


Figure 14　　Schematic diagram of the relationship between the size of the exit pupil and the pupil of the human eye with a 10x sniper lens (Adapted by the author)

Source: Jin-Kai Kuo, Sniper Ballistics, Third Edition (Kaohsiung, Taiwan, Army Infantry Training Command, R.O.C. 110) p70.(Date of retrieval: September 16, 2021)

3. Eye Relief:

Also known as visual distance or eye relief, it refers to the specific distance that must be maintained between the goggle and the eye in order to obtain the clearest and brightest image. This distance is mainly governed by the magnification, usually the higher the magnification, the shorter the eye relief. Most of the variable magnification scopes are designed with a value between 8-10 centimeters, and the actual parameter can be obtained by



checking the original manufacturer's information. For example, the TS95 10x scopes are designed with an eye relief of 86 centimeters. However, if there is no original factory information available, you can point the objective lens of the sniper scope to the sunlight, like the way to burn through the paper with the heat of the magnifying glass, when the refracted beam is found to be the most concentrated when the distance between the objective lens and the paper, that is, the appropriate eye relief of the scope at that magnification. (Figure 15)

Figure 15 Schematic of Eye Distance

Source: Jin-Kai Kuo, Sniper Ballistics, Third Edition (Kaohsiung, Taiwan, Army Infantry Training Command, R.O.C. 110) p72(Date of retrieval September 16, 2021)

Once the pupil diameter and eye relief are determined, the position of the scope can be determined or the length of the stock can be adjusted so that the optimal position of the eye relief can be reached every time the cheekpiece is attached to the gun in a way that is most natural and comfortable for the individual to hold the gun, and a bright and clear sight picture can be obtained. Then, with the fine adjustment of the height of the cheek pad, the pupil diameter can be easily reflected into or over the pupil of the human eye, and ultimately obtain a clear, bright, round, and No Shadow

Effects (No Shadow Effects) image. The result is a clear, bright, round, and no-shadow-effect image. This makes man, gun, and mirror one in the same, shortens the shooting preparation time, and reduces the impact of optical sights on shooting accuracy.

4. Optical Parallax:

The reason for this is that the imaging plane of the eyepiece does not fall on the same plane of the cross hairs, resulting in the target moving around the cross hairs when the shooter sticks the cheekpiece with a little bit of shaking or position change, making the aiming picture inconsistent and affecting the accuracy greatly. (Fig. 16) To explain in a simple way, as in a conventional car actually traveling at 120 km/hour at high speed, due to the slight height difference between the pointer and the dashboard plane, the speed seen by the driver from the dashboard pointer is only 115 km/hour, resulting in the speeding problem.

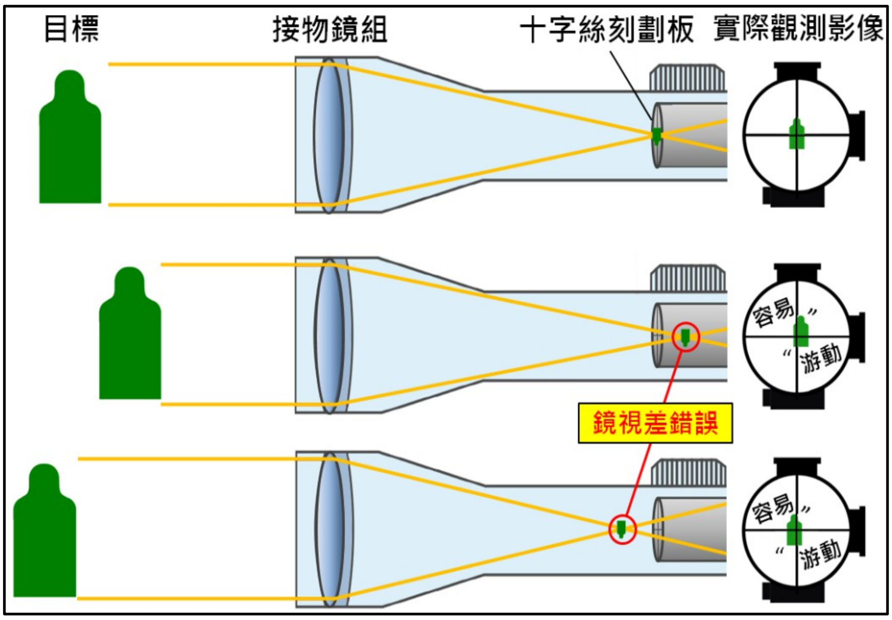


Figure 16　Schematic diagram of the causes of mirror aberration

Source: Authors' own moderation, referenced at http://www.sportingshooter.com.au/news/riflescope- parallax-problem. (moderation date December 3, 2021)

By adjusting the parallax adjusting screw so that the imaging plane and the crosshair are exactly in the same plane, the situation of the target traveling over the crosshair no longer exists. Different ranges have different parallax positioning. Although the parallax adjusting screws of some sniper scopes can mark the distance markings, it can seldom eliminate the problem of mirror parallax completely (Fig. 17). The shooter still needs to shake his head gently before shooting, to check the crosshairs to see if there is any movement of the crosshairs and try to minimize or eliminate the movement (Parallax Free), and it is also recommended to complete a specific distance to make the imaging plane and the crosshairs fall exactly in the same plane, so that the target will not move over the crosshairs. Parallax Free) It is also recommended that after confirming the parallax of a specific distance lens (usually every 100 meters) a small white paint pen can be used to make a direct record on the parallax adjusting screw for subsequent shooting reference. In addition, when using a sniper scope with adjustable magnification, the higher the magnification adjustment, the greater the actual parallax observed by the shooter when the distance difference between the two focal planes inside the barrel is the same, so it is necessary to pay special attention to this.

