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The Classification and Analysis of Damaged Bullets Using IBIS® BULLETTRAX-3D™

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The Classification and Analysis of Damaged Bullets Using IBIS® BULLETTRAX-3D™

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ABSTRACT

Rifling constitutes the helical grooves created on the surface of the bore of a firearm barrel allowing spin to be imparted on the projectile (Heard, 2008, p. 154). This spin allows the projectile to become more stable, but leaves markings, upon the surface of the projectile. "These lands and grooves create corresponding engraved areas–dubbed land engraved areas and grooved engraved areas (and commonly abbreviated as LEAs and GEAs) –on the bullet surface, separated by shoulders…are the principal areas of interest for observing striations" (Cork, D. et al., 2008, p. 46). The markings left on bullets are necessary for firearms identification. If those markings are damaged, it makes it more difficult for Firearm and Tool Mark examiners and imaging systems to visualize and analyze the markings.

There has been a great deal of research regarding terminal ballistics in which the duration of the bullet striking the target is studied, but most of those studies focus on the target being struck, rather than damage to the actual bullet. The majority of these studies determine the velocity and damage caused upon tissue or tissue simulants, such as gelatin, while little research has been completed on other surfaces (Ben-Tovim, 1993, p. 31). In these studies, however, the marks and deformations of the surfaces being struck are assessed, but the damage the bullet has incurred is not generally examined. When the damage to bullets is presented, the data relies on information about velocities of impact rather than the ability to visualize markings and patterns on the surface contours of the bullets themselves (Haag, M. & Haag, L., 2011, p. 114). For the studies that do concentrate on the bullet, none of them concentrate solely on basal damage. There is a lack of bullet deformation research regarding impression evidence.

Keywords: basal deformation, bullet damage, classification, nomenclature

To my husband, Patrick, my rock and my soul mate.

and

To Samuel, my little ray of sunshine.

I would not have been able to complete this without your love and support!

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Introduction

Rifling constitutes the helical grooves created on the surface of the bore of a firearm barrel allowing spin to be imparted on the projectile (Heard, 2008, p. 154). This spin allows the projectile to become more stable, but leaves markings upon the surface of the projectile (see Figures 1 and 2). "These lands and grooves create corresponding engraved areas–dubbed land engraved areas and grooved engraved areas (and commonly abbreviated as LEAs and GEAs) –on the bullet surface, separated by shoulders…are the principal areas of interest for observing striations" (Cork, D. et al., 2008, p. 46).

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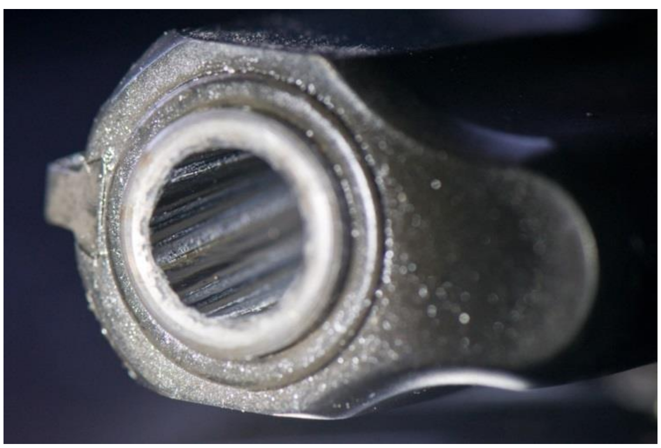

Figure 1. Rifling inside of a pistol barrel. [Photograph], by ArtBrom, 2011, Retrieved from https://www.flickr.com/photos/art-sarah/5554842728

Figure 2. LEAs and GEAs on a fired bullet.

