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BALLISTICS: THE PROJECTILE CHARACTERISTICS OF WEAPON IN FORENSIC SCIENCE

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ABSTRACT

Ballistics is the field of mechanics concerned with the launching, flight behaviour and impact effects of projectiles, especially ranged weapon munitions such as bullets, unguided bombs, rockets or the like; the science or art of designing and accelerating projectiles so as to achieve a desired performance. A **ballistic body** is a free-moving body with momentum which can be subject to forces such as the forces exerted by pressurized gases from a gun barrel or a propelling nozzle, normal force by rifling, and gravity and air drag during flight. A ballistic missile is a missile that is guided only during the relatively brief initial phase of powered flight and the trajectory is subsequently governed by the laws of classical mechanics; in contrast to (for example) a cruise missile which is aerodynamically guided in powered flight like a fixed-wing aircraft.

KEYWORDS: Ballistics, Gene gun, Bullets, Micro Stamping, Identification.

Introduction and History: The earliest known ballistic projectiles were stones and spears, and the throwing stick.

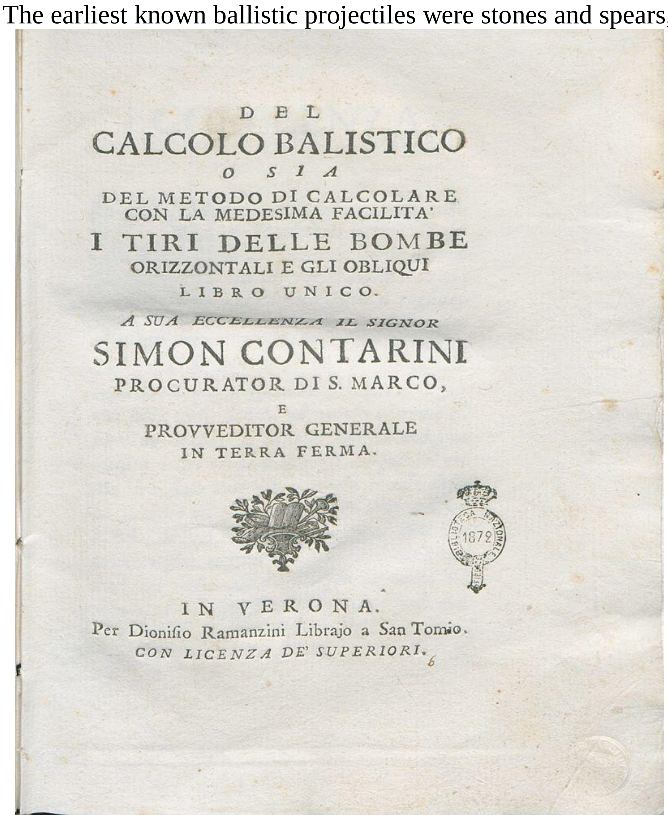
DEL
CALCOLO BALISTICO
O SIA
DEL METODO DI CALCOLARE
CON LA MEDESIMA FACILITA'
I TIRI DELLE BOMBE
ORIZZONTALI E GLI OBLIQUI
LIBRO UNICO.
A SUA ECCELLENZA IL SIGNOR
SIMON CONTARINI
PROCURATOR DI S. MARCO,
E
PROVVEDITOR GENERALE
IN TERRA FERMA.
IN VERONA.
Per Dionisio Ramanzini Librajo a San Tomio.
CON LICENZA DE' SUPERIORI.

Figure-1: Gaetano Marzagaglia, *Del calcolo balistico*, 1748.

The oldest evidence of stone-tipped projectiles, which may or may not have been propelled by a bow (c.f. atlatl), dating to c. 64,000 years ago, were found in Sibudu Cave, present day-South Africa. The oldest evidence of the use of bows to shoot arrows dates to about 10,000 years ago; it is based on pinewood arrows found in the Ahrensburg valley north of Hamburg. They had shallow grooves on the base, indicating that they were shot from a bow. The oldest bow so far recovered is about 8,000 years old, found in the Holmegård swamp in Denmark. Archery seems to have arrived in the Americas with the Arctic small tool tradition, about 4,500 *years ago*. The first devices identified as guns appeared in China around 1000 AD, and by the 12th century the technology was spreading through the rest of Asia, and into Europe by the 13th century.[1]

After millennia of empirical development, the discipline of ballistics was initially studied and developed by Italian mathematician Niccolò Tartaglia in 1531, although he continued to use segments of straight-line motion, conventions established by Avicenna and Albert of Saxony, but with the innovation that he connected the straight lines by a circular arc. Galileo established the principle of compound motion in 1638, using the principle to derive the parabolic form of the ballistic trajectory. Ballistics was put on a solid scientific and mathematical basis by Isaac Newton, with the publication of Philosophiæ Naturalis Principia Mathematica in 1687. This gave mathematical laws of motion and gravity which for the first time made it possible to successfully predict trajectories. The word *ballistics* comes from the Greek βάλλειν *ballein*, meaning "to throw".

Ballistics is the science that deals with the flight, behavior and effect of a projectile. A projectile, such as a bullet, is an object that leaves the source of its energy behind and is affected only by gravity. The flight path of the projectile is also studied.

Three Categories of Ballistics: *Internal Ballistics*- what physically occurs inside the gun barrel once a projectile is fired.

External Ballistics- what physically happens to the projectile once it leaves the barrel. *Terminal Ballistics*- how a projectile act when it encounters a target.

Forensic Ballistics: Forensic Ballistics is the science of analysing firearms, bullets and bullet impacts. Ballistic fingerprinting is analysing firearm evidence to determine if that particular firearm was used in the crime.

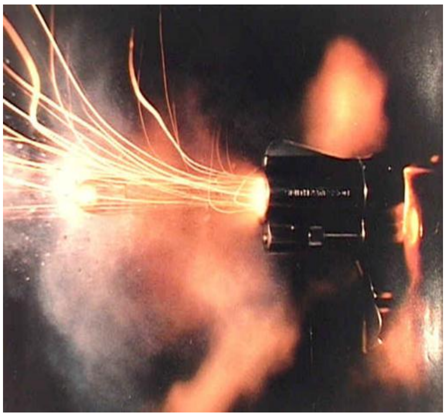

Figure-2: Bullet projectile.

Projectiles: A projectile is any object projected into space (empty or not) by the exertion of a force. Although any object in motion through space (for example a thrown baseball) is a projectile, the term most commonly refers to a ranged weapon. Mathematical equations of motion are used to analyze projectile trajectory. Examples of projectiles include balls, arrows, bullets, artillery shells, wingless rockets, etc.[2]

Projectile launchers

Throwing

Throwing is the launching of a projectile by hand. Although some other animals can throw, humans are unusually good throwers due to their high dexterity and good timing capabilities, and it is believed that this is an evolved trait. Evidence of human throwing dates back 2 million years. The 90-mph throwing speed found in many athletes far exceeds the speed at which chimpanzees can throw things, which is about 20 mph. This ability reflects the ability of the human shoulder muscles and tendons to store elasticity until it is needed to propel an object.[3]

Sling: A sling is a projectile weapon typically used to throw a blunt projectile such as a stone, clay or lead "sling-bullet". A sling has a small cradle or *pouch* in the middle of two lengths of cord. The *sling stone* is placed in the pouch. The middle finger or thumb is placed through a loop on the end of one cord, and a tab at the end of the other cord is placed between the thumb and forefinger. The sling is swung in an arc, and the tab released at a precise moment. This frees the projectile to fly to the target.

