Introduction to the Ballistics Evidence

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[Editor's note: *John Ritchson enlisted in the US Army in 1969 and served nearly two tours of duty as a Special Operations Scout before being medically discharged. He settled in Black Eagle, Montana and opened up the Black Eagle Gunworks with his father Vernon, who had taught him gunsmithing and ballistics as a young man. Since 1995 Ritchson used his expertise to examine the ballistics evidence of the JFK assassination. Here he presented an introduction to the physics underlying the science of ballistics, and explained in simple terms why the Warren Commission failed in this area of its investigation. John Ritchson died just prior to the publication of this issue of* Assassination Research.]

In the subject of ballistics with respect to firearms it is important to gain an understanding of the forces and moments that affect the intrinsic behavior of bullets from the moment they are discharged through their terminal impact.

The modern science of ballistics as first developed by Julian Hatcher is divided into three principal areas: *internal*, which deals with the weapon and projectile during the firing process; *external*, which deals with the projectile in flight; and *terminal*, which deals with the processes involved at the point of Impact.

In this article, I will be dealing with those three principals in the light of showing the reader, in a manner I hope can be easily understood, that most if not all of the assertions made by the Warren Commission Report in this field are patently false.

The flowfield around a traveling bullet

Shadowgraphs have shown that the flowfield in the vicinity of a bullet most generally consists of laminar and turbulent regions. The flowfield depends in particular on the velocity at which the bullet moves, the shape of the bullet, and the roughness of its surface, to mention just the most important factors. The flowfield obviously changes tremendously, as the velocity drops below the speed of sound, which is about 1115 ft/s (340 m/s) at standard atmosphere conditions.

The mathematical equations, by means of which the flowfield parameters (for example pressure and flowfield velocity at each location) could be determined are well known to the physicist. However, with the help of powerful computers, numeric solutions to these equations have been found up to now for very specific configurations only.

Because of these restrictions, ballisticians all over the world consider bullet motion in the atmosphere by disregarding the specific characteristics of the flowfield and apply a simplified viewpoint: The flowfield is characterized by the forces and moments affecting the body. Generally those forces and moments must be determined experimentally, and this is done by shooting experiments and wind tunnel tests.

Generally, a body moving through the atmosphere is affected by a variety of forces. Some of those forces are *mass forces*, which apply at the *center of gravity* (CG) of the body and depend on the body mass and the mass distribution. A second group of forces is called *aerodynamic forces*. These forces result from the interaction of the flowfield with the bullet and depend on the shape and surface roughness of the body. Some aerodynamic forces depend on either yaw or spin or both. The following discussion will be restricted only to drag, lift and the Magnus force.

Wind force and overturning moment

Now let us consider the most general case of a bullet having a *yaw angle*. By saying so, the ballistician means that the direction of motion of the bullet's CG deviates from the direction into which the bullet's axis of symmetry points. Innumerable experimental observations have shown that an initial yaw angle is principally unavoidable and is caused by perturbations like barrel vibrations and muzzle blast disturbances.

For such a bullet, the pressure differences at the bullet's surface result in a force, which is called the *wind force*. The wind force seems to apply at the *center of pressure of the wind force* (CPW), which, for spin-stabilized bullets, is located in front of the CG. The location of the CPW is by no means stationary and shifts as the flowfield changes.

It is possible to add two forces to the wind force, having the same magnitude as the wind force but opposite directions. If one let those two forces attack at the CG, these two forces obviously do not have any effect on the bullet as they mutually neutralize.

There are two further forces that form a couple that is called the *aerodynamic moment of the wind force* or, for short, the overturning moment MW. The overturning moment tries to rotate the bullet around an axis, which passes through the CG and is perpendicular to the bullet's axis of form.

To summarize: The wind force, which applies at the center of pressure, can be substituted by a force of the same magnitude and direction plus a moment. The force applies at the CG, the moment turns the bullet about an axis running through the CG. This is a general rule of classical mechanics (see any elementary physics textbook) and applies for any force that attacks at a point different from the CG of a rigid body.

One can proceed one step further and split the force, which applies at the CG, into a force which is antiparallel to the direction of movement of the CG, plus a force which is perpendicular to this direction. The first force is said to be the *drag force* FD, or simply *drag*; the other force is the *lift force*, FL, or *lift* for short. Obviously, in the absence of a yaw angle, the wind force reduces to the drag.

So far, we have explained the forces, which compose the wind force and the overturning moment, but we haven't dealt with their effects.

Drag and lift apply at the CG and simply affect the motion of the CG. Of course, the drag retards this motion. The effects of the lift force will be met later.