Statement of the Problem

There has been a great deal of research regarding terminal ballistics in which the duration of the bullet striking the target is studied, but most of those studies focus on the target being struck, rather than damage to the actual bullet. The majority of these studies determine the velocity and damage caused upon tissue or tissue simulants, such as gelatin, while little research has been completed on other surfaces (Ben-Tovim, 1993, p. 31). In these studies, however, the marks and deformations of the surfaces being struck are assessed, but the damage the bullet has incurred is not generally examined. When the damage to bullets is presented, the data relies on information about velocities of impact rather than the ability to visualize markings and patterns on the surface contours of the bullets themselves (Haag, M. & Haag, L., 2011, p. 114). For the studies that do concentrate on the bullet, none of them concentrate solely on basal damage. This is unfortunate, due to the fact that examiners concentrate on the "portion of a bullet's outer surface that comes into direct contact with the interior surface of the barrel" (AFTE 2009). This bearing surface is found on the base (basal) of the bullet.

Background and Need

Bullet identification is not a new scientific technique. Rather, it has been around for over a century. Nickell (1999) explained that in an 1835 homicide investigation, investigator Henry Goddard looked at the "bullet removed from the body of a murder victim, [and] noticed a distinctive flaw, a ridge-like blemish. At the home of the suspect, Goddard discovered a bullet mold that had a correspondingly distinctive gouge at the same location as the bullet" (pp. 91-92). Furthermore, Dr. Albert Llewellyn Hall (1900) asserted that rifled weapons leave rifling marks on bullets, he described lands and grooves, and surmised that although weapons of different makes and types may have the same caliber, the rifling marks impressed upon the bullets varied (p. 731). Colonel Calvin Goddard attributed the 1925 development of the comparison microscope for use in bullet identification to Philip Gravelle (Heard, 2008, p. 147). Since then, examiners now use modernized comparison macroscopes that have binocular eyepieces and multiple objectives, allowing them to view and compare two separate objects simultaneously.

Title 18 of the United States code defines a firearm as “(A) any weapon (including a starter gun) which will or is designed to or may readily be converted to expel a projectile by the action of an explosive; (B) the frame or receiver of any such weapon; (C) any firearm muffler or firearm silencer; or (D) any destructive device” (p. 1). Presently, there are four basic types of small arms: they consist of pistols, revolvers, rifles, and shotguns. These firearms may be differentiated by their ignition systems, firing mechanisms, action, presence of rifling, and size. Class characteristics are measureable features that are predetermined prior to manufacture. The chemical combustion of materials found within ammunition allows modern firearms to eject projectiles at a high velocity. Haag & Haag listed examples of the class characteristics of ammunition, (2011) including: “caliber, weight, method of construction, composition, design and location of cannelures, base shape, heel shape, nose shape” (p. 35). In small arms ammunition, bullets may be jacketed of unjacketed, most unjacketed bullets are lead, and even jacketed bullets have a plain lead core (Heard, 2008, p. 67).

Rifling constitutes the helical grooves created on the surface of the bore of a firearm barrel allowing spin to be imparted on the projectile (Heard, 2008, p. 154). Hatcher clarified that “In the case of elongated bullets, rifling is even more necessary than it was with round balls, for in the absence of rifling, an elongated bullet will tumble end over end, and [have] no sort of accuracy” (p. 556). Class characteristics of barrel rifling, for instance, include the number and widths of the lands and grooves and direction and inclination of twist. Conventional rifling possesses sharp, distinct lands and grooves, while polygonal rifling has smoother hills and valleys that are less pronounced. This causes some difficulty for examiners as the individual bore characteristics will be more difficult to decipher. Another anomaly that occurs involves revolvers. Although the barrel of a revolver contains rifling, the chambers, that hold the ammunition, are smooth bored. The gap between the cylinder and the barrel causes skidding and may impart skid marks upon the projectile (Heard, 2008, p. 155-156).