Bow: A bow is a flexible piece of material which shoots aerodynamic projectiles called arrows. A string joins the two ends and when the string is drawn back, the ends of the stick are flexed. When the string is released, the potential energy of the flexed stick is transformed into the velocity of the arrow. Archery is the art or sport of shooting arrows from bows.[4]

Catapult: A catapult is a device used to launch a projectile a great distance without the aid of explosive devices — particularly various types of ancient and medieval siege engines. The catapult has been used since ancient times, because it was proven to be one of the most effective mechanisms during warfare.

Figure-3: Catapult.

The word "catapult" comes from the Latin *catapulta*, which in turn comes from the Greek καταπέλτης (*katapeltēs*), itself from κατά (*kata*), "against" and πάλλω (*pallō*), "to toss, to hurl". Catapults were invented by the ancient Greeks.

Gun: A gun is a normally tubular weapon or other device designed to discharge projectiles or other material. The projectile may be solid, liquid, gas, or energy and may be free, as with bullets and artillery shells, or captive as with Taser probes and whaling harpoons. The means of projection varies according to design but is usually affected by the action of gas pressure, either produced through the rapid combustion of a propellant or compressed and stored by mechanical means, operating on the projectile inside an open-ended tube in the fashion of a piston.

Figure-4: Gun.

The confined gas accelerates the movable projectile down the length of the tube imparting sufficient velocity to sustain the projectile's travel once the action of the gas ceases at the end of the tube or muzzle. Alternatively, acceleration via electromagnetic field generation may be employed in which case the tube may be dispensed with and a guide rail substituted. A weapons engineer or an armourer who applies the scientific principles of ballistics to design cartridges are often called a **ballistician**.[5]

Categories of Firearms: There are three categories of firearms: Handguns – includes pistols, revolvers and derringers, Long Guns – includes rifles and shotguns, Mounted Guns – includes cannons and anti-aircraft gun.

Figure-5: Parts of handgun.

Parts of a Handgun: An understanding of the parts of any gun is essential in forensic ballistics.

Parts of a Bolt-Action Rifle

Figure-6: Rifle parts.

Parts of a Pump-Action Shotgun

Figure-7: Shotgun parts.

Components of Ammunition: In addition to the parts of a gun, it is essential to know the components of ammunition.

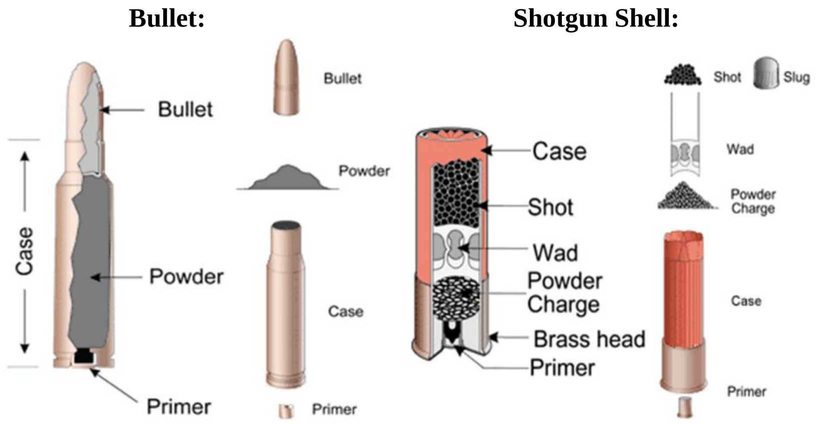

Figure-8: Bullet & Shotgun shell.

Parts of a Gun – The Barrel

The diameter of a rifled gun barrel is the calibre. Calibre is normally recorded in millimetres. For example, a 9 mm handgun.

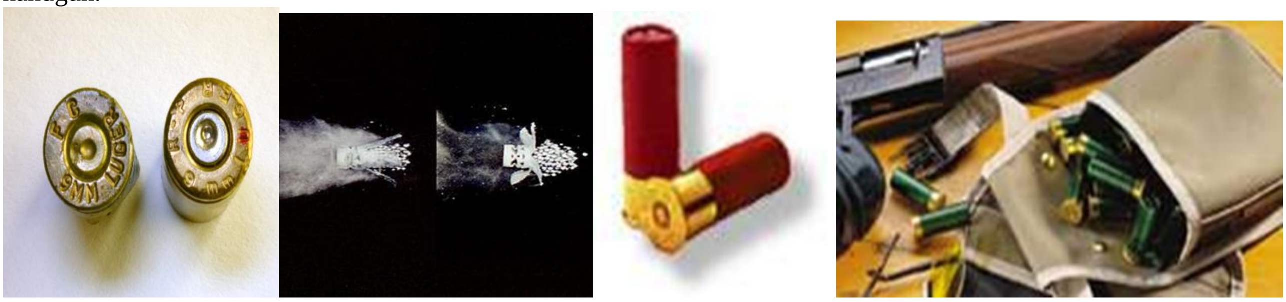

Figure-9: Parts of gun.

The Shotgun Barrel: Unlike rifled firearms, shotguns have a smooth barrel. They fire small lead balls or pellets contained within a shotgun shell. The diameter of a shotgun barrel is expressed in terms gauge. The higher the gauge number, the smaller the barrel's diameter.

Parts of a Gun- The Barrel: Most gun barrels are hollow tubes of steel. Except for a shotgun, the inside surface of the gun barrel is rifled. The process of rifling creates spiral grooves in the barrel. The areas between the grooves are called lands.