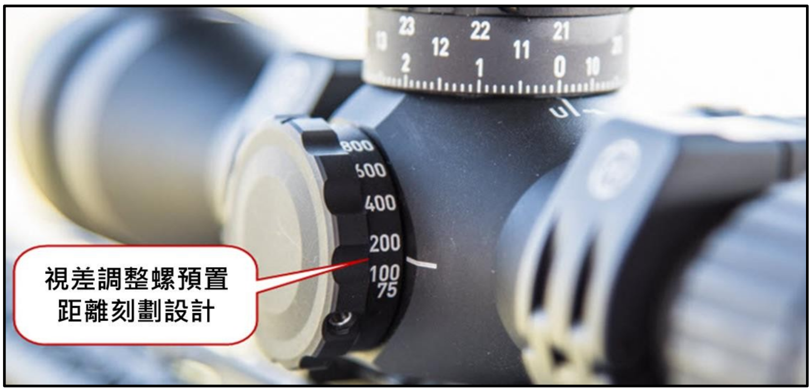


Figure 17 Parallax Adjustment Screw and Distance Scoring

Source: Photographed by the author (September 28, 2021)

5. Cant Errors:

Before understanding the real issue of face tilt, if the scopes are mounted with a tilt angle, i.e., the elevation screw rotation vector is not perfectly centered on the plane of the Plumb Line, the point of impact at different ranges will produce an additional and unpredictable amount of horizontal deviation (too much tilt will also result in a vertical deviation) In order to know whether there is any tilt angle problem in the installation of the scope, you can implement the 100-meter vertical target test (Tall Target Test) the target paper specification is shown in Figure 18, and you must use a horizontal bubble ruler or hammer line to ensure that the target paper is not skewed when you put it on the target paper. Then shoot 3-5 rounds with 10MOA adjusting screws each time, and carry out a total of 30MOA adjusting test, by checking whether the average point of impact of each group of rounds is accurately located on the vertical line to judge.

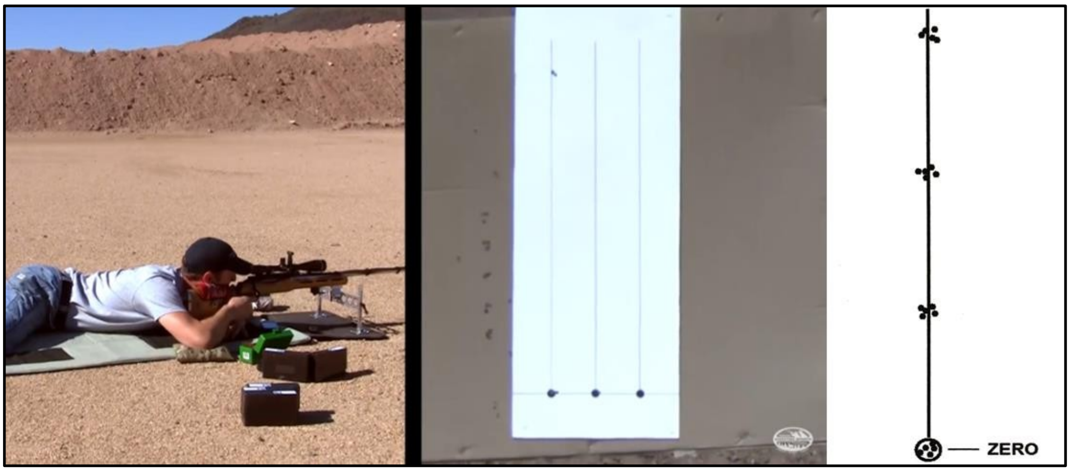


Figure 18 Ballistician Bryan Litz conducting a Tall Target Test.

Source: Bryan Litz, "Applied Ballistics for Long Range Shooting" Screenshot of instructional video accompanying the original book (retrieved September 16, 2021)

The real problem of gun face tilt angle refers to the man-made problem that makes the vertical plane formed by the sniper scope and barrel axis tilt to the right or left before shooting, even if the tilt angle is very small (the general error of human eyes is about plus or minus 3 degrees) the barrel axis pointing will still deviate from the original vertical plane, resulting in the trajectory level deviation, with .308 Win. ammunition tilted at a 3-degree angle to shoot at an IPSC target. Take .308 Win. ammunition tilted at an angle of 3 degrees to hit the IPSC standard target as an example, at 600 yards, the point of impact will be horizontally shifted by about 17 centimeters and will be off target. (Fig. 19) However, although the tilt angle problem affects the impact of the bullet, it is also one of the factors affecting the point of impact that is easiest for snipers to overcome. Generally speaking, all that is needed is to install an Anti-Cant Bubble Level/Scope Level on the scope, and then use the light out of the corner of the eye to confirm whether the bubble is centered or not (or at least confirmed to be roughly centered when shooting time is tight), and then the target can be controlled. When you check whether the bubble is centered before shooting (or at least roughly centered if you have a tight shooting schedule) you can control the tilt angle within 1 degree.

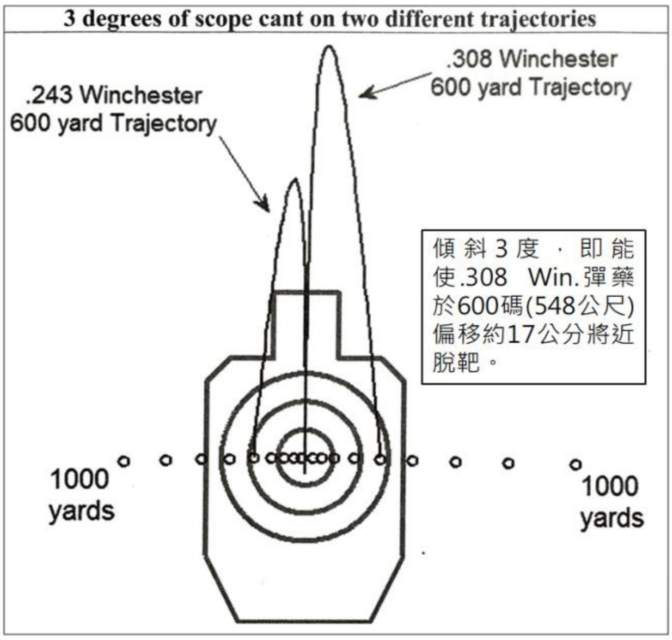


Figure 19 Schematic diagram of the trajectory offset for a 3 degree inclination angle shot

