ADVANCED RIFLE TRAINING

FOR THE

OBSERVER/SNIPER

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Advanced Rifle Training for the Observer/Sniper

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1. Definition

The military definition of a sniper is "an individual highly trained in field craft and marksmanship who delivers long range, precision fire at selected targets from concealed positions." Although accurate for the military sniping mission, this definition is too broad in scope for the concept of snipers in law enforcement.

Military snipers act independently against a wide variety of both specified targets and targets of opportunity. They need not be concerned with questions of authority to act, criminal and civil liabilities, innocent bystanders, or the necessity to justify their actions in court after the fact. They operate in a hostile environment in which friends and foes are clearly delineated.

Military snipers will generally engage targets at extreme ranges in order to better avoid detection and counteraction by the enemy. Thus a military sniper need not be concerned about the effects of shooting. A killing shot is as good as a wounding one. Either will remove an enemy from action. There are no hostages or victims whose welfare would be imperiled by a miss or a wounding shot. Further, identification of the target is not as critical as it is in civilian law enforcement.

In war, everyone on the other side of the line is an enemy against whom the application of force is proper. Destruction of the enemy is the goal, and to attain that goal military force is brought to bear against both the enemy and the environment in which the enemy operates.

In addition to shooting, the military sniper's mission includes a function that is shared in its entirety with the law enforcement sniper. This is the observation and reporting of intelligence, a function which is crucial to the success of law enforcement operations.

By virtue of training, position, and optical equipment the sniper has the best vantage point and ability to observe and report activities and information about subjects, hostages, and the locations in which they are situated. This intelligence has unique value to all facets of crisis management in law enforcement, including assault planning, negotiations, and decision-making.

Accordingly, the mission of the sniper in law enforcement is more specific and detailed. It must account for the need to operate in a friendly civilian environment in which indiscriminate destruction is not allowed. It must account for the responsibility to act in a manner that does not unnecessarily endanger the lives of hostages or bystanders. It must account for the need to operate within the law and have those operations subsequently reviewed in court. Further, the law enforcement sniper must be absolutely sure of the identity of any target to be engaged.

The requirement for absolute identification is the single limiting factor that governs the range at which the law enforcement sniper can reasonably be required to engage a target. Although the marksmanship skills necessary to hit a man sized target at extreme range are readily taught, positive identification is difficult if not impossible at ranges in excess of 200 yards.

The law enforcement sniper is an individual highly trained in marksmanship, field skills, and observation who delivers precision fire on positively identified targets *ONLY* upon command from legitimate authority. This individual is called an Observer/Sniper.

2. Concept and Utilization

The Observer/Sniper is an integral element of Specialized Weapons and Tactics Training, and as such is a vital part of crisis management. Crisis managers are taught to take two immediate actions in the event of a crisis such as a hostage situation or barricaded subject. These actions are to deploy Observer/ Sniper Teams and initiate contact with trained Hostage Negotiators.

The immediate deployment of the Observer/Sniper Teams is twofold in importance. First and foremost, from their positions and with the optical equipment available to them, they can collect and relay vital intelligence about the situation. The primary intelligence objectives are to identify all the players in the crisis situation; to identify any and all weapons and explosives; to develop group and individual profiles including patterns, locations, and tendencies; and to analyze the crisis point.

The greatest errors committed by Observer/Sniper Teams are failing to report what is seen in complete detail; failing to report the intensity of observed activity; and failing to utilize the optics. There is a tendency to try to be too physically close to the target area.

Examples of the specific intelligence available are listed in the table below.

Examples of Specific Intelligence

Subject descriptions
Hostage descriptions
Subject/Hostage locations
Weapons
Entry points
Location description
Construction details
Photographs
Activities
Patterns of behavior
Avenues of approach
Avenues of escape
Obstacles to approach
Booby traps
Alarm systems
Animals
Ventilation systems
Water supplies
Power sources
Flammable substances
Door/window details

An excellent, and often overlooked, role that can be played by Observer/ Snipers is providing photographic intelligence from their advantageous positions. The more detailed the intelligence that is reported, the better and more effective are the planning and subsequent actions of the decision makers in command.

Secondly, by putting Observer/ Sniper Teams in place, the option of resolving the incident by sniper fire is available should innocent lives be in imminent danger of loss and the option of tactical assault either unwanted or unavailable.

When a tactical assault is to be made, the assault teams will approach under the covering surveillance and control of the Observer/Sniper Teams. In direct communication with the assault teams, the Observer/Sniper Teams will advise them when it is clear to move; when they should maintain position for fear of discovery; and if the element of surprise has been lost, order the assault executed immediately.

The latter is called "Compromise" authority. Once an assault team has passed the point of no return and loses the element of surprise prior to the assault, the "Compromise" signal keys the immediate execution of the assault plan. The "Compromise" signal can be initiated by any member of the tactical unit who identifies the loss of the element of surprise.

Coordinated sniper fire can also be utilized as a planned diversion for assault team entries, or against targets of opportunity in concert with the entry. After assault team entry, the Observer/Sniper Teams are responsible for identifying subject escape attempts; attempts at rescue or assistance by confederates or sympathizers outside the location; and hostage/victim escapes.

The reluctance of command authority to authorize the use of Observer/ Sniper fire must be resolved prior to any actual utilization of Observer/Snipers. The killing of one or more subjects can be perceived as an execution when done by sniper fire from distant and hidden positions.

However, in actuality it is extensions of the well accepted, and legitimate, policy of shooting to protect life and prevent grievous bodily harm. Sniper fire should be authorized only in accordance with that policy. Where feasible, and within the guidelines of protecting innocent lives, the utilization of sniper fire is far preferable to making a tactical assault. It is a tactically clean measure that does not expose other officers and agents to the risks and hazards of a close range assault.

Prior to deployment several operational matters must be defined relative to the Observer/Sniper Teams. Teams should be thoroughly briefed regarding their missions for the periods before, during, and after any assault. Key times for supply, relief, and rotation must be decided. Proposed initial positions must be identified, as well as the locations of other Teams and elements. Each Team must be allowed to select its own position, subject only to the needs of the mission as defined for the incident.

It is vital that the position chosen be sufficiently close to allow effective observation yet far enough from the site to insure concealment of the team. Positions must be at a sufficient distance from the target site to avoid detection and remain concealed, yet close enough to allow positive identification of targets and to assure a first shot kill. Communications and reporting codes must be standardized. And lastly, the authority and rules of fire must be defined.

The latter is a critical matter. The authority to order sniper fire must be specifically defined and invested in one command figure. There is no margin for any confusion among deployed Observer/Sniper Teams as to whether or not an order to fire is duly authorized. Often, the tactical commander will be the individual to order sniper fire after authorization is given by higher command. This is done because the tactical commander's voice will be readily recognized and thus eliminate possible confusion over the validity of the order.

Further, rules of fire must be decided for exigent situations. Observer/Sniper Teams must know when and under what circumstances they can fire. To illustrate: what if hostages are being harmed, or the assault team is about to be ambushed, or if outside confederates appear and threaten violence, or if subjects present the clear opportunity to fire? These examples are a few of the issues that must be considered in establishing rules of fire. As a guide, rules of fire should be grounded in policies of clear defense of self and others.

An Observer/Sniper Team is composed of two men, both equally trained in marksmanship, field craft, and observation. The duty cycle for an Observer/Sniper Team should be four hours in position, with responsibility on the rifle rotating every 30 minutes. The team member not on the rifle is the primary observer, log keeper, and communicator. Time on the rifle is devoted to maintaining the critical concentration necessary to make the shot no matter how suddenly it might be ordered. That level of necessary concentration cannot be maintained longer than approximately 30 minutes at a time.

Ideally, two Teams (four men) will be assigned each subject in an incident to better assure a killing shot should one be ordered, and to better insure that each subject is in view of at least one Team at all times. In reality, that many trained individuals are seldom available, nor is a four hour duty cycle always possible.

For example, in a Midwestern city a police Observer/Sniper who made a successful shot had been in position by himself for almost 12 hours before the shot. By his own account, the only reason he was able to make the shot was because the subject happened to peek out an opening at the precise moment the officer happened to be looking there through his scope. He had been authorized to shoot hours before, but the subject never showed himself until that moment.

Realistically, almost all crisis situations in the United States involving hostages or innocent lives are resolved through negotiation. Accordingly, the intelligence function of the Observer/Sniper Teams in concert with the efforts of the Hostage Negotiators is the most important function of the Teams in actual situations. Nevertheless, the potential to resolve the situation by sniper fire remains real and viable. The consequences of being unprepared, or unable, to exercise the requisite marksmanship are severe. Sniper training must emphasize skill and ability with the rifle.

3. Capabilities

Skill and ability with the sniper rifle is a matter of equipment, training, knowledge of ballistics, and expertise in the effects of environmental conditions that can only be acquired through practice and experience. The shooter and the rifle should be capable of firing groups no larger than one minute of angle (MOA) out to 300 yards as a minimum.

Accuracy with a rifle is customarily expressed in MOA. MOA is a unit of angular measurement that increases directly with range. One MOA at one hundred yards is approximately equal to one inch, three inches at 300 yards, 10 inches at 1000 yards, etc. For example, if a group is fired at 100 yards measuring one inch in its greatest spread, then the group measures one MOA. If its greatest spread is four inches, it is a four MOA group. However, at 300 yards, a one MOA group will measure three inches across its greatest spread.

It should be noted that groups are measured from center to center of the two most widely separated holes, and not from outside edge to outside edge. The measurement is made from the outside edge of one hole to the inside edge of the other. In groups clustered too tightly to allow this measurement to be made, the measurement is taken from outside edge to outside edge at the widest point, and then the diameter of one hole is subtracted from the figure obtained. In this case, it is best to fire one shot and measure the resulting hole for subtraction rather than to simply subtract the bullet diameter.

Another way to look at it is that the MOA capability of the shooter and/or rifle represents the size of the smallest target that shooter/rifle combination can hit with certainty. Ideally, a one MOA shooter/rifle can hit a one inch target at 100 yards, a two inch target at 200 yards, or a five inch target at 500 yards, ignoring the effects of other factors like wind, sights, and ammunition. Given a nominal diameter of eight inches for a man's head, a MOA rifle/shooter could expect to make consistent headshots out to 800 yards.

In actuality, the effects of factors such as wind, sights, position, and ammunition combine to make 800 yard head shots extremely difficult. At realistic law enforcement ranges of 200 yards or less, one MOA (or better) capability affords the precision and certainty necessary to make a shot with confidence, minimizing risks to any bystander or hostage in close proximity to the target. In addition to having the skill and equipment to shoot one MOA or better, the Observer/Sniper must be well versed in ballistics, external effects, and the capabilities and limitations of equipment and ammunition. All of these factors have interrelated effects on the ability of the Observer/Sniper to shoot accurately and consistently. The first factors to resolve are the rifle and the ammunition.

4. Internal Ballistics

Internal ballistics is the science of projectile motion within the rifle. More simply, it is concerned with all that happens within the rifle from the instant of primer ignition until the bullet leaves the muzzle of the barrel. Although its duration is in milliseconds, the consequent effects upon the inherent accuracy of the rifle/cartridge combination are major. The effects of the factors of internal ballistics dictate the features of a sniper rifle and the elements of its manufacture. Resolving these effects is the job of the gunsmith building the rifle. An understanding of internal ballistics begins with ignition.

Until the advent of modern "smokeless" gunpowder and the centerfire cartridge design, firearms advances and ballistic development were relatively limited. For hundreds of years black powder was the only gunpowder used. The powder charge was ignited by a separate powder charge or priming compound.

Black powder does not cause sufficient pressure to generate the high velocities associated with modern calibers. Also, the necessity of providing vents into the breech to allow ignition of the main charge by the separate priming compound limited the integrity of the breech relative to maximum sustainable pressures. The metallurgy of the day also limited sustainable pressures. Low-pressure black powder charges (under 20,000 psi) matched perfectly the separately primed, low-pressure weapons of the day. Velocities stayed under 2100 feet per second (fps). Because separate priming is unreliable and inconvenient, the search for a better method was a motive factor in firearms development until the arrival of "smokeless" powder in the late 19th Century.

The earliest form of ignition was nothing more than a lighted match held in a serpentine lever which, when pulled, rotated the end of the match until it came in contact with the flash hole leading into the chamber of the weapon. These early weapons are called matchlocks.

In the 16th and 17th Centuries, firearms development resulted in weapons called wheel locks. The ignition system of a wheel lock consists of a spring-wound serrated wheel pressed against a piece of flint or steel called a striker. When released by pulling the trigger, the wheel spins against the striker and the resultant shower of sparks ignites the powder. The same concept is used in modern day cigarette lighters for ignition.

Another development of the 1600's was the flintlock. This ignition system consists of a piece of flint held in the striking hammer of the weapon. When fired, the hammer would hit a striker plate covering the flash pan containing gunpowder. As the flint struck the plate, knocking it back from the flash pan, it would send sparks into the flash pan igniting the gunpowder. The gunpowder would burn through the flash hole into the chamber of the rifle and ignite the main powder charge. The flintlock, being far cheaper to manufacture than the wheel lock, dominated firearms design for over two hundred years.

Although fulminates of gold and of mercury had been known since the mid-1600s, they were not considered as priming compounds. These compounds were far too sensitive and tended to detonate at the slightest blow or shock.

In 1805, the Reverend John Forsyth of Scotland developed a less sensitive fulminate that he called "Detonating Powder". He announced it as a way to aid shooters too long dependent upon flint and steel. Several different methods of using it as a priming compound came about. One of the more unusual was the "scent bottle" design.

In this system, the Detonating Powder was contained loose in a small bottle shaped like a perfume bottle. A small amount was released into the flash pan and hit by the hammer. It would detonate and set off the main powder charge. All too frequently the scent bottle itself would detonate as well. The effect can be likened to a small fragmentation grenade.

Another design contained the powder in a soft metal tube. When the hammer fell, it would shear off a piece of the tube, mashing it under the hammer and setting it off. This, too, was short lived, as the tube would also occasionally go off. An American named Guthrie designed "pill locks" using the Reverend Forsyth's powder. He mixed the powder with gum, rolled it into small pills and sealed it with wax. Placing one under the hammer primed the weapon.

Numerous attempts followed to enclose the pills in better materials. A Frenchman named Pauly tried paper caps. In 1824, a German named Dreyse developed metal caps. But Joshua Shaw, an Englishman who immigrated to America in 1814, developed the first reliable and convenient system.

Shaw designed a cup shaped container to hold a small amount of priming compound. He covered the compound with a piece of foil shellacked in place. The cups fit onto a nipple and, when hit by the hammer, would detonate. The resultant flash was directed through the nipple into the chamber, igniting the main powder charge. Thus was born the percussion cap firearm.

Initially, Shaw used potassium chlorate as the priming compound. Due to its excessive sensitivity, it was not long lived. He finally standardized on a mixture of fulminate of mercury, chlorate of potash and ground glass. The purpose of the ground glass was to increase the effect of the hammer blow and better insure detonation. This composition lasted nearly the entire percussion era.

Shaw's first percussion caps were made of steel. Next he tried pewter and finally, in 1816, he used copper. This basic design has been in use ever since. Modern percussion weapons and black powder shooters use percussion caps that are identical in design to those Shaw created in 1816. For the first time, a firearms ignition system was available that was reliable, waterproof, and safe. Dozens of copies and other claimants followed, but Shaw was first.

The next design endeavor was largely devoted to eliminating separate priming. For every shot with the then existent weapons, the weapon had to be reloaded and reprimed manually. A wide assortment of systems was tried, but none surpassed the simple percussion cap system devised by Shaw. Shaw's ideas reigned supreme in firearms usage until the development of practical, self contained metallic cartridges. Two of the more notable alternative systems were the Lawrence disk primer and the Maynard tape primer.