Individual characteristics, on the other hand, as defined by Mozayani and Noziglia (2006), are “imperfections or irregularities produced accidentally during manufacture, growth, or use, or those caused by abuse, corrosion, damage when broken, are required to distinguish it from all others” (p. 278). They are unique and individual to all tools. Individual characteristics imparted on the barrel on a firearm may be caused by the rifling cutter that slowly wears with each cut, rotational drilling and reaming of the bore of the barrel, corrosion pits, swarfs that may build up in the barrel, muzzle damage and the lack of care or improper cleaning (Heard, 2008 p. 171). When a firearm is fired, the gases inside the chamber cause the base of the bullet to swell causing the projectile to obturate the bore of the barrel. The land and groove rifling inside the bore of the barrel cause marks to be imparted onto the projectile as the projectile slides down and grips the surface of the barrel (Heard, 2008 p. 174). “These lands and grooves create corresponding engraved areas–dubbed land engraved areas and grooved engraved areas (and commonly abbreviated as LEAs and GEAs) –on the bullet surface, separated by shoulders…are the principal areas of interest for observing striations” (Cork, D. et al., 2008, p. 46). Moran clarifies that, “through scientific empirical research that the probability of another tool producing the same ‘signature’ is so low that it is for all practical purposes not possible” (p. 229).

The role of a Firearm Examiner is to use his or her knowledge, expertise, and experience to analyze and examine evidence that would otherwise be impeded. The preamble of the AFTE Bylaws states the following:

> The role of the firearm and/or tool mark examiner in formulating opinions relative to evidence which otherwise stands mute before the bar of justice significantly affects the administration of justice. Fully qualified firearm and/or tool mark examiners, based on their training, research, and acquired knowledge, stand prepared to give voice to this otherwise mute evidence. (Association of Firearm and Tool mark Examiners, 2011)

Using a comparison macroscope, in conjunction with other tools, the firearms examiner is able to assess fired and unfired firearm and ammunition components. With this information, the examiner has the ability to upload the information about bullets and casings to national databases and compare the samples to other evidence found at the crime scene or fired from certain weapons.

When a projectile is fired from a gun, the kinetic energy desires to continue the current velocity in a straight path, but is unable to maintain a perfectly straight line due to air resistance and gravitational pull (Hatcher, 1962, p. 550). Michael and Lucien Haag (2011) explicated that a "true trajectory is a curved path…Most shooting cases are…a few feet to 10 to 20 yards…As a practical matter, the flight paths of projectiles over [short] distances for common handgun and even low-velocity bullets amounts to less than an inch" (p. 175). As the nose of the projectile first hits the target, the nose absorbs the majority of the bullet damage. The ricochet phenomenon increases the likelihood that damage will occur on other portions of the projectile. Haag & Haag (2011) defined ricochet as "the continued flight of a rebounded projectile and/or major projectile fragments after a low-angle impact with a surface or object. Another way of describing ricochet is that it is the occurrence of deflection without penetration or perforation" (p. 144). During this phenomenon, the path of the projectile undergoes approach, impact, ricochet, and deflection: measureable features include α: Angle of incidence, β: Angle of ricochet, γ: Lateral or deflection angle, I_i: Initial impact point, I_d: Departure point, and I_i-I_d: Trace (Haag & Haag, 2011, p. 145).

Automated systems have been created as a search tool to help examiners with the imaging and comparison of projectiles and cartridge cases. One such system, BULLETPROOF created by Forensic Technology, Inc. [FTI], was adopted by the Bureau of Alcohol, Tobacco, and Firearms in 1993. After BRASSCATCHER was added in 1995, the system was renamed the Integrated Ballistic Identification System [IBIS]. In 1997, the FBI, in joint cooperation with the ATF, created the National Integrated Ballistics Information Network [NIBIN] database (Cork, Ralph, Meieran, & Petrie, 2008). According to Heard (2008), FTI released the IBIS® BULLETTRAX-3D™ in 2005 and the IBIS® BRASSTRAX-3D™ system in 2006 (p. 151). The IBIS® Heritage™ systems are still currently in use and are compatible with the new IBIS® TRAX-3D systems. The IBIS® BULLETTRAX-3D™ is a highly automated, bullet acquisition workstation that has the ability to capture 2D and 3D images to create 3D topographic models by taking quantitative measurements of the bullet surface on the nanometer level. This imaging system is purported to be capable of imaging a wide spectrum of damaged bullets by automatically adapting "to surface deformations for a more consistent image quality, including convex, flat and concave surfaces" (FTI, 2009).