Source: Bryan Litz, Accuracy and Precision for Long Range Shooting (U.S.A., Applied Ballistics, LLC, 2012), P95. (retrieved September 16, 2021)

6. Scope Correction Factor (SCF)

Correction factor is a factor that compensates for the error between the movement of the mean point of impact (MOA) and the actual movement of the scope after the adjusting screw has been turned for one click. The above vertical target test can be used to observe the relationship between the number of clicks and the movement of the average point of impact, and then convert the actual correction amount per click of the scope to obtain the correction amount coefficient (applicable to both MOA and meterscope) Taking the example of the national T93K1 sniper rifle with TS95 sniper scope shooting at a 100 meter vertical target, assuming that the 10MOA adjustment should theoretically raise the impact by 29 centimeters, however, the actual shooting reveals that although the group of bullets meets the accuracy requirements, the average point of impact is only 28 centimeters higher, which translates to a real correction of only 0.966 MOA (28/29) for every 2 clicks (1MOA), and the correction factor for the scope is 0.966 MOA (28/29) 2 clicks. The correction factor of the scope is 0.966. Therefore, when shooting at a target of 800 meters, theoretically, the elevation (number of impacts) required to compensate for its fall value is 32MOA (64 impacts) but since the correction factor per impact is 0.966, rotating the 64 impacts will only provide a ballistic compensation of about 30.9MOA, which is insufficient to meet the requirement of 800 meters. It is necessary to rotate 33MOA (66 repercussions) in order to obtain the full 32MOA of ballistic compensation. Although the effect of this correction coefficient is not significant at short and medium ranges, when the range increases, especially when shooting over 1000 meters, the number of impacts that need to be compensated will increase. If snipers do not have this concept or deliberately ignore it, it will result in a serious lack of correction and a low point of impact.

(d) Whether accurate zeroing has been completed:

The relationship between range and angle of fire is based on internal and external ballistic calculations and should be accurate. As long as the distance to the target is correctly estimated and the barrel is given a specific angle of fire, the projectile should hit the point of aim on the target without regard to accuracy. However, the above statement is purely theoretical. Whether or not a projectile will hit the point of aim on the target is closely related to how the shooter zeros in on the target. The so-called Zero/Zeroing refers to adjusting the sights (elevation and windage adjusting screws) barrel a specific elevation and direction angle, so that the direction of the trajectory is correct, and at the same time to allow the center of the group of bullets (i.e., the trajectory) and the second intersection of the line of sights in the Zero Range, so as to achieve the goal of the gun to be one with the gun, and to achieve the goal of an accurate hit. Since the acquisition of shooting parameters above 600 meters distance is highly dependent on the assistance of a technologically equipped ballistic calculator, the reason why the ballistic calculator is able to calculate the required angle of fire (compensation angle) at the desired shooting distance, in addition to the actual measurement of ammunition capacity (such as ballistic coefficients and muzzle velocities) and environmental factors (such as wind and air density), it is also because we informed the ballistic calculator of the two important benchmark parameters, i.e., zero range and the second point of intersection of rifling and aiming line, to achieve the purpose of the gun and accurate hits. Zero Distance and Bore Height (the difference in height between the center axis of the scope and the barrel axis) Using this as a reference point, the ballistic calculator is able to calculate the additional angle of fire (impact) produce the second meeting point of the trajectory at the new distance. Therefore, if the sniper's zeroing result is inaccurate at the beginning of the zeroing process due to man-made problems such as shooting stability, shot distribution control, or bullet correction, or if the rifling height is incorrectly measured, resulting in a difference of more than 1/4 inch (0.65 centimeters) height entered into the Ballistic Calculator and the actual rifling height of the gun, a datum error is very likely to occur, and a discrepancy will occur between the value predicted by the Ballistic Calculator and the actual required corrected impact number. The difference between the ballistic calculator's predicted value and the actual corrected magnitude is likely to result in a datum error.(Figure 20)

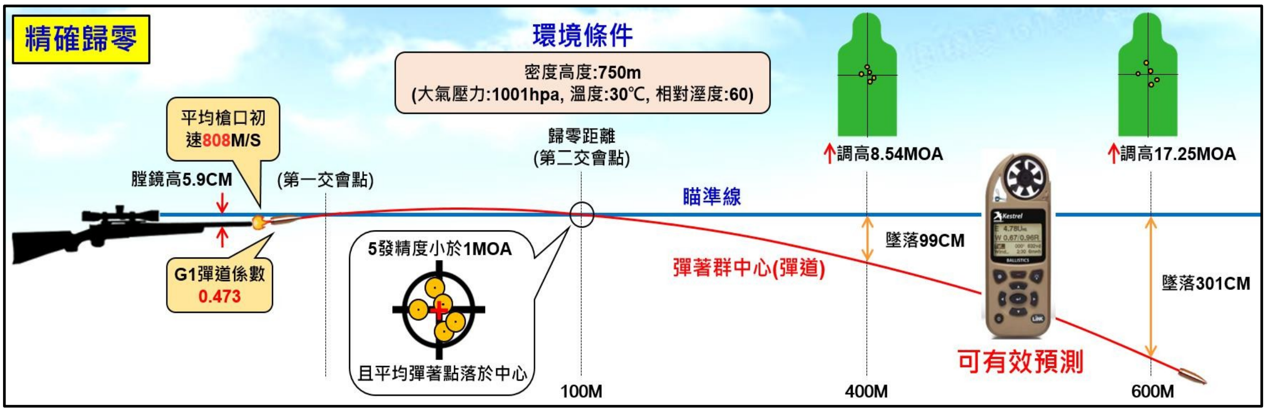


Fig. 20 Precise zeroing is the key to the accuracy of ballistic computers in predicting trajectories.