The Lawrence disk primer used small copper disks that contained the priming compound. When fired, the system would fling one of the disks like a little Frisbee under the hammer, hopefully timed so the hammer would hit it. Maynard developed a tape on which pellets of priming compound were contained. Every time the weapon was cocked the mechanism fed the tape under the hammer, presenting a new pellet of priming compound. The same idea can be seen today in roll caps for children's cap guns.

Other efforts involved inside priming in which the priming compound was contained inside the cartridge case. In 1858 the first successful rimfire cartridges were developed. Nevertheless, the Civil War (1860-1865) was fought with percussion caps. Since the case heads of inside primed cartridges had to be soft enough to easily indent under the blow of the hammer/firing pin, they were too weak to contain pressures sufficient for effective rifle velocities. However, the Civil War gave considerable impetus to efforts to develop self-contained, inside primed cartridges.

From the Civil War period into the late 1870's, a huge number of priming systems were created. Of them all, three survived the test of time and usage. One was the venerable rimfire system now seen in modern .22-rimfire ammunition. The priming compound is contained inside the rim of the case. It is detonated when the rim is crushed between the firing pin and the breech face of the barrel. Rimfire cases are not reusable after firing, nor are they suitable for high-pressure loads (20,000 psi or more).

The other two priming systems are centerfire designs. A centerfire cartridge holds a separate primer cup in a primer "pocket" in the center of the base of the cartridge. Centerfire cartridge cases are reusable after firing, requiring that the case be resized to original dimensions, the spent primer cup be replaced in the base, the powder charge installed and a bullet seated in the case mouth.

The Berdan primer was invented by Colonel Hiram Berdan, U.S. Army, at Frankford Arsenal. It consists of an open metal cup containing the primer compound that fits into a "pocket" in the base of the cartridge case. When struck by the firing pin, the priming compound is crushed against an "anvil". The anvil is a tripod shaped device. The legs of the anvil rest against the inside of the pocket and the top of the anvil is directly under the priming compound. In Berdan primers the anvil is an integral part of the case head. There are one to three flash holes under the anvil legs in the case head through which the resultant flash can enter the case.

In Britain, Colonel Edward Boxer developed a different design. In the Boxer primer, the priming compound and the anvil are both contained in the primer cup. The cup fits into the primer pocket in the base of the cartridge case. There is one large flash hole in the center of the pocket.

Both primers work the same way. The firing pin strikes the base of the primer cup, mashing the priming compound against the anvil and detonating it. The resultant flash enters the case through the flash hole and ignites the powder charge. Both primers are equally reliable and no discernible difference in accuracy results between the two.

However, by the late 1880's to early 1890's, the U.S. designed Berdan primer became commonly used outside the United States, and the British Boxer primer was standard within the United States. A possible reason is the ease of reloading cartridges using the Boxer system. Reloading ammunition was common among both civilian and military shooters. The difficulty and inconvenience of reloading Berdan primed cases may have contributed to the decline in usage within the United States.

Priming compound is an explosive that is detonated by the shock of being struck with the firing pin, as opposed to modern smokeless gunpowder, which is a combustible and generates its energy by burning. Early priming compounds were composed of various mixtures, central to which was potassium chlorate. When potassium chlorate oxidizes, it leaves a residue of potassium chloride, which is blown into the pores of the metal. All chloride compounds are hydroscopic salts that attract and hold water. Inattentive or incomplete cleaning can result in a rusted bore literally overnight. These salts are not soluble in oil or solvents used to clean barrels. They are soluble in hot, soapy water. The same cleaning procedure using hot, soapy water is required for black powder residue for the same reasons.

Fulminate of mercury was also used in basic priming compounds. It does not leave a corrosive salt-based residue, but the mercury particles amalgamate with the brass of the cartridge case and erode its strength and malleability. Some cases would be brittle beyond reuse after only one firing. The higher the pressures generated within the cartridge, the faster the effect. Cartridge case design also has an effect. Straight walled cases are more slowly eroded than bottle necked designs.

The advent of modern powders raised the need for hotter primer flashes due to their significantly higher ignition temperatures. Hotter temperatures could only be attained by using more priming compound, resulting in even more salt and mercuric residue. The development of the bottle necked, high-pressure case finally eliminated mercury from primer compounds.

Mercuric primers were eliminated from U.S. military ammunition about the turn of the century and from U.S. commercial ammunition in the 1930's. Some foreign ammunition was still manufactured with mercuric primers as recently as the 1950's. For high-pressure cartridges and modern smokeless powder, antimony sulfide, lead sulfocyanate and TNT were added to the priming mix. These priming mixtures were used through World War II.

The first noncorrosive (i.e., free of salt residue) primers were developed in Germany in 1910 in .22-rimfire ammunition. Switzerland followed in 1911. Remington introduced noncorrosive .22-rimfire ammunition in the United States in the 1920's. By the 1930's, noncorrosive primers were standard in all commercial ammunition. It wasn't until the 1950's that all military ammunition was made with noncorrosive primers. Today, all ammunition (civilian and military) is noncorrosive and non-mercuric. Modern primers are built around lead styphenate.

The explosive nature and power of primers cannot be overemphasized. Many police departments reload ammunition for training and for service use. Primers should be stored in their original containers and handled with care. A glass jar full of primers can detonate if dropped on a hard floor with hazardous consequences.

In fact, all incidents of a cartridge going off when dropped on the ground or "cooking off" when excessively hot are caused by the sensitive primer compound detonating. Modern powder does not ignite under the shock of being dropped or hit. Its ignition temperature is sufficiently high (about 600 degrees Fahrenheit) that it will not ignite by itself under accumulated ambient heat, such as occurs when a round is left out in the sun. Of course, when the primer detonates it ignites the powder charge. In an unconfined cartridge, the brass case fractures like a small fragmentation grenade. Sharp, jagged shards of brass can inflict painful cuts and be hazardous to the eyes. There is no apparent hazard from the bullet itself.

The primer is the first step in the combustion of gunpowder, which starts the process of internal ballistics. Originally, the only gunpowder was black powder. Black powder is a low order explosive. It is a mechanical mixture of sulfur, carbon (usually charcoal, hence the name) and saltpeter, which burns with a great deal of smoke and corrosive salt residue resulting. Black powder can be detonated by shock.

Modern smokeless gunpowder, on the other hand, is a combustible, not an explosive, although it can have an explosive effect if burned in confinement. It burns much cleaner than black powder, which is why it was originally known as "smokeless" powder.

Modern smokeless powder is of two types. Single based powder is composed of nitrocellulose, a mixture of nitric acid and cellulose such as cotton. Double-based powder is a mixture of nitrocellulose and nitroglycerin. All modern powders are either single based or double based powders. They are manufactured in three different forms - flake powders, ball powders and extruded powders.

The energy generated by smokeless powder results from combustion. The powder rapidly converts to gas as it burns. The volume of the gas produced is huge, approximately 4700 times the volume of the powder in its solid state. When confined, as in a cartridge case, the resultant pressure propels the bullet down the barrel. Modern cartridges such as the .308 or .223 attain pressures over 50,000 pounds per square inch (psi) in milliseconds.

Modern powders are progressive in their combustion rates. This means the rate of combustion is controlled. Some powders are fast, some slow. Burning rate is determined by the manufacturers in "closed bomb" tests wherein a small sample of the powder being tested is ignited in an instrumented container (the "bomb").

Burning rate is relative. In actual use it varies with cartridge capacity, temperature, humidity, primer flash heat, and a host of other variables. It is controlled by the size of the powder granules, their shape and chemical retardants added as a coating to the powder. Close examination of extruded and flake powders will reveal small holes through the center of each granule. These are provided so the granule will have a constant surface area while burning. As the outer surface decreases, the inner surface of the hole increases, keeping the total surface area constant.

As the powder burns, the pressure generated increases. On a graph, it appears as a rising curve over time to the maximum, or "peak", pressure. Ideally, peak pressure will be attained just prior to the bullet exiting the muzzle. Hence the need for various burning rates. Theoretically, the shorter the barrel (or lighter the bullet), the faster the powder needed for best efficiency. The ideal barrel length will be just long enough to allow the peak pressure to form. As the pressure rises, it accelerates the bullet to higher velocities.

Maximum velocity is reached at the point just past peak pressure. If the barrel is too short, the bullet exits and the pressure dissipates to zero before peak pressure is reached, sacrificing acceleration. In a .22 long rifle, peak pressure is reached in about 16 inches of barrel. If a .22 has a barrel longer than 16 inches the bullet is actually retarded by friction with the barrel after the moment of peak pressure. However, the loss of velocity is inconsequential in normal barrel lengths.

In a modern centerfire such as the .308, a barrel length of roughly 30-36 inches is required to attain complete combustion and peak pressure. A barrel that length would be unwieldy, heavy, and impractical. So some potential velocity is given up as a practical compromise for ease of handling and efficiency of rifle design.

This explains why the .308 (and comparable high-pressure calibers) has a visible muzzle flash. Since the barrel is too short to allow complete combustion of the powder before the bullet leaves the muzzle, combustion is completed in the air behind the bullet. The shorter the barrel, the greater the flash if the powder charge remains the same. The muzzle blast (sound and concussion) is caused by expanding gas escaping from the muzzle at supersonic speeds behind the bullet.

The generation of 50-55,000 psi within the rifle is the driving force of internal ballistics. It has numerous effects upon the cartridge case, the rifle and the bullet, all of which affect the inherent accuracy of that rifle and cartridge combination. None of these effects can be eliminated. The manner in which sniper rifles are built is intended to control these effects so that they occur in the same way shot after shot.

Accuracy in a rifle is a direct function of consistency. Every time a shot is fired, the various parts of the rifle, the cartridge case and the bullet all move and interact with each other. The more nearly these parts move and interact exactly the same way for each shot, the more accurate that rifle/cartridge combination will be.

The cartridge case has four functions. First, it acts as the container holding the powder, bullet and primer. Upon ignition of the powder charge, the pressure builds equally in all directions. To the rear and the sides, the pressure expands the case within the chamber of the rifle forming a gas tight seal (the second function). To the front, the pressure pushes the bullet out of the case into the rifling of the bore and down the barrel.

Cartridge cases are made of brass because brass expands easily and uniformly, and when the pressure dissipates, the brass shrinks enough to be easily extracted. It does not return to its original dimensions, however. If it is to be reused it must be resized to those original dimensions. The third function of the case is to provide proper head space for the cartridge.

Headspace is a critical internal dimension. It is defined as the fit of a cartridge in a chamber measured as the distance from the face of the bolt to that part of the chamber that stops the forward movement of the cartridge. Insufficient headspace hinders complete chambering, and could prevent the bolt from closing. In effect, the case is too long for the chamber dimensions. Excessive head space can cause case stretching or separation as the case over expands to fill the chamber, or can cause misfires by allowing the cartridge to move forward under the impact of the firing pin, cushioning the blow.

Cartridges are designed to headspace one of four ways: on the case rim (example: .22 rimfire ammunition); on the mouth of the case (example: .45 ACP); on the shoulder of the case (example: .308) or on a raised belt around the base of the case (example: 7mm Remington Magnum).

Cartridges which headspace on the shoulder such as the .308 measure headspace from the face of the bolt to a "datum point" located approximately at the midpoint of the shoulder.

To illustrate, when a .308 cartridge is in the chamber of a rifle, it is held by the base against the bolt face and the datum point against the corresponding point on the chamber wall. A .45 ACP round would be held by the base of the case at the back and the mouth of the case at the front. A .22 rimfire is held by the base against the bolt face and the other side of the rim held against the back of the breech. In all these cases, the bolt face pushes the cartridge forward until the head spacing point contacts the interior of the chamber and further forward movement is stopped.

The final function of the case is to provide uniformity of position within the chamber, both at the base and the neck. If the case head is not square to the face of the bolt, the pressures generated will torque the case within the chamber since the part of the base not in contact with the bolt is free to move. One result is that the bullet does not enter the bore concentrically. This alone can cause an increase in group spread of 0.6 to 2.2 times the average.

A second effect is to create lateral vibrations which course down the barrel. These vibrations are due to the buckling of the action in response to the violent, off center push of the cartridge case. Barrel vibrations are discussed more fully below.

The case must hold the bullet in perfect alignment with the bore of the barrel, a condition termed concentricity. Without concentricity, the bullet will enter the bore slightly off-center. This causes a deformation of the bullet in the bore. Upon exiting the muzzle, the bullet will not spin true about its longitudinal axis, causing the trajectory to vary. Group size will be expanded up to double the average.

Uniformity of the case neck is also important. If the bullets are not held in the neck of the case with equal resistance, then the bullets will get faster or slower starts into the rifling. Inconsistent resistance causes the rate of pressure increase within the cartridge to vary, which varies the acceleration of the bullet down the barrel, increasing average group size.

These considerations regarding the effects of ammunition are resolved by using the best quality ammunition available. Commercially manufactured match quality ammunition is readily available in caliber .308, which is a primary reason for the prevalence of .308 sniper rifles.

Match ammunition is manufactured to higher standards of dimensional uniformity and component consistency. Without it, no rifle will realize its full accuracy potential, regardless of how well it is built. For example, a rifle that shoots groups under one half MOA with match ammunition can shoot groups one or two MOA or larger with general sporting ammunition.

The tremendous pressure within the chamber forces the locking lugs of the bolt back into the lug recesses of the receiver. As with the base of the case, the locking lugs must be square to the bearing surfaces of the recesses, and in full, even contact. Otherwise the pressure is exerted unevenly and a bending force called "locking lug dispersion" is applied to the receiver.

Generally, locking lug dispersion will occur opposite to the plane of the lugs. In a two lug system (examples: M1 Garand, M14, Mauser and Ruger bolt actions) the dispersion will be greater than in a system employing three or four lugs. In building a sniper rifle, care must be taken to insure that the locking lugs of the bolt are square and true within the receiver. Locking lug dispersion is also a source of lateral vibrations imposed upon barrel motion through the bending of the receiver.

As the powder charge oxidizes and the pressure increases, the bullet begins to move. The initial resistance of case neck friction holding the bullet is overcome and the bullet enters the rifling. The bullet will enter the rifling more smoothly and with less distortion if it is allowed to begin moving before impact.

If the bullet is in contact with the rifling at the start, pressure can build up too fast and more randomly as the bullet is forced into the lands of the rifling. More consistent bullet movement and pressure formation is obtained when the bullet has a small distance to move before impacting the rifling.

As a rule, the bearing surface of the bullet (that part which contacts the rifling) should be 0.010 inches from the rifling. This is accomplished by limiting the overall length of the cartridge and head spacing the rifle to exact dimensions.

For example, the .308 ammunition used by the FBI is loaded with Sierra Match 168 grain hollow point boat tail bullets. Overall length is specified at 2.800 inches. (Overall length is the length of the loaded cartridge from the base to the tip of the bullet). The chambers of the rifles are then hand cut into the barrels so that the headspace is exactly 1.631 inches. The bearing surface of the bullet is then held 0.010 inch from the rifling.

The temperature of high-pressure powder combustion and the repeated impact of bullets into the start of the rifling cause barrel throat erosion. The flash temperature within the chamber exceeds 3500 degrees Fahrenheit. The melting point of steel is about 2700 degrees Fahrenheit. The result is that little by little the throat of the barrel where the rifling starts is eroded away. The start of the rifling is, in effect, moved farther and farther down the barrel. Eventually, the distance will be so great that accuracy is destroyed and velocity is decreased.