Purpose of the Study

Firearm and Tool Mark examiners must have confidence in their ability to image, correlate, and provide sufficient information to analyze severely damaged bullets. There is no current classification system for basal deformation that has been generally accepted by the field. To create such a nomenclature list, bullets with basal deformation will be produced, the damage thereupon will be visualized and analyzed, and a preliminary classification system will be created. A questionnaire constructed from the provisional nomenclature will be administered to Firearm and Tool Mark examiners for their evaluation.

Research Questions

Projectiles expelled from firearms are often damaged because they have come in contact with unyielding surfaces at a high velocity. It is necessary to examine the marks left on the projectile to identify which firearm the projectile was ejected from. This deformation to the bullet base (basal damage), along with possible fragmentation, impedes the firearm and tool mark examiner's ability to analyze the bullet rifling characteristics.

It is hypothesized that discharging several types of projectiles using different weapons onto multiple unyielding surfaces will cause damage to the projectiles, and therefore, changing the angle of shooting will affect the angles of impact and increase the chances of ricochet and the amount of bullet basal damage. This proof of concept study has attempted to acquire, measure, and analyze severely damaged bullets of multiple calibers, metal compositions, and rifling and to create a methodology to classify the level of damage on sample bullets. The proposed nomenclature includes the following terms: Abraded, Sheared, Torn, Full core/jacket separation, and Flattened.

The principal questions governing this study are: How is basal damage caused? How does basal damage affect visual analysis by examiners? What nomenclature could be used to describe the basal deformation?

Significance to the Field

The Bureau of Alcohol, Tobacco, Firearms, and Explosives [ATF] (2011) reported that "as of 2011, there are approximately 5,400 licensed firearms manufacturers and 950 licensed importers in the United States" ("Firearms Commerce", p. 3) and the number of pistols manufactured in 2013 totaled 4.4 million, compared to 3.4 million in 2012. The number of rifles manufactured also increased, with 3.9 million produced in 2013 compared to 3.1 million in 2012. ("Annual Firearms Manufacturing and Export Report" [AFMER], 2015, p. 1). Moreover, Okoro et al. (2005) stated "32% of adults reported that firearms were kept in or around their home" (p. 371). With such a substantial amount of firearms, it is no surprise that "in a given year, firearms accounted for over half of all known suicides [and] two-thirds of all reported homicides" (Wellford, Pepper, & Petrie, 2005, p. 53). As the percentage of crimes involving firearms continues to remain high, it is crucial for law enforcement to be able to identify a projectile to the firearm it was expelled from. Likewise, firearms examiners necessitate better equipment and resources in the undertaking of bullet identification.

When these components are damaged, deformed, or fragmented, the difficulty for the examiner, as well as imaging systems, to visualize the markings is greatly increased. Examiners must have confidence in their ability, together with the ability of their peers, to image, correlate, and provide sufficient information to analyze severely damaged bullets.

Definitions

In the context of this study, the word *bullet* describes "a non-spherical projectile for use in a rifled barrel" (AFTE 2009). The AFTE glossary has also defined the following terms; the *nose* is defined as, "the point or tip of a bullet", while, the *base* is defined as, "the rear portion of a bullet that is opposite the nose. Also known as the heel". The *ogive* is defined as "the curved portion of the bullet forward of the bearing surface".

Limitations

If this study were to have unlimited funding and time, the researcher would be inclined to examine every firearm type, firearm manufacturer, firearm, caliber, ammunition manufacturer, grain, cartridge type, firing type, target medium, angle, distance, and atmospheric condition, along with other variables. Even with these assets, the researcher would not be able to recreate every deformation or damage that could ever be caused to a bullet for such an expansive and expensive study.

CHAPTER 2: REVIEW OF LITERATURE

Introduction

There has been a great deal of research regarding terminal ballistics, in which the duration of the bullet striking the target is studied, but most of those studies focus on the target being struck, rather than damage to the bullet itself.