Source: author's survey (November 8, 2021)

Therefore, is the sniper able to zero accurately? This is the key to whether the ballistic calculator can accurately predict the trajectory. In order to accomplish precise zeroing, the author has collected professional books and experts' practices, and has organized the following important concepts or application methods for readers' reference:

First, the distance to zero must be measured carefully, and it is recommended to use more than two laser distance measurement devices.

The laser rangefinder or a laser rangefinder with a tape measure of 100 meters for duplicate verification (when using a tape measure, be sure to tighten both ends and measure in the air, not along the ground undulation, to avoid the results of the measurement and the actual error is too large) Unless you have measured the distance yourself, you should not trust the distance indicated by the existing shooting line on the range.

Secondly, the zeroing target paper used must have the same grid as the adjusting screw unit of the scope (e.g., 100 meters with 1 grid of 0.5MOA or 1 grid of 0.1 meters) in order to facilitate the measurement of deviation and the conversion of the required correction amount. If the pattern of the bull's-eye can be matched with the design of the cross-hatch in the scope, such as "circle on circle", "line on line", or to facilitate the cutting of smaller targets into equal portions, it will be a better target paper. (As shown in Fig. 21) In this way, it can fulfill the maxim of sniping: "Aim Small; Miss Small." The more the shooter focuses or the more the target is divided, the better the target paper will be. The more the shooter focuses on or has the ability to control the relationship between the sight picture and the target more correctly, the more it will reduce the deviation of the point of impact caused by the shooter's aiming error, and the denser the group of bullets will be. Of course, in order to avoid additional aiming or bullet deviation, the elimination of pre-mirror parallax, the confirmation of the tilted state of the gun, the adjustment of the shooting posture (to ensure that the muzzle of the gun can still achieve the natural pointing of the first principle of the whole body muscle relaxation) and even to maintain the consistency of the shooting state of the whole process of zero (such as not adjusting the height of the tripod in the middle of the process, changing the degree of the grip on the ball of sand, changing the position of the buttstock and the contact position with the socket of the shoulder, changing the position of the cheekpiece in front of the back, or the height of the cheekpiece). position, etc.) are all details that must be closely controlled throughout the zeroing process.

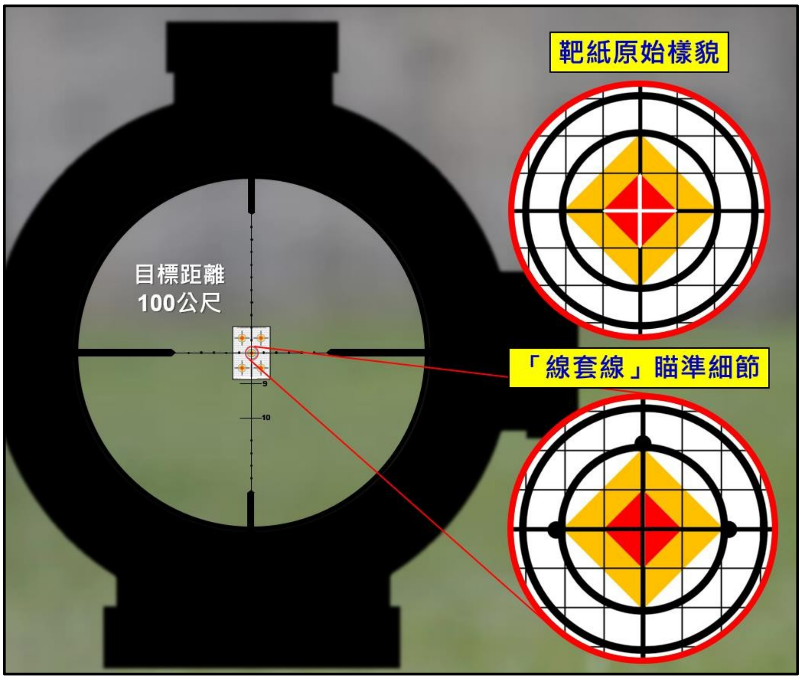


Fig. 21 Schematic diagram of the concept of "Aim High; Error Low".

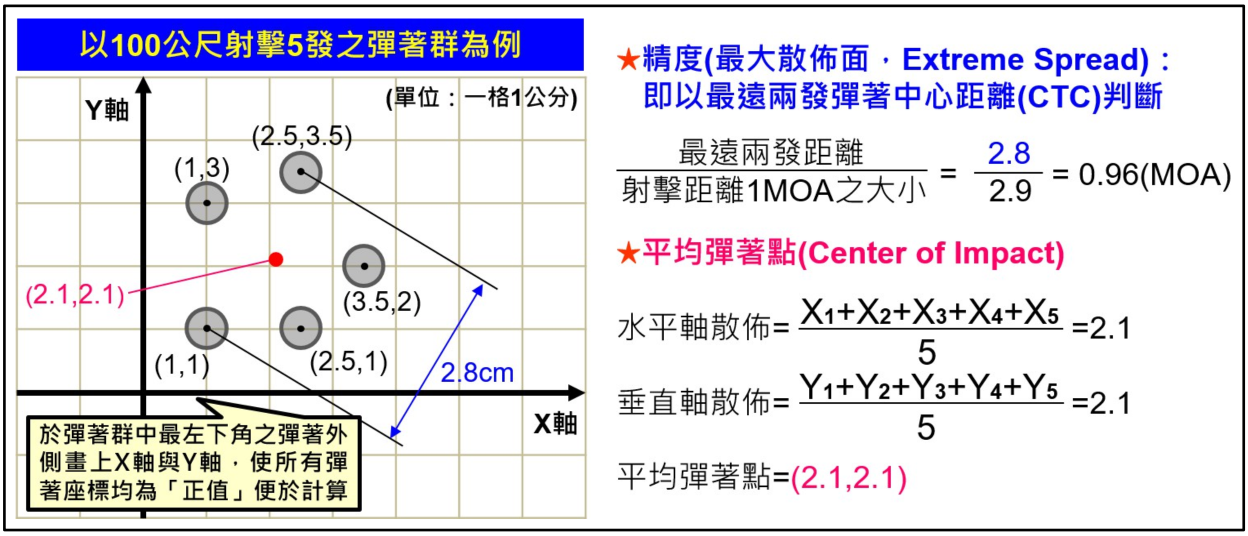
Source: author's survey (November 12, 2021)