The rifling eventually erodes enough that the bullet base leaves the case before the bearing surface impacts the rifling. The bullet is in free flight within the chamber for a short distance. Accuracy is ruined because the bullet is no longer concentric with the bore. Velocity decreases as throat erosion progresses due to the increasing volume of space in which the pressure can expand before meeting the resistance of the rifling. The pressure curve is more gradual in its slope and acceleration is decreased. To correct throat erosion the barrel must be either replaced or shortened and rechambered.

The Hornady Manufacturing Company conducted a test with a 7mm Remington Magnum test barrel that illustrates the velocity loss due to erosion. Five rounds were fired and chronographed when the barrel was new. Average velocity was 3044 fps. Then 2000 rounds were fired through the barrel after which another five rounds were chronographed. Average velocity was 2758 fps.

Hornady Throat Erosion Test

New (fps):	3038	3074	3024	3039	3050
2000 rds:	2729	2765	2769	2765	2762

The rate of throat erosion and velocity loss will vary with the size of the bore, size of the powder charge being used, rate of fire, and burning rate of the powder. Generally, the smaller the bore and/or larger the powder charge, the faster the rate of erosion. Competitive shooters using large capacity magnum calibers such as the 7mm Remington or .300 Winchester will wash out a barrel throat in 2000 rounds or less. The same rifles in .308 can last 5000-8000 rounds or more.

The bullet impacts the rifling of the bore with considerable force. The bullet is larger in diameter than the bore diameter between the lands of the rifling. It strikes the rifling sharply before being pressed into the bore. The effect can be likened to striking the end of the barrel with a hammer. It creates "longitudinal" vibrations within the barrel.

At the same time, the rifle is recoiling to the rear in accordance with Newton's Law that for every action there is an equal but opposite reaction. The direction of the recoil force is directly opposite to the movement of the bullet down the barrel, and thus *above* the point where the butt contacts the shoulder. The impact of the bullet into the rifling coupled with the impact of the stock against the shoulder below the line of recoil force causes the rifle to literally buckle in the middle. It bends at the junction of the barrel and the receiver, and springs back. The result is an up and down whipping motion of the barrel called "vertical" vibrations.

Side to side "lateral" vibrations caused by any flaws in bedding, inconsistencies in the shooter's grip or position, case head or locking lug dispersion will also be imposed on the barrel. Finally, as the bullet is forced down the bore against the turning of the rifling a fourth, spinning vibration is imparted to the barrel called "torsional" vibration.

These four different vibrations are simultaneously imposed upon the barrel. The speed of sound in steel is approximately 17,000 fps. Accordingly, the vibrations reverberate lengthwise within the barrel several times before the bullet leaves the muzzle. The resultant motion is barrel whip. Simply stated, the barrel is moving in space about its longitudinal axis while the bullet is moving the length of the bore and exiting the muzzle.

If plotted on an oscilloscope, barrel whip forms a sine wave pattern. The high points of the pattern are called anti-nodes or overtones. Anti-nodes are where the barrel movement is greatest. The intersecting low points are nodes. Nodes are points of little or no movement. It can be likened to whipping a fishing rod.

The actual frequency of the barrel whip will be relatively constant, dependent upon the steel of the barrel, its mass and dimensions, the bedding, the bullet, the pressure curve and its magnitude. Barrel whip can be anywhere within a 360 degree circumference about the axis of the barrel, but will tend to move predominantly in the vertical plane.

Barrel whip would be an inconsequential consideration if the muzzle of the barrel were always a node (a point of little or no motion). If that were the case, the muzzle would always be at the same point in space every time a bullet exited. Such a uniform "launching site" would be an accurate rifle. However, the muzzle is *always an* anti-node (a point of maximum vibrational motion).

The muzzle has the greatest vibrational effect on the direction of the bullet's flight. The stiffer the barrel, the less the angular displacement of the muzzle. Barrel stiffness rises as the cube of barrel diameter, and inversely as the square of barrel length. This explains the use of large diameter, heavy barrels for accuracy.

Therefore, in order to be accurate the barrel must always whip with exactly the same motion from shot to shot in order for the muzzle to be always at the same point in space when the bullet exits. This is accomplished in four ways: by using heavy, large diameter barrels of exceptionally high manufacturing quality; by using ammunition of uniform characteristics and pressures; by building the rifle in such a manner that barrel whip is unimpeded and no extraneous vibrations are created; and by shooting the rifle in a manner that does not impair the vibrational pattern of the barrel.

First, although manufacturers make barrels in several different ways, the uniformity of the steel used and the consistency of the bore and rifling are the primary considerations regardless of the manufacturing method used. Custom made barrels are made to more exacting standards than mass-produced barrels.

For example, Hart Barrel Company of New York estimates that of every 100 barrels made, no more than six are perfect and of the highest possible quality. This means that they will have steel of uniform density and composition, a bore perfectly straight through the steel and of unvarying diameter throughout, and perfectly cut rifling. Of the remaining 94 barrels, approximately 30-40 will be of sufficient quality to be sold as lower grade custom barrels. The remainders are discarded.

On the other hand, mass produced barrels are manufactured to more liberal standards. They are intended to provide sufficient accuracy to hit a deer at 150 yards. Mass producers discard few, if any, barrels. If not perfectly straight or uniform, the barrel can still be used because the resultant accuracy remains within the nominal standards. Barrels can even be bent until they are straight. General sporting use does not require minute of angle accuracy, nor does it require the considerable cost of using only best quality barrels.

The vital area on a deer is about 16 inches in diameter. To hit a 16-inch target at normal hunting ranges can be accomplished quite effectively with a rifle having a 3 MOA capability. Mass produced weapons and barrels made for general sporting use shoot 2-3 minutes of angle. This is fine for that purpose, but not for the law enforcement observer/sniper.

This is not to say that an off-the-shelf rifle is not suitable for sniper utilization. A number of rifles currently available would make excellent sniper weapons with some minimal gunsmithing. The uncertainty is that they are not individually built to meet accuracy standards needed for sniper rifles.

There is no way to tell if any one commercially available rifle has a good barrel except by shooting it. Headspace can also be excessively generous for ultimate accuracy because the manufacturers must insure the rifle will readily chamber a wide variety of commercial and reloaded ammunition. If the rifle is properly bedded, lugs fitted and it is precisely headspaced, failure to attain acceptable accuracy indicates an imperfect barrel.

Using a less than perfect barrel creates vibrational motion that varies randomly. The muzzle is not at the same point in space from shot to shot. A mass produced weapon may have a good barrel, or it may not. The accuracy achieved can vary widely even among rifles of the same make and model.

A variety of flaws can be present. Inconsistent steel composition results in "soft" or "hard" spots in the steel itself. Compositional inconsistencies alter barrel vibrations randomly. They also cause the barrel to contort as it heats up through firing. Barrels that have been bent tend to revert to their original lines under the stresses of heat and pressure. Flaws in the bore and rifling result in high or low spots impeding the progress of the bullet through the bore and causing variations in barrel whip, pressure curve, and bullet deformation. A custom barrel is expensive, but the necessary quality is guaranteed.

Secondly, the ammunition must be consistent in its composition, dimensions and characteristics. Ammunition produced for general sporting use is manufactured to lower standards than is match ammunition. Variations in pressure are greater from one cartridge to the next. This causes wider disparity in velocity from shot to shot and wider variations in barrel whip. Any variation in the speed of the bullet means more or less time spent in the barrel. Since the muzzle is constantly moving, such variations mean that the bullets are not all leaving the barrel at the same point in space. A variation of 30 fps between two shots by itself can result in a vertical spread on the order of one half MOA.

The bullets used in sporting ammunition are not of match quality. Variations in the bullet composition may be acceptable for sporting use, but they can cause an increase in average group size beyond acceptable limits. The importance of the bullet to accuracy is discussed in detail below. (See pages 20-21 and 25-27).

Ammunition is manufactured in uniform lots. Every lot is assigned its own unique lot number, which is printed on the carton case as well as each individual box of ammunition. This is important to record, since each lot of ammunition is different. When a manufacturer changes any single component, a new lot number is assigned. The internal capacity of the brass casing will vary from one manufacturing lot to another. The uniformity of the bullets, heat and pressure of the primers, and burning rate of the powder all vary to one degree or another every time they are changed.

It is not unusual to find one lot of ammunition that shoots extremely well in a particular rifle, and a different lot of the same ammunition from the same manufacturer that is not at all accurate in that rifle. Rifle data records must include the lot of ammunition used. When an accurate lot is discovered, it must be reserved for the rifle that shoots it best. Mixing lots results in meaningless accuracy records because uniformity of ammunition is lost.

Third, construction of the rifle affects the consistency of barrel vibration. The locking lugs must be precisely fitted to the locking lug recesses in the receiver. The chamber must be precisely headspaced. All the metal parts move and rebound in the stock with each shot. If this movement is uniform, the metal parts arrive back in the same relationship with each other and with the stock after each shot. And they will react in the same manner from shot to shot while the bullet travels down the barrel.

The receiver and recoil lug are glass bedded to assure uniform movement of the action within the stock under recoil. Glass bedding maintains all the major parts of the rifle in the same exact relationship from shot to shot. Also, since glass bedding is impervious to moisture, there is no warping pressure on the action within the stock as occurs with wood stocks which change shape as the moisture content of the air changes. The glass bedding must extend forward from the receiver for about one inch under the barrel. This "pad" supports the barrel at its junction with the receiver so the weight of the barrel is not hanging on the threads in the receiver.

From the pad forward, the barrel is "free floated" within the stock. The barrel channel in the stock is widened so the barrel is clear of any contact with the stock. Any part of the stock in contact with the barrel will alter barrel whip patterns.

Finally, the shooter must insure that the rifle is fired in a manner that does not impair the vibrational patterns. Nothing can be allowed to contact the barrel. The point of impact can be changed by merely resting a pencil on the barrel while firing it. The shooter can also cause vibrational variations by holding the rifle differently from shot to shot, by shouldering it with varying pressure, gripping it differently or resting the rifle on too hard a surface. For example, if the rifle is firmly gripped and tightly shouldered for one shot and then held and fired with a relaxed grip and shouldering, a vertical difference of at least 1-2 MOA with some lateral dispersion will result. Understanding these aspects of the barrel and its vibrational characteristics is vital to accurate shooting.

The last factor of internal ballistics concerns the bullet and its movement through the barrel. The bullet is engraved upon the rifling and is forced to spin as it is accelerated down the barrel. Barrel length and the rate of twist of the rifling will affect velocity and accuracy. Given the same powder charge and bullet, the longer the barrel the higher the velocity until the peak pressure is passed, after which the bullet is no longer being accelerated. As previously stated, a barrel this long may not be practical and does not contribute to inherent accuracy.

For example, in the sport of benchrest shooting the goal is to fire five or ten shots into as small a group as possible at 100 and 200 yards. Benchrest shooters routinely use short, thick barrels of about 20 inches in length. The loss of velocity is more than compensated by the reduced, more uniform barrel whip of the shorter, thicker barrel.

Of greater concern for its affect on accuracy is the rate of twist of the rifling, expressed as the length (in inches) of barrel necessary for the rifling to make one complete turn. For example, 1 in 12 rifling makes one complete turn every 12 inches of barrel and is called a 12-inch twist. The twist controls how fast the bullet will spin.

The spin stabilizes the bullet in flight so it will fly nose first. The longer and heavier the bullet in a given caliber, the faster the twist necessary to stabilize it. A lighter bullet in that same caliber requires a slower twist to be stable in flight. (The reason for this is explained below on page 21). The velocity of the bullet also affects the choice of twist. Increasing velocity increases the revolutions per minute (RPM) of the bullet. Optimum accuracy is obtained by using one bullet weight and barreling with the best twist for that caliber, weight, and velocity combination. Typical RPM for rifle calibers range from 150,000 to 200,000. The .308 cartridge loaded with the Sierra 168 grain HPBT bullet as used by the FBI is best stabilized with a 12 inch twist.

The critical feature of the bullet while within the barrel is the base. The base of the bullet must form a perfect gas seal containing the pressure behind it. The bullet acts like a piston as increasing pressure accelerates it down the barrel. If the base of the bullet is not square, at the instant the bullet exits the muzzle an uneven push is exerted by the pressure. In effect, the bullet is tipped slightly off line. The result is called "axial error", defined as an angular displacement of the axis of rotation. Axial error can also be mechanically induced by nonconcentric ammunition, which does not hold the bullet in perfect alignment with the bore. An axial error of 0.001" can result in a group increase of approximately one MOA.

This is one reason boat tail bullets are better. It is technologically difficult to manufacture a flat base bullet with a perfectly square base. Some bases can suffer distortion in the manufacturing process, or the lead core may not fully fill the base allowing the pressure during firing to distort the base. In the boat tail design, the "base" is the full diameter circumference ahead of the stepped down boat tail. It is technologically easier to manufacture a perfect boat tail "base" that is square to the bullet axis for the pressure to push against. A second reason to use boat tail bullets is the more efficient aerodynamic design, which is discussed more fully below. (See pages 26-27).

Axial error can also be induced by a damaged or out of square muzzle, which allows the high-pressure gas to escape from one side of the base sooner or more forcefully as the bullet exits. For this reason, the muzzle of the rifle is recessed so the bore is countersunk into the end of the barrel. This is called crowning, and is done to protect the muzzle. This is also why cleaning a rifle must be done from the breech end in order to minimize abrasion or damage to the muzzle.

As long as the bullet is contained within the barrel, it rotates about its center of form. Center of form is the center of the shape of the bullet. Once the bullet leaves the barrel, it rotates about its center of gravity. Center of gravity is the center of the mass of the bullet. In a bullet, the center of form is *ALWAYS* in front of the center of gravity. Thus a bullet is not a form stable projectile. In the air, it would tumble in flight putting the center of gravity in front of the center of form. The spin imparted by the rifling creates gyroscopic stability, which keeps it flying nose first.

By comparison, a dart is a form stable projectile. The center of gravity of a dart is in front of its center of form, and it will always fly point first. The greater the distance between a projectile's center of form and its center of gravity, the more unstable the projectile. This explains why, in a given caliber, a heavier bullet needs a faster twist to stabilize than a lighter bullet. In a heavier bullet of the same caliber, the center of gravity is moved farther from the center of form as the bullet is lengthened for greater weight.

For optimum accuracy, the center of gravity must be located exactly on the longitudinal axis of the bullet. Otherwise, as the bullet is spun down the barrel centrifugal force progressively increases from the breech to the muzzle. This can exert considerable force. A 190 grain .308 bullet at 2550 fps with the center of gravity displaced 0.001" creates a centrifugal force at the muzzle of 26 foot/pounds. This magnitude of displacement can be caused by the bullet jacket being thicker on one side than the other. It can be caused by some fouling, or an imperfection in the barrel "denting" one side of the bullet.

Regardless, the result is more lead on one side of the longitudinal axis than on the other, shifting the center of gravity to the "heavier" side. When the bullet exits the muzzle, the centrifugal force creates a sideways "hop" as the bullet, freed from the constraints of the barrel, rotates around its center of gravity. Instead of spinning true about the longitudinal axis, point first through the air, the bullet will follow a spiraling course about the "true" line of flight and its trajectory will vary tangent to the spiral. A center of gravity displacement of 0.0005" in a .308 match bullet can increase group size approximately one MOA. This is called "radial" error. Axial and radial errors tend to supplement each other.

Mechanical distortions are another source of error. No centered bullets, non-concentric ammunition, imperfect throat, or flawed rifling are mechanical distortions. They misalign the bullet with the centerline of the bore, or displace the center of gravity by distorting the integrity of the bullet. An error of 0.001" can increase group size one MOA.

