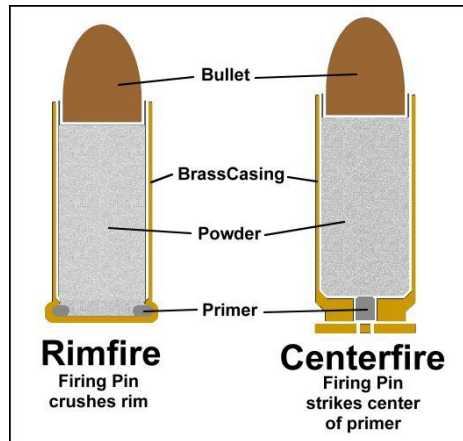


“Cartridges for Dummies”

Summary Overview of Cartridges:

CARTRIDGE:

casing (usually brass)
projectile (bullet – usually Lead based)
gunpowder/propellant
primer



Specific Cartridge Identifiers:

Caliber: diameter in fraction of an inch or mm

Mass: mass of bullet in grains

Casing: the size/geometry of the brass container, unique to each cartridge type- relates to powder mass.

Secondary characteristics: geometry/solid vs hollow/Jacketing/bonding/partition/tip/lead alternatives

EXAMPLE: .270 Winchester 150gr Power Point (Jacketed soft point)
caliber: .270
mass: 150 gr
cartridge/casing type: “Winchester” (as opposed to others like .270 “Weatherby”)
jacketed with soft point tip

EXAMPLE: There can be many casing types for any individual caliber
Example .30 cal: .30 carbine, .300 blackout, .30-06; .307 Winchester, .308 Winchester

Internal ballistics: what happens in the firearm after firing pin hits primer.

External Ballistics: what happens upon exit: velocity/energy/ trajectory.

Terminal Ballistics: what happens when it hits the target; degree of penetration/expansion
Of note is that terminal ballistics is also a f(target characteristics).

What effects the behavior of the bullet?

Velocity

Mass

Energy – $\frac{1}{2} mv^2$

“Cartridges for Dummies”

Caliber

Cartridge casing type as it relates to powder charge mass

Hardiness - does bullet fragment en-route? Does it fragment with hard (bone) target?

Density – mass/surface area

Geometry - round ball, flat head, spitzer, boat tail

Sectional density

Terminal ballistics – including expansion/penetration characteristics

Biology of target

Jacket vs no jacket; solid vs hollow point, FMJ, semi-jacketed, case hardened, etc...

Weather Conditions

Lead: most commonly used metal for bullet.

dense, cheap, deformable, and easy to work with.

deteriorates with temperatures at velocity > 1400 fps – relatively low melting point - (it is because of this that modern cartridges often have “jacket of copper”; see “jacketed”).

Geometry:

Round ball:

Flat Head:

Spitzer: more aerodynamic and better for long distances.

Boat Tail: improves aerodynamics even more (on backside of projectile).

Metal Jackets are applied to minimize lead deposition in barrel and for stability of lead core at high velocities, pressures, and temperatures.

full metal jacket vs. semi-jacketed (semi-jacketed allows for better expansion with impact).

The more velocity you have the tougher the bullet must be in order to hold together and penetrate.

As velocity drops, the absolute requirement for the “best” bullets diminishes.

Soft point SP (metal jacket surrounds all of bullet except the tip).

Full Metal Jacket FMJ (metal jacket completely surrounds bullet).

Hollow Point HP (metal jacket would leave hollow point exposed).

Ballistic Tip will enhance aerodynamics of hollow point bullets.

Jacketed Bullets:

“cup-and-core bullets”: lead core is pressed into the jacket – most standard factory loads.

Larger animals and magnum cartridge velocities tend to over-stress cup-and-core projectiles.

Hunting loads usually semi-jacketed or with soft point exposed to enhance expansion.

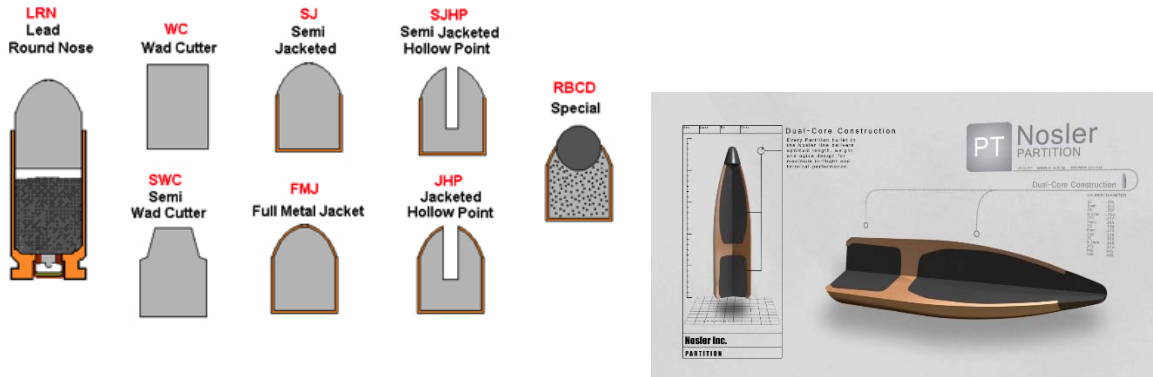
“Controlled expansion bullets”: designed to retain more weight, penetrate deeper and withstand higher impact speeds: These are the “PREMIUM” cartridges.

Monometals copper (see BARNES)

Bonded: electrochemical enhancement of jacket bonding to core

Partition: Nosler (fully jacketed rear partition to “push” expanding tip for greater penetration).

“Cartridges for Dummies”



“Partition” bullet



PENETRATION IS MORE IMPORTANT THAN EXPANSION IN LARGE GAME:

PENETRATION IS THE PRIMORDIAL ENDPOINT

EXPANSION IS THE SECONDARY ENDPOINT

“Sectional Density” (SD) is the relationship of a bullet's diameter to its weight, a simple ratio that has much to do with penetration.

Given equal construction, **a high SD means deeper penetrating qualities**, and an SD approaching or exceeding .300 is very high – recommended for large game.

In other words, a skinny bullet of a given weight tends to penetrate better than a fat bullet of the same weight, because it concentrates the same force on a smaller area of the target.

For a given mass the bullet will be more “skinny” with a smaller caliber. For example, if other factors are equal, a 150 grain .270 bullet will penetrate better than a 150 grain .35 caliber bullet. Long narrow shank to minimize friction and promote penetration

“Cartridges for Dummies”

Sectional Density:

BULLET WEIGHT (POUNDS)
DIAMETER SQUARED (INCHES)

Supplemental Notes:

The “First” Question: “What type of game and over what distance”?

Hard Cast: A hard lead alloy intended to reduce fouling of rifling grooves (especially of the polygonal rifling used in some popular pistols). Benefits include simpler manufacture than jacketed bullets and ***good performance against hard targets; limitations are an inability to mushroom and subsequent over-penetration of soft targets.***

“Cup-and-core bullets” usually mushroom easily when they strike soft tissue. ***At higher velocities they can expand too much, increasing frontal surface area and limiting penetration.*** Often cup-cores break into two or more pieces, especially if they strike large bones. ***When cores split and separate from jackets, the lighter mass of each piece reduces penetration.*** On the plus side, these pieces sometimes fan out to tear vital tissue the main bullet might have missed. The ultimate manifestation of this dispersion comes from frangible varmint bullets engineered to disperse fragments and kinetic energy dramatically. If they enter the chest cavity near the heart, they can induce quick, humane kills. ***Unfortunately, they can also fail to penetrate adequately, leading to mere flesh wounds.*** This is why varmint bullets are not recommended for big game. They aren’t even legal for hunting big game in most states.

Sectional Density of:

- .180 is good for small animals,
- .200-.230 is good for medium size animals CXP2 - DEER
- .270-.280 is good for large animals – CXP3 ELK
- .300+ is good for larger and tougher animals – CPX4 THICK SKINNED

Long Distance Shooting and Ballistics:

Ballistics: the study of the factors affecting the trajectory (flight path) of a projectile.

Line of Sight (**LOS**)

Scope View: slightly angled to LOS as the scope is mounted ~ 1.5" inches above the bore.