Thirdly, at least 5 rounds will be corrected as 1 ballistic group. The correction is made by taking 5 rounds of a ballistic group.

The average point of impact is more representative and usually closer to the true center of the trajectory than for 3 rounds, in order to

This is the basis on which the bullet correction can be made more accurately. However, because of the manual calculation of the level of the 5 rounds of the load group, it will be more accurate.

The average point of impact is more complex and time consuming (Figure 22) and it is recommended that accuracy measurement software such as SubMOA, Ballistics X, etc. be downloaded to assist



in the calculation to increase the efficiency of zeroing. Unless the clusters are very dense and almost perfectly overlapping, it is important not to determine the mean point of impact directly by visual inspection.

Fig. 22 Manual calculation of precision and mean point of elasticity

Source: author's survey (November 12, 2021)

In addition, since it is difficult to maintain the same accuracy as 3 rounds for 5 rounds, it is suggested to refer to the book "Modern Advancements in Long Range Shooting" by Bryan Litz, "Conversion Theory of Different Number of Shots and the Size of the Bullet Groups", p.8, author.

After collecting large amount of data, it is found that the size of a 5-shot distribution is usually about 1.28 times the size of a 3-shot distribution. It is

Therefore, if the original shooter adopts 3 rounds and 1 group for zeroing, the best accuracy can reach 0.8MOA, then if the shooter wants to change to 5 rounds and 1 group for zeroing, and the accuracy can be maintained within 1MOA, it is qualified (0.8MOAX1.28 times), and the average point of impact can be calculated and adjusted accordingly.

Fourth, referring to page 3-51 of the U.S. Army Specialty Sniper Field Instruction (FM3-05.222), the zeroing distance recommendation should be:"Zero at 200 meters to correct for elevation, 100 meters to correct for windage, and if the windage is also zeroed at 200 meters, make sure to do it in windless conditions to avoid windage error.

The windage should be zeroed at 200 meters to avoid windage error.

Why was 200 meters chosen as the precise zeroing distance? The reason is closely related to the ballistic trajectory. Taking the simulated ballistic trajectory of a TC94 sniper round as an example, when 100 meters is chosen as the distance to zero, its first meeting point falls at about 67-70 meters, and then it rises by only 0.2 centimeters and falls to about 1.5 meters.

The second meeting point is at 100 meters. From the data, it can be found that the zeroing trajectory of a sniper rifle is not a typical rifle with an obvious parabola between the two trajectory intersections, but a trajectory that is very close to the aiming baseline and similar to a straight line. Within the range of 100 meters, the normal bolt-action sniper rifles can achieve an accuracy of about 0.5 MOA under the best conditions, but the difference in height of the zeroing trajectory of a sniper rifle from 100 meters is less than 0.5 MOA (about 1.5 centimeters) within the range from 50 meters to 130 meters. MOA (about 1.5 centimeters, making it difficult to detect the true height of the ballistic trajectory) so it is impossible to ensure that the muzzle has been given a specific elevation angle by a live round.

So that the second meeting point of the trajectory falls perfectly at 100 meters? And what if the return could be implemented at 200 meters instead?
Zeroing, the first point of convergence is approximately 33 meters, and within the very short distance of 190 meters to 210 meters, the ballistic trajectory elevation already produces a 0.3 MOA (approximately 2 centimeters) difference sufficient to perceive the point of impact. Therefore, the use of the traditional 100-meter distance for zeroing the angle of projectile elevation will likely result in a higher impact point at longer distances than the traditional 100-meter distance.
At a range of 800 meters, it produces an error of nearly 1MOA (about 20 centimeters) This is not to mention that the ballistic impact will be even greater when shooting at ranges of 1000 meters or more. However, if the environmental conditions of the range do not allow
(e.g., if wind interference is high) conventional 100-meter zeroing is preferred.

Fifth, regarding the control of the final zeroing quality, it is recommended to aim for the distance between the average point of impact of the last group of rounds (at least 5 rounds) and the zeroing aiming point to be less than 1/2 of a round correction. Taking the TS95 sniper scope as an example, since each shot is 0.5 MOA, the distance between the above two must be controlled to be less than 0.25 MOA. However, whether such a high quality can be achieved depends on the actual integration of the gun, scope, and ammunition, and whether the shooter can maintain consistent and stable shooting during the zeroing process.