Body of the Review

Rathman's (1987) study concentrated on the "(1) determination of the ricochet angle and how it is affected by different surfaces, (2) how much velocity is lost after striking different surfaces, and (3) can the bullet and/or surface damage offer clues to the incident angle" (p. 374). He fired two firearms of different calibers (.32 automatic and .45 automatic) at incident angles of 10º, 20º, and 30º to demonstrate the effects of ricochet to bullets on multiple surfaces: including, 3" thick concrete block, smooth concrete flooring, 1.5" thick pine board (wood), .25" thick laminate glass, .5" thick vinyl plastic pad, 4" thick asphalt, .5" Lexan (bullet resistant plastic), and .25" thick steel plate (1987, p. 374). After firing the projectiles and measuring their ricochet angles and velocity loss, he measured the fired projectiles at their diameters, which he noted were their widest points (1987, pp. 375-377).

The results suggested that the bullet diameter (width) increased similarly to the increase in incident angle, but noted a few exceptions. "There was no significant damage or increase in width for any shot from wood", for plastic, "beyond 20º, the diameter either remained the same (.32 automatic) or decreased (.45 automatic)", and even though the texture of asphalt was somewhat erratic, the "bullets' average width (diameter) increased with the increased incident angles" (1987, p. 378). He included eight images of the damaged bullets (Figures 5-12, p. 378) and all but two, the images of wood and plastic, showed that at 20º, the .32 caliber bullets were damaged from the tip to the base of the bullet. Rathman concluded that the "harder the impact surface, the smaller the ricochet angle, while the yielding surfaces produce the highest ricochet angles. An exception to this is Lexan" (1987, p. 375).

Although the tables included were concise and easy to read and understand, there was a lack of detail in the study. Rathman did not explain the importance of the angle of incidence, why 10º, 20º, and 30º were chosen or how those angles were measured. After the bullets were fired he measured their widest point on each bullet. If it difficult to understand why he chose to call this measurement the "diameter" while some of the bullets were damaged and no longer held a cylindrical shape. To extend this study, he could have not only measured the widest points of the bullets, but also imaged and described in detail the physical damage the bullets incurred.

Studies that have been completed on bullet base deformation have focused on rifle bullets, as opposed to pistol ammunition. Lucien Haag's (2001) study, focused on the basal deformation of full metal jacketed rifle bullets. He argued that a direct relationship exists between the flattening of the shank portion of the bullet and impact velocity in tissue. "This cross-sectional flattening begins at impact velocities on the order of 2100 f/s (640n/s) for most bullets of this type and continues until a kidney-bean cross-section is produced" (p. 11). Haag recognized that several of his cases shared a common objective: to determine a possible range or impact velocity of the fatal projectiles (2011, p.11). He explained that, as long as the bullet remains in a nose-forward direction, the deformation will be negligible, but once the bullet yaws, the overall force will lead to characteristic fragmentation (2011, p.12). Barrels that have slow twist, such as 1 in 12" twist barrels, do not adequately spin-stabilize SS109 bullets and the bullets will therefore "arrive at the medium already in substantial yaw" (Haag, L., 2001, p. 12).

In this study, Haag disassembled and reloaded SS109 and M855 bullets so that their impact velocities ranged from 2000 f/s to 3000 f/s when fired “into a horizontal water recovery tank at a 30º intercept angle with the surface of the water” using a rifle with a 1 in 7” rate of twist (2011, p. 12). This 5.56mm ammunition was reloaded due to the fact that the full powered, factory loads caused fragmentation. Alternating to a rifle with a 1 in 14” twist rate, the SS109 bullets were fired at the same velocity, but there was a slight decrease in fragmentation and less conspicuous twisting effect in this rifle (Haag, 2001, pg. 13). He also compared American-made Winchester steel-jacketed .30 caliber bullets and British copper-jacketed bullets by firing them from the same 7.62NATO rifle and into a horizontal water recovery tank. The results indicated that the “Winchester bullets began to acquire a kidney-shaped base at an impact velocity of 2200 f/s (670 m/s) whereas the British bullets required an impact velocity of 2700 f/s (823 m/s) to produce an obvious kidney-shaped base” (Photo 6, p. 19). For all projectile tested, he noted that as the impact velocities increased, the shank portions of the bullets became progressively flatter and continued towards fragmentation (Photo 1, p. 16).