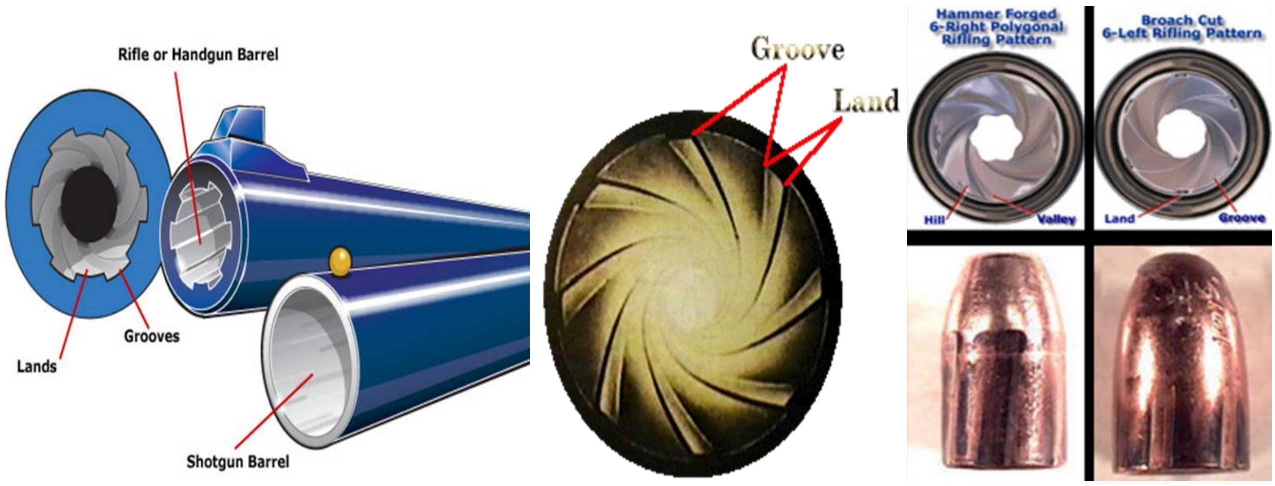

Figure-10: Shotgun barrel.

FBI Database: The General Rifling Characteristics File is a record maintained by the FBI.

This file lists land and groove width dimensions for known weapons. For example, Marlin rifles undergo a unique rifling process known as micro grooving.

A gun manufactured by Colt has lands and grooves that have a left-hand twist. Are these from a Colt?

Figure-11: Bullets.

Is This a Match?
Striations: As the bullet travels through the barrel, the grooves guide the bullet and cause it to spin. Striations, or fine lines, in the gun barrel make the same striations on the bullet. These striations are unique to the firearm.
How Exact is the Comparison? A perfect match is rare. Dirt, rust, minute changes in the gun barrel as more bullets are fired and distortion of the bullet on impact may change the striations.

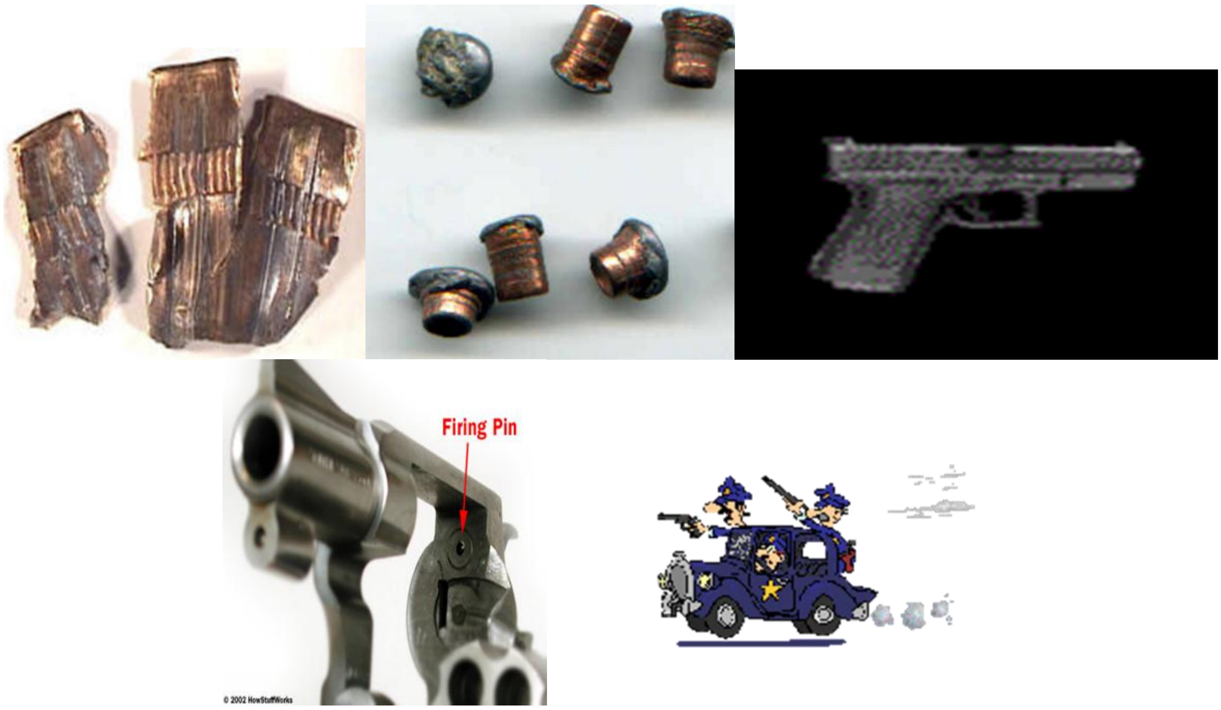

Figure-12: Revolvers.

Bullet Comparisons: Every bullet can be matched to a particular weapon through comparing striation marks. Other Marks on a Fired Bullet: Basically, all gun's fire by applying explosive pressure behind a projectile to launch it down a barrel. This firing process also leaves unique marks and/or impressions on the bullet and bullet case.

What is the Firing Process? The ammunition is loaded into the gun, the hammer is cocked and then the trigger is pulled.

Pulling the trigger initiates the process and a firing pin strike and ignites the primer. The primer explodes and ignites the propellant.

Rocket: A rocket is a missile, spacecraft, aircraft or other vehicle that obtains thrust from a rocket engine. Rocket engine exhaust is formed entirely from propellants carried within the rocket before use. Rocket engines work by action and reaction. Rocket engines push rockets forward simply by throwing their exhaust backwards extremely fast.

While comparatively inefficient for low-speed use, rockets are relatively lightweight and powerful, capable of generating large accelerations and of attaining extremely high speeds with reasonable efficiency. Rockets are not reliant on the atmosphere and work very well in space.

Rockets for military and recreational uses date back to at least 13th century China. Significant scientific, interplanetary and industrial use did not occur until the 20th century, when rocketry was the enabling technology for the Space Age, including setting foot on the Moon. Rockets are now used for fireworks, weaponry, ejection seats, launch vehicles for artificial satellites, human spaceflight, and space exploration.

Chemical rockets are the most common type of high-performance rocket and they typically create their exhaust by the combustion of rocket propellant. Chemical rockets store a large amount of energy in an easily released form, and can be very dangerous. However, careful design, testing, construction and use minimizes risks.