(v) Mastery of environmental and climatic factors:

As mentioned in the previous section on the definition of long range (1000 meters or more), for most sniper ammunition, when the warhead travels more than 1000 meters, the trajectory of the ballistic missile itself is subject to a wide range of controllable and uncontrollable internal and external influences, to the extent that it may not be able to make a significant difference. Especially the mastery of environmental and weather factors. In terms of the practical point of view of ultra long-range shooting, it can be divided into three aspects, namely, the mastery of temperature and muzzle velocity, the mastery of air density, and the influence of thermal disturbance, and so on, which are explained in the following order:

1. Mastery of temperature and muzzle velocity:

   It is mainly to explore the relationship between ambient temperature and the burning rate of gunpowder. According to the official data of Applied Ballistics, Inc., the rate of increase or decrease in the burning efficiency of propellant and muzzle velocity of small caliber sniper rounds as a result of changes in ambient temperature is about 1°C. The rate of increase or decrease in the burning efficiency of propellant and muzzle velocity of small caliber sniper rounds is about 1°C. The rate of increase or decrease in the burning efficiency of propellant is about 1°C.

   When the temperature changes by about 10 degrees, the muzzle velocity increases or decreases by 3.25 feet per second. Therefore, when the temperature changes by about 10 degrees, the muzzle velocity will change to a certain extent, thus affecting the trajectory. The same is true for a 10 meter per second increase in muzzle velocity due to a change in the rate of ignition of the ammunition as a result of exposure to the sun. As Major John L. Plaster of the U.S. Army Special Forces Reserve stated in his book "The Ultimate Sniper", snipers must maintain the consistency between the temperature of the ammunition and the temperature of the environment, for example, avoiding carrying ammunition close to the body in winter, loading ammunition into an overheated chamber, or exposing ammunition to the sunlight...etc., which are the reasons for snipers to use ammunition at long range. Snipers should pay special attention to this when shooting at long range.

2. Mastery of air density:

   The main focus is on the relationship between air density and air resistance. When a warhead is flying in the air, if the density of the air in the environment is different, the actual air resistance of the warhead will be different.

This will make the ballistic trajectory change to a certain extent. Generally speaking, the environmental factors affecting the air density are altitude, atmospheric pressure, temperature, relative humidity, etc. Therefore, snipers must measure the environmental parameters before shooting in order to make appropriate ballistic corrections. However, traditional snipers have to examine the effects of "altitude, atmospheric pressure, temperature, and relative humidity" on the ballistic trajectory to calculate the actual effects on the ballistic trajectory. Since the calculation is too complicated and not in line with the timeliness of firing, the practical value is not high. After referring to the relevant literature and professional books of the advanced countries on ultra-range firing, the authors found that most of the ultra-range firing shooters use the "Density Altitude" (DA) as an index to measure the air density. The so-called Density Altitude (DA) refers to the density of the air at the location, which is equivalent to the density of the air at a certain altitude under standard atmospheric conditions (Figure 23) It can be calculated from temperature, atmospheric pressure and humidity, or read directly by a Kestrel 4000 or higher grade wind meter. The higher the density altitude, the lower the air density and the higher the trajectory. Knowing the density altitude can shorten the time required to enter environmental parameters into the ballistic calculation software or simplify the traditional manual calculation procedure, which is an important reference for environmental factors affecting the ballistic trajectory. After all, as far as the warhead itself is concerned, it does not distinguish between temperature and humidity or atmospheric pressure during flight, but only cares about how much air resistance is caused by the overall density of the generated air, which in turn affects flight. Therefore, for ultra long-range firing, in order to more accurately grasp the environmental factors and make appropriate ballistic corrections, "density altitude" becomes a more efficient and feasible method.

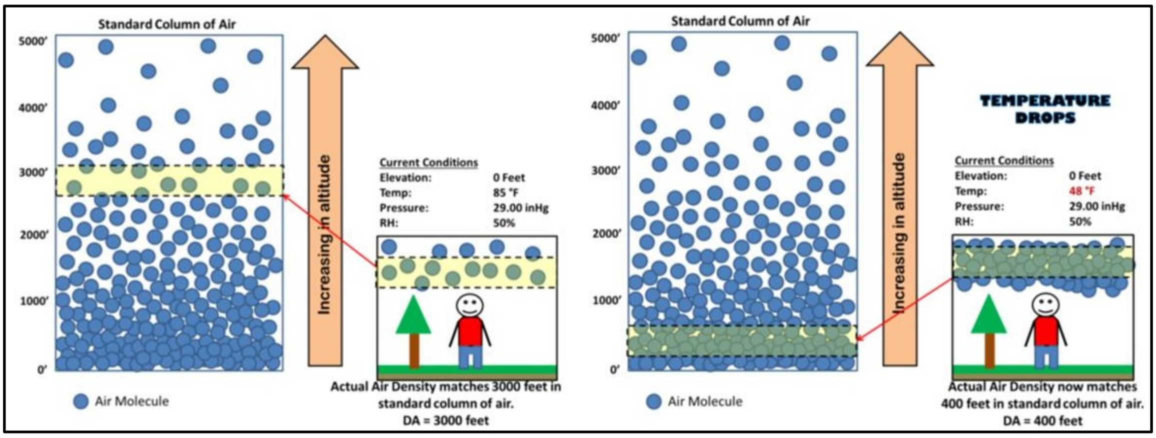


Figure 23 Density Height Schematic

Source: kestrel official website (kestrelmeter.com)(retrieved September 16, 2021)

3. Thermal disturbance effects:

It refers to a phenomenon in which light is refracted due to the heat flow rising from the earth's surface or the existence of different density and temperature changes in the air layer, resulting in a mirage-like (i.e., the original meaning of the word "mirage") view. Usually, the hotter the weather, the higher the surface temperature difference, the higher the humidity, or the higher the magnification of the scope, the more pronounced the effect of thermal disturbances, the greater the impact on the aiming and accuracy, which is one of the main environmental factors affecting the accuracy of ultra-telephoto shooting. (Figure 24)

Figure 24 Schematic diagram of the effect of 1000 meter thermal disturbance on viewing effect.