Elevation Angle

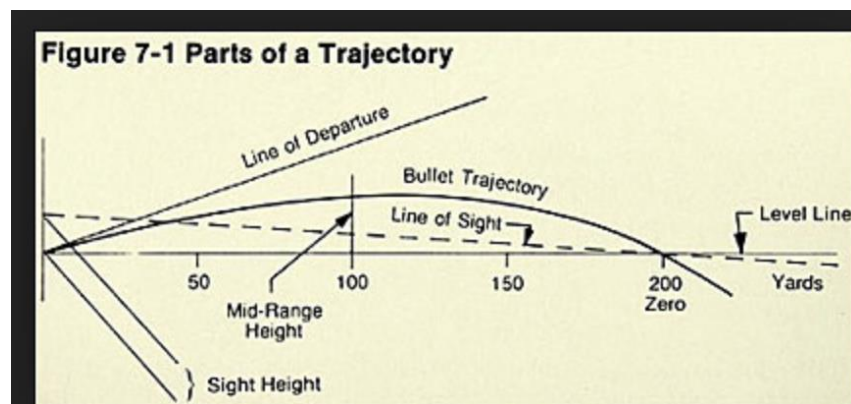
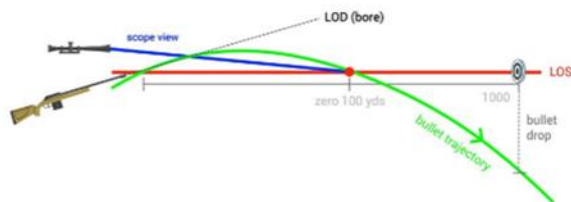
Sight Height

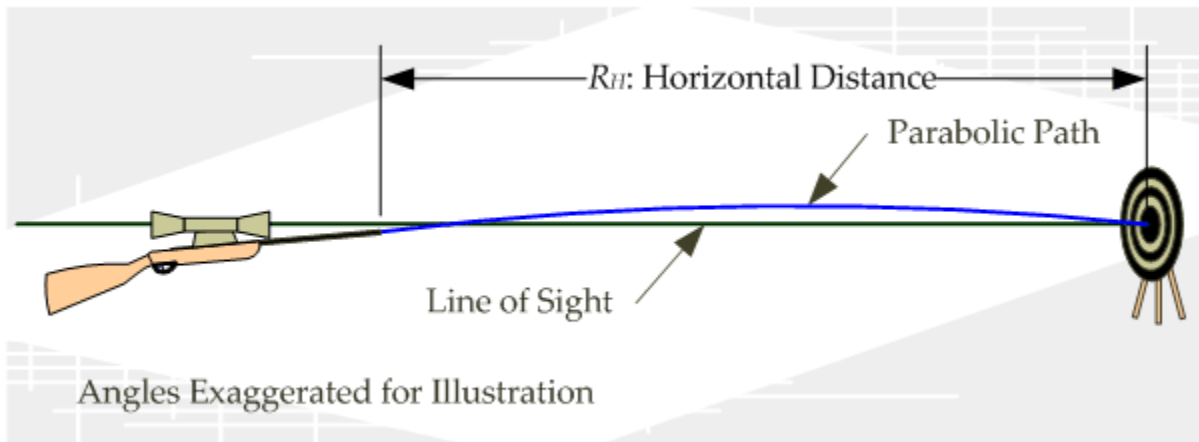
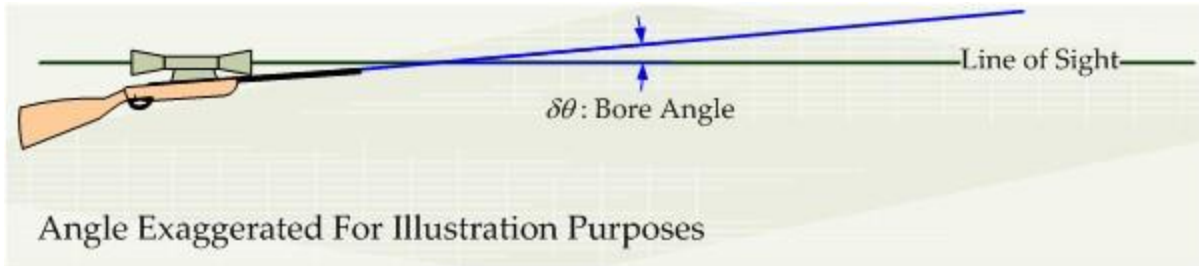
Line of Departure (**LOD**) – BORE

Flight Path is **PARABOLIC**. This Parabolic path changes shape with each change in distance, in addition to specific cartridge variables.

Changes in position of scope to bore angle allow variable distance end points. "Dialing" your scope up or down changes the relative position of scope to bore. Although your reticle may be on target, your bore is actually pointed to a variable point in space above the LOS and Scope View. Increasing distance to target increases the angle of scope to bore.

Bullet trajectory





- Internal Ballistics
- Transitional Ballistics
- External Ballistics
- Terminal Ballistics

Internal Ballistics:

Throat/Freebore: bullet “jumps” into rifling. The throat is the area where the bullet leaves the cartridge and has not yet encountered rifling; the length of the throat is the freebore.

Right Hand vs Left Hand spin: See **Bullet Drift** ...

Barrel is not static during firing: Harmonics, Whip, Ringing. Anything touching the barrel will affect harmonics.

Shorter Barrel and more Mass have less amplitude to arc of movement.

This is reason for “free-floating” barrel.

This is the reason nothing should be touching barrel when firing.

Crown: need symmetric crown for gas escape for consistency of flight; last point of rifle to affect accuracy.

Need Temperature stable Powders for consistency of muzzle velocity. Stable powders produce stable Pressures which lead to stable velocities and reproducible Point of Impact (**POI**).

Follow Through: for at least 2 seconds; wait for the recoil to settle the rifle back into position

There is a measurable difference between two identical factory rifles and the same factory ammunition. Hand loading allows fine tuning of cartridge to a specific rifle.

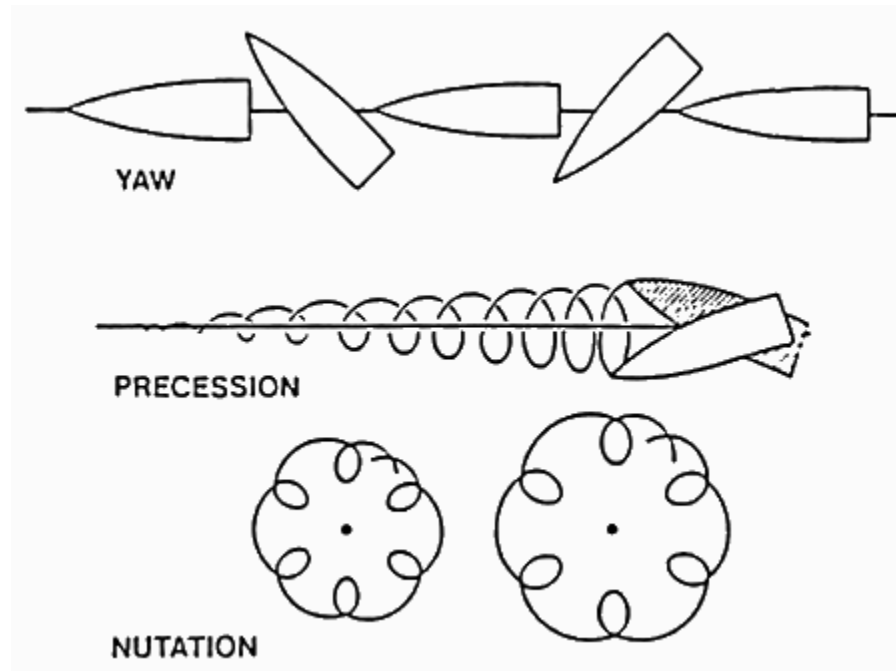
Transitional Ballistics:

A brief period of instability when the projectile first exits the barrel, before all the external ballistic variables apply to stabilize the projectile.

At exit from muzzle projectile immediately affected by:

- YAW
- PRECESSION
- NUTATION

Upon muzzle/crown exit, atmospheric resistance exerts pressure against the nose and ogive of projectile to cause the projectile to “**yaw**” away from its venter axis.



Precession exerts angular force at 90 degrees, in relation to direction of rotation and the orientation of the longitudinal axis.

The rifling spin causes a wobbling effect and rotational inertia that takes time to stabilize along the longitudinal axis, causing the nose of the projectile to follow a helical motion until it is dampened, and this is called **Nutation**.

External Ballistics:

Trajectory and POI affected by:

Gravity

Drag/Ballistic Coefficient/Air Density

Wind Force

Spin Drift

Coriolis Effect

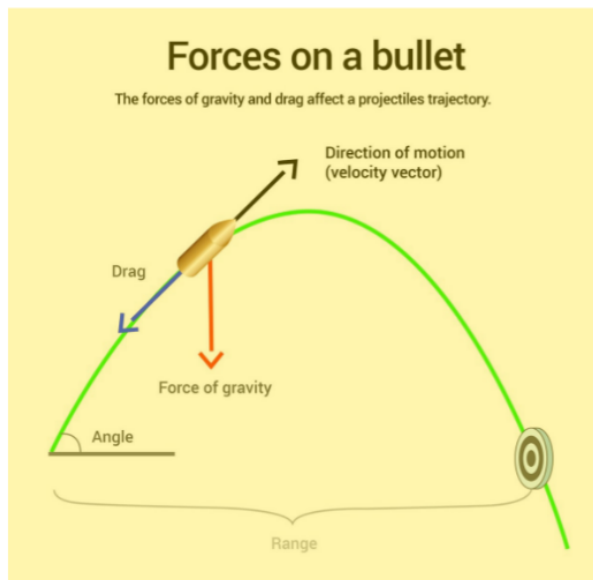
Eotvos Effect

Stability

Light Effects

Projectile Speed

Gravity: effect is bullet drop; this is a function of **bullet speed** – the longer the time of flight (**TOF**) the greater the gravitational effect. Speed is not a constant, as projectile is immediately affected by **Drag** and will slow over the course of its trajectory.



Drag:

Drag = *air resistance* on a bullet during flight; **decreases velocity** and thereby increase time of flight (TOF). Increased TOF increases the effects of gravity and thus the degree of projectile drop.