Obviously, the overturning moment tends to increase the yaw angle, and one could expect that the bullet starts tumbling and become unstable. This indeed can be observed when firing bullets from an unrifled barrel. However, at this point, as we consider spinning projectiles, the *gyroscopic effect* comes into the scene. This can be explained and derived from general rules of physics and can be verified by applying mathematics. For the moment we simply believe what can be observed: Due to the gyroscopic effect, the bullet's longitudinal axis moves aside into the direction of the overturning moment.

As the global outcome of the gyroscopic effect, the bullet's axis of symmetry thus would move on a cone's surface, with the velocity vector indicating the axis of the cone. This movement is often called *precession*. However, a more recent nomenclature defines this motion as the *slow mode oscillation*.

To complicate things even more, the true motion of a spin-stabilized bullet is much more complex. A fast oscillation superposes the slow oscillation. However, we will return to this point later.

Magnus Force and Magnus Moment

Generally, the wind force is the dominant aerodynamic force. However, there are numerous other smaller forces, but we will concentrate on the Magnus force, which turns out to be very important for bullet stability.

If one imagines looking at a bullet from the rear, and supposes that the bullet has right-handed twist, we must additionally assume the presence of an angle of yaw in which the bullet's longitudinal axis should be inclined to one side.

Due to this inclination, the flowfield velocity has a component perpendicular to the bullet's axis of symmetry, which we call v_n. However, because of the bullet's spin, the flowfield turns out to become asymmetric. Molecules of the air stream adhere to the bullet's surface. Air stream velocity and the rotational velocity of the body add at one point, A, and subtract at another, B. Thus one can observe a lower flowfield velocity at A and a higher streaming velocity at B. However, according to Bernoulli's rule, a higher streaming velocity corresponds with a lower pressure and a lower velocity with a higher pressure. Thus, there is a pressure difference, which results in a downward directed force, which is said to be the *Magnus Force* (MF) (Heinrich Gustav Magnus, 1802–1870, German physicist).

This explains why the Magnus force, as far as flying bullets are concerned, requires spin as well as an angle of yaw, otherwise this force vanishes.

If one considers the whole surface of a bullet, one finds a total Magnus force, which applies at its *center of pressure* (CPM). The center of pressure of the Magnus force varies as a function of the flowfield structure and can be located behind as well as in front of the CG. The magnitude of the Magnus force is considerably smaller than the magnitude of the wind force. However, the associated moment, the discussion of which follows, is of considerable importance for bullet stability.

You can repeat the steps that were followed after the discussion of the wind force. Again, you can substitute the Magnus force applying at its CP by an equivalent force, applying at the CG, plus a moment, which is said to be the *Magnus Moment* (MM). This moment tends to turn the body about an axis perpendicular to its axis of symmetry.

However, the gyroscopic effect also applies for the Magnus force. Remember that due to the gyroscopic effect, the bullet's nose moves into the direction of the associated moment. With respect to the conditions reflected in the associated moment, the Magnus force thus would have a stabilizing effect, as it tends to decrease the yaw angle, because the bullet's axis will be moved opposite to the direction of the yaw angle.

A similar examination shows that the Magnus force has a destabilizing effect and increases the yaw angle, if its center of pressure is located in front of the CG. Later, this observation will become very important, as we will meet a dynamically unstable bullet, the instability of which is caused by this effect.

Two-arms model of yawing motion

We have now finished discussing the most important forces and aerodynamic moments affecting a bullet's motion, but so far we haven't seen what the resulting movement looks like. For the moment we are not interested in the trajectory itself (the translational movement of the body), but we want to concentrate on the body's rotation about the CG.

The yawing motion of a spin-stabilized bullet, resulting from the sum of all aerodynamic moments, can be modeled as a superposition of a fast and a slow mode oscillation, and can most easily be explained and understood by means of a *two-arms model*.

Imagine looking at the bullet from the rear. Let the slow mode arm CG to A rotate about the CG with the slow mode frequency. Consequently point A moves on a circle around the center of gravity.

Let the fast mode arm A to T rotate about A with the fast mode frequency. Then T moves on a circle around point A. T is the bullet's tip and the connecting line of CG and T is the bullet's longitudinal axis.

This simple model adequately describes the yawing motion, if one additionally considers that the fast mode frequency exceeds the slow mode frequency, and the arm lengths of the slow mode and the fast mode are, for a stable bullet, continuously shortened.

Imagine looking at a bullet approaching an observer's eyes. Then the bullet's tip moves on a spiral-like (also described as helical) path, while the CG remains attached to the center of the circle. The bullet's tip periodically returns back to the tangent to the trajectory. If this occurs, the yaw angle becomes a minimum.

Internal ballistics

We will conclude with a short introduction to internal ballistics so that the reader can perhaps gain an understanding as to just how poorly the WWII M38 Carcano performs, and how this relates to the JFK assassination.