Source: Photo by author (August 23, 2021)

(vi) Ballistic calculator operation:

Can range setting and wind deflection corrections be accurate when shooting over long distances? It depends on how the sniper obtains the ballistic parameters. Currently, the most practical and scientific method is to obtain the ballistic parameters by means of a ballistic calculator (software). However, the operation of the ballistic calculator is highly specialized and all input parameters must be accurate (especially the above mentioned ballistic coefficient and muzzle velocity, which are the two key parameters determining the performance of external ballistics) otherwise, it will be impossible to obtain the accurate values. This is also a very important concept for modern snipers when using ballistic calculator: "If you want to have accurate output parameters, it depends on whether you have accurate input parameters (Garbage in, garbage out.)Don't reject or even abandon the ballistics calculator just because the output value is different from the actual value; and don't arbitrarily adjust the trajectory coefficient or muzzle velocity just to match the output value with the actual value, which may result in a bigger error in the output parameters of other distances. Therefore, how to operate the ballistic calculator "correctly", and then scientifically enhance the effectiveness of ultra long-range shooting? This has become one of the topics that modern snipers must study in depth.

The logic behind the current advanced ballistic calculation software is basically the same.

[13]However, some of the free software has the problem of insufficient parameter input items (over-simplified design) to

Due to the inaccuracy of the results obtained, based on the author's experience in live firing, it is recommended to use the Kestrel 5700 Elite wind gauge with built-in ballistic calculation function or the Trasol or other ballistic calculation software (machine) with higher accuracy to ensure better ballistic parameters are obtained. In general, under the condition that all input parameters and settings are correct, the ballistic velocity of the bullet is lower than Mach 1.3 (about 442 meters per second) in the front range (about 700 meters for TC94 sniper rounds and about 1000 meters for M33 regular rounds), and the ballistic velocity of the bullet is lower than Mach 1.3 (about 442 meters per second) in the front range.

[13] Current ballistic calculation methods can be categorized into at least four types: Siacci, Pejsa's, Point Mass, and 6-DOF Simulations, as described in the article "How External Ballistics Programs Work" by Bryan Litz, a practical ballistician from the United States. methods. Although each method requires different input parameters or models and produces simulated ballistics in a different way, the authors of the article consider it more important to explore which method produces more accurate ballistics. More importantly, it is better to try to ensure that all input parameters are as accurate as possible in order to obtain accurate ballistic parameters.

Error can be controlled within 0.5-1MOA. If you find that the difference is too large, you can first check whether there is any parameter input error or setting error according to the contents of this article.

"G1/G7 ballistic coefficient model is incorrectly set, the latitude of the location or the direction of fire is not set (this will change the degree of influence of the Coriolis force) the right deflection and Coriolis force calculations are not turned on (in this case the ballistic calculator will simply output the wind deflection correction parameter) and the unit of the output parameter is incorrectly selected (MOA/meters/centimeters/inches)". If all parameters and settings are correct, then consider whether the speed of the bullet has entered the subsonic range at that range. In this case, it is recommended to use the G7 ballistic coefficient if the original setting was G1. If the original setting was G7 and the velocity of the round is below the speed of sound at that distance, the Kestrel 5700's built-in DSF calibration can be used to correct the drag coefficient value that has changed as a result of the reduced muzzle velocity, thus restoring accuracy to the trajectory.

[14]However, for DSF calibration with live ammunition, Bryan Litz, a practical ballistics expert in the US, recommends that a minimum of 5 rounds per group with a dispersion of less than 0.5MOA should be used as a baseline for accuracy (i.e., it is not recommended that DSF be corrected if it does not meet this requirement, which is evident that DSF is extremely difficult to implement) Due to the above unavoidable errors in the G1/G7 ballistic coefficients, the U.S. Department of Ballistics (DOB) has developed a new ballistic coefficient for the G1/G7.

Bryan Litz suggests the use of a Custom Drag Model (CDM) which uses at least 200 rounds of live fire and a radar wave velocity meter to actually collect the average ballistic changes at various distances, and then builds a complete model that perfectly matches the ballistic performance of the round. However, since there is no such type of ballistic laboratory and equipment in China, it is impossible to obtain customized resistance model parameters. Therefore, for practical consideration, snipers should at least choose to use G7 ballistic coefficients to meet the basic needs of long range shooting.

(vii) Range error control and range setting:

Is the range determination accurate when shooting at long range? Each range measurement method has its own theoretical error, and the range tolerance depends on the characteristics of the ammunition used by the shooter.

(For example, for 7.62mm sniper rounds, the tolerance range at 600 meters can be within plus or minus 8%, which means that if it can be controlled within this range, and the range can be scientifically fitted, the ballistic drop will be less than plus or minus 50 centimeters, and it will not be off-target when shooting at a standard humanoid target of 50X101 centimeters;

12.7mm sniper rounds at the same distance, because the trajectory is more low-extended, the range error tolerance can be increased by plus or minus 10%) usually using the meter position or MOA mark in the scope to achieve the above error control. However, it is a completely different story when firing at long range, even with the LRF (Laser Rangefinder) technology.

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[14] For example, the Kestrel 5700 Elite has a built-in DSF (Drag Scale Foctor/Drop Scale Foctor) correction function, which is to correct the drag coefficient at the end of the trajectory, and it is usually recommended to use the distance at which the bullet enters Mach 0.9 (i.e., about 306 meters per second) at a speed of 80-90% of the distance as a benchmark. Calibration distance (Take the example of the T93K1 sniper rifle with TC94 sniper bullet, it enters 0.9 Mach at 1080 meters, so it is recommended to correct the distance between 864-972 meters) After the bullet reaches this distance, the muzzle velocity decreases, the drag coefficient changes, and the ballistic coefficient also changes. If the original ballistic coefficient is still used, it will not be able to meet the actual trajectory height. Therefore, it is necessary to verify the ballistic trajectory at the proposed calibration distance, enter the difference between the actual and original adjustments, and then the software will calculate a correction factor for the ballistic coefficient at that distance (and beyond), thus completing the DSF calibration.