Drag is a function of:

Bullet Speed – increase drag with *increasing* bullet speed

Air Density – the higher the air density the higher the drag

function of **Altitude/Atmospheric Pressure**

function of **Relative Humidity**

function of **Temperature**

Ballistic Coefficient – bullets with higher BC are more efficient against drag

changes with bullet shape and bullet speed

Spitzer and BoatTail bullet configurations add to BC efficiency

Velocity has complex relationship to ballistics:

Higher Velocity decreases TOF which lessens gravity effect.

Increasing velocities have higher Drag effect.

Increasing Velocity ≠ High Velocity

Magnum cartridges generally have less drop with distance (eg .308 Win vs .300 Win Mag), more terminal energy and less TOF.

Drag Models:

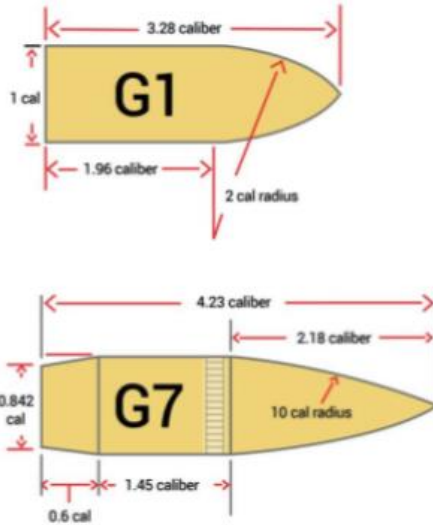
Drag Models a function of bullet shape – **based on Ballistic Coefficients**

G1 Flat base/Blunt nose

G7 Long Boattail, 10 calibers tangent ogive – for very low drag bullets

Generic ballistic formulas

G1 & G7 Ballistic Coefficients



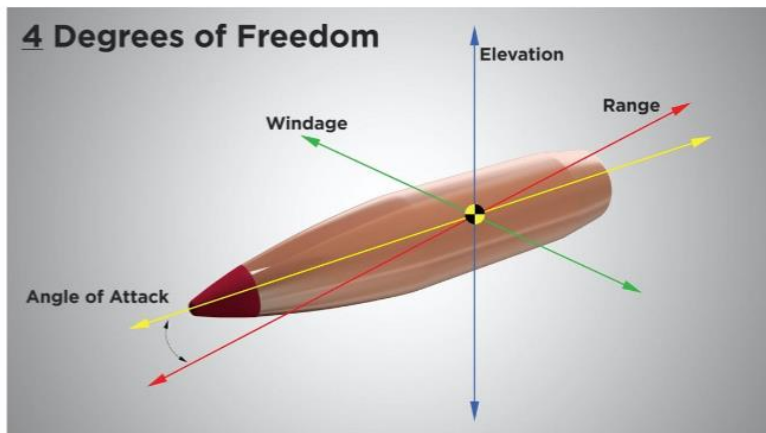
G1 – Also known as Ingalls, G1 projectiles are flatbase bullets with 2 caliber nose ogive and are the most common type of bullet.

G7 – Bullets with the G7 BC are long 7.5 degree boat-tails, with 10 caliber tangent ogive, and are very popular with manufacturers for extremely low-drag bullets.

Drag Models vs Doppler Output (eg Hornady 4DOF Solver)

4DOF = 4 Degrees Of Freedom

Doppler models



Provides trajectory solutions based on **projectile drag coefficient**, not ballistic coefficient.
Uses exact physical modelling of the projectile, its mass and aerodynamic properties.

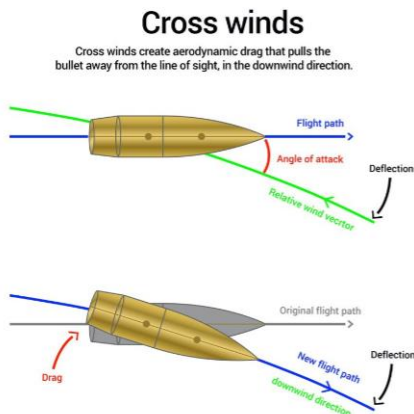
WIND:

Wind does NOT exert its effect by blowing on the projectile and pushing it to the side

Horizontal deflection is produced by Drag and not directly by the force of the wind itself.

“Angle of Attack” is the direction from which the air approaches the bullet.

A Crosswind has the effect of altering the Angle of Attack, and the aerodynamic drag has a lateral component that pulls the bullet away from the Line of Sight (LOS), in the downwind direction.



The **DIRECT effect of wind** is when it blows against a tall object such as a mountainside or hillside, it generates a vertical component that blows upward or downward, and a bullet flying through that can be deflected in the corresponding direction.

Aerodynamic Jump: the vertical shift of a projectile that occurs with encountering a cross wind. It is a function of the direction of spin, that is, direction of barrel twist. **Most rifles have a right handed twist and this will be assumed.**

When the bullet encounters a crosswind it tries to yaw slightly to align itself with the airflow – “Aerodynamic jump”.

Right to left wind causes upward and right deflection; left to right wind causes the opposite effect.

The amount of wind drift is a function of spin rate relative to bullet length – the higher the spin rate the higher the drift. Spin rate a function of barrel twist and bullet velocity - the shorter the twist and the higher the bullet velocity the higher the spinning rates.

Wind deflection a function of:

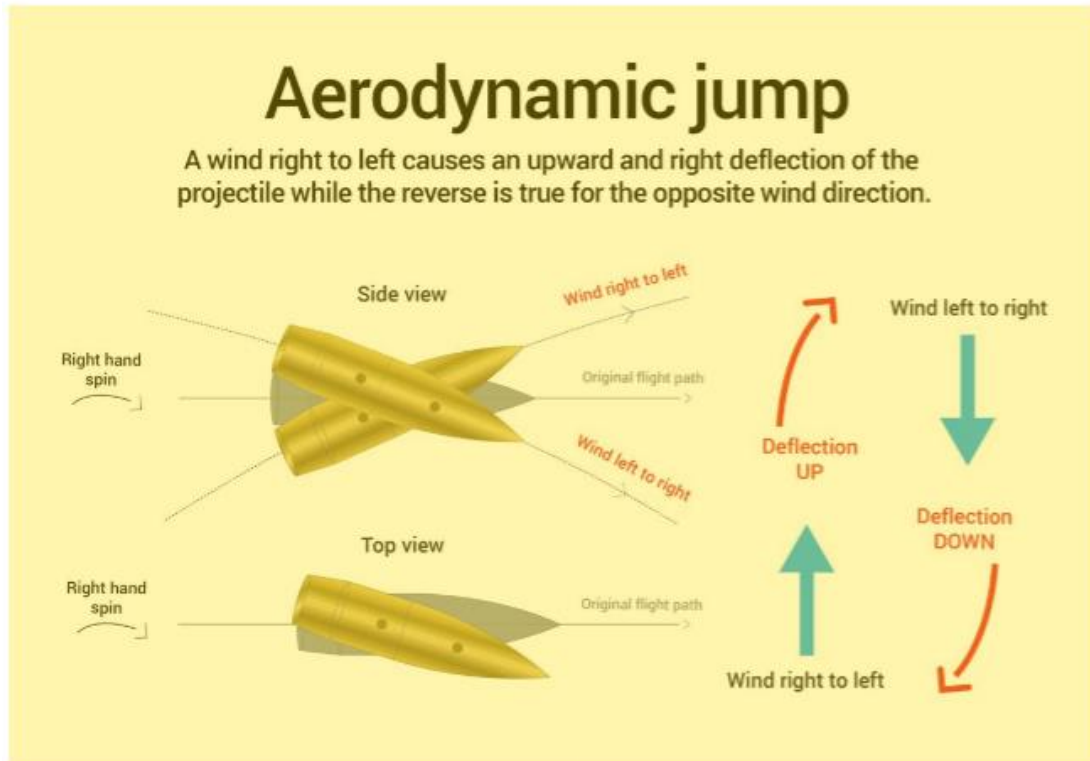
Wind Speed; the higher the wind speed the higher the deflection

TOF: the greater the TOF the greater the deflection

Angle of incidence: Head and tail winds have no effect on horizontal flight

Ballistic coefficient: deflection less with higher BC

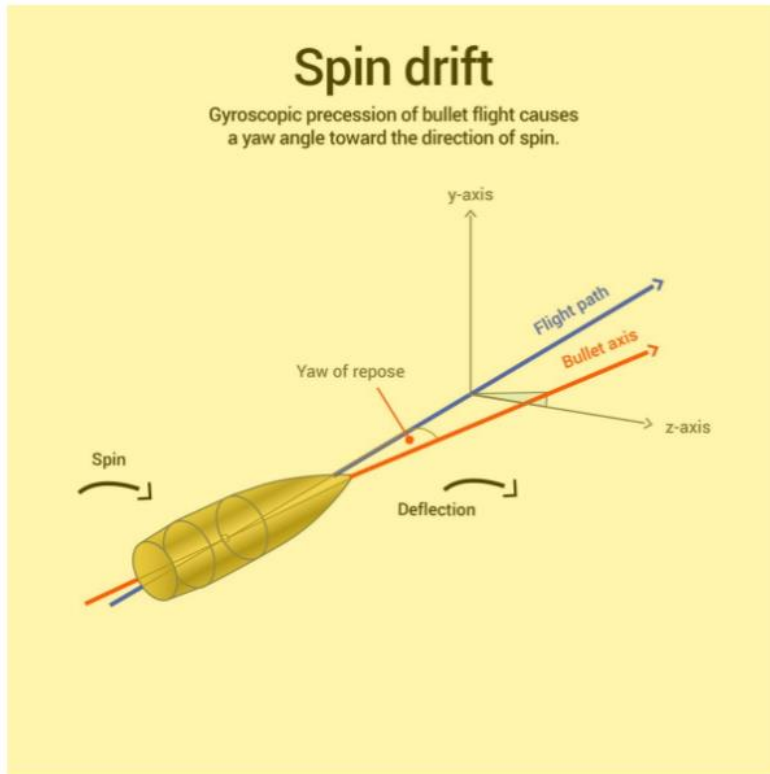
Bullet weight: deflection inversely related to bullet weight.