Subfields: Ballistics is often broken down into the following four categories:

- *Internal ballistics* the study of the processes originally accelerating projectiles
- *Transition ballistics* the study of projectiles as they transition to unpowered flight
- *External ballistics* the study of the passage of the projectile (the trajectory) in flight
- *Terminal ballistics* the study of the projectile and its effects as it ends its flight

Internal ballistics: Internal ballistics (also interior ballistics), a sub-field of ballistics, is the study of the propulsion of a projectile. In guns internal ballistics covers the time from the propellant's ignition until the projectile exits the gun barrel. The study of internal ballistics is important to designers and users of firearms of all types, from small-bore rifles and pistols, to high-tech artillery. For rocket propelled projectiles, internal ballistics covers the period during which a rocket engine is providing thrust.[6]

Figure-13: Ballistics can be studied using high-speed photography or high-speed cameras. A photo of a Smith & Wesson revolver firing, taken with an ultrahigh speed air-gap flash. Using this sub-microsecond flash, the bullet can be imaged without motion blur.

What is the Firing Process? As the propellant burns, gases build up inside the bullet case and the bullet is pushed forward into the barrel. The bullet is forced down the barrel by the expanding gases and the bullet case is slammed back against the breech face. Imperfections in the barrel and on the breech, face are transferred to surfaces of the bullet and bullet case. As the bullet moves down the barrel and exits the gun, the cartridge either stays in the back of the barrel or it is ejected by an ejector mechanism.

Figure-14: Bullet & Cartridge.

Identifying Marks from the Firing Pin: Metal-to-metal contact between the bullet case and the firing pin leaves an impression on the case. This impression is in the shape of the firing pin.

Identifying Marks from the Breech Face and Ejector Mechanism: Markings from the breech face that occur when the bullet case is slammed back as the bullet moves forward. Markings from the ejector mechanism that occur when the bullet case is ejected from the gun.

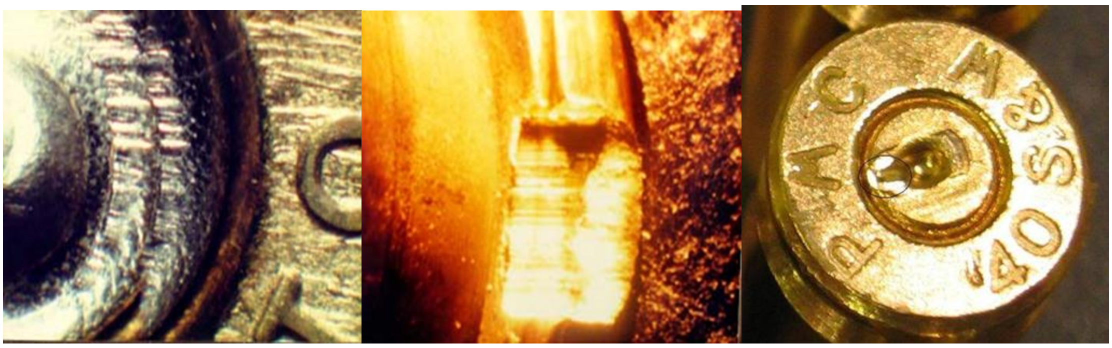

Figure-15: Breech & Ejector.

The Data Base for Firearm Information: Originally, the information about firearms, ammunition and identifying marks was kept by two different agencies; the FBI and the ATF&E. The FBI maintained a system known as DRUGFIRE and the ATF&E maintained a system known as Integrated Ballistics Identification System (IBIS).

The Data Base for Firearm Information: This two-agency system was confusing and unproductive. So in 1999, the two systems were combined into the National Integrated Ballistics Information Network (NIBIN). This system has over 800,000 computerized images.

Identifying marks on a Shotgun Cartridge Shell: A shotgun has a smooth barrel so the projectile is not marked with any type of striation. However, the shotgun cartridge may have the same markings as a bullet case.

Gunpowder Residues: When a firearm is discharged, unburned and partially burned particles of gunpowder in addition to smoke are propelled out of the barrel along with the bullet towards the target. If the muzzle of the weapon is sufficiently close to the target, gunpowder residue is deposited on the target.

Figure-16: Gunpowder residues.

Distance Determination: The process of determining the distance between the firearm and the target is usually based on the distribution of powder patterns or the spread of a shot pattern (shotgun). As the distance increases the residue decreases.

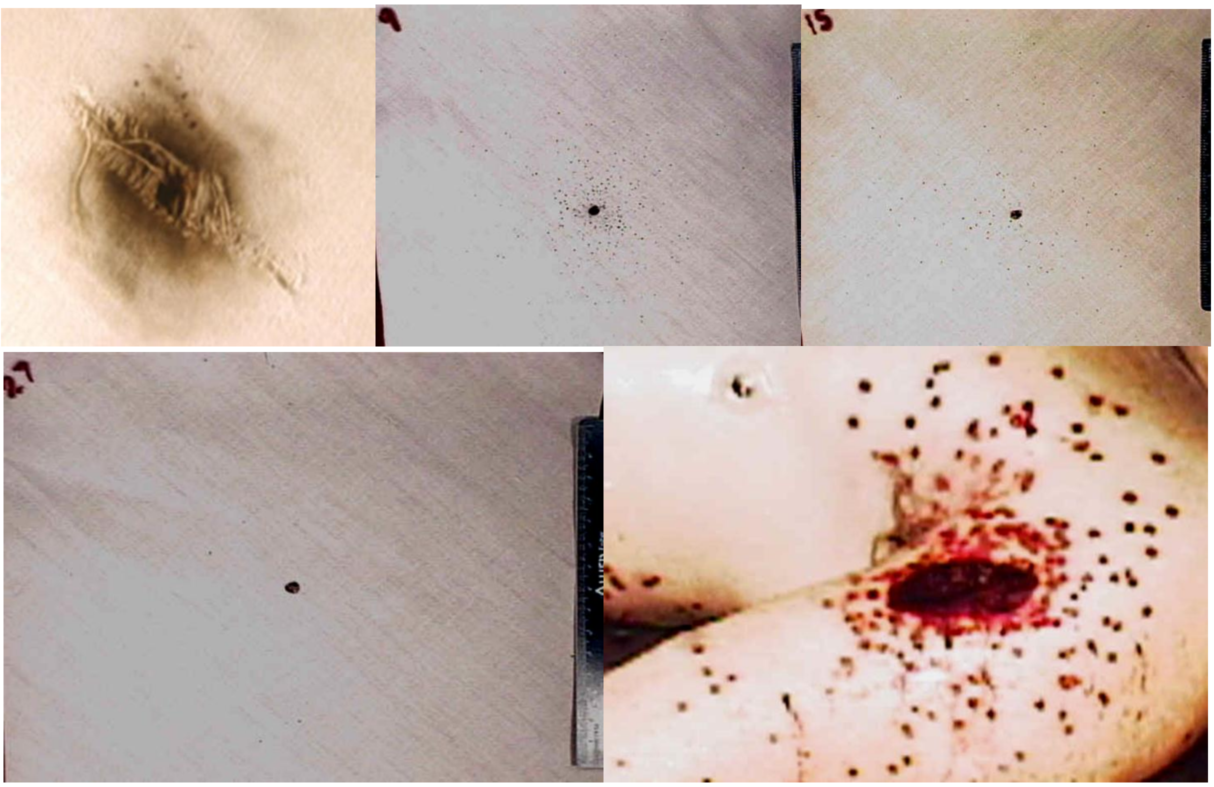

Figure-17: Contact shot, 9-inches shot, 15-inches shot, 27-inches shot.