When all firearms are discharged, their barrels vibrate in the same manner as the tine of a tuning fork. These vibrations will cause the barrel to move considerably and with violence. Accuracy is absolutely dependent upon the uniformity of these vibrations and a fundamental requirement of a good gunsmith is the ability to forge and work steel in such a manner as to maximize the barrel's capability of ringing true with each and every shot.

Barrel vibrations are divided into two parts: *fundamental* and *secondary* vibrations. With fundamental vibration the entire barrel vibrates as a single unit from one fixed node (the point at which the barrel is calm) which is at the breech where the barrel is fixed to the receiver. Secondary vibration is a series of overtones in which the barrel is divided longitudinally into a number of vibrating sections each terminating in a node at the end of a particular section nearest the breech.

Some of the things which, if not done just right, which will adversely effect the true ring of a barrel are headspace, screws, crowning, throat, bore and bedding. Bedding screws that are not perfectly true, improper bedding, and bolt lugs and barrel bands that are not uniform, and (especially noteworthy) *set-screws in the receiver-ring which apply a point of force at a single node on the barrel-breech* can and will cause conflicting stresses when the rifle is fired, altering the barrel vibrations to the point of irregularity, thus destroying any hope of uniform downrange accuracy.

Many of these enumerated defects are known to be present in WWII M38 Carcanos. Fundamental vibration is set in motion by the shock of discharge. The breech end of the barrel, when it is properly melded to the receiver, remains relatively calm and is the single node. The muzzle oscillates in a circular path and can move in any direction through 360 degrees. The position of the muzzle at the instant of bullet exit greatly influences the point of impact on the target.

When fundamental vibration is extreme and when the muzzle position (at the instant of bullet exit) varies from shot to shot, all hope of down range accuracy is lost.

Secondary vibration occurs at the same instant as, but independently of, fundamental vibration. In it are a series of nodes and overtones traveling along the length of the barrel producing oscillations similar to that of a snapping whip. Any factor, such as the condition of the firearm, heat of the barrel, powder charge variation, support of the firearm, etc., which introduce small variations in vibration will effect down range accuracy.

Almost every aspect of a rifle–cartridge combination will have some effect on barrel vibration. A heavy load will set up a more violent vibration than a light load. On the other hand, when the velocity is low (such as the light loaded Carcano), vibrations have more time to develop before the bullet leaves the muzzle. Note carefully that *the total disturbance from a light load, though less violent and rapid, will be greater than that of a heavy load.*

A properly sized bullet fits the barrel and forms a nearly perfect gas seal. Thus expanding gas is trapped behind the bullet and is pushing equally in all directions. The force of the gas actually expands the barrel behind the bullet. Note again that *any change in this force not only creates a change in muzzle velocity due to a change in friction, but also changes the barrel stresses which effects vibration.*

To give the reader a sense of the real-world impact of barrel vibration on a bullet's terminal ballistic point of impact: Tests conducted by the US Army on the venerable old M1903 Springfield Rifle (which is superior to any M38 Carcano by several orders of magnitude), using standard military ammunition, the angular movement of the muzzle due to vibration equal to more than 40 ft. at 1,000 yards. This is the reason why the M38 Carcano is generally considered to be a very poor weapon.

Proper twist is an absolute requirement for bullet stability leading to down range accuracy. Heavier (longer) bullets need a faster twist for in-flight stability, and smaller lighter bullets require a slower twist. When the M38 Carcano was first developed, it was chambered for a 7.35 mm cartridge which was the same case as the 6.5 mm but with the neck expanded to accommodate the larger 7.35 mm bullet. The 7.35 mm barrel was cut for a 1 in 10" turn twist which was suitable for this bullet. However—and here is the problem—some time around the beginning of WWII, the Italians decided not to proceed with the retooling for the 7.35 mm, and instead went back to the 6.5 mm bullet. Now, the original 6.5 mm barrels on the model 91 Carcanos were cut with a progressive or gain twist starting with a 1 in 19" turn at the breech and ending with a 1 in 8" turn twist at the muzzle. Such barrels are considered superior to a standard-cut barrel (which may explain why the Italian National Shooting Team still uses the M91s in competition match shooting), but when the M38 Carcanos were rebarreled to 6.5 mm, only a very few were rebarreled with a gain twist barrel—probably only until the existing stock was used up—and the rest (composing the vast majority of all M38 Carcanos ever made) were fitted with standard rifled barrels, which unless the gun factories retooled their groove cutters to the faster 1 in 7" turn twist, which is optimum for the 6.5mm bullet, would have produced the slower 1 in 8.5" to a 1 in 10" turn twist. There is no evidence that such retooling ever took place.

During wartime production, the gun factories were under extreme pressure to produce the massive number of firearms required to prosecute the war. As a result the factory gunsmiths could not simply shut down production to perform basic maintenance on their machines, resulting in a situation where the cutting tools would become dull and start “hogging” the steel, producing a wide variation in bore diameters. Also, they were unable to properly finish their production models, resulting in sloppy actions, poor bedding, crowning and improper headspacing.