Headwind: slightly increases the *relative velocity* of the projectile, thus increasing drag and corresponding drop – higher drag, increased TOF, smaller terminal velocity, increased drop.

Tailwind: reduces drag and drop, decreased TOF, more remaining velocity, less drop

Spin Drift: (>500 yds)



When the projectile exits the barrel, it **wobbles** because of **gyroscopic precession**, and when it becomes dynamically stable, it now has a yaw angle toward the direction of spin called the "**yaw of repose**", and that leads to a drift away from the line of sight in the direction of the spin.

The gyroscopic motion keeps the bullet stable and pointed forward, but it also causes it to deflect in the direction of the spin.

The amount of drift is a function of the **spin rate relative to the bullet length**. The higher the spin rate, the higher the drift. The **spin rate depends on barrel twist rate and bullet speed**. Shorter twist rates and higher bullet speeds produce higher spin rates.

THIS CAN BE OVER 1 MOA OF DEFLECTION AT 1000 YDS - ~10.5"

Spin drift is the **deflection** caused by the **gyroscopic motion** of the projectile. This is only significant for long range shooting, **out past 500 yards**.

Coriolis effect (>1,000 yds)

HORIZONTAL

This effect is negligible until 1000 yards

Coriolis effect is the effect of the Earth's rotation on a projectile in flight in the **horizontal plane**.

The Coriolis effect requires compensation based on your location, in either hemisphere.

The error due to Coriolis force can be significant, up to a minute of angle adjustment out to 1000 yards, and is ***always toward the right on the northern hemisphere***, and always toward the left on the southern hemisphere.

The Eötvös effect

VERTICAL

The Eötvös effect is the change in perceived gravitational force caused by the ***change in centrifugal acceleration, resulting from eastbound or westbound velocity***. When moving ***eastbound***, the object's angular velocity is increased (in addition to the Earth's rotation), and thus, the centrifugal force also increases, ***causing a perceived reduction in gravitational force***. The reverse is true ***west bound***. Thus, this effect is pushing it away from or towards the Earth's surface, and if the projectile is shot westward, in the opposite direction of the Earth's rotation, ***centrifugal force pushes the object toward the ground*** concurrently to gravity force.

With Eötvös a projectile's trajectory to the east is higher, and west is lower.

Coriolis effect is negligible until 1000 yards and the deflection is not east or west, as it doesn't matter in which direction you shoot, the effect will be to the right or left with reference to the shooting direction.

The key effect is the ***Eötvös effect***, and it means ***bullets fired to the east fly a little higher***, and ***bullets fired to the west fly lower***.

LIGHT EFFECTS

Light angle and intensity changes can lead to detectable changes in point of aim and consequently in point of impact.

Light angle and intensity changes can lead to detectable changes in point of aim, and consequently in point of impact. However there are no "rules" to use for compensation, you need to rely solely on your own DOPE.

STABILITY:

For a projectile to be stable, it must be both gyroscopically (static stability) and dynamically stable.

Gyroscopic (static) stability

The spinning motion, induced by the rifling of the barrel, keeps the bullet stable because of gyroscopic effect. Gyroscopic stability is expressed in Sg, and if the Sg is greater than 1.0, the bullet can be said to be gyroscopically stable. The gyroscopic force induced in the projectile is a function of the spin rate of

the barrel. A higher spin rate (discussed in the topic "Rifling") will induce a greater gyroscopic stabilizing force. Just like a "spinning top".

In general, if a projectile is gyroscopically stable at the muzzle, it will stay so for the duration of its flight to the target.

Dynamic stability

A bullet is said to be dynamically stable, if the angle of yaw, induced at the muzzle, is damped out with distance, by the action of the air flow pushing along the bullet surface. The amount of dynamic instability is a function of bullet length and the spin rate.

Longer bullets, and bullets with higher spin rates, have higher amounts of instability and are more difficult to stabilize. Dynamic stability is expressed in Sg. A projectile that is dynamically stable will have an Sg equal to 1.0. If Sg is more or less than 1.0 Sg, it may become unstable during flight.

PROJECTILE SPEED:

These differing speeds are called supersonic, transonic, and subsonic speeds.

Keeping the flight in the supersonic zone, and avoiding the transonic zone, are the main issues long distance shooters concern themselves with on this topic. Air turbulence is created when the projectile breaks the sound barrier, and again, when it slows down to below the speed of sound. The trajectory of the projectile does not change, just the direction of travel. When going for pure accuracy, this deviation in path can be significant.

The speed of sound is not a constant, but depends on the temperature at that altitude and not the barometric pressure.

Supersonic travel is a rate of travel of an object that exceeds the speed of sound (Mach 1). For objects traveling in dry air of a temperature of 20 °C (68 °F) at sea level, this speed is approximately 1,125 ft/s (343 m/s).

Transonic flight:

As the name suggests, this is simply the "transition" zone between super and subsonic flight. As a projectile flies, it loses its initial speed, due to drag, and reaches the "***transonic region***", about ***1340 fp/s***. Then it crosses the sound barrier at Mach 1, and exits from the transonic region when its speed falls below Mach 0.8 - transitioning from supersonic to subsonic flight.

When a projectile flies through the transonic region, the aerodynamics may change. Bullets flying near the sound barrier that are spin-stabilized, can be subject to a de-stabilizing effect. The center of pressure moves forward, and the over-turning moment on the bullet gets greater. This can lead to gyroscopic instability (amplifying static and dynamic instability) that's experienced at transonic speed.

To avoid the transonic region, shooters should consider the distance at which bullets sent from our rifle system go transonic as their maximum effective range.

Subsonic flight As stated above, if the projectile flying at less than Mach 1 (1,125 ft/s (343 m/s), it is now sub-sonic. Once again, the flight is more stable and predictable. The main benefit of this zone to shooters is the lack of noise, but the lower speed requires a higher trajectory.

ANGLE OF ELEVATION:

uphill or downhill shooting causes you to hit high.

The projectile "drop" is measured vertically (perpendicular to the line of sight), irrespective of the line of departure angle, and that's why it's always a high shot whether shooting up or down a hill. **Assume no effect of air density**, which is a valid approximation under 500 yds. At over 500 yds you also need to add the effect of air density – would use ballistic calculator for this.

Also assumes linear projectile trajectory, which in fact is parabolic.

The realities of air density (drag) and parabolic projectile trajectory come into play most significantly at distances of over 500 yds.

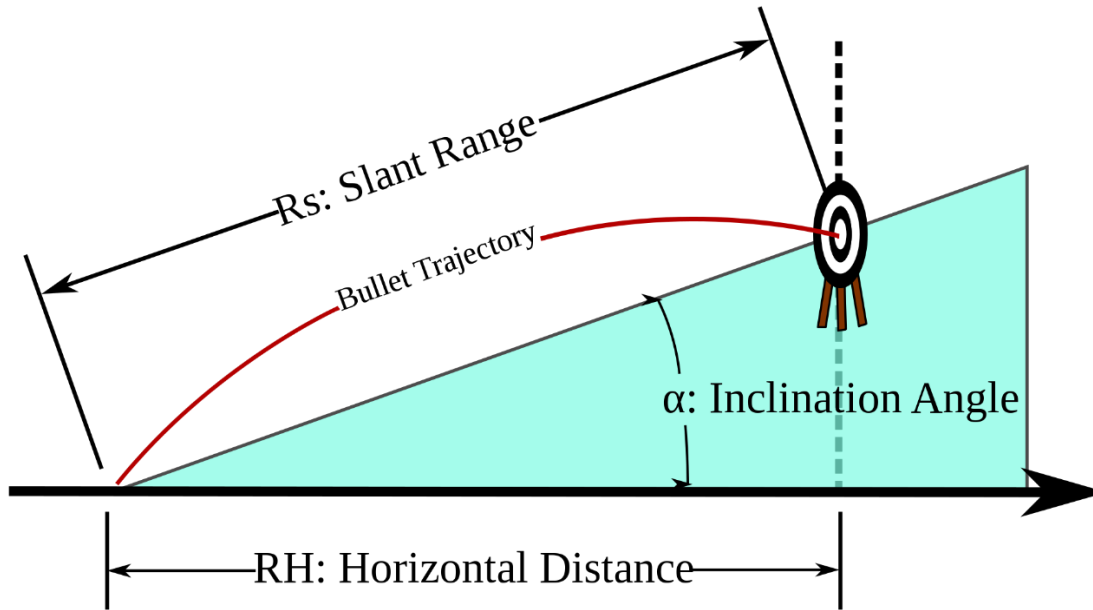
LOS Angle	Cosine
10°	0.985
15°	0.966
20°	0.940
25°	0.906
30°	0.866
35°	0.819
40°	0.766
45°	0.707
50°	0.643
55°	0.574
60°	0.500

RIFLEMAN'S RULE

Rifleman's rule is a "rule of thumb" that allows a rifleman to accurately fire a rifle that has been calibrated for horizontal targets at uphill or downhill targets. The rule says that only the horizontal range should be considered when adjusting a sight or performing hold-over in order to account for bullet drop. Typically, the range of an elevated target is considered in terms of the slant range, incorporating both the horizontal distance and the elevation distance (possibly negative, i.e. downhill), as when a rangefinder is used to determine the distance to target. The slant range is not compatible with standard ballistics tables for estimating bullet drop.