Distance Determination of a Shotgun. Up close, the pellets create similar patterns as residue.

Distance determination is necessary for many gunshot wounds. If the shooter pleads self-defence, it is very important to know the distance between the shooter and victim. Suicide victims will also have residue on close wounds. Lack of residue may indicate foul play.

Residue on Clothing: Clothing of the victim is chemically tested for gunshot residue to confirm the distance determination. The Griess Test indicates a positive result with a color change to pink.

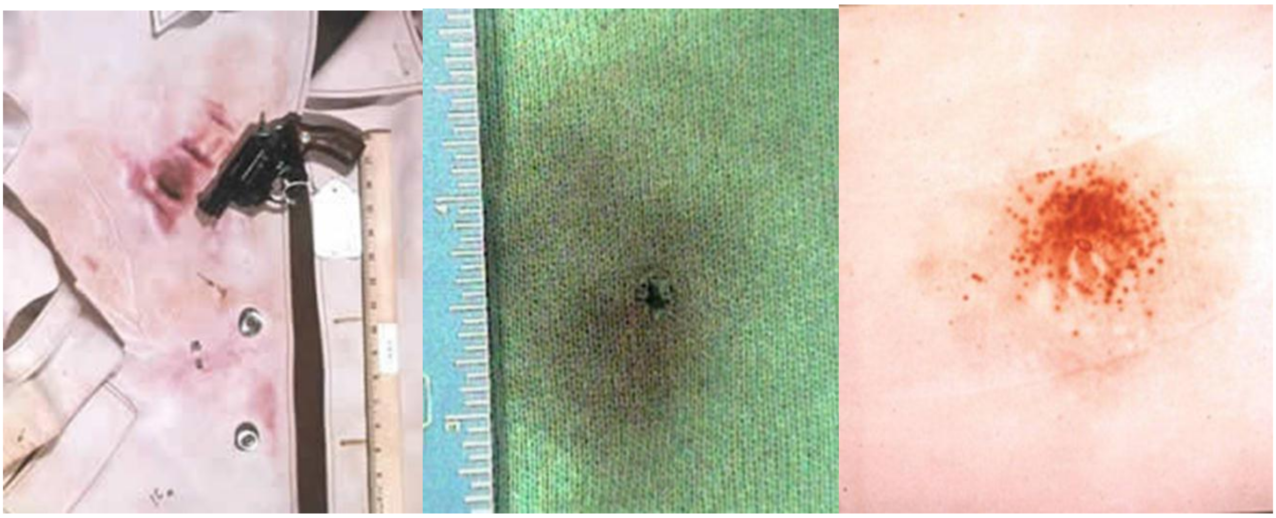

Figure-18: Residue on clothing.

Gunshot Residue (GSR) on Hands: When a weapon is fired residue is propelled both forward and backward. The residue that is propelled backwards leaves traces on the shooter's hands as well as anyone within very close range.

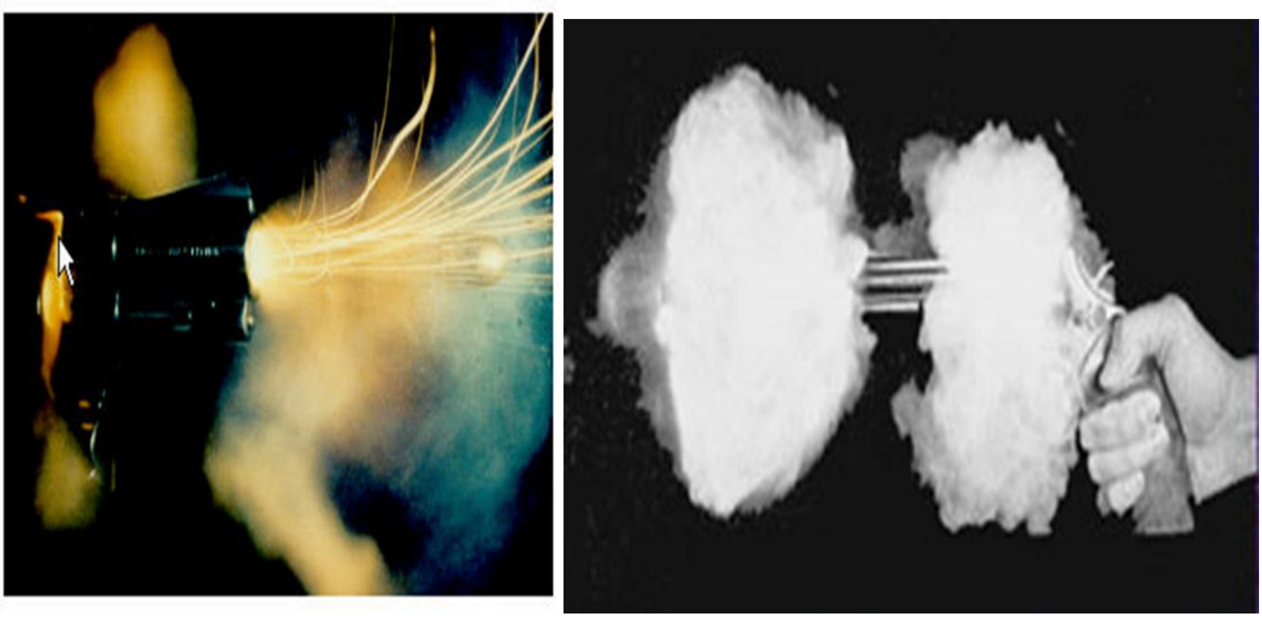

Figure-19: Gunshot residues.

GSR on Hands: The GSR is most likely concentrated on the thumb web and the back of the firing hand. The GSR stays on the hands for approximately 2 hours and is easily removed by washing or wiping the hands. In a suicide, the hands will be bagged and tested for GSR at the Medical Examiner's office. The Dermal Nitrate Test, developed in 1933, was used for many years. However, it gave many false positives with cigarette ash, urine and cosmetics. During the test, the suspects hands were covered in wax. After the wax hardened it was removed and chemically tested. A blue color indicated a positive result for GSR.