One effect of internal ballistics that impacts directly upon the shooter is recoil. It starts the moment the firing pin moves forward. The spring propelling the firing pin in a rifle will exert a force of 16-30 foot/pounds. The rifle, in accordance with Newton's law, moves in the opposite direction. When the firing pin starts forward, the rifle starts backward and upward. The upward motion is an angle of moment caused by the location of the stock below the line of force of the recoil.

The rifle accelerates to the rear as the bullet accelerates down the barrel. Fortunately, the acceleration is applied only for milliseconds. If the period of acceleration lasted half a second, the rifle would be traveling rearward at a velocity in excess of 100 miles per hour. The bullet attains its high velocity in its equally short time of acceleration because it has a much smaller mass and less inertia than the rifle.

Recoil effects are produced by the rearward velocity of the rifle and the recoil energy that results. It is controlled by a combination of three factors.

Stock design affects the apparent effects of recoil upon the shooter although it does not change actual recoil energy at all since energy is a function of velocity and mass. However, if a stock design permits the point of contact in the shoulder to be closer to the line of bore, the upward moment will be reduced. When there is less upward moment, the recoil "seems" less to the shooter, and the rifle is easier to control.

Increasing the cross sectional area of the butt will reduce apparent recoil. The actual recoil energy remains the same, but spreading it out over a larger butt area makes it "seem" less.

Since energy is a function of mass and velocity, it can be increased or reduced by altering either variable. Decreasing recoil velocity decreases recoil energy. That can only be accomplished by decreasing the bullet's velocity, since the rifle is merely reacting to the forces accelerating the bullet. Lower velocity ammunition is not particularly desirable for the Observer/Sniper. It limits range, decreases penetration and killing power, and increases drop and wind drift.

Increasing the mass of the rifle will decrease recoil. The increased mass has increased inertia, which takes longer for the acceleration force to overcome. Since acceleration continues to be limited in duration, the result is lower recoil velocity and energy. The limitation then becomes one of size and portability.

Generally, a total weight (rifle and scope) between eleven and fourteen pounds will be sufficient to dampen recoil to controllable levels, yet not be too heavy or bulky for field use. Some examples are listed below.

Recoil Examples

Caliber	Rifle Wt (lbs)	Bullet Wt (gr)	Velocity (fps)	Recoil (ft/lbs)
.223	6.5	55	3200	4.1
.308	11.75	168	2600	11.009
7mm Mag	11.5	168	3000	18.183
300 Mag	11.5	180	3000	21.858

The third means of resolving recoil is the shooters position and manner of gripping the rifle. Holding the rifle with a firm, strong grip and keeping it tightly against the shoulder will reduce felt recoil. It will also better insure the recoil is engaged the same way shot after shot, which is conducive to more uniform barrel whip and accuracy. A loose grip, or relaxed position, allows the rifle to recoil differently from shot to shot. It also increases the apparent recoil effects.

If the weapon is firmly shouldered and gripped, some of the shooters mass is added to that of the rifle and the resultant recoil velocity is less. If held 0.25" away from the shoulder and fired, the recoil would be much worse because the rifle by itself will reach a higher recoil velocity. Accuracy will suffer greatly, as will the shooter's shoulder.

A final factor critical to the accuracy and life of the rifle is proper cleaning. This is totally within the control of the shooter. Improper or inadequate cleaning will destroy accuracy and limit barrel life to 25-50% of its potential.

With each shot fired, powder residue and bullet fouling is blown into the surface of the bore under extreme heat and pressure. The result is that the bore is gradually made smaller and uneven. The pressure curve is altered, the bullet is deformed, barrel whip is randomly altered, and the bore is damaged in the process. Thorough cleaning is the only solution, and it must be done religiously.

As a rule of thumb, one complete pass (in and out) should be made through the bore with a brass brush and solvent for every shot fired, but never less than 20 complete passes. Even better would be to then leave the bore wet with solvent for 24 hours and repeat the process before wiping it dry.

The bore should be left dry, not oiled, unless the rifle is to be stored for a period of months. The bore is sufficiently work hardened by the passage of the bullets that it will not rust in normal usage and climatic conditions. If it is oiled, it must be wiped completely dry before firing or else the first shot or two will not be on zero.

5. External Ballistics

External ballistics is the science of the bullet in flight. It involves everything that occurs from the instant the bullet leaves the muzzle until it impacts its target. An understanding of the factors and effects of external ballistics is imperative. Sound marksmanship, experience, and a solid understanding of those factors and effects will enable the Observer/Sniper to compensate and hit the intended target.

Two forces influence the bullet in flight. One is gravity, which is constant. The other is air resistance; more commonly called "drag". Of the two, gravity has the least effect. If a .30/06 bullet were fired in a gravity free atmosphere, it would travel slightly less than two miles and stop in midair.

That same bullet, fired in a vacuum but with gravity present, would travel about 43 miles and strike the earth at the same velocity it left the muzzle. In the world of reality where both forces exist, gravity pulls the bullet down while drag simultaneously slows the bullet.

Gravity is a constant acceleration of the bullet downwards at the rate of 32 feet per second, per second. A simplified example is that after one second, a falling object has a velocity of 32 fps. After two seconds, its velocity is 64 fps, and so on. It acts independently of the bullet's weight, shape or velocity. The instant a bullet exits the muzzle, gravity accelerates it down at the constant rate of 32 fps/ps.

Theoretically, if a bullet were dropped from beside the muzzle at the exact instant an identical bullet was shot from the muzzle, they would both hit the ground at the same time, albeit widely spread apart. This is true in a vacuum. In actuality, the fired bullet lands slightly after the dropped bullet because it generates some lift as it flies through the air. The lift counteracts gravity to a small degree.

The longer the time of flight, the faster the bullet's falling velocity becomes, until it reaches a terminal velocity on the order of 250 fps. "Terminal velocity" is that velocity at which drag has increased to the point gravitational acceleration is counteracted. Bullets do not have a time of flight long enough to reach terminal velocity as they drop. A typical .308 round takes approximately one tenth of a second to travel two hundred yards.

Drag works in opposition to the direction of velocity. Although all objects fall at the same rate regardless of shape, size, or weight, they do not all reach the same terminal velocity because drag varies with shape, weight, and surface area. Thus a feather and a rock do not hit the ground at the same time when dropped simultaneously, although they would if dropped in a vacuum.

Gravity gives the bullet's line of flight, called the "trajectory", its curving shape. The trajectory of a bullet is a "parabolic curve", which is defined as a constantly increasing curve. The slope of the curve becomes steeper as range increases. The distance a bullet is below the line of bore is called "drop". Since the trajectory is a parabolic curve, the drop increases with range. For example, at the muzzle drop is zero. At 100 yards, the drop of a typical .308 flat base bullet is 2.56 inches. At 200 yards, the drop is 11.09 inches, and at 1000 yards it is 478.28 inches.

In order to hit a target, the line of bore, as represented by the barrel, must be angled up relative to the horizontal. This angle is called the "angle of departure". The result is that the bullet crosses the shooter's line of sight twice.

Line of sight is a straight line through the sights to the target, and is above the barrel. The bullet crosses it once close to the muzzle on the way up, and again at some point down range on the way down. With scoped rifles the line of sight is typically 1.5 inches above the muzzle, and the bullet first crosses it at a range between 22 and 25 yards.

The second intersection with the line of sight is the zero point of the rifle. The zero point is altered by raising or lowering one of the sights until it coincides with the desired zero for the weapon. Raising or lowering the sight changes the angle of departure, moving the zero point closer or farther away. The actual dimensions involved are very small, yet their effects are monumental. For example, to be zeroed at 1000 yards, the angle of departure for a typical .308 match bullet will be on the order of 3 degrees. This also accentuates the large effects of the small errors discussed in the section above on Internal Ballistics.

Velocity is the only factor that influences the perceived effects of gravity, and then only relative to a specific range. Gravity acts on the bullet only for the duration of its horizontal flight vector. The faster a bullet arrives at the target, the less time gravity has to pull it down. The result is less drop and a flatter trajectory. As an example, if a bullet takes one second to reach its target it will drop 32 feet. A faster bullet reaching the same target in one half second will drop 16 feet. The faster bullet will require less sight adjustment, and will travel closer to the line of sight between the muzzle and the target.

The second force that influences the bullet’s flight is drag. Drag resists velocity, increasing exponentially as velocity increases. The higher the velocity, the greater the drag and the greater the rate at which velocity is lost.

As an example, a 180 grain .308 flat base bullet with a muzzle velocity of 2100 fps will have a retained velocity at 1000 yards of 1045 fps - a loss of about 50 percent. That same bullet with a muzzle velocity of 3200 fps will have a retained velocity at 1000 yards of 1433 fps - a loss of 55 percent. The faster bullet has a higher rate of velocity loss. It has a greater retained velocity because it had a greater initial velocity. This illustrates the increase of drag with an increase of velocity. It also affects the trajectory since the time of flight increases as the velocity decays, thereby giving gravity more time to act upon the bullet.

Drag represents energy given up by the bullet pushing the air aside as it flies. The air is compressed by the nose of the bullet and forced out of the way. As the air stream moves down the sides of the bullet, friction with the sides causes turbulence. The turbulence "drags" against the bullet, another component of the retarding effect of drag. As the air spills off the rear of the bullet, more turbulence is created along with a partial vacuum at the base, both of which act to further slow the bullet. Bullet shape and design are the important factors relative to drag.

Bullets are designed for various purposes. A particular purpose may not be conducive to an aerodynamically efficient design. For example, ammunition intended for use in tubular magazines is loaded with flat nosed or round nosed bullets to prevent accidental discharges in the magazine when recoil bangs the nose of the bullet against the primer of the round ahead of it. Flat nosed or round nosed designs are not aerodynamically efficient. A sharp pointed bullet would be far more efficient relative to drag, but not at all useful in a tubular magazine.

The aerodynamic efficiency of a bullet is expressed as "ballistic coefficient". Ballistic coefficient is a three-digit number less than one, which denotes the bullets ability to overcome drag. The higher the number, the more efficient the bullet. A ballistic coefficient of 1.000 would represent a bullet that did not lose any velocity to drag, an impossibility.

According to the Sierra Bullet Manufacturing Company, their 180 grain .308 round nosed bullet has a ballistic coefficient of 0.250. The Sierra 180 grain .308 hollow point boat tail match bullet has a ballistic coefficient of 0.538. As would be expected, the hollow point boat tail bullet is far more aerodynamically efficient than its round nosed counterpart. To illustrate this, assume each bullet is started with a muzzle velocity of 2600 fps. At 500 yards, the round nosed bullet has a retained velocity of 1296 fps - a loss of 50 percent. The boat tail bullet has a retained velocity of 1853 fps - a loss of 29 percent. The higher velocity of the boat tail bullet translates into a flatter trajectory and decreased wind deflection. It also means more energy delivered on target. These are all vital considerations for the Observer/Sniper selecting a bullet for use.

.308

180gr Bullet	B.C.	MV	100	200	300	500
RN	.250	2600	2271	1967	1702	1296
Bullet Path:		-1.5	2.64	0.0	-11.66	-74.96
HPBT	.538	2600	2439	2284	2134	1853
Bullet Path:		-1.5	2.17	0.0	-8.82	-50.48

Ballistic coefficient is independent of bullet weight and caliber in its effect, although increasing weight in a specific caliber will increase ballistic coefficient. The ballistic coefficient for a 150-grain round nosed .308 is 0.213, and for a 180 grain round nosed .308 it is 0.267. If two bullets have the same ballistic coefficient, and the same muzzle velocity, they will have identical trajectories *regardless* of their caliber, shape, or weight. Sierra's .224 caliber 45 grain spitzer with a ballistic coefficient of 0.213 and the above cited 150 grain .308 round nosed bullet will have the exact same trajectories, given the same muzzle velocity.

Small differences in ballistic coefficient have relatively insignificant effect, especially at ranges under 500 yards. For example, if the .308 caliber Sierra 168 grain HPBT (ballistic coefficient 0.475) and the .375 caliber Sierra 300 grain soft point boat tail (ballistic coefficient 0.493) are both started at 2600 fps, they will have essentially the same trajectory out to 500 yards.

Comparison of Similar Coefficients

300gr .375 SPBT v. 168gr .308 HPBT

Muzzle Velocity: 2600 fps

Bullet	BC	100	200	300	500	1000
300sp	.493	2449	2304	2163	1897	1329
Bullet Path:		2.14	0.0	-8.67	-49.28	-349.6
168hp	.475	2417	2241	2073	1758	1145
Bullet Path:		2.22	0.0	-9.13	-53.06	-407.1

Bullets suitable for the Observer/ Sniper are of two basic designs. One is the traditional flat base design, the other the boat tail design. Of the two, the boat tail is far superior. As discussed in the section on Internal Ballistics above, a boat tail bullet has a more uniform base than a flat base design.

Secondly, boat tail bullets are more aerodynamically efficient. They create less drag in their flight. The air stream spills off the tapered rear of the bullet more smoothly, creating less turbulence and less of a vacuum. That equates to less drag. A small hollow point will reduce the compaction of air at the nose and the resultant turbulence. It acts like a small cookie cutter against the denser, compacted air. The shock waves that are caused by the bullet's passage are more streamlined. In actuality, the improvement in aerodynamic performance is not significantly greater than that of equal quality flat base bullets except at extreme range, but it <u>is</u> better. Lastly, boat tail bullets are less damaging to the barrel of a rifle.

Frankford Arsenal ran an extensive test of the effects of bullet design on barrel life. Their tests determined that using flat base bullets improved the accuracy of a barrel for the first 2000 rounds. The accuracy leveled off up to about 5000 rounds. After 5000 rounds accuracy fell off as the barrel deteriorated. With boat tail bullets, accuracy improved dramatically the first 300-500 rounds. It continued to improve up through 3000 rounds. Through 8000 rounds accuracy showed minor but continuing improvement before leveling off. The barrels did not begin to deteriorate until about 10,000 rounds were fired. The exclusive use of boat tail bullets coupled with proper cleaning can double the effective life of the barrel.

Once the trajectory is understood, the rifle can be fired accurately. Knowing the trajectory allows the shooter to know either where to aim or how to adjust the sights in order to hit a precise target. For example, the FBI uses .308 ammunition loaded with Sierra 168 grain hollow point boat tail (HPBT) bullets to a muzzle velocity of 2650 fps at standard temperature/pressure. (Standard temperature and pressure is 59 degrees Fahrenheit at sea level, or 29.92 inches of mercury). The bullet has a ballistic coefficient of 0.475. Specifying the temperature and air pressure is important because the velocity and trajectory will vary. Most published ballistic tables and trajectory data are listed for standard temperature/pressure.

When zeroed at 200 yards, the bullet is never more than 2.1" above the line of sight from the muzzle to the zero range. The zero range is where the point of aim and the point of impact coincide - 200 yards in this example. At 250 yards, the bullet is 3.5" low. At 300 yards, it is 8.8" low. The Observer/Sniper will know that with this zero, he must aim 3.5" high to hit his point of aim at 250 yards, and almost nine inches high to hit at 300 yards.

Knowing the trajectory of the bullet is half the problem facing the Observer/Sniper. The range must also be known, or accurately estimated, for precise shooting. There are a number of methods for estimating range. An experienced Observer/Sniper will use a combination of them.