The Rifleman's rule provides an estimate of the horizontal range for engaging a target at a known slant range (the uphill or downhill distance from the rifle). For a bullet to strike a target at a slant range of $R_{\{S\}}$ and an incline of α , the rifle sight must be adjusted as if the shooter were aiming at a horizontal target at a range of $R_{\{H\}}=R_{\{S\}}\cos(\alpha)$

$R_H = R_S \cos(\alpha)$. Figure 1 illustrates the shooting scenario. The rule holds for inclined and declined shooting (all angles measured with respect to horizontal). Very precise computer modeling and empirical evidence suggests that the rule does appear to work with reasonable accuracy in air and with both bullets and arrows.



DISTANCE D = distance effected by GRAVITY (NOT LOS!)

BULLET DROP EFFECTED BY DISTANCE D

CALCULATION OF THE SAME SHOOTING UP OR DOWN

WITHOUT Δ in CALCULATION YOU WILL ALWAYS SHOOT HIGH

CENTER EARTH'S GRAVITY

TARGET

LOS = HYPOTENUSE

SHOOTER

$\cos(\alpha) = \frac{\text{Adj}}{\text{Hyp}}$

$\cos(\alpha) = \frac{D}{\text{LOS}}$

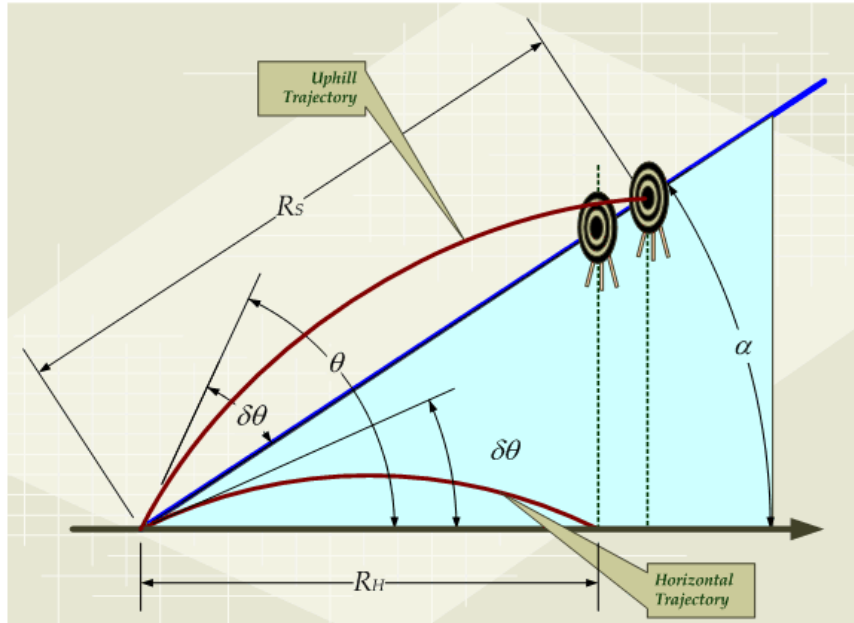
$(\cos(\alpha)) \times \text{LOS} = D$

$\cos(25^\circ) = .906$

$\cos(45^\circ) = .707$

$\cos(60^\circ) = 0.500$

Also assumes linear projectile trajectory, which in fact is parabolic.



RIFLE CANT ERROR:

This is an aiming-related error, shooting with the rifle not perpendicular to the ground, inducing an angle into the shot and a point of impact change.

By twisting the stock slightly as you are aiming/shooting, the shot will travel in the direction of the cant, and low. The greater the cant angle the greater the point of impact change.

Shooting with the rifle canted to one side or another, you will be rotating the line of departure and not the line of sight.

On scope installation, you must mount the scope with the reticle perpendicular to the rifle's bore axis, using a **plumb bob**, to have a rifle setup without any cant.

Terminal Ballistics:

The choice of **bullet design** and its final **impact velocity** will be key to how that energy is transferred and how effective that cartridge will be.

Penetration

Cavitation: Temporary vs. Permanent

Bullet weight/Sectional Density: for a given caliber, increase weight only achieved via increased length.

Bullet Tip/Shape

Jacket Design

Velocity at impact: There is a range of effective terminal velocities for proper bullet behavior. A **balance between Penetration and Bullet Destruction**.

The aim for our cartridge of choice is to **deliver a wound cavity that is halfway across the thoracic cavity**, and **causes large amounts of damage in order to cause exsanguination** (bleeding out), as that tends to be the way the majority of animals die in the field. Therefore, differing sizes of game will need differing bullets to penetrate deep enough, and expand widely enough to be effective.

Debate: full energy transfer with no exit wound vs. full penetration with exit wound

Environmental Conditions: how they effect **air density**

Most Important past 500 yds

Dynamic Variables: These change **air density** which in turns changes **Drag** effect.

Temperature: warm air less dense

Humidity: high humidity air less dense

Barometric Pressure: high altitude air less dense

Increased air density and drag will increase TOF and thus increase gravitational effects.

Warm air is less dense and therefore a projectile will experience **less drag**. As the air cools, the opposite is true. Temperature changes can also effect the powders being used in your cartridge. If they are not temperature stable then the muzzle velocity may change up or down and this will also affect the point of impact of shot.

Barometric Pressure: adjusted relative to sea level

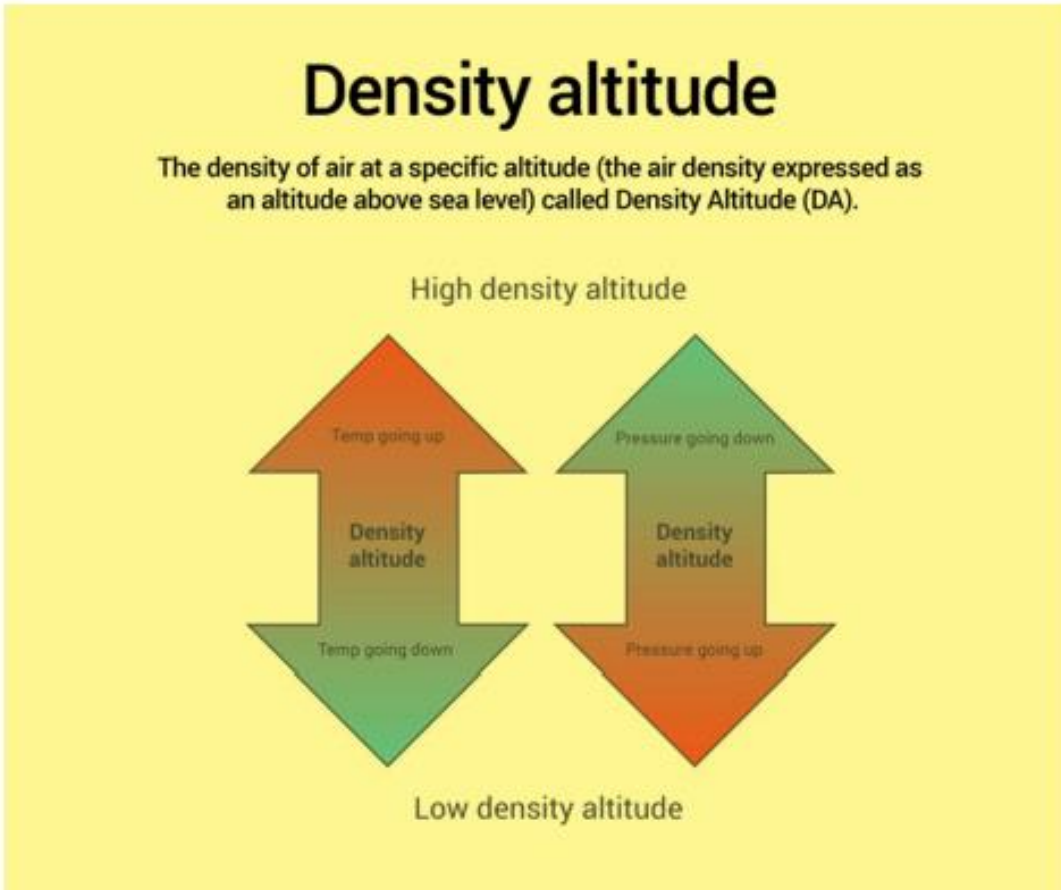
Station Pressure: is absolute pressure;