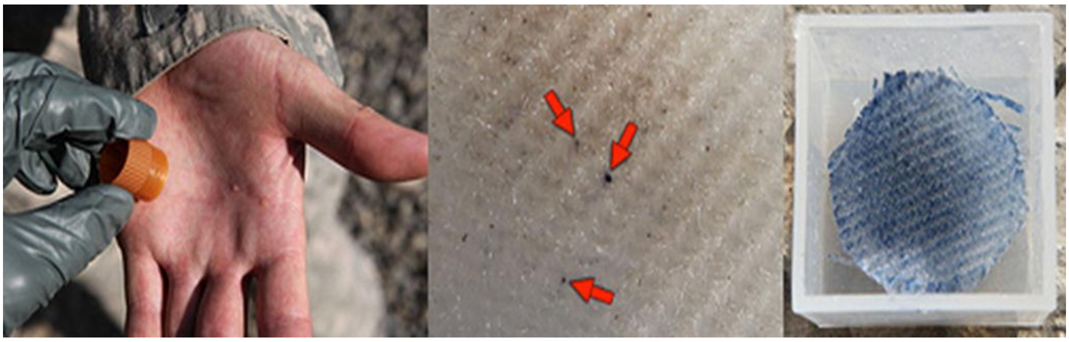

Figure-20: Gunshot.

Today's tests for GSR on Hands: Barium and Antimony are both components in GSR. Several techniques are used to test for these elements. First, the investigator will remove the GSR particles with tape or swabs. Next, the particles may be examined with a Scanning Electron Microscope (SEM), Neutron Activation Analysis (NAA) or Flameless Atomic Absorption Spectrophotometry (AAS). The presence of Barium and Antimony is considered a positive for GSR.

Serial Number Restoration: Firearms are "stamped" with an identification serial number. These numbers are linked to the buyer of the firearm. Identification numbers are usually etched on the metal body, frame or plate of the gun. Many times, criminals "erase" the serial number and it has to be restored once the weapon is at the crime lab.

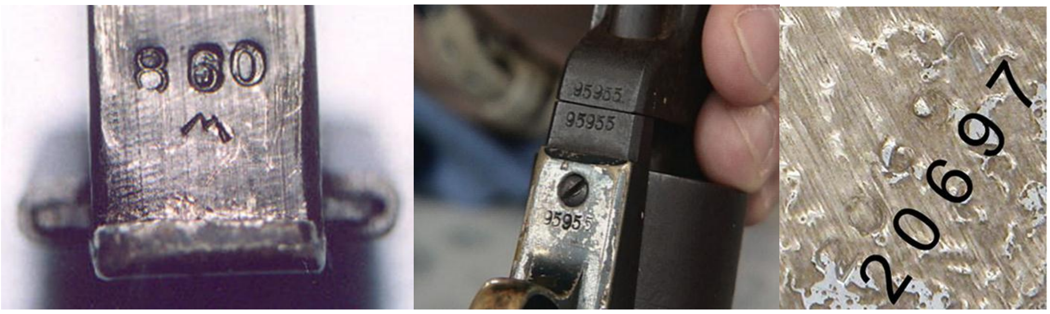

Figure-21: Serial number restoration.

To restore a serial number that has been removed or obliterated, the area must be thoroughly cleaned and polished. An etching reagent is applied which will react with the strained area faster than the unaltered metal, allowing the numbers to appear.

Collection and Preservation of Firearm Evidence: Firearms

Safety is the most important precaution, preventing all accidental discharge of a loaded weapon in transit. All firearm evidence should be marked for identification with evidence tag attached to the trigger guard. Firearm recovered from an underwater location should be transported in the submerged in the water found to prevent rust.

Ammunition: Bullets recovered at a crime scene are scribed with the investigator's initials and should be wrapped in tissue paper before transport to protect any trace evidence. The exact location of shell casings should be noted.

Transitional ballistics: Transitional ballistics, also known as intermediate ballistics, is the study of a projectile's behaviour from the time it leaves the muzzle until the pressure behind the projectile is equalized, so it lies between internal ballistics and external ballistics.

External ballistics: External ballistics is the part of the science of ballistics that deals with the behaviour of a non-powered projectile in flight.

Figure-22: Transitional & External ballistics.

Gunpowder Deposit: A firearm victim's clothing must be preserved to prevent damage or disruption to the gunpowder residues deposited around the bullet hole. Wet clothing should be air dried out of direct sunlight and then folded for protection. Each item should be placed in a separate paper bag.

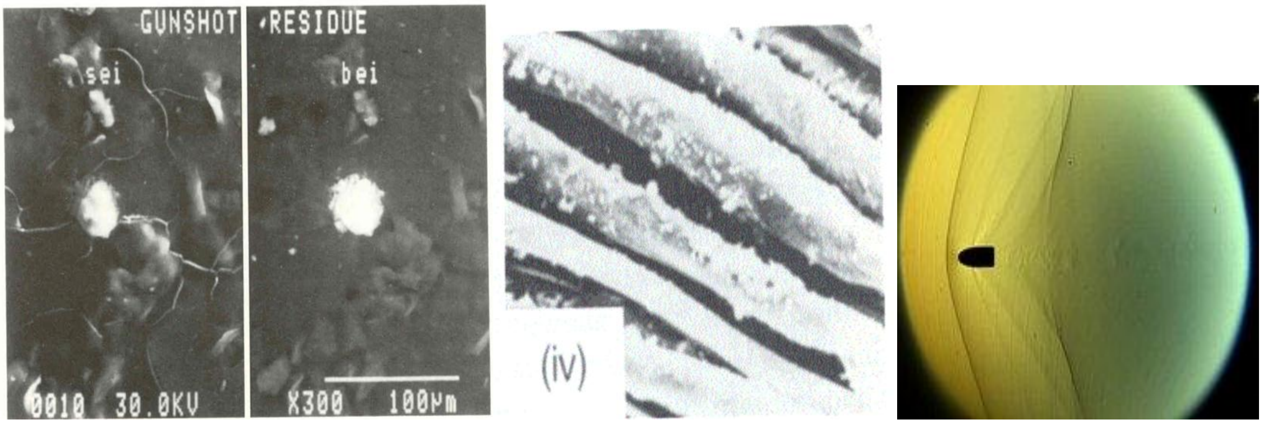

Figure-23: Schlieren image of a bullet travelling in free-flight demonstrating the air pressure dynamics surrounding the bullet.

External ballistics is frequently associated with firearms, and deals with the unpowered free-flight phase of the bullet after it exits the gun barrel and before it hits the target, so it lies between transitional ballistics and terminal ballistics. However, external ballistics is also concerned with the free-flight of rockets and other projectiles, such as balls, arrows etc.

Terminal ballistics: Terminal ballistics is the study of the behaviour and effects of a projectile when it hits its target.

Terminal ballistics is relevant both for small calibre projectiles as well as for large calibre projectiles (fired from artillery). The study of extremely high velocity impacts is still very new and is as yet mostly applied to spacecraft design.