These methods are: actual distance measurements using range measuring devices, maps, blueprints, estimation by eye, comparison with known dimensions, and the use of the scope reticle. The reticle of the scope can be an excellent range finding device, about which more is discussed below. (See pages 41-42). Most commercially available range finders sold for sporting use have too great a margin of error to be effective. The readings can be off by plus or minus 10-20%. On the other hand, currently available laser range finders are extremely accurate, to plus or minus one half of one percent, and are small, convenient, and expensive.

Actually measuring distances is a practical preparatory step to take in locations where Observer/Sniper utilization can be anticipated, such as airports and around government buildings. Another preparatory step is to measure the distance of various common dimensions, such as the spacing of electric poles, the length of street blocks, the width of streets, etc. Knowing these common dimensions allows the Observer/Sniper to estimate range by comparing the location of the target with known common dimensions in between the Observer/Sniper and the target. Many locations are accurately mapped, and these maps can provide detailed range data for the Observer/Sniper. Again, airports are a prime example.

Estimation by eye is a matter of experience, practice, and learning the appearance of common objects at various ranges. Estimation by eye can be severely influenced by the nature of the terrain, the light and atmospheric conditions, and the amount of the target visible.

Looking across a hidden depression, downward from high ground or along a straight open road will make objects appear closer than they are. Looking across a visible depression, looking upward from low ground or when the field of vision is narrowly confined as in forest trails or crooked streets will make objects appear farther than they are. Objects will appear closer when clearly seen and outlined, or when seen over uniform surfaces like snow or water, or when the sun is behind the observer. They will seem farther away when obscured or small in relation to the surroundings, when they blend into the background, when seen in poor light such as dusk or dawn, when seen in the rain, snow or fog, or when the sun is in the observer's eyes. Estimation by eye should never be used as the sole means of estimating range except as a last resort.

Proper zeroing of the rifle can simplify the range estimation problem greatly. Refer again to the example cited above using the Sierra 168 grain HPBT zeroed at 200 yards. Since the bullet is never more than 2.1" from the line of sight to about 225 yards, in practice the Observer/Sniper can take headshots out to 225 yards merely by holding center. This virtually eliminates the problem of range estimation at practical law enforcement ranges. In effect, the Observer/Sniper with a 200 yard zero has a "point blank" range of approximately 225 yards.

Point blank range is that distance within which the shooter need not estimate range. The bullet is close enough to the line of sight that the shooter for all practical purposes can consider the point of aim and the point of impact to coincide. Beyond the point blank range, the Observer/Sniper must either aim above the desired target or adjust the sights on the rifle to raise the point of impact. Hold off or sight adjustments are the only options for targets beyond the point blank range. They require accurate range estimation, thorough knowledge of the trajectory, and experience. That is why a 100 yard zero is not recommended.

Using the same example, if the Sierra 168 grain HPBT were zeroed at 100 yards, it would be over 4 inches low at 200 yards, and over 15 inches low at 300. The point blank range is about 160 yards. Any target farther away will require the shooter to estimate hold over, or adjust the sights. In either case, it needlessly complicates the problem for the Observer/Sniper and limits his effective range.

Although gravity and drag are the only forces that act on the trajectory, there are other external factors that influence the trajectory *relative to the point of aim.* These factors are wind, altitude, temperature, humidity, and barometric pressure. Wind is by far the most significant.

Wind is nothing more than air in motion. Since the bullet is moving in the air, as the air moves so does the bullet. If the wind is blowing at right angles to the bullet's line of flight, the deflection will be the greatest. Wind deflection is always in the same direction as the wind. A wind blowing from the left will move the bullet to the right. Deflection decreases as the angle of the wind to the line of flight decreases. When the wind is parallel to the line of flight (either a head wind or a tail wind) horizontal deflection is zero. Some vertical deflection will occur with a head wind or tail wind, but it is noticeable only at ranges in excess of 600 yards. This vertical deflection is caused by the bullet velocity being augmented by the tail wind velocity or diminished by the head wind velocity.

The amount of deflection caused by the wind is determined by the direction of the wind, its velocity, and the range to the target. The greater the range, the longer the wind will have to move the bullet. And the faster the wind blows, the faster it will move the bullet.

Wind deflection is not a constant curve. Just like the trajectory, the wind deflection curve is parabolic, i.e., constantly increasing. Therefore, the deflection at 400 yards will be more than twice the deflection at 200 yards.

For example, the Sierra 168 grain HPBT cited above will have a deflection of three inches at 200 yards in a 10 MPH wind at right angles to the line of flight. At 400 yards, the bullet will be deflected over 13 inches. At 1000 yards, an undetected change in the wind velocity of one MPH by itself can move the bullet more than 7 inches.

Although wind deflection varies with the angle of the wind to the line of flight, the difference between related angles is small. Since the greatest deflection occurs with right angle winds, these deflections must be learned. Winds are classified according to the direction from which they are blowing. Right angle winds are called "full value" winds, which means the full value of the deflection will apply. Winds at less than right angles to the trajectory are called "half value" winds.

In practical use, the Observer/Sniper need only take half the full value for that wind velocity. Headwinds and tailwinds cause no significant deflection and are called "zero value" winds.

To shoot accurately in wind, the Observer/Sniper must know wind velocity, wind direction, and the "full value" deflection for the range at which he is shooting. If it is a full value wind, the shooter must correct for the full value deflection. If the direction of the wind is quartering to the trajectory, the shooter corrects for *half* of the full value. The correction is made by either "holding off", which means aiming into the wind a distance equal to the deflection, or by adjusting the sights an amount equal to the deflection value.

Wind velocity can be measured by a wind meter or estimated by observing its effects. On a range, estimate the angle of the range flag from the flagpole and then divide the angle by four. The result is a rough approximation of the wind velocity. The following table lists some common effects of various wind velocities, which can be used for estimation.

Wind Effects Table

Under 3 MPH:	Barely felt; drifts smoke
3 to 5 MPH:	Lightly felt on the face
5 to 8 MPH:	Tree leaves in constant motion
8 to 12 MPH:	Raises dust and loose paper
12 to 15 MPH:	Causes small trees to sway

Because of obstructions and terrain features such as buildings, tree lines, hills or valleys, the wind can be blowing from several different directions between the shooter and the target. The differences can be extreme. At the shooter's position there could be a full value wind from the left while a half value wind from the right is blowing at the target. Since the wind deflection is minimal close to the shooter, and maximal at the target, it is necessary to determine the wind direction and velocity at a point in between which will best average out the effects. This is called "reading" the wind.

As a rule, read the wind at a point between two thirds and three quarters of the way to the target. Estimate the direction and velocity at that point, and apply correction accordingly. Although various ballistics tables give wind deflection values, as do the ballistics tables at the end of this manual, and there are various wind charts available which also give wind deflections for a range of velocities and directions, there is no substitute for practice and experience.

The tables and charts are approximations at best. Several are included in the appendices of this manual. In order to learn how to read wind and shoot well in wind, the Observer/Sniper must practice in windy conditions and keep accurate records of the effects on him and his shooting.

Temperature will affect both the muzzle velocity of the bullet and its trajectory. Ammunition will assume the ambient temperature of the environment. The hotter it is, the higher the pressure created by the combustion of the powder and the faster the muzzle velocity. A 30-degree increase in ambient temperature will increase muzzle velocity by about 50 fps. Ammunition should not be left in direct sunlight. It will absorb heat and grow considerably hotter than the surrounding atmosphere. Dangerous pressures can result.

Temperature changes can also affect the point of impact of the bullet relative to the point of aim. If a rifle is zeroed in 50-degree weather, then shot in 90-degree weather, it will shoot high. Point of impact will follow the temperature. A rule of thumb is to expect to have to make a sight change for every 10 to 15 degree change in temperature. The amount of the change will vary with the rifle, ammunition and shooter. It can only be determined by frequent practice in varied temperatures and accurate record keeping of the results.

Altitude affects the trajectory because of the decreased air density with elevation. The higher the elevation, the less dense the air. As air density decreases, drag decreases. The result is a flatter trajectory and higher retained velocity over any given range. The point of impact relative to the point of aim will rise with altitude. Sight corrections should be necessary for approximately every thousand feet of change in altitude.

Barometric pressure is a measure of air density. Changes in barometric pressure are no different than changes in altitude. It is measured in inches of mercury. Standard sea level air pressure is 29.92 inches of mercury. As air density decreases, the barometric pressure decreases. The standard barometric pressure at 1000 feet altitude is 28.92 inches of mercury. One inch of mercury is equivalent to one thousand feet of altitude, up or down.

For example, if a rifle is zeroed on a day when the barometric reading is 30.15 inches then fired when the barometer has fallen to 28.15, the effect will be as if the shooter had moved to an altitude 2000 feet higher. The point of impact of the bullet relative to the point of aim will move in a direction opposite to the barometer. As with altitude, barometric changes less than one inch of mercury are relatively inconsequential.

Humidity has a small effect on the flight of the bullet relative to the line of sight, but it is sufficiently small to be of little significance. As relative humidity increases, the density of the air increases which adds drag. Unless going from one extreme of humidity to another, the effects can be generally ignored. They are apparent only at extreme ranges.

Mirage is a poorly understood factor that has limited effect upon the shooter. Mirage is nothing more than the sight of heat waves in the air, most noticeably in sunny conditions. As the sun warms the ground, heat is radiated back into the air. The warmer air, being less dense, rises. The heat waves are seen as a shimmering ripple in the air, and are especially evident through the magnified view of a scope.

Mirage is a good indicator of wind velocity and direction. The direction of the ripples indicate wind direction while the amount of ripples vary with wind velocity. At a velocity of about 12 MPH, the ripple effect disappears and the appearance is that of a stream. Velocities in excess of 15 MPH or so will dissipate mirage. Ripples straight up indicate a head or tail wind, or no wind at all, for example. This particular mirage is called a "boil".

The most valuable use of mirage is as an indicator of changes in wind direction or velocity. Since mirage is literally nothing, it will reflect a wind change before more physical effects materialize, i.e., before leaves can stop fluttering, or before flags moving in one direction can stop and move in a different direction. In long range shooting this can be critical because a wind change taking effect between pulling the trigger and the bullet hitting the target can deflect the bullet sufficiently to cause a miss.

A large number of shooters maintain that mirage also optically affects the shooter by displacing the target image in the direction of the mirage flow. Common sense and simple physics show this view to be wrong.

The speed of light varies with the density of the medium through which it is passing. In a vacuum, light travels at 186,270 miles per second (MPS). In air it travels about 186,000 MPS, and in water about 140,000 MPS. A comparison of the speed of light with the speed of air movement caused by wind (represented by mirage) leads to the inescapable conclusion that even if it were possible to move or bend light rays by air movement, the effects would be infinitesimally small.

The refraction (bending) of light rays is the result of their passing from a medium of one density through a medium of different density at an angle. Refraction results from the change in the speed of light due to differing densities. An example is the apparent displacement of an object seen at an angle under water.

Mirage is caused by the release of heat from the earth and other solid objects into the ambient air. The rate of heat transfer and absorption varies with the heated surface, the shape of the surface, the composition of the surface, the moisture content in the vicinity of the surface, and the variety of air conditions about the various surfaces. Consequently, there are an infinite variety of heat transfer and absorption rates over the course of any specific range with an equal variety of air densities resulting. Further, all of these small air masses are constantly changing in size, shape, density, and movement. Light will be refracted when it passes from one density through another.

Mirage is thus better described as eddies, or turbulence, in an infinite number of small air masses of differing densities. The light from the target to the shooter is refracted and the target appears to shimmer, waver, and change shape because all the intervening air masses are constantly changing in size, density, shape, and their relation to each other.

There cannot be any displacement of the target any constant amount or constant direction, even for periods of time as short as fractions of a second under conditions existing on most rifle ranges. The best example of the actual, and negligible, effects of mirage is the fact that even in precision surveying mirage is ignored because the refraction of light in the line of sight is constantly changing and cannot be "averaged out".

Mirage is noticed for the distortion produced in the outlines of any object viewed through it, leading to apparent alterations in shape and size of the object, but *not* in its average position. There can be a displacement in situations involving considerable elevation differences between shooter and target, or over water or swampy areas, because there is possible widespread, consistent heat transfer and absorption over the range in such conditions. At law enforcement ranges, mirage can be safely ignored except as an indicator of wind changes.

A final external factor affecting the trajectory relative to the point of aim is the question of shooting uphill or down. The fact is that regardless of whether the shooter is aiming up or down, the shot will *always* strike high relative to the trajectory, as it would have been on the horizontal. This means that if the Observer/Sniper is firing on an angle up or down at a slanted range of 100 yards, the point of impact will be higher than it would be for a level shot of 100 yards. How high depends on the angle.

The reason is that gravity acts on a bullet only during the horizontal component of its flight. The horizontal component is the horizontal distance from the shooter to the target measured as if they were both at the same level. Since the horizontal component will always be less than the slanted range, gravity will not pull the bullet down as far as it would if the slanted range were level. The shot is thus high relative to the point of aim.

A simple example is a shooter firing up or down on a 45-degree angle at a target 200 yards away from him on the slant. The horizontal component is 140 yards since a right triangle with a hypotenuse of 200 yards will have two equal legs of 140 yards each. Gravity acts on the bullet for a distance of 140 yards, not 200 yards. The result is that although the slanted range is 200 yards, the trajectory is that which would apply to 140 yards. If the rifle were zeroed at 200 yards level range, the shot will strike high because at 140 yards the bullet is about 1.5 inches above the line of sight.

The rise in the point of impact is always relative to the point of aim. Using the same example, if the rifle were zeroed at 100 yards on the horizontal, it would be 4.2 inches low at a level range of 200 yards. When fired at a slanted range of 200 yards, it will be only 2.7 inches low (- 4.2 inches + 1.5 inches). The change in impact is relative to the point of aim, and is always high.

A simple method for knowing how high the bullet will strike when firing on an angle is to estimate the horizontal distance to the target. Shoot at the target as if it were on the same level and the range was equal to the horizontal distance. A hypothetical and overly simplified illustration is to imagine shooting from the top of the Empire State Building at a target on the ground across the street. The Empire State Building is 1200 feet tall, so the slanted range is 400 yards. The street is 25 yards across. The horizontal distance from the shooter to the target is therefore 25 yards. The shooter should aim at the target as if it were 25 yards directly in front of him.

A complicating factor in shooting up or down is that the wind will affect the shot over the entire slanted range. Using the Empire State Building example again, although the shooter should aim at the target as though it were 25 yards away, he must correct for wind deflection as if it were a 400-yard shot. The field expedient method for shooting uphill or downhill is to hold elevation based on the horizontal range; correct for wind deflection based on the slanted range.

6. Terminal Ballistics

"Terminal ballistics" is the science of the bullet's motion and action from the instant of initial impact with the target until it stops. It is more properly termed "wound ballistics" when dealing with the human target. Wound ballistics includes the motion of the bullet through the human body, its interaction with living tissue, and the effects which gunshot wounds have on people.

Law enforcement Observer/Snipers shoot for one reason, and one reason only - to save someone's life or prevent serious physical injury. The shot must immediately incapacitate the subject. "Immediate incapacitation" is the sudden physical or mental inability to initiate or complete any physical act. Immediate incapacitation requires very precise shooting on the part of the Observer/Sniper.

The only reliable way to force immediate incapacitation on a human target is to destroy the central nervous system by hitting either the brain or the spinal column. All bodily functions and voluntary actions cease when the brain is destroyed. If the spinal column is broken, then all functions cease *below* the break. However, the spinal column is a small, difficult target to hit with reliability. Additionally, muscular functions still exist above the break. For example, the arms can still be used if the break occurs below the shoulders. A violent subject could still kill or injure those about him in such a case.