Auxiliary assistance may not always be able to fulfill the purpose of ballistic correction. Take the example of a commercially available laser rangefinder, which has a range error of less than plus or minus 1% of the normal standard. Using the Kestrel 5700's built-in Elite Ballistics function to simulate the trajectory of a .50-inch M33 round (with an average muzzle velocity of 880 meters per second), it can be found that when a 1,000-meter shot is fired, the error of plus or minus 1% is less than the normal standard.

The maximum distance misjudgment of 10 meters will be generated, which will make the actual installed range higher or lower than the actual ballistic range of about 0.5 MOA (15 centimeters), resulting in a lower hit rate, so the farther the distance of the shot, the more important the distance determination and the control of ranging error.

(H) Wind reading and wind deflection correction: Wind is the biggest uncertainty that affects the impact point when shooting at long range, however, if it can be accurately read and corrected, it will be the most effective way to improve the hit rate at long range. Therefore, before shooting, what are the snipers' basis and considerations for reading wind speed and wind direction and correcting wind deflection? Are the wind speed and direction measured by a wind meter? Or are they just rough guesses based on visual inspection and experience? (It is observed that the use of anemometers by snipers in the National Army has not been popularized yet.) If anemometers are not available, what can be done to improve the accuracy of wind speed and wind direction? When the terrain has obvious ups and downs, are advanced concepts such as wind speed gradient and wind layer height taken into consideration? Can different wind conditions in the near, middle and far ends be grasped? Most importantly, is it possible to implement wind bias calculation based on scientific wind direction correction coefficients? Instead of using the traditional clockwork method (e.g., 1-2, 4-5, 7-8, 10-11 o'clock can be regarded as half-value winds, so the wind deflection value is multiplied by 1/2) the constants of the clockwork method have been simplified to make it easier for snipers to calculate the empirical values in the field, which is feasible in the case of close range and low wind speed, but will not be possible when the range is increased (especially for the ultra-long-range shooting in the present paper) or when the wind speed increases to over 10 miles. However, when the range increases (especially in the case of long range shooting discussed in this paper) or the wind speed increases beyond 10 mph, the sniper will not be able to shoot accurately. The reason is that there is a discrepancy between the constants of the clockwork method and the theoretical effect of different wind directions on wind deflection, and this discrepancy is the mystery of long-range shooting according to Emil Praslick III, a well-known wind deflection expert in the United States. Or is the effect of crosswind bounce taken into account when there is a homogeneous crosswind with a wind speed greater than 10 mph at the near end of the shooter (within 100 meters)? (For more information, see Infantryman's Quarterly No. 282)

A Study on the Effects of Wind on Long-Range Precision Shooting of Sniper Rifles (〈風力對狙擊槍遠距精準射擊的研究〉一文)

(ix) Consideration of rightward flow and Coriolis force: Is the amount of rotational deflection produced by the right-hand rotation of the bullet (commonly known as rightward flow) combined with the effect of the Coriolis force in the northern hemisphere to be taken into account in the correction? Although for most ammunition characteristics, the effect of Coriolis forces at all distances is only about one-fourth or one-fifth of the rotational deflection of the warhead, and therefore most shooters choose to ignore it and not correct for it. **However, the essence of precision shooting at long distances lies in "fully controlling the controllable factors and minimizing the effects of uncontrollable factors".** During the flight of the bullet, the rightward deflection due to the high-speed rotation of the bullet itself and the influence of the Coriolis force is an inevitable phenomenon. Instead of ignoring it and not correcting for it, it is better to combine the rightward deflection caused by the rightward rotation of the bullet and the rightward deflection caused by the Coriolis force to form the "Combined Deflection".

The "combined right deviation" is corrected in advance and eliminated (**i.e., the spirit of fully mastering the controllable factors is realized**) Using the Kestrel 5700's built-in Elite Ballistics function to simulate an approximate U.S.-made M33 common bullet (661 grains) under the conditions of 23 degrees north latitude, density altitude of 1,000 meters, and an average muzzle velocity of 880 meters per second, the combined right-hand deflection values are as follows: 1,000 meters 0.9 MOA, 1,100 meters 1.1 MOA, 1,200 meters 1.25 MOA, 1,300 meters 1.25 MOA, 1,300 meters 1.25 MOA, 1,000 meters 1.25 MOA, and 1,000 meters 1.25 MOA. 1.25MOA, 1300 meters 1.5 MOA, 1.7 MOA for 1400 meters, 1.9 MOA for 1500 meters, available for reference.

Conclusion

The long-range shooting above 1000 meters is often neglected in the training of snipers in the National Army. Since most of the snipers at this stage are still weak in the concept of scientific ballistic application, the effectiveness of the shooting is not satisfactory even though they have had a number of opportunities to validate the long-range shooting. The author of this paper has been working as a sniper instructor in the Infantry Department and has been engaged in teaching and training for many years, and he is aware of the difficulties faced by domestic snipers' training resources, so he has devoted a lot of efforts to studying the theory of scientific ballistics, collecting advanced scientific ballistics knowledge and technology from overseas and compiling relevant teaching materials, and this paper is part of the results of this study.

The application of scientific ballistics, although it may not be able to achieve "immediate effect", has the effect of "subtle influence", and it is an important method that snipers must be proficient in if they want to break through the bottleneck of long-distance shooting. It is hoped that this study will encourage the sniping troops of the National Army to pay attention to the practical benefits of scientific ballistic application, and try to rectify the past practice of relying on empirical parameters (careful aiming) to the practice of relying on ballistic data (careful calculations), which will surely lead to the development of the most powerful weapon in their hands.
(Heavy Sniper Rifle) which is utilized to its fullest extent by the Soldier (a sniper with ballistic thinking and technology), creating the advantage of a

long range of over 1000 meters.

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