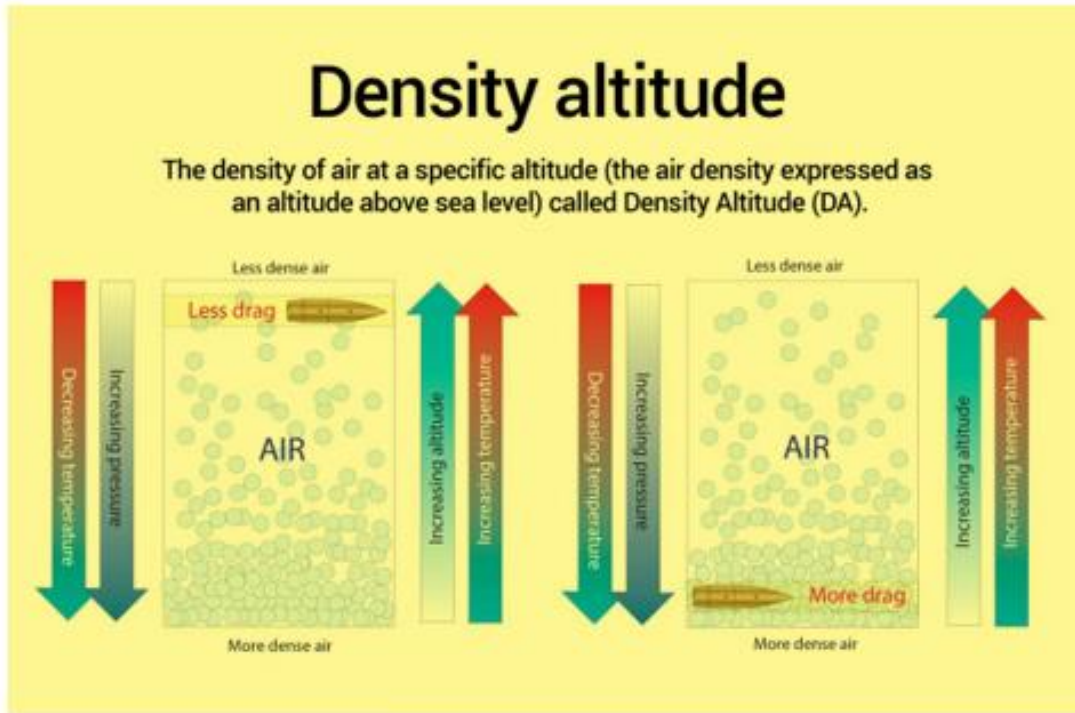
Rough rule of thumb: As altitude increases, you lose 1" of pressure for every 1000 ft. of elevation you gain. So if your location is 5000 ft. above sea level, the adjusted altitude, is barometric pressure of 29.92 - 5 (5000/1000) = 24.92.

Higher humidity reduces the air density, however the effect is very small.

For example, as you go up the mountain, both the air temperature and pressure are lower, meaning that the temperature change makes air more dense, while the altitude makes it less dense - so they will partially cancel each other out - this is called the additive effect.

In general, any shot less than 500 ft. requires no changes to the elevation, as the likely change is too small to matter at that range. Over 500 ft. the approximate rule of thumb is 0.25 MOA for every 1000 ft. of altitude or 20deg change in air temperature. Always use station pressure only.





READING WIND:

Is your cartridge superior in the wind? Ballistic coefficient, velocity and time to impact.

Wind is 3-dimensional !!

It is different over the course of flight, between shooting point, and POI.

Importance of a “Non-Wind Zero”

Making an “Educated Guess”

SWAG – “Scientific Wild Ass Guesses”; it is an Art that tries to use Science

Always read the wind and always correct for it.

Determine wind speed/Determine wind direction

THE WIND DIRECTION IS BASED ON THE DIRECTION THE WIND IS COMING **FROM**.

Wind Direction and Wind Value

Shoot **into** the Wind.

3 O'clock winds come from the right 100% correction
9 O'clock winds come from the left 100% correction
12 O'clock winds blow from target to your face – Head winds – moves bullet down a bit – **zero value**
6 O'clock winds blow from behind towards the target – Tail winds – moves bullet up a bit – **zero value**

Full value

No value

75% value Cosine of 45° is 0.707, which for simplicity is approximated to be 75%

Quartering winds have 75% value – “three quarter value wind”

A Rising Wind is more predictable, even, and lasts longer

Calculate a “Wind Hold” or “Call”

Some Shooters print ballistic drop tables assuming 10mph wind at full value

Wind at various points along the flight path – Firing point, Midway point, Target point

Average these speeds for a final net wind estimate

Wind at shooter location is probably the most important – has cumulative effect over entire flight path.

1-3 mph

3-5 mph

5-8 mph

8-12 mph *raises dust and loose paper, small branches clearly move, tree tops begin to move*

12-15 mph

15- 20 mph

20-25 mph *Large tree trunks sway, difficulty walking, whistling wind, water spray*

Flag Method

determine direction of wind from direction away from flag pole

determine speed of wind by how far the lower edge of flag is lifted in degrees

15°

30°

45°

60° 15 mph wind speed

90°

Mirage Method – for wind speeds < 15 mph – for crosswind effects only.

Wind at Maximum Ordinate: wind speeds are higher above ground

Terrain Effects:

Vertical winds across canyons; “Aerodynamic jump”

Mechanical Turbulence

Thermal Turbulence

Wind through Canyons

Uphill Vertical Winds
Wind in Confluence of Tributaries
Lee-side turbulent Winds
Venturi (Bernoulli) Effects
Wind across terrain with Vegetation

Wind least active from 4:00 am to 7:00 am

As morning air heats up, wind rises up a slope.
As evening air cools down, wind falls down a slope.

Wind on slopes

APPENDIX:

Short distance: up to 300 yds
Intermediate distance: up to 600 yds
Long distance: up to 1,000 yds
Extreme Long distance: over 1,000 yds

The **Coriolis Effect** is caused by the fact that different parts of the Earth rotate at different speeds, i.e. the rotational speed is higher at the Equator compared to the poles.

YOU SEE THIS EFFECT WHEN SHOOTING NORTH TO SOUTH AND VICE VERSA

At what shooting distances does Coriolis have an effect?

The effect of the Coriolis phenomenon can already be seen on medium firing distances, but it becomes an essential variable for the hit ***with shooting distances of 1,000 m/yds and beyond.***

The Coriolis phenomenon affects the flight of a bullet ***in the Northern Hemisphere so that when firing north or south, the bullet sways to the right*** and in the Southern Hemisphere to the left. ***The more your firing line is in the east-west direction, the less the effect of the Coriolis.***

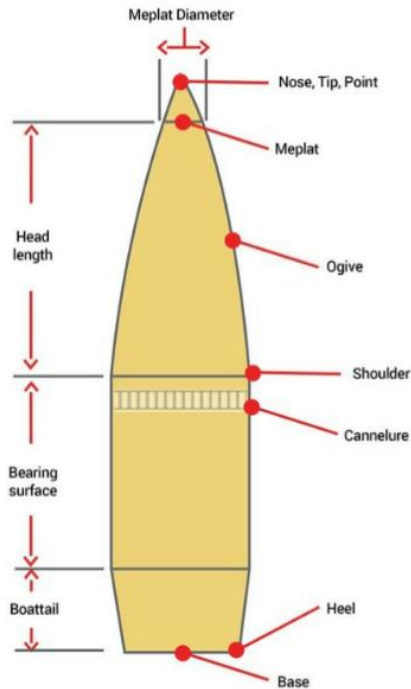
The magnitude of the deviation depends on the location latitude and the flight time of the bullet. The maximum deviation is at the poles and the smallest at the Equator, because the difference in rotational speed between the shooter and the target is at maximum at the poles and zero when firing symmetrically over the Equator.

The Eötvös Effect

When shooting a bullet to the east or west, the Eötvös Effect also affects the flight. When a bullet is fired in the direction of rotation of the earth, i.e. to the east, the shots hit high. If the bullet is shot west, the shots hit low. The reason behind it is that when you're firing east, in the direction of the Earth's rotation, the target has time to move during the flight time below what the aiming point was, so the hit is at the top. When shooting west against the direction of the Earth's rotation, the target has time to move higher than the aiming point during the flight, so the bullet hits low. The more your firing line is in the north-south direction, the less the effect of the Eötvös phenomenon.

Often the Eötvös Effect is considered to be part of the Coriolis phenomenon, but it is in fact its own separate phenomenon. The Eötvös Effect is at its strongest at the Equator and at zero at the poles. The deviation caused by Coriolis and Eötvös effects are around +/- 10 cm / 3.9'' at a distance of 1,000 m/yds.