A hit anywhere else in the human body is not certain to force immediate incapacitation. Even if the heart is completely destroyed, there is sufficient oxygen in the brain to support full, unaffected, voluntary actions for a period of 10-15 seconds. During that time a subject can run, fight, or otherwise react, as he will. It is common on the battlefield as well as the street to see people with grievous, unsurvivable wounds continue to fight and function for a period of time after receiving the wounds.

Barring a central nervous system hit, incapacitation is forced upon the unwilling human target only when hemorrhaging is sufficient to drop blood pressure to zero, and/or deprive the brain of oxygen. That takes time. Although incapacitation can occur with a hit other than in the central nervous system, it is a strictly fortuitous event. It is not reliable, and it is not reproducible from one case to the next. The human target is a complex one, and there are many factors that affect the likelihood of incapacitation.

Physiologically, the subject may be under the influence of narcotics, alcohol, or just pure adrenalin. Many narcotics are disassociative in effect. The individual under the influence of a disassociative drug such as cocaine, PCP, or heroin, "exists" outside of the body. They do not experience trauma inflicted on the body. They can "see" it and may be aware of it, but as an outside observer. Adrenalin, a natural stimulant produced in the body in times of stress, can also prevent awareness of injury. The individual can remain totally unaware of even a grievous and fatal wound until he eventually collapses from loss of blood, often to his great surprise.

As with most sudden, severe wounds, the onset of pain is delayed until some time after the injury has occurred. Without pain, there is no awareness of injury and there may be no reaction. The individual can be devoid of any stimulants, narcotics or alcohol, and simply not react to the shot for an indeterminate period of time because he is simply unaware an injury has occurred.

Psychologically, the individual may have a strong will to survive that compels him to continue to fight or flee. Rage or a commitment to fight to the death can delay or prevent incapacitation. There are people who are simply not afraid of pain or the possibility of dying. Sheer will power, strong emotion, or a lack of fear will all work to keep a subject fighting despite severe wounds, or perhaps because of those wounds.

Physically, a bullet simply is not capable of knocking a man down. The ratio of bullet mass to target mass is too extreme. This is simple physics. If a bullet had the energy to knock a man down, there would be equal energy exerted back at the shooter. The sudden, violent physical reactions to being shot seen in some cases are caused by spasmodic muscular contractions, not by the impact of the bullet. A change of position can only be forced if the bullet strikes and destroys a load bearing structure such as a hip joint or knee.

These factors can be present singly or in various combinations. Incapacitation may occur, or it may not. In many cases, incapacitation occurs regardless of the bullet used or its placement. The reason is largely psychological. The individual knows he has been shot and he falls down, perhaps because he believes he is supposed to do so or because he simply quits. It happens with superficial wounds as well as severe ones. Unfortunately, the only way to determine whether or not any particular individual will be incapacitated by a gunshot wound other than through the brain is to shoot them and see. Given the role of the Observer/Sniper and the purpose of his shooting, this is unacceptable.

A bullet has two primary wounding effects in flesh. The first, called the "crush" factor, is the destruction of tissue in the path of the bullet. Tissue is crushed and disintegrated ahead of the bullet as deeply as the bullet penetrates; leaving a hole that is called the "permanent cavity". The second, or "stretch" factor, is the temporary cavity that is caused by tissue around the permanent cavity being propelled radially outward from the path of the bullet. The tissue stretches away from the bullet's path forming a cavity that is approximately 10-12 times the bullet diameter, and then collapses to its original configuration. The duration of the temporary cavity is so short that damage is minimal except in very fragile brain tissue or inelastic tissue such as liver.

Any effects due to temporary cavity are too short lived to be recognizable by the brain. Tissues such as muscle, blood vessels and lungs are very elastic and will be stretched by the temporary cavity with little or no damage. The outward velocity of the tissues in which the temporary cavity forms is no more than one tenth of the velocity of the projectile. This is well within the elasticity limits of such tissues.

Two secondary events can occur, either of which will dramatically increase the wounding effect of a bullet. The first is "fragmentation" which occurs if the bullet breaks up. When fragmentation happens, the bullet jacket and lead core break up into small, jagged, sharp edged pieces, which are propelled outward radially with the temporary cavity. The fragments sever tissue that is already stretched and somewhat weakened by the temporary cavity. The result is large, seemingly "explosive", wounds that are characterized by damage beyond the permanent cavity. Bone fragments caused by the bullet's passage can cause the same effect.

It must be stressed that if there is no fragmentation, remote damage due to temporary cavitation is minor, even with high velocity rifle projectiles. The Sierra 168 grain HPBT used by the FBI fragments reliably. It causes devastating wounds, which are almost explosive in nature due to the extreme fragmentation of the bullet.

The second event is bullet tumbling. When a bullet tumbles in flesh it turns over and travels base first. In the process of tumbling, the bullet is traveling sideways through the tissue at one point. This causes a significantly more severe permanent cavity during that portion of the bullet's passage when it is sideways to its track. Tumbling can also cause the bullet to change direction erratically within the body.

It is not widely understood that all bullets tumble in flesh, assuming the bullet is not significantly deformed by fragmenting or expanding. As previously discussed, a bullet is not form stable. The spin imparted by the rifling (150,000-220,000 RPM) is necessary to stabilize the bullet in air. In the far denser medium of flesh, the bullet simply cannot be spun fast enough to be stabilized. The result is that the bullet tumbles in order to fly with the center of gravity forward of the center of form.

An expanding bullet may or may not tumble. It depends upon whether the mushroom-like expansion (which moves mass to the rear) is sufficient to bring the center of gravity forward enough to make the bullet essentially form stable. Although tumbling can significantly increase the wounding capacity of a bullet, it can also cause extreme deflections in the path of the bullet within the target. The best bullet for the Observer/Sniper is a reliable expanding or fragmenting design.

As can be seen, the single most important wounding criterion is penetration. A bullet absolutely must be able to penetrate through the major blood bearing organs within the body. The minimum penetration necessary is 10-12 inches of soft body tissue. The penetration required could be greater if the target is unusually large, or includes intervening arm bones, layers of thick clothing or other such obstacles.

The single most important factor affecting penetration is bullet mass. Heavier bullets penetrate more predictably, and more reliably. The lighter the bullet, the more susceptible it is to deflection, both by wind externally and by obstacles such as bone, glass, or clothing terminally.

Secondly, as a bullet deforms or fragments within a target, it loses mass. A light bullet has little mass to lose before becoming extremely susceptible to extreme deflections as well as decreased penetration. A 50% loss of mass (which is not unusual) in a 55-grain bullet leaves a progressively smaller bullet to do the work. The greatly increased drag of flesh (far denser than air) will quickly stop the projectile. A similar loss of mass in a 168-grain projectile leaves a large enough projectile to still penetrate to vital organs.

Mass is vitally important externally for decreased wind deflection and terminally for reliable penetration, especially through intervening obstacles such as glass, clothing, or bones. For this reason, the smallest caliber suitable for Observer/Sniper use is 7mm (.284 caliber).

It is obvious that the Observer/Sniper must strive for a headshot. The shot is made to prevent the death or serious injury of others. Immediate incapacitation must be forced upon the subject. That can be accomplished reliably only by destroying the brain.

The target is best described as a two-inch diameter area in the center of the head, directly behind the eyes. It can be envisioned as a two-inch lateral band around the head, centered on the eyes. A shot in that area which penetrates through the center of the head will invariably result in immediate incapacitation.

One final distinction must be drawn, between immediate incapacitation and "no reflex" death. Ideally, the two are synonymous. In reality, they are not. When the subject is shot, ideally there would be no reflex action which could result in a trigger being pulled or some other totally involuntary but potentially hazardous physical action.

Unfortunately, "no reflex" death is not a reliable product of an instantly incapacitating shot. It can occur, but equally likely is spasmodic muscular twitching, contractions, and contortions. Such reactions are totally mindless and involuntary, but could be enough to pull a trigger.

The Observer/Sniper must be aware of any weapons in the subject's hands and where they are pointed. He must plan his shot to minimize the hazard posed by an uncontrolled, spasmodic trigger pull by the subject, should it occur.

7. Optics

Optical equipment is vital to the Observer/Sniper. The most obvious item of optical equipment is the telescopic sight, or "scope", for short. A scope provides the shooter with two significant assets.

The first is the presentation of the sights (the reticle in the scope) and the target on the same focal plane. This allows the shooter to see both the sights and the target in focus, presenting a clear and unambiguous sight picture.

The second asset of a scope is magnification. Magnification aids target identification. It enhances precision shooting by enabling the shooter to aim at a small, precise spot on the target rather than an indeterminate area of the target. Magnification brings the target visually closer, which aids shooter confidence and enables exact and detailed observation and identification.

Since scopes are available in a wide range of magnifications, including variable magnification powers, this is the first feature that must be considered for Observer/Sniper use. Although magnification is an asset, too much can be a severe detriment. As a rule, magnification greater than 10x to 12x power is not suitable.

The higher powers, from 16x on up, are too difficult to shoot. In addition to magnifying the relative size of the target, a scope also magnifies the ever present, inherent motion of the rifle. A shooter accustomed to the small, regular "wobble" of iron sights or a low powered scope can become thoroughly disconcerted looking through a high powered scope and seeing that same motion magnified 16 times or more. Although the actual movement is the same, the magnification creates the illusion that it is far more. With practice, a good shooter can learn to "hold" a 10x or 12x scope.

By "hold" is meant the shooter can control the motion, keep it within the desired impact area of the target, and fire an accurate shot. The magnification effect and illusion of uncontrollable motion apparent with a scope of 16x or greater power is so extreme that many shooters can never learn to hold them. This problem is further discussed in the Basics of Marksmanship section below.

A second limiting factor that comes with increased magnification is decreased "field of view". Field of view is the diameter of the total area that can be seen through the scope. The higher the power, the more restricted the field of view. For example, according to specifications for Leupold scopes, the field of view at 100 yards for a 6x scope is 17.7 feet; for a 12x scope it is 9.1 feet; and for a 24x scope it is 4.7 feet.

Thirdly, eye relief for a scope becomes increasingly more critical as magnification is increased. Eye relief is the distance behind the scope's eyepiece at which the optimal view through the scope is attained. At 16x or greater powers, there is no margin for error. The eye must be exactly that distance or the scope is optically unusable.

Lower powered scopes such as 4x or 6x have very forgiving eye relief dimensions in that moderate differences of eye distance behind the eyepiece do not prevent a full field of view. However, inconsistent location of the eye behind the scope is not conducive to accurate shooting.

A magnification of 10x to 12x power is optimum for the Observer/Sniper. This is ample magnification for precision shooting and for positive identification of the target at law enforcement ranges. Shooters can readily learn to hold a scope of such magnification. The eye relief allows minor inconsistencies in eye distance behind the scope, which means the shooter will not waste precious time in a critical situation trying to find the proper eye position to see through the scope. The field of view is sufficient for quick and efficient target acquisition through the scope.

There is considerable controversy over the use of fixed power scopes versus variable powered scopes. The argument in favor of variables is that the lower power settings provide greater fields of view for easier target acquisition. Once the target is acquired in the scope, the higher power setting can be selected for accurate shooting.

The argument against variables is that they require internal telescoping parts that must be manufactured to looser tolerances than the internal parts of a fixed power scope. The moving parts wear against each other with use. Over time the accuracy and reliability of the scope are reduced. Further, shooters seldom actually use the low power settings because they do not shoot as well since real precision aiming is not possible. Neither should an Observer/Sniper be trying to adjust power settings in a crisis situation when he is supposedly concentrating on the target and the shot. Variable scopes can also change point of impact and focus as the power setting changes. This effect increases in magnitude the more the variable feature is used and the affected parts wear against each other.

Finding a target in a scope is done the same regardless of magnification. The shooter keeps both eyes open and focused on the target, raising the rifle and interposing the scope in his line of sight. The scope will be immediately on target. With minimal practice, target acquisition becomes as fast and certain as with open sights. Since the main argument for variable scopes is field of view and target acquisition, clearly a fixed power scope is a better choice for the Observer/Sniper.

A critical scope feature is the method of adjusting the crosshairs, more properly called the "reticle". The reticle is the sight. It combines the functions of front and rear sights in one image. The scope adjustment knobs move the reticle left and right, and up and down, which in turn moves the point of impact in the same direction relative to the point of aim. By adjusting the reticle, the point of impact is shifted until it coincides as desired with the point of aim and the rifle is then zeroed at that range.

Scope adjustments are made by one of two ways: a positive adjustment system or a friction ring system. The friction ring system, which is found on most scopes, is not suitable for Observer/Sniper use. The problem with it is that sight changes are neither precise nor repeatable. The system employs two or more friction rings which are screwed in or out against each other. There are no positive stops by which precise adjustments can be made, nor can there be uniform friction as the rings are tightened in one direction or loosened in the other. Since the friction constantly changes, the amount of change in the reticle constantly varies as well as the rings tighten or loosen against each other. Positive sight changes cannot be made with a friction ring scope.

A shooter using a friction ring scope must zero at one specific range and learn how much to hold off in order to shoot at different ranges. It is not possible to zero at 200 yards, for example, and then simply change the sights to be zeroed at 300 yards. The sight change as reflected by the scale on the adjustment knobs can easily be plus or minus several MOA. In order to change zero from one range to another, the shooter must employ a trial and error method of shooting and adjusting the scope until the new zero is acquired.

A positive adjustment system provides precise and repeatable adjustments. The scope can be zeroed at one range and then rezeroed at a different range by simply adding or subtracting the necessary sight adjustments. The test of a positive adjustment system is to first zero the rifle and shoot a group. Add 6 MOA of "up" adjustment and shoot a group. Then add 6 MOA of "right" adjustment and shoot a group. Adjust the scope 6 MOA "down" and shoot a group. Finally, add 6 MOA "left" and shoot. The final group should be in the same place as the first one.

Ideally the adjustment will be in quarter MOA steps, and should never be more than half MOA steps. Otherwise the adjustment is too coarse to allow precise zeroing of the rifle. Plus or minus more than one half MOA is too much for Observer/Sniper use. Another advantage of the positive adjustment system is that every change can be heard and felt. For example, a shooter zeroed at 200 yards wants to hit a target at 300 yards. Knowing his bullet is 6 inches low at 300 (2 MOA), he adjusts the scope 8 clicks "up" (assuming a quarter MOA scope) and can hold "point of aim - point of impact" at 300 yards.

Reticles come in many forms. The most common is the simple cross hair composed of two intersecting lines. The lines may vary from thin and fine to thick and coarse. A tapered reticle consists of cross hairs that are thin and fine at the intersection and taper out to thick, coarse lines at the four bases. Dot reticles and duplex (or four plex) reticles are also commonly available. A dot reticle is merely a small dot in the center of the scope's field of view. It is sometimes combined with a fine crosshair. A duplex reticle consists of four coarse lines that project towards the center of the field of view where they abruptly change to thin, fine lines forming the intersection. There are many other reticle shapes and combinations too numerous to list.

Choice of a reticle must account for several factors. A fine cross hair or small dot cannot be seen in moderately poor light. A thick cross hair or large dot is visible in poor light but covers too much of the target, which inhibits precise shooting. A coarse cross hair can completely cover a man's head at 100 yards. In such a case, the Observer/Sniper can have no idea exactly where he is aimed or where the bullet will strike.

The best all purpose reticle for Observer/Sniper use is the duplex. In good to moderately poor lighting the fine crosshair intersection is visible. In worse lighting conditions, the four coarse bases are still visible and the target can be seen and centered precisely amid the four thick ends. The duplex reticle can also be used as a range finder.