Haag concluded that the “cross-sectional dimensions and shape of a recovered full metal jacketed rifle bullet can be a useful indicator as to the impact velocity of such a bullet with body of a gunshot victim” (2001, p. 14). The terms he used to describe the bullets included, “pristine”, “out-of-round”, “ovoid”, “cylindrical”, “kidney”, “pinched”, “twisted”, “torn”, and “fragmented” (Photo 1, Photo 2, and Photo 6, pp. 16-19). Plotting the cross-sectional deformation against the impact velocity in tissue would allow examiners to determine if certain circumstances are possible; for example, “a fragmented 5.56mm military bullet with a kidney-shaped cross-section at its base and removed from a wound involving on soft tissue could *not* be the consequence of an errant shot from target shooters a quarter mile away” (2001, pg. 14). Although the terms provided would help examiners with overall shape, the study resulted in few projectiles with basal damage. He suggested a future, detailed study involving bullet measurement and bullet deformation behavior (2001, pg. 15).

The latest study proposed information regarding bullet deformation was performed at the Institute of Criminalistics in Prague, Czech Republic.   As reported by Planka (2011), the researchers were interested in the "kinematics during bullet deformation and destruction as well as the determination of the relationship between bullet terminal parameters and/or sub-structure (by metallography), and impact velocity" (p. 218). The calibers of ammunition chosen include: 4.5mm, .22 short and long rifle, 7.65mm, 9mm luger, and .38 special. Using a Pneumatic Ballistic Gun system with exchangeable barrels, the researchers were able to fire the bullets at a steel plate with an impact velocity between 50 m/s and 200 m/s (p. 218). Specific terms were created to describe the terminal bullet shape and the types of secondary fragments; including (2011, p. 220):

- Bullet terminal shape – final geometric shape after impact
- Head of deformed bullet – front part of mushrooming shape
- Forefront of deformed bullet – plane of front park of mushrooming shape
- Primary deformation – caused by the initial contact with target
- Partial destruction – one fragment or more leaves the body of the bullet
- Full destruction – bullet body was fragmented
- Primary fragments – in the kinematics of bullet destruction are generated first

Planka also included a diagram to illustrate the measurements and locations of each fragment type. He ascertained that the "area of the internal deformed border is not linear but depends on the shape of the bullet nose tip and shape of the bullet base" and the Specific Terminal Shape is a function of impact velocity, but the Common Terminal Shape is not (pp. 223-224). Subsequently viewing the metallography of the lead bullet after impact deformation, a strain-hardening border is able to be seen. The locality and shape of the border may be influenced by the impact velocity and shapes of the nose and base of the bullet. According to Planka, "the complete explanation of this effect, which is probably caused by physical/chemical changes in the lead elastoplastic stress wave propagation and interaction in solids will require a most detailed study" (p. 227)

This article is the foremost article thus far, in terms of readability, ample photographs and diagrams, and extensive content. Despite having titled the article "Bullet Deformation on Unyielding Targets", there was only one type of unyielding target used: a steel plate. Nonetheless, examiners will be able to use this information and formulas to determine possible shooting distances for ongoing casework. Although the author spent a considerable amount of detail describing bullet deformation, the only bullets that incurred basal deformation were completely destroyed. Planka understands that these "metallographic methods are no applicable for impact energy determination through bullet examination" for non-orthogonal impact (p. 227) and if the angles of impact and target materials had been varied, the results would have been much more exhaustive in regards to bullet deformation on multiple unyielding surfaces.