Parts of a bullet (projectile)



AR Bull Barrel:

1:9 twist; 24"

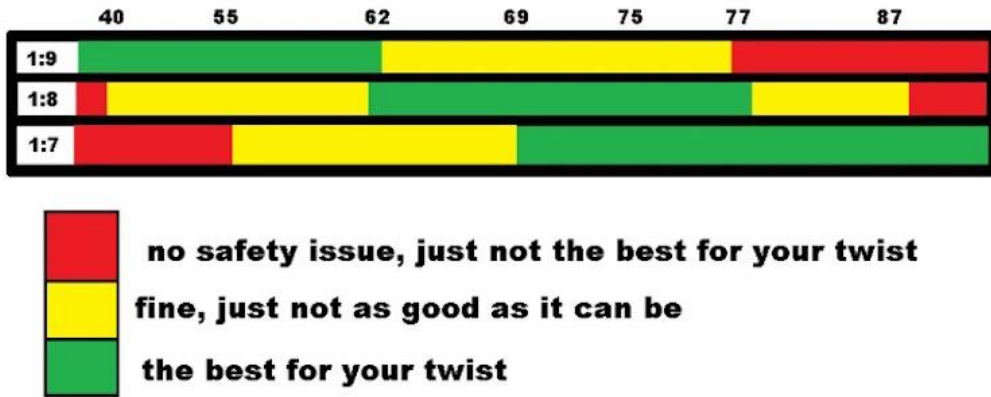
AR-15 rifles with a one-in-9-inch twist will stabilize bullets weighing from **55 to 75 grains**. This allows them to be useful for varmint hunting and competitive on 600-yard "match" targets. ***In this respect, this twist is clearly the most versatile and best all-around twist rate offered in an AR-15 and explains why it is the most common in use today.***

The heavier the bullet the faster the needed twist.

This is the beginning of the road for the shooter wanting to take advantage of the heavy bullet trend. ***The 1-in-9 is a great compromise twist rate—not too fast to cause problems with the 55-grain bullets, but fast enough to stabilize all but the heaviest bullets under most circumstances. This twist will stabilize most***

traditional bullets up to 75 grains, and monolithics up to 70 grains — but they do so right at the edge of the envelope so not all rifles will do it.

Most modern AR-15 barrels will come in three twist rates: 1:9, 1:8, and 1:7. The 1:9 barrel is best for stabilizing lighter and mid-weight bullets between 45 and 77 grains.



Twist Rate	Ideal Bullet Weight (grains)	Acceptable Bullet Weight Range (grains)	Bullet Weights to Avoid (grains)
1:7	62 or 77	55-90+	40-55
1:8	62 or 77	40-90	90+
1:9	55	45-77	77-90+
1:12	45	40-55	55-90+

1-in-7 Inches Twist Rate

This is the twist chosen by the military since the switch was made to the M16A2 — and the 62-grain M855 cartridge — in the 1980s. This twist is found on the M4 carbine, the M16A4, the Mk12 Special Purpose Rifle and even the HK416. Its ability

to stabilize tracer rounds in-flight is one of the reasons that the military chose this twist rate.

This barrel will stabilize bullets of up to 90 grains, and can handle the 70- to 77-grain bullets at just about any velocity, which makes it well suited for carbines with very short barrels. If you want a Mil-Spec clone, the 1-in-7 twist is the way to go.

AR-15 BARREL TWIST RATE CHART			
TWIST	1:7	1:8	1:9
MIN	69gr	62gr	45gr
MAX	80gr	77gr	62gr

OPTIMAL BULLET GRAIN WEIGHT RANGE FOR COMMON BARREL TWIST RATES



Bullet Flying with minimal drag at Zero Yaw



Pitching and Yawing motion induces extra drag



.308

1:15 up to 150 grains

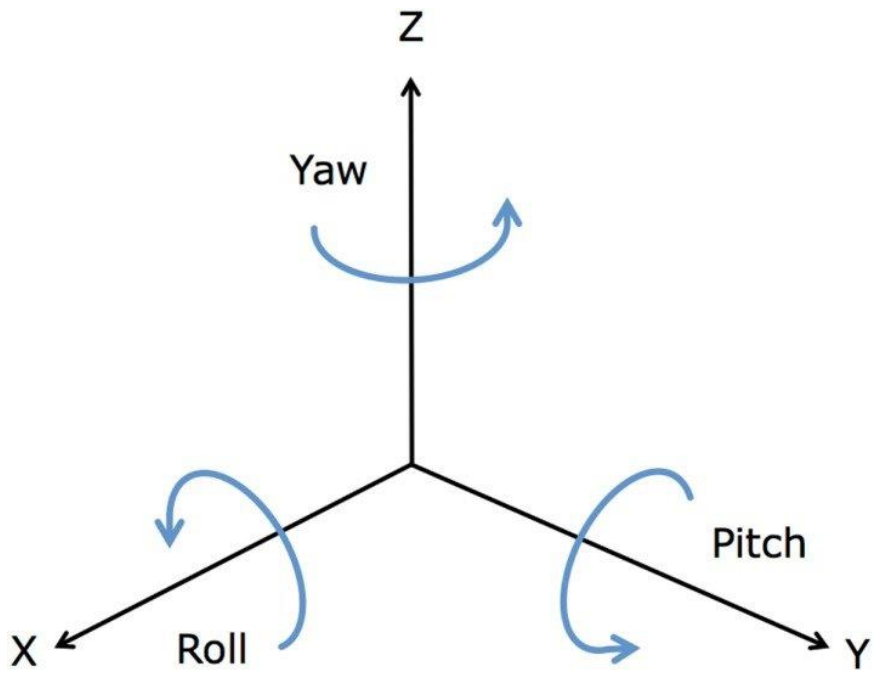
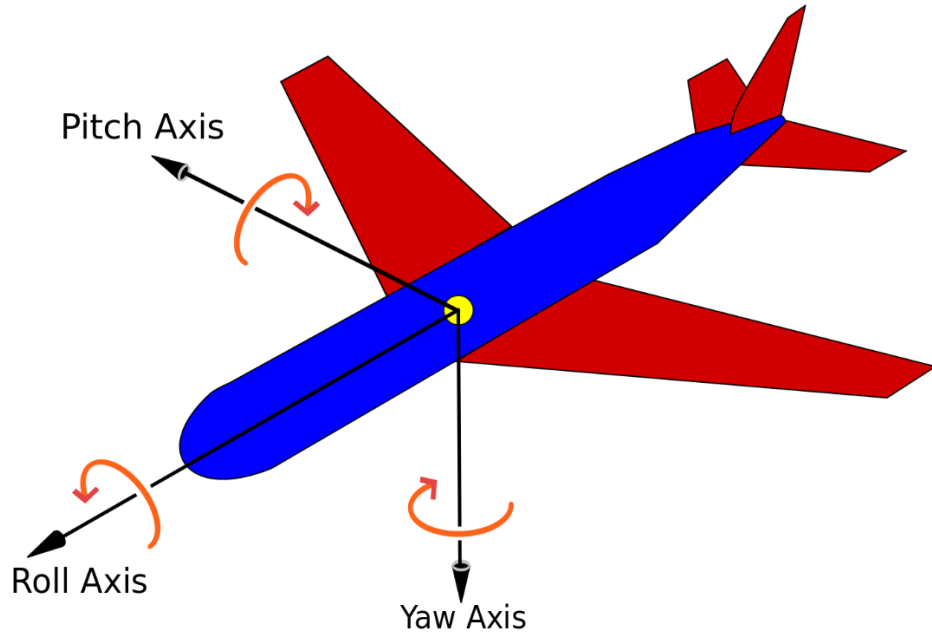
1:14 150 to 168 grains

1:12 168 to 170 grains

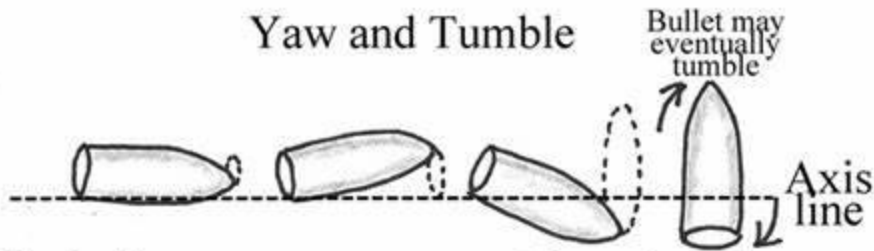
1:10 170 to 220 grains

1:8 220 grains or more

.224 / 5.56 (your .223 Ar)	
1:16	Up to 55 grains, 4300 fps or more
1:15	Up to 55 grains, 4100 to 4300 fps
1:14	Up to 55 grains, less than 4100 fps
1:12	55-63 grains
1:9	63-70 grains
1:8	70 grains or more