The dimension covered by a part of a reticle at a specific range is called "subtension". For example, a dot that covers a one-inch circle at 100 yards "subtends" one inch at 100 yards, two inches at 200 yards, etc. If a shooter knows the subtension of his reticle he can use the reticle as a range finder. For example, assume the distance from the end of one thick line to the opposing end of another in a duplex reticle subtends 6 inches at 100 yards. If the shooter then looks at a 12-inch object and it fills the same space, that object is 200 yards away. A 6-inch object filling half the space would be 50 yards away.

Subtension values are published by all scope manufacturers. Of better use would be knowing how the reticle subtends a man's head at a specific range such as 100 yards. It would then be easy to later accurately estimate range by observing the subtension of a target's head.

Being an optical lens system, all scopes are subject to "parallax". Parallax is defined as an optical error where the target image, or focal plane, does not coincide exactly with the plane of the reticle. Like the eye, a scope can be focused only at one specific range. Parallax will exist at all other ranges because the focal plane will be either ahead of, or behind, the reticle plane. The effect of parallax is to present a false image of the location of the reticle on the target. However, the effect only exists if the eye is not directly centered behind the scope. Better scopes have an adjustable objective lens to permit focusing the scope at any range.

If parallax exists, it can be seen by slowly moving the eye around the rear of the scope while aiming at a small spot on a target. The reticle will appear to move about the point of aim. If there is no parallax, the reticle will remain on the point of aim regardless of whether the eye is centered behind the scope or not. Parallax induced error is greatest inside the focused range, decreasing in magnitude outside the focused range. The magnitude of the error is on the order of one half MOA, decreasing slightly as range beyond the focused point increases. The effect of parallax is relatively inconsequential at law enforcement ranges.

Scope lenses are coated with a chemical compound such as magnesium oxide to reduce the amount of light lost through reflection. An uncoated lens will reflect three to four percent of the light at each surface. Each lens has two surfaces and will lose 6-8 percent of the light passing through it. A scope may have 6-8 lenses. If it were not for the coating, only 45-55 percent of the available light would reach the eye. The coatings increase the amount of light through the lens system to 90 percent or more.

The coating is approximately one millionth of an inch thick and very delicate. Scope lenses must be cleaned <u>only</u> with high quality lens paper, lens cleaning fluid, and an airbrush such as photographers use on camera lenses. Great care must be taken to avoid getting any oil or gun cleaning solvents on the lenses. A solvent will quickly remove the lens coating.

In addition to the riflescope, two other items of optical equipment are necessary for an Observer/Sniper. These are a pair of 7x50 binoculars and a 20x power spotting scope with a tripod mount.

The Observer/Sniper must be equipped to observe and report intelligence as well as to shoot. A riflescope is ill suited for intelligence gathering responsibilities. It is unwieldy, being mounted on a long, heavy rifle, and if being so used, the rifle and the shooter are not immediately ready to take a shot should one be required.

The Observer/Sniper Team is composed of two trained Observer/Snipers, one on the rifle concentrating on the target and one using the binoculars to constantly observe as much of the crisis site and subjects as possible, reporting any and all intelligence. The binoculars are used for regular scanning and observation. The spotting scope is used to closely examine any specific item, individual, or event, which are found with the binoculars and need more detailed observation. The tripod mount eliminates induced motion in the spotting scope.

Eye relief on a spotting scope is zero (place the eye right behind the eyepiece, almost in contact with it) so there is no faltering or time lost in gaining the view through the scope. The eye relief on a riflescope cannot be so close because of the recoil of the weapon and scope.

8. Support Equipment

There are a number of items that should be included as basic support equipment for the Observer/Sniper. The single most important is a good record book. Without a record book, any shot taken in a crisis situation amounts to an educated guess.

A record book is used to keep a log of every shot fired in practice by the shooter. The shooter uses the book to record his zero, the temperature, wind velocity and direction, light conditions, range, altitude, ammunition used, and sight changes necessitated by the various factors. As the shooter continues to practice and maintain the record book, he compiles a comprehensive reference regarding his performance and that of his rifle under a variety of conditions.

When in position during an actual crisis situation, the shooter can refer to the record book, find conditions matching those he sees about him, and know exactly where to aim or how much sight change is necessary. There is no substitute for a record book. The mark of a professional shooter is a complete, detailed, and meticulously kept record book. It is an invaluable asset.

Some sort of rifle rest should be included. Traditionally, small sand bags are used to provide a solid shooting rest for a rifle. Sand is heavy, however. The same small bags filled with sawdust or crumbled Styrofoam serve just as well and have negligible weight.

A detachable bipod is a handy item to have in the event the Observer/Sniper's position does not lend itself to the use of sandbags. Shooting from a bipod attached to the rifle will change the point of impact relative to the point of aim. The amount of change will vary with the shooter, the position, and the bipod being used.

A good sling for carrying the rifle is necessary. It should be mounted with quick detachable swivels so it can be removed when in position. Resting the rifle on the sling will affect the zero and the ability to shoot precisely as the rifle is somewhat unstable with the sling between it and the sandbags.

The sling should not be used as a shooting aid. When worn properly as a shooting aid, a sling is strapped tightly around the upper arm and then wound tautly across the arm and about the wrist. The tightness and tension on the arm cannot be maintained long without great physical discomfort to the shooter. An Observer/Sniper simply cannot stay in a sling for the period of time he will be in position. Nor can he wait until he is going to shoot to get into the sling. It takes too long to get into a sling.

9. Basics of Marksmanship

Six factors comprise the basics of marksmanship: Sight Alignment, Sight Picture, Breathing, Trigger Control, Position, and Follow Through. These six factors are applicable to all forms of rifle shooting. Regardless of the rifle being used, the course of fire being pursued, or the conditions under which it is being fired, the basics of marksmanship must be applied in order to fire effectively and accurately. In order for the shooter to gain proficiency it is necessary to practice extensively in both live firing and dry firing exercises.

Factors of Marksmanship

1. Sight Alignment
2. Sight Picture
3. Breathing
4. Trigger Control
5. Position
6. Follow Through

"Sight alignment" is the image formed when the front and rear sights are properly aligned with each other. With conventional open sights, the proper sight alignment is attained when the front sight is centered in the rear sight.

To do so, the shooter should position the eye directly behind the rear sight and as close as comfortably possible to it. Look through the rear sight and focus the vision on the top of the front sight. The eye will center the top of the sight and keep the proper sight alignment *as long as* the vision remains focused upon it. The shooter must discipline himself to keep the vision focused solely upon the front sight. If focus on the front sight is not maintained, correct sight alignment is lost.

Using a telescopic sight simplifies sight alignment. The front and rear sights are combined in the crosshairs of the scope, called the "reticle". Because the reticle represents both sights in the same focal plane, there is no alignment required. However, the vision must be focused on the reticle with the same concentration used on the front sight of an open sight system.

"Sight picture" is the correct sight alignment imposed upon the target. Correct sight alignment requires the vision to be focused upon the front sight, or on the reticle if a scope is being used. The human eye can only focus upon one point in space at a time. It can change focus almost instantaneously, but cannot focus at two or more distances at once.

To form a sight picture with open sights, the shooter is dealing with three points in space - the rear sight, the front sight, and the target. By focusing upon the front sight, the remaining two points (rear sight and target) can be seen well enough to align all three. If the vision is focused anywhere other than the front sight at the moment the weapon fires, the sight picture is lost and the shot will not go where the shooter thought it was aimed.

Aperture sights are faster and more efficient than open sights. The shooter has only to look through the rear sight, ignoring it while focusing upon the front sight. The eye will automatically center the top of the front sight in the rear aperture better than the shooter can consciously do it. Thus there are only two points in space to align - the front sight and the target. This is faster and more accurate than conventional open sights in which the rear sight, front sight and target must be aligned.

The advantage of a telescopic sight (other than magnification) is that the sights and the target are presented on the same focal plane. Instead of two or three points in space to align, there is only one point at which the sights and the target are displayed. However, the eye will be drawn to the image of the target since that image is also on the same focal plane as the reticle.

The Observer/Sniper must be disciplined enough to look AT the reticle, and not at the target. Failing to do so means the shot will be fired without any awareness of precisely where on the target the reticle was held. It is the difference between shooting a half MOA group and shooting a two or three MOA group.

Focusing on the reticle is the most difficult aspect of shooting with telescopic sights. If the shooter lapses and looks past the reticle at the target, he should look away from the scope for a moment. It is extremely difficult to regain focus without taking the eye away from the scope first.

A second element critical to using a scope is proper eye relief. Proper eye relief results in a full, clear, and bright picture with no noticeable “edges” or boundaries visible. If the eye relief is not correct, fuzzy edges and dark “shadow” can be seen about the outer limits of the sight picture. The shadow will appear to slip about the curved edge of the picture from one side to the other, or to the top or the bottom. Any shot fired with shadow in the sight picture will not impact at the point of aim. It will be off to the side opposite the shadow. The shot will always be away from the shadow, relative to the point of aim. The error can be significant, often exceeding one MOA or more. Shadow is a visible symptom of incorrect eye relief.

Of course, a second symptom of incorrect eye relief is scope bite. It occurs when the shooter’s eye is too close to the rear of the scope and the recoil of the rifle drives the rear edge of the scope against the shooter’s forehead. The result is a small scar uniquely identifiable by its half moon shape.

Having attained correct sight alignment and the proper sight picture, the shooter must control breathing. As breathing occurs, the weapon (and the sight picture) moves up and down in rhythm with the respiration cycle. In order to fire accurately, respiration must be controlled at the moment of firing.

Conventionally, shooters have been instructed to let half of their breath out and then hold what is left until the shot is fired. Holding one's breath instills a tension in the body through the abdomen and diaphragm that affects the shooters muscle relaxation and control. Rather, a shooter should employ what is termed the "natural respiratory pause".

In the normal respiration cycle the individual breathes in for a second or two then breathes out for a second or two. For several seconds thereafter no breathing occurs at all. This is the natural respiratory pause. The shooter should merely extend this pause in order to be still through the shot.

To accomplish this, align the sights while breathing normally. Prior to starting the trigger squeeze, breathe in deeply and breathe out through the mouth. During the natural pause that follows, simply do not breathe while squeezing the trigger. After the weapon fires, resume breathing. The natural respiratory pause can be extended easily for 15-20 seconds. However, it is important that the shot be fired within 8 seconds, and certainly no more than 10, from the start of the respiratory pause. To go longer will begin to incur blurred vision and inability to retain clear focus upon the sight as the oxygen level in the brain is depleted. If the shot is not fired within the optimum interval, resume breathing and begin again from the start.

Breathing is controlled this way even in rapid fire. To do so in a rapid-fire situation either extends the pause for all the shots or increase the rapidity of the cycle. The latter is done by breathing through the mouth deeply and quickly. Force the air in hard, blow it out hard, then shoot; force it in and out then shoot; repeating for however many shots are being fired.

"Trigger control" is pulling the trigger in such a fashion that the sight picture is not disturbed while the shot is fired. Trigger control is the most critical element of marksmanship and the most difficult to master. Because the trigger pull of a rifle is short and easy, requiring little strength, the untrained shooter is inclined to jerk or snap the trigger in an attempt to make the weapon fire when the sight picture looks perfect. In so doing the weapon is moved, the sight picture is misaligned, and the shot does not go where the shooter thought it was aimed.

As a matter of common sense it should be apparent that since the rifle is moving any trigger pull started when the sights are just right is too late anyway. Usually, the shot will strike low and off to one side. Which side depends on whether the shooter is right or left handed? This occurs because the weapon is moved and its alignment is changed at the instant of firing. The shooter is unaware of it because it is masked by the recoil of the rifle. Dry firing and "ball and dummy" exercises will amply demonstrate to the shooter the effects of jerking or snapping the trigger. The motion imparted to the weapon will be apparent.

Proper trigger control consists of a steady application of pressure to the trigger until the rifle fires. Initially, the shooter will not know when the trigger will release, or "break", to use a rifleman's term. A thoroughly trained and proficient shooter will in fact know when the trigger is going to break. Depending upon the stability of the position being used, the trigger pull can be either continuous or interrupted.

Given a solid, steady position such as that gained by shooting from a sandbagged rest, the trigger pull can be continuous. The weapon is sufficiently stable that the sight picture remains practically undisturbed throughout the firing process. The shooter need only concentrate on the sight picture, control breathing, and softly but steadily press the trigger until the weapon fires.

An "undisturbed sight picture" means the sights remain aligned within the part of the target the shooter wants the bullet to hit. Some motion may be evident but it remains within the desired target area.

Squeezing the trigger can be likened to using an eyedropper from which only one drop is wanted. Gradually increasing pressure is applied to the bulb of the eyedropper while watching the end of it. When the one-drop forms and falls, no further pressure is added. Shooting is done the same way. Focus on the sight while adding gradually increasing pressure to the trigger until the shot fires.

In a less stable position the apparent motion of the weapon and the sights are more evident. This is especially true when using a scope. The magnification of the scope amplifies all motion of the rifle. A scope will show some motion even in the most stable of positions. A lot of the motion visible through a scope is not visible to the naked eye when using open sights. As the magnification power of the scope is increased even more motion will be observed, and the perceived magnitude of the motion will be exaggerated. Scopes of

16x or greater power will display the shooter's heartbeat. Seeing the reticle bounce around the target in time with one's pulse is distracting at best.

The most extreme example of sight motion is the offhand position in which the shooter must fire while standing erect without external support. The shooter must employ an interrupted trigger squeeze. To accomplish this, align the sights, control the breathing, and start the trigger pull. As the sight alignment moves out of the area the shooter wishes to hit, the trigger pressure should be held. It is essential to neither relax it nor apply additional pressure. As the sights return to the desired target area, add additional pressure in a gradual and gentle manner. Continue in this fashion until the shot is fired. Ideally, the shot will occur as the sights are moving into the center of the target or are at the center. Control of the trigger is paramount to accurate shooting.

As proficiency increases the interrupted technique should be employed in all positions. Even in the steadiest of positions there is some motion imparted to the rifle and sights. Proficiency in trigger control will result in smaller groups being fired.

"Position" is the platform by which the weapon is held and fired. Common to all positions are three position elements: Bone Support, Muscular Relaxation, and Natural Point of Aim.

Bone support means that the weight of the weapon is supported by the skeletal structure of the body and not by muscular strength alone. For example, if a shooter holds a rifle in one hand extended at arm's length away from the body it is supported by muscular strength alone. In a short time the muscles fatigue and the weapon sinks lower and lower. Contrarily, if the arm is bent so the elbow is directly under the weight of the weapon and close in to the body, the weight is borne by the bone structure of the arms and can be held indefinitely without duress.

Muscular relaxation means precisely that. Once the position is attained, the shooter should be totally relaxed without any muscular tension or duress in the arms, legs, or torso. Given bone support and muscular relaxation, the weapon will remain aligned on the target without any effort or muscular control on the part of the shooter, assuming a natural point of aim has been established.

Natural point of aim is adjusting the position so that when the shooter relaxes and the weapon is fully supported the sights are aligned upon the target without any muscular control being exerted by the shooter. Accomplish this by first aiming the rifle. Then close the eyes and relax completely. After a short pause, open the eyes and see if the sight picture changed. If the sights have moved, adjust the position as necessary to bring the proper alignment into effect. Retest the natural point of aim again.

Position Elements

Bone Support

Muscular Relaxation

Natural Point of Aim

Once the position has been adjusted to the point that the sight picture remains unchanged after closing the eyes and relaxing, then a natural point of aim has been established. This is important in any position for shooting with the greatest possible degree of accuracy.