Applications

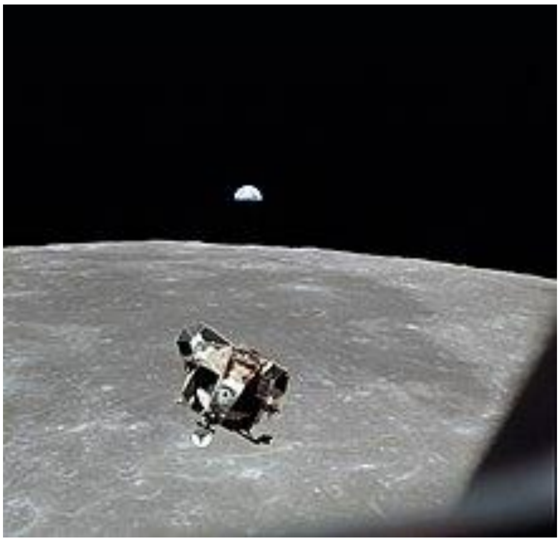

Figure-24: Apollo 11 — Astrodynamics calculations have permitted spacecraft to travel to and return from the Moon.

Forensic ballistics: Forensic ballistics involves analysis of bullets and bullet impacts to determine information of use to a court or other part of a legal system. Separately from ballistics information, firearm and tool mark examinations ("ballistic fingerprinting") involve analyzing firearm, ammunition, and tool mark evidence in order to establish whether a certain firearm or tool was used in the commission of a crime.[7]

Examination of the firearm: Any firearm collected during the course of an investigation could yield viable evidence if examined. For forensic firearm examination specific evidence that can be recovered includes weapon serial numbers and potentially fingerprints left on the weapon's surface.

Figure-25: Multiple serial numbers provide redundancy and make it difficult to fully remove the numbers from a weapon.

Fingerprint recovery: Fingerprint recovery from the surface of firearms is done with cyanoacrylate (more commonly known as superglue) fuming. Firearms are placed in a specially designed fume hood designed to evenly distribute fumes instead of removing them. Liquid superglue is placed in a container and heated until it is in a gaseous state. The circulating fumes adhere to the oils left behind by the fingerprint, turning the print white. The resulting white print can be enhanced with fingerprint powder to increase the contrast of the white print against the weapon's finish. While using the fuming technique on recovered guns is commonplace, the recovery of fingerprints from the surfaces of a firearm is challenging due to the textured grip and the general condition of recovered weapons. If fingerprints are recovered, they can be processed through fingerprint databases such as the Integrated Automated Fingerprint Identification System (IAFIS). Various parts of the recovered weapon can also be tested for touch DNA left by whomever handled it. However, the low levels of DNA that can be recovered present numerous issues such as contamination and analysis anomalies such as allele drop-out and drop-in.

Serial number recovery: Serial numbers became commonplace after the United States passed the Gun Control Act of 1968. This law mandated that all guns manufactured in or imported into the country have a serial number. Prior to 1968, many firearms either did not have a serial number or the serial numbers were not unique and were reused by a manufacturer on multiple firearms. If a recovered weapon has had the serial numbers altered or destroyed, examiners can attempt to recover the original numbers. The two main methods for the restoration of serial numbers are magnetic particle inspection and chemical restoration. It is recommended that magnetic particle inspection be performed first due to the non-destructive nature of the method. If magnetic particle inspection fails, chemical restoration is the next step in the forensic analysis. If the serial number is successfully restored it can be used to help investigators track the weapon's history, as well as potentially determine who owns the weapon. Firearm databases such as the National Crime Information Centre of the United States and INTERPOL's Firearm Reference Table can be used by investigators to track weapons that have been lost, stolen, or used previously in other crimes.

Magnetic particle inspection: Originally developed as a method to detect flaws or irregularities in magnetic materials, magnetic particle inspection can be used on firearms to visualize the serial number underneath the obliterated area. When performing this technique, examiners place the weapon in a magnetic field. The irregularities in the metal, in this case the serial number, cause the field to deform. When a solution of ferrous particles is added to the weapon's magnetized surface they will be attracted to the area where the magnetic field has deformed and will build up in the area. If fluorescent particles are added to the ferrous solution, ultraviolet light can be used to make it easier to visualize any recovered serial number.[8]

Chemical restoration: Chemical restoration is a type of chemical milling. Typically, chemical milling is used to slowly remove material to create a desired shape. In serial number restoration, small amounts of metal are removed until variations in the metal corresponding to the serial number are visible. This is possible because stamping the numbers distorts the grain boundary structure underneath the surface of the metal. However, chemical restoration is limited to that depth and is only successful when the obliteration of the serial number is superficial. Examiners performing a restoration first sand the area where the serial number used to be. This removes any debris from the area left when the serial number was obliterated. The examiner then chooses a chemical, usually an acid, that will be used to slowly bring the number back to the surface. The type of chemical that is used depends on the material the weapon is made of. These acids can range from Fry's Reagent for a magnetic metal, which is a mixture of hydrochloric acid, cupric chloride, and distilled water, to an acidic ferric chloride solution for a non-magnetic, non-aluminium material.

Examination of cartridges: Spent cartridges found at a scene can be examined for physical evidence such as fingerprints or compared to samples that match them to a weapon. The examination of the cartridge relies on the unique tool marks left by the various parts of the weapon including the firing pin and the ejector in semi and fully automatic firearms.

Figure-26: Two test-fired cartridges under magnification. Matching striations can be seen.

These markings can be compared and matched to known exemplars fired from the same weapon using the same parts. The examination of the marks left on the cartridge is done using a comparison microscope. Examiners view the questioned cartridge and the known exemplar simultaneously, looking for similar microscopic marks left during the firing process.

Cartridges are also routinely examined for fingerprints as the act of loading the ammunition into the magazine, or chamber, leaves recoverable impressions. These fingerprints can survive the firing processes and, while a rare occurrence, fingerprints have been obtained from cartridges recovered from the scene. Cartridges are subjected to cyanoacrylate fuming and examined for any usable prints. Usable prints are photographed and can be uploaded to fingerprint databases such as IAFIS for comparison with known exemplars.[9]

Figure-27: Example of micro stamping. Insert shows a close up of the serial number imprinted into the cartridge.

Cartridges can also be swabbed for trace DNA left by the individual who loaded the magazine. The extremely low levels of recoverable DNA present the same issues as swabbing a firearm for DNA. Advancements in microscopic stamping have led to a push for the inclusion of firing pin micro stamping. The micro stamp is etched onto the firing pin and is transferred to the cartridge during the firing process. Each firing pin would have a unique serial number allowing investigators to trace casings found at a crime scene to a known firearm. The practice is not in use as of 2022, although California has enacted legislation that requires micro stamping on all newly sold firearms. The law, and micro stamping in general, has received significant opposition from gun manufacturers due to increased costs associated with introducing the micro stamps into the manufacturing lines.