Such weapons, under the right circumstances, could be as dangerous to the shooter as the target, resulting in cases of catastrophic breech failure in which the weapon could and would literally blow up in the shooter’s face. It wasn’t until the 1990s that Dave Emory, chief ballistican for Hornady Arms, was able to produce a bullet that can be safely fired from a war-time production M38 Carcano—provided, of course, one can find one in fairly good shape. However, it is still strongly recommended that anyone contemplating using a M38 Carcano to have it checked out by a competent gunsmith before loading and firing it, as in the event of a cartridge or primer rupture or a condition of excessive breech pressure due to improper headspacing such a shooter will most definitely notice the after-effects.

This problem with respect to the production of the rifle is just one more reason why the M38 Carcano, with the possible exception of the Japanese Arisaka, is considered by many in the trade to be the worst rifle ever made.

Equipped with this rifle, a shooter of the caliber of Lee Harvey Oswald on his best day couldn’t have hit the water if he fired it off of a boat, much less accomplish what the Warren Commission said he did.

The cartridges

Some time ago, researcher Walt Cakebread sent the author a photo-reproduction of Warren Commission Exhibit CE-738 taken at Dallas Police Headquarters around 10:00–10:30 pm on 22 November 1963. Among the items inventoried, allegedly connected to Lee Harvey Oswald, are two spent brass cartridges identified as Winchester/Western Cartridge Corporation 6.5 x 52 mm Mannlicher Carcano cartridges, and one live round identified as an unfired WCC 6.5 x 52 mm Mannlicher Carcano cartridge. These two items are the focus of the following. (Measurements are made by Starrett precision instruments, and a Dietzgen precision protractor, and will be in the English system.)

The unfired cartridge designated as Item 6 of Exhibit CE-738 and identified as a WCC 6.5 mm MC Cartridge *appears* not to be as represented (“appears”, due to the fact that in the blow-up the author worked from it is impossible to read the make of the cartridge). However, the primer is clearly visible and is markedly similar to the odd-sized Berdan primer that is characteristic of Italian GI Ammunition, and is different in size than the American primers that would be used in WCC ammunition. Also in evidence is a banded neck-crimp just above the shoulder, that locks the neck into the bullet's cannula which would not be present in Winchester/Western ammunition.

Conclusion: The unfired cartridge represented as Item 6 of Exhibit CE-738 more closely resembles an L.B.C. 936, 6.5 x 52 mm MC Italian GI cartridge, than it does an American made WCC 6.5 x 52 mm MC Cartridge. (Note: Virtually all American bullets are jacketed with Gilder's Metal, which is an alloy of copper and zinc, with a distinct brassy appearance. The color photos of the unfired cartridge shows a bullet that is distinctly silver in color, consistent with the copper–nickel alloy used by European bullet makers, but not their American counterparts.)

The MC Cartridge possesses a shoulder width of .160" and a shoulder bevel of 25 degrees. This is an extremely critical point as measurement of the spent cases show a shoulder width of .186" and a shoulder bevel of 24 degrees, for a difference of .026" in shoulder width and 1 degree of angle in the bevel.

Conclusion: The two spent cases much more closely resemble a 6.5 x 54 mm Mannlicher–Schoenauer (MS) cartridge then they do a 6.5 x 52 mm MC cartridge, while one spent cartridge case, due to the presence of counter-bored neck steps, would be of European design and make.

The distinction made in the above conclusion, if it holds up, is an important one as the Austrian-designed MS rifle is prized for its smooth action, magazine efficiency, chambering characteristics and accuracy, as opposed to the dismal performance of the MC rifle. (Note: Many a custom Mauser is chambered for this cartridge, which makes for an excellent medium-range deer rifle as well as a sniper rifle.)

Finally, it must be pointed out that Western Cartridge Corporation manufactured 6.5 x 52 mm Carcano cartridges under a military procurement contract from the US Marine Corps so that all such munitions produced would have possessed lot and batch numbers head-stamped on the cartridge bases as per military protocol. The only cartridges produced by Western in the 6.5 mm caliber that would have possessed the factory logo "Western" with the caliber, "6.5 mm" stamped on the cartridge base would be pre-WWII 6.5 x 54 mm Mannlicher–Schoenauer factory-loaded hunting ammunition with soft round-nosed semi-jacketed bullets.

So what we are dealing with here is two spent cartridges which cannot be chambered in any Carcano rifle, and a live round that would not have been made in America.

Simply put, this represents another rather large hole in the Warren Commission Report, and not only tends to exonerate Lee Oswald as the lone assassin, but provides *prima facie* evidence of evidence-tampering and obstruction of justice.