If a natural point of aim is not attained, then the sights must be held aligned by muscular effort. When the weapon recoils, the effects of the recoil overcome muscular control of the rifle. The rifle reverts to wherever the natural point of aim would be. This movement occurs while the bullet is in the barrel and causes the shot to be off relative to the point of aim.

In rapid fire a natural point of aim keeps the rifle on target from shot to shot. This enhances recovery and makes possible faster accurate shots. If a natural point of aim is not established, then the weapon moves in recoil away from the point of aim towards the natural point of aim, which increases recovery time.

Follow through is controlling the rifle and the trigger after the trigger breaks in order to not disturb the alignment of the weapon. Once the shot is fired, the bullet must travel the length of the barrel and exit the muzzle. It is common for a shooter to cause an inaccurate shot after "breaking" the trigger.

Given good trigger control, more shots are lost in the few milliseconds between the time the shooter's senses inform him that he has released the trigger and the actual moment the bullet exits the muzzle than in any other way. The shooter can disrupt the alignment of the rifle before the bullet exits the muzzle. The disruption is masked from the shooter by the recoil effects. The symptom is a shot or a group consistently below the point of aim. This is remedied by follow through.

To follow through on a shot means the shooter tries to maintain the sight picture, the position, and the grip through the recoil. Do not relax or let the trigger forward until the recoil is finished. Otherwise the position of the rifle is altered while the bullet is traveling down the barrel. Most expert shooters will follow through in slow fire for one or two seconds after the recoil ends. The process is still employed, but more quickly, in rapid fire.

Another aspect of follow through is the ability to "call" the shot. The shooter concentrates on trying to see the sight picture through the recoil. At the moment of firing the shooter will have a mental image of where the sights were the instant the rifle fired. He must consciously recall this image or it is quickly lost. By recalling the image of the sight picture the shooter can "call" where the shot struck. If the rifle is sighted in and the shooter controlled the trigger, the shot will strike where it is "called."

If a shooter is consistently "on call" then the weapon is sighted in and the shooter's techniques are sound. If the techniques are sound but the shooter is "off call" (hitting other than where the shot is called), then the sights are off. If unable to "call" the shot, then the shooter's techniques are not sound and additional instruction and practice is necessary.

List of Appendices

BALLISTIC TABLES - Sierra 168 grain HPBT at 2650 fps

BULLET PATH TABLES - Sierra 168 grain HPBT at 2650 fps

Appendix A1
Explanation of Terms

1. REMAINING VELOCITY is listed in Feet Per Second (fps).

2. REMAINING ENERGY is listed in foot/pounds (ft/lb).

3. DROP is listed in inches. It is the distance below the line of bore the bullet will drop at the indicated range.

4. ELEVATION is angle of departure in minutes of angle (moa) necessary to be zeroed at the indicated range. Additionally, the difference in elevation between two ranges is the correction necessary to change zero from one to the other. Using Appendix A2 for example, if zeroed at 200 yards (elevation 6.2 moa) and you wish to be zeroed at 400 yards (elevation 12.5 moa) the sight correction is 12.5 - 6.2 = plus 6.3 moa.

5. MAXIMUM HEIGHT is given in inches. It is the maximum height above the line of sight the bullet will reach, if the rifle is zeroed at the indicated range. For example, if zeroed at 500 yards, the bullet will be 22.3 inches above the line of sight at its highest point in the trajectory.

6. WIND DEFLECTION is given in inches, calculated for a 10mph wind blowing at right angles to the flight of the bullet.

7. Height of sight used in table = 1.5 inches.

Appendix A2: Ballistics Table
Ballistics @ Sea Level, 59 degrees F

.308 Winchester -- Sierra 168 gr Hollowpoint Boattail
Ballistic Coefficient: 0.475

Standard Temperature/Pressure -- 59 Degrees F at Sea Level

Range (yds)	Remaining Velocity	Remaining Energy	Drop	Elevation	Maximum Height	10 MPH Deflection
0	2650	2619	0.0	0.0	-1.5	0.0
50	2556	2438	0.6	4.3	0.0	0.2
100	2465	2266	2.6	4.1	0.1	0.7
150	2375	2104	6.0	5.0	1.0	1.6
200	2287	1951	10.9	6.2	2.3	3.0
250	2201	1807	17.5	7.6	4.1	4.9
300	2117	1672	25.9	9.1	6.4	7.2
350	2035	1544	36.2	10.8	9.3	9.9
400	1954	1424	48.6	12.5	12.9	13.1
450	1875	1311	63.1	14.4	17.2	16.8
500	1799	1207	80.3	16.4	22.3	21.3
550	1725	1110	100.4	18.5	28.4	26.4
600	1654	1020	123.4	20.8	35.5	32.2
650	1585	937	149.5	23.2	43.7	38.6
700	1518	859	178.7	25.7	53.1	45.5
750	1454	788	211.9	28.4	63.8	53.2
800	1394	724	249.5	31.4	76.2	61.8
850	1337	667	291.9	34.5	90.3	71.3
900	1284	615	339.0	37.8	106.1	81.5
950	1234	568	391.3	41.4	123.9	92.5
1000	1190	528	449.9	45.1	144.0	104.3

Appendix A3: Ballistics Table
Ballistics @ 5333 ft, 59 degrees F

.308 Winchester -- Sierra 168 gr Hollowpoint Boattail
Ballistic Coefficient: 0.475

59 degrees F at 5,333 feet Altitude

Range (yds)	Remaining Velocity	Remaining Energy	Drop	Elevation	Maximum Height	10 MPH Deflection
0	2650	2619	0.0	0.0	-1.5	0.0
50	2573	2469	0.6	4.3	0.0	0.1
100	2497	2326	2.6	4.1	0.1	0.6
150	2423	2189	5.9	4.9	0.9	1.3
200	2350	2059	10.7	6.1	2.2	2.4
250	2278	1935	17.1	7.4	3.9	3.9
300	2207	1817	25.2	8.9	6.1	5.7
350	2138	1705	35.1	10.4	8.9	8.0
400	2069	1597	46.8	12.1	12.2	10.5
450	2002	1495	60.5	13.8	16.1	13.4
500	1936	1398	76.3	15.6	20.7	16.8
550	1872	1307	94.4	17.4	26.0	20.6
600	1809	1221	115.2	19.4	32.2	25.1
650	1748	1140	138.8	21.6	39.4	30.1
700	1689	1064	165.4	23.8	47.5	35.6
750	1631	992	194.9	26.2	56.7	41.7
800	1575	925	227.5	28.6	67.0	48.1
850	1519	861	263.2	31.1	78.4	55.1
900	1467	802	303.1	33.8	91.3	62.7
950	1416	748	347.1	36.7	105.7	71.1
1000	1369	699	395.9	39.7	121.9	80.2

Appendix A4: Ballistics Table
Ballistics @ Sea Level, 89 Degrees F

.308 Winchester -- Sierra 168 gr Hollowpoint Boattail
Ballistic Coefficient: 0.475

89 degrees F at Sea Level

Range (yds)	Remaining Velocity	Remaining Energy	Drop	Elevation	Maximum Height	10 MPH Deflection
0	2700	**2720**	0.0	**0.0**	-1.5	**0.0**
50	2611	**2543**	0.6	**4.2**	0.0	**0.2**
100	2523	**2375**	2.5	**4.0**	0.0	**0.7**
150	2437	**2215**	5.7	**4.8**	0.9	**1.5**
200	2353	**2065**	10.4	**6.0**	2.1	**2.7**
250	2270	**1922**	16.7	**7.3**	3.9	**4.4**
300	2189	**1788**	24.7	**8.7**	6.1	**6.5**
350	2110	**1660**	34.5	**10.3**	8.8	**9.1**
400	2032	**1540**	46.2	**11.9**	12.2	**12.0**
450	1956	**1426**	60.0	**13.7**	16.2	**15.4**
500	1881	**1319**	75.9	**15.5**	20.9	**19.2**
550	1809	**1220**	94.5	**17.5**	26.5	**23.8**
600	1739	**1128**	116.0	**19.6**	33.0	**29.1**
650	1671	**1041**	140.3	**21.8**	40.6	**34.9**
700	1605	**961**	167.7	**24.2**	49.2	**41.3**
750	1541	**886**	198.2	**26.6**	59.0	**48.2**
800	1479	**816**	232.4	**29.2**	70.1	**55.8**
850	1421	**753**	270.7	**32.0**	82.7	**64.2**
900	1366	**696**	313.8	**35.0**	97.0	**73.5**
950	1314	**644**	361.7	**38.2**	113.1	**83.5**
1000	1265	**597**	414.3	**41.6**	131.0	**94.1**

Appendix B1
Explanation of Terms

1. BULLET PATH ABOVE LINE OF SIGHT (LOS) is the distance in either minutes of angle (moa) or inches the bullet is above or below the line of sight at the indicated zero range. It also provides the necessary correction to change the zero, or hold off the point of aim. The positive figures given for ranges less than the zero range indicate the bullet is above the line of sight and the sights must be adjusted lower, or the point of aim lowered, the indicated amount. The negative figures for ranges greater than the zero range indicate the bullet is below the line of sight. The sights must be adjusted higher, or the aiming point raised, the indicated amount. Using Appendix B3 for example, to hit a target at 500 yards either adjust the sights UP 10.2 moa or aim 50.9 inches ABOVE the desired point of impact at 500 yards.

2. WIND DEFLECTION is given in inches. It represents the distance the bullet will be moved by a 10mph wind at right angles to the flight of the bullet at the indicated range. For example, at 500 yards a 10mph wind from the left will move the point of impact of the bullet 21.3 inches to the right. A 20mph wind will cause a deflection of double the amount (42.6 inches), and a 5mph wind will cause half as much (10.7 inches). The wind deflection figures can be interpolated for any wind strength.

Appendix B2: Bullet Path Table
100 yd Zero @ Sea Level, 59 Degrees F

.308 Winchester -- Sierra 168 gr Hollowpoint Boattail
Ballistic Coefficient: 0.475
Muzzle Velocity: 2650 fps

100 Yard Zero at Sea Level, 59 Degrees F

Range (Yds)	Velocity (fps)	Bullet Path Above Line of Sight		10 MPH Deflection
		MOA	Inches	
50	2556	**-0.2**	-0.1	**0.2**
100	2465	**0.0**	0.0	**0.7**
150	2375	**-0.9**	-1.3	**1.6**
200	2287	**-2.1**	-4.2	**3.0**
250	2201	**-3.5**	-8.8	**4.9**
300	2117	**-5.1**	-15.2	**7.2**
350	2035	**-6.7**	-23.4	**9.9**
400	1954	**-8.4**	-33.7	**13.1**
450	1875	**-10.3**	-46.2	**16.8**
500	1799	**-12.3**	-61.4	**21.3**
550	1725	**-14.4**	-79.4	**26.4**
600	1654	**-16.7**	-100.4	**32.2**
650	1585	**-19.1**	-124.4	**38.6**
700	1518	**-21.7**	-151.6	**45.5**
750	1454	**-24.4**	-182.7	**53.2**
800	1394	**-27.3**	-218.3	**61.8**
850	1337	**-30.4**	-258.6	**71.3**
900	1284	**-33.7**	-303.7	**81.5**
950	1234	**-37.3**	-354.0	**92.5**
1000	1190	**-41.0**	-410.5	**104.3**

Appendix B3: Bullet Path Table
200 yd Zero @ Sea Level, 59 Degrees F

.308 Winchester -- Sierra 168 gr Hollowpoint Boattail
Ballistic Coefficient: 0.475
Muzzle Velocity: 2650 fps

200 Yard Zero at Sea Level, 59 Degrees F

Range (Yds)	Velocity (fps)	Bullet Path Above Line of Sight		10 MPH Deflection
		MOA	Inches	
50	2556	**1.9**	1.0	**0.2**
100	2465	**2.1**	2.1	**0.7**
150	2375	**1.2**	1.8	**1.6**
200	2287	**0.0**	0.0	**3.0**
250	2201	**-1.4**	-3.5	**4.9**
300	2117	**-2.9**	-8.8	**7.2**
350	2035	**-4.6**	-16.0	**9.9**
400	1954	**-6.3**	-25.3	**13.1**
450	1875	**-8.2**	-36.7	**16.8**
500	1799	**-10.2**	-50.9	**21.3**
550	1725	**-12.3**	-67.8	**26.4**
600	1654	**-14.6**	-87.8	**32.2**
650	1585	**-17.0**	-110.7	**38.6**
700	1518	**-19.5**	-136.8	**45.5**
750	1454	**-22.3**	-166.9	**53.2**
800	1394	**-25.2**	-201.4	**61.8**
850	1337	**-28.3**	-240.7	**71.3**
900	1284	**-31.6**	-284.7	**81.5**
950	1234	**-35.2**	-334.0	**92.5**
1000	1190	**-38.9**	-389.4	**104.3**

Appendix B4: Bullet Path Table
200 yd Zero @ 5333 ft, 59 Degrees F

.308 Winchester -- Sierra 168 gr Hollowpoint Boattail
Ballistic Coefficient: 0.475
Muzzle Velocity: 2650 fps

200 Yard Zero at 5,333 Feet, 59 Degrees F

Range (Yds)	Velocity (fps)	Bullet Path Above Line of Sight		10 MPH Deflection
		MOA	**Inches**	
50	2573	**1.8**	0.9	**0.1**
100	2497	**2.0**	2.0	**0.6**
150	2423	**1.2**	1.8	**1.3**
200	2350	**0.0**	0.0	**2.4**
250	2278	**-1.3**	-3.4	**3.9**
300	2207	**-2.8**	-8.4	**5.7**
350	2138	**-4.4**	-15.3	**8.0**
400	2069	**-6.0**	-24.0	**10.5**
450	2002	**-7.7**	-34.6	**13.4**
500	1936	**-9.5**	-47.3	**16.8**
550	1872	**-11.3**	-62.4	**20.6**
600	1809	**-13.4**	-80.2	**25.1**
650	1748	**-15.5**	-100.8	**30.1**
700	1689	**-17.8**	-124.3	**35.6**
750	1631	**-20.1**	-150.7	**41.7**
800	1575	**-22.5**	-180.3	**48.1**
850	1519	**-25.1**	-213.0	**55.1**
900	1467	**-27.8**	-249.8	**62.7**
950	1416	**-30.6**	-290.8	**71.1**
1000	1369	**-33.7**	-336.5	**80.2**

Appendix B5 Bullet Path Table
200 yd Zero @ Sea Level, 89 Degrees F

.308 Winchester -- Sierra 168 gr Hollowpoint Boattail
Ballistic Coefficient: 0.475
Muzzle Velocity: 2700 fps

200 Yard Zero at Sea Level, 89 Degrees F

Range (Yds)	Velocity (fps)	Bullet Path Above Line of Sight		10 MPH Deflection
		MOA	Inches	
50	2611	1.7	0.9	0.2
100	2523	2.0	2.0	0.7
150	2437	1.1	1.7	1.5
200	2353	0.0	0.0	2.7
250	2270	-1.3	-3.3	4.4
300	2189	-2.8	-8.3	6.5
350	2110	-4.3	-15.2	9.1
400	2032	-6.0	-23.9	12.0
450	1956	-7.7	-34.6	15.4
500	1881	-9.5	-47.6	19.2
550	1809	-11.5	-63.2	23.8
600	1739	-13.6	-81.7	29.1
650	1671	-15.9	-103.1	34.9
700	1605	-18.2	-125.5	41.3
750	1541	-20.7	-155.0	48.2
800	1479	-23.3	-186.2	55.8
850	1421	-26.1	-221.5	64.2
900	1366	-29.1	-261.7	73.5
950	1314	-32.3	-306.6	83.5
1000	1265	-35.6	-356.2	94.1