Examination of bullets

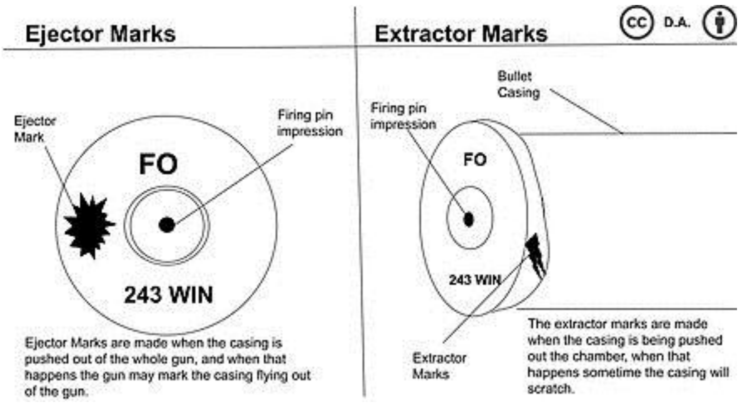

Figure-28: This cartridge casing impression image shows the markings of circular line, centrefire, extractor, ejector and, what heads taming shows on a spent cartridge.

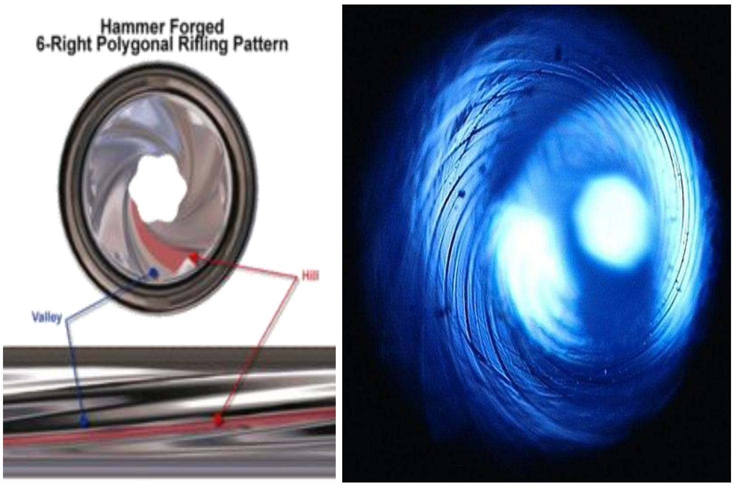

Figure-29: Rifling pattern for a Remington rifle showing a clockwise (right-handed) twist.

Class characteristics: Preliminary examination of the bullet can exclude a large number of weapons by examining the general characteristics of a recovered bullet. By determining general aspects of the fired ammunition, a number of weapons can be immediately excluded as being incapable of firing that type of bullet. The make and model of the weapon can also be inferred from the combination of different class characteristics that are common to specific manufactures. The three main class characteristics of all bullets are the lands and grooves, the calibre of the bullet, and the rifling twist. All three can be tied directly to the type of barrel that was used to fire the bullet. The lands and grooves of barrel are the bumps and valleys created when the rifling is created. The calibre is the diameter of the barrel. The twist is the direction of the striations left by the barrel's rifling, clockwise (right-handed) or counter clockwise (left-handed). Most barrels will have a right-handed twist with the exception of weapons created by the Colt's Manufacturing Company which uses left-handed twists. Weapon barrels that match the class characteristics of recovered bullets can be examined further for individual characteristics to determine if the bullet came from that particular weapon.

Individual characteristics: In order to compare individual striations, examiners must obtain a known sample using the seized weapon. For slower-traveling bullets, such as pistols or revolvers, known bullet exemplars are created by firing the weapon into a water tank. The spent bullet can be recovered, intact, as the water slows down the bullet before it can reach the tank walls. For faster traveling bullets, such as those fired from high-powered rifles and military style weapons, water tanks cannot be used as the tank will not provide enough stopping power for the projectiles. To examine these weapons, investigators must fire them at a target at a controlled range with enough backing to stop the bullet and collect the spent round after it has been fired.

Once a known exemplar is produced, the evidence sample can be compared to the known by examining both at the same time with a comparison microscope. Striations that line up are examined more closely, looking for multiple consecutive matches. There is no set number of consecutive matches that equates to a match declaration, and examiners are trained to use the phrase "sufficient agreement" when testifying. The degree to which an examiner can make that determination is based on their training and expertise. All findings by examiners are subject to questioning by both sides, prosecution and defence, during testimony in court.

Striation databasing: Bullets and casings found at a scene require a known example to compare to in order to match them to a weapon. Without a weapon, the striation pattern can be uploaded to a database such as the National Integrated Ballistic Identification Network (NIBIN) maintained by the ATF or the United Kingdom's National Ballistics Intelligence Service (NABIS). Information uploaded to these databases can be used to track gun crimes and to link crimes together. Maintainers of these databases recommend that every recovered firearm be test fired and the resulting known exemplar be uploaded into the database. In the 1990s, there were two databases that were formed for storage of pictures of shell casings and bullets in gun crimes. The first was the Drug fire system which was used by the FBI. The second, the IBIS (Integrated Ballistic Identification System) was created by Forensic Technology, Inc. and eventually bought by the Alcohol Tobacco and Firearms (ATF) in 1993. The FBI and ATF realized that their systems would not work together, and they needed to find a way to share information between them. The NIBIN board was created in 1997, in hopes of creating one imaging system. A year after the creation of the NIBIN board, both the ATF and FBI decided to put their resources together toward one of the systems, and created the National Integrated Ballistics Information Network, with IBIS as the system.[10]

Astrodynamics: It is the application of ballistics and celestial mechanics to the practical problems concerning the motion of rockets and other spacecraft. The motion of these objects is usually calculated from Newton's laws of motion and Newton's law of universal gravitation. It is a core discipline within space mission design and control.

CONCLUSION

In fall 2020 a paper was written by Itiel E. Dror and Nicholas Scurich and presented in their paper, *The (Mis)Use of Scientific Measurements in Forensic Science*. The paper looked at the validity of ballistic forensic experts when attempting to make an identification of a shell or bullet. In their study they found that while some experts would come to the conclusion that the bullets were a definite match, another expert looking at the same evidence would determine it inconclusive. Dror and Scurich argue an “inconclusive” determination affects the error rate for the study, and provides very little confidence in the overall findings of the scientists. According to Dror and Scurich, the error rate, which was zero to one percent, could be higher. Their reasoning behind this is that if an “answer” was marked as inconclusive, it must count as a correct answer which decreases the error rate making it lower than it probably should be. They wondered how different the error rate would be if inconclusive was not an option. In addition, Dror and Scruich noted that the scientists seemed to come up with a more conclusive decision on the evidence if there was the added part of a human life hanging in the balance. In 2021 Alex Biederman and Kyriakos N. Kotsoglou responded to the Dror and Scurich paper and raised issues. Some of the issues raised by Biederman and Kotsoglou included: a paradox in which examiners' results agreed with ground truth but would be considered "error" via Dror and Scurich's proposals. Biederman and Kotsoglou also pointed out that Dror and Scurich's proposals would set false incentives where examiners would be directed to be "diving what the mythical forensic wisdom of the consensus opinion might (and hence enshrine the false belief in the existence of such wisdom), be rather than the ground truth". Biederman and Kotsoglou concluded "In all, our analysis does not leave much intact from recent attempts to label 'inconclusives as errors."

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