Yaw and Tumble

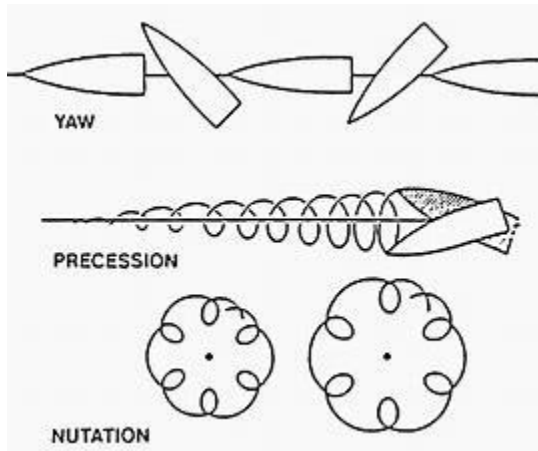


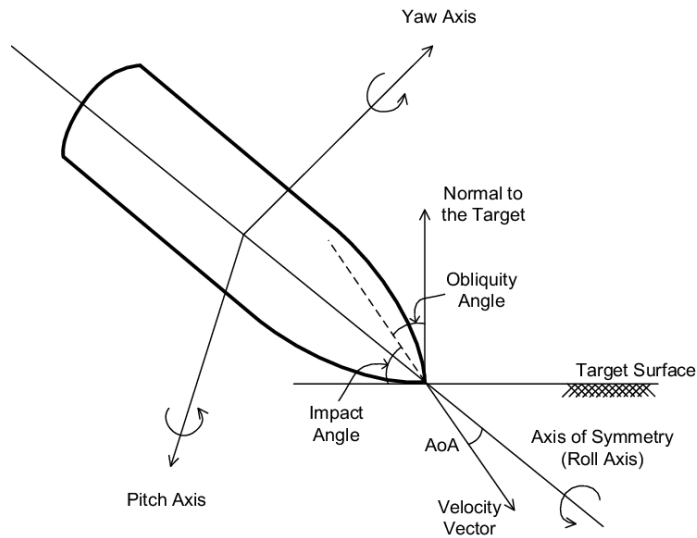
The bullet starts out as yaw (above), and may eventually tumble.



The yaw shown here is the base spinning around the axis.

Illustration © Marilyn McLeod





YAW is “left to right wobble” – YAW Axis

PITCH is “up and down” wobble” – PITCH Axis

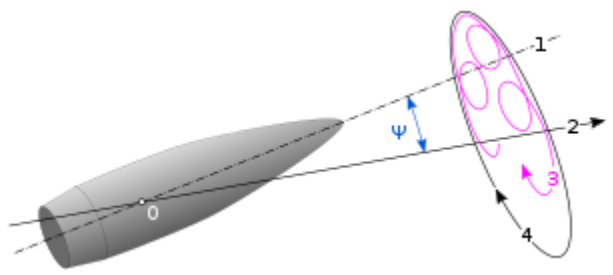
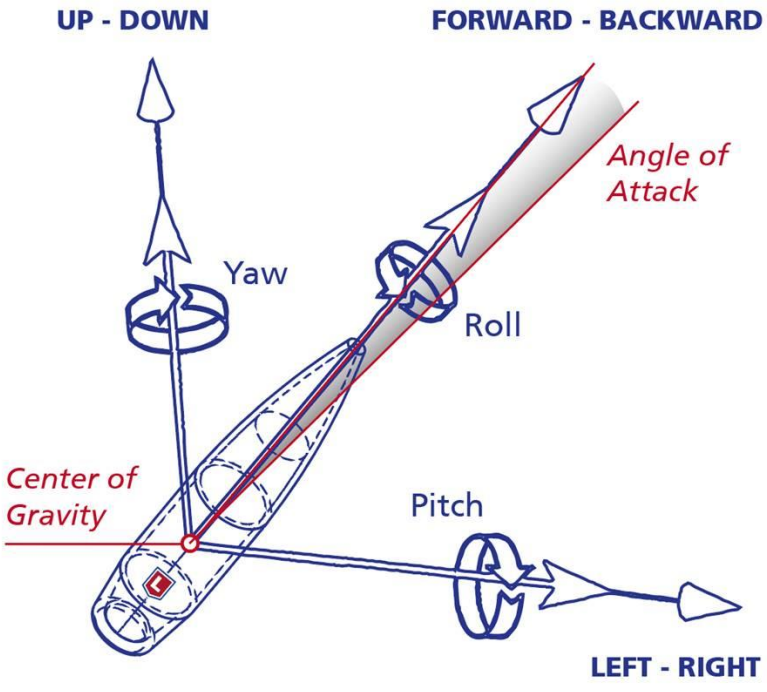
All of this occurring as bullet is rotating around axis of direction of flight (ROLL AXIS).

PRECESSION is a *secondary rotation* around the ROLL AXIS in the direction of flight.

NUTATION is a *tertiary rotation* around PRECESSION



ANGLE OF ATTACK



BULLET NUTATION



What is your Mission?

Distance:

Target: Paper, Wild Game – Type, LE/Military

Short distance (0-300 yds):

Marksmanship.

Optics.

Gravity.

Wind effects at far end.

Wide variety of calibers, cartridges, and loads available.

Premium Hunting loads may extend yardage and game species range of given cartridge.

Cant effect not that significant; Extreme shooting angle effects.

Intermediate Distance: (300-600 yds):

Marksmanship.

Optics.

Gravity.

Wind.

Shrinking variety of calibers, cartridges and loads for acceptable/competitive results.

Premium loads with definite advantage; ***Ballistic Coefficient.***

Cant/Shooting angle begin to be more significant.

Long Distance: (600-1000 yds):

Marksmanship.

Optics.

Gravity.

Wind.

Premium loads required; ***Ballistic Coefficient.***

Cant/Shooting angle are significant.

Spin Drift.

Atmospheric effects.

Coriolis/Eotvos effects start to be significant.

Start of /Transonic Subsonic effects in some loads.

Extreme Long Distance: (>1000 yds):

Marksmanship.

Optics.

Gravity.

Wind.

Premium loads required; ***Ballistic Coefficient.***

Cant/Shooting angle are significant.

Spin Drift.

Atmospheric effects definite significant effect.

Coriolis/Eotvos effects are significant.

Transonic/Subsonic considerations are significant variables.

5 RINGS IN BLACK: X=1.4, 10=2.8, 9=5.8, 8=8.8, ◆ 7=11.8, 6=BLACK CIRCLE=17.8,
DIAMETER

NRA Official F-Class Rifle Targets Repair Center MR-63FC 300 Yard

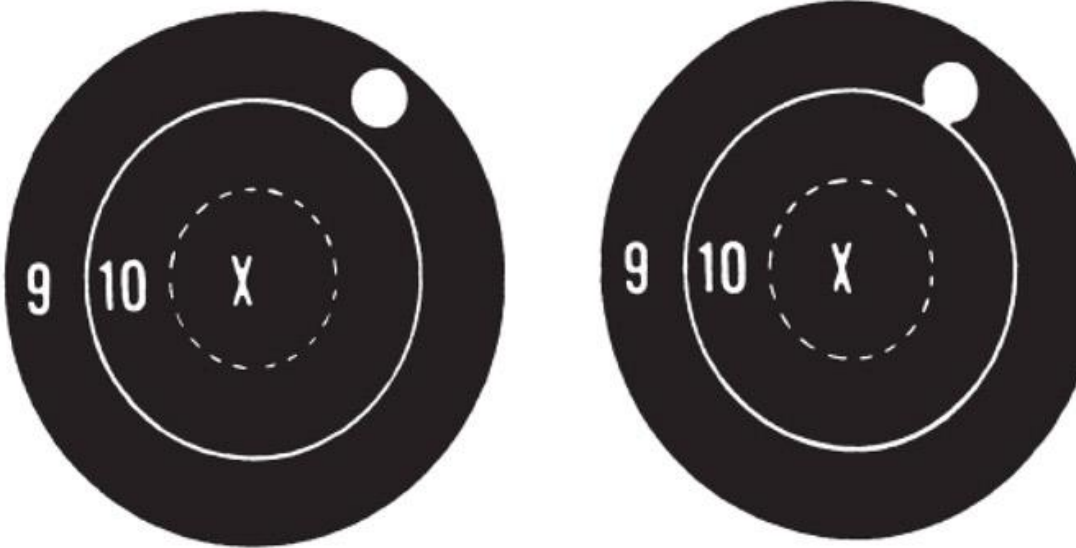
F Class is a subdivision of NRA High Power Rifle shooting in which shooters shoot at paper targets at known distances at medium and long range at a slow fire pace. Where traditional High Power Rifle shooters use slings without additional support, F Class shooters may use either bipods or front rests in combination with rear sand bags. Because the additional support allows for greater precision, the F Class targets have smaller scoring rings than their traditional High Power Rifle counterparts. The X ring on an F Class target is about 1/2 MOA regardless of the distance, so very high precision is required to score well.

Competitors shoot slow-fire (1 minute is permitted per shot fired), and targets are scored between each shot, allowing the shooter to see where his previous shot hit the target.

A typical match might consist of three 20-shot strings for a total of 60 shots for record. Additionally, two or more sighters are allowed prior to the record shots for each string of fire. The exact number of sighters depends on the particular match. **Sighters** are shots that are fired that do not count towards your score. Competitors use them to confirm their zeros and to get a feel for the predominant wind conditions. **Record shots** are just that - they count as part of your recorded score.

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Each shot is scored (Xs count as 10s, and are used as tie breakers), and the competitor's score is that total for all of his shots. The largest target ring has a value of 5 points. Anything outside that ring counts as a miss (zero points) even if the shot hits the target board.



The shot on the left should be scored as a nine, and the right is a 10. This is because the hole on the right is clearly touching the 10-ring.

Consider the average prone shooter capable of putting 19/20 shots in a 20" group at 1000 yards with no wind.