Few articles have been published regarding the efficacy of the new IBIS® BULLETTRAX-3D™ system. Brinck (2008) performed a comparison of the IBIS® Heritage™ to the Forensic Technology WAI Inc.'s the newest imaging system the IBIS® BULLETTRAX-3D™. The purpose of this study was to evaluate the ability of the systems to "identify bullets fired by the same weapon in a large database of images" (p. 677). Para-Ordinance supplied the researchers with ten slide assemblies consisting of the “slide, barrel, firing pin, extractor, and breech face” (p. 677). The ten handgun barrels were broached and consecutively rifled with six lands and grooves with a left hand twist (p. 677). These assemblies were not test fired in the manufacturing facility so that the first shots ejected from the firearms into a water tank were used to create the reference and known match sample pairs using copper-jacketed, as well as lead projectiles for the study (p. 678). These sample bullets were uploaded onto both imaging system databases, performed until the known match sample was found, and ranked correlation lists were examined to determine the percentage of time the known match would populate in the top 10 and 20 ranked positions (pp. 677-678).

According to the study, both the IBIS® Heritage™ and IBIS® BULLETTRAX-3D™ systems correlated 100% of the reference sample to their known matches within the top ten positions, while the heritage system only placed one match below the top position (Brinck, 2008, p. 678). In regards to the lead bullet comparisons, the heritage system only correlated 70% of the reference samples outside the top twenty positions with zero matches in the first position, which leads the researcher to believe that these matches would probably not have identified in actuality. The IBIS® BULLETTRAX-3D™, on the other hand, correlated 100% of the reference samples with 70% known matches in the first position (p. 679). For an inter-composition comparison, the researchers compared the copper to lead bullets through both systems. Again, the heritage system correlated 80% of reference samples outside of the top twenty correlations, while the IBIS® BULLETTRAX-3D™ correlated 100 % of the reference samples within the top twenty positions.

Brinck (2008) explained that lead is a softer metal and therefore incurs poorer quality, less defined markings (p. 681); and therefore, it is more difficult for the systems to adequately make comparisons using lead projectiles. He concluded that the IBIS® BULLETTRAX-3D™ was more effective than the heritage system "in the analysis of a wider range of bullet types and it was also found to produce images of superior quality" (p. 677). He suggests that the "features an examiner considers during the examination of an item such as a bullet cannot be accurately captured in a 2D image" (p. 677). In addition, examiners who follow the consecutively matching striations methodology have the option to the CMS function on the IBIS® BULLETTRAX-3D™ which "counts and color codes the consecutive striations according to the number of striations in agreement between two bullets" (p. 682). Most importantly for examiners who currently have the heritage system or those who want to compare to the heritage database, the IBIS® BULLETTRAX-3D™ database is compatible with the heritage system database, so that the new samples can still be compared to the existing samples located in the older database (p. 682). This study is susceptible to bias due to the fact that the databases used in the study "were provided by FTI and each contained 475 entries of various 45 caliber bullets with six lands and grooves, land widths ranging from 0.057 to 0.095 inches, and a left hand twist" (p. 678). To further improve this study, a larger database consisting of samples obtained outside of FTI is suggested.

Summary

There is a history of terminal ballistic study and research, but most of those studies do not focus on damage to the bullet. The majority of these studies determine the velocity and damage caused upon tissue or tissue simulants, such as gelatin, while little research has been completed on other surfaces (Ben-Tovim, 1993, p. 31). In these studies, however, the marks and deformations of the surfaces being struck are assessed, but the damage the bullet has incurred is not generally examined. When the damage to bullets is presented, the data relies on information about velocities of impact rather than the ability to visualize markings and patterns on the surface contours of the bullets themselves (Haag, M. & Haag, L., 2011, p. 114). For the studies that do concentrate on the bullet, none of them concentrate solely on basal damage.

CHAPTER 3: METHODOLOGY

Introduction

The purpose of this study was to create a list of nomenclature to describe the possible types of damage that would occur on the basal portion of a bullet. To accomplish this, three questions would have to be considered: how basal damage is caused, how does basal damage affect visual analysis, and what nomenclature could be used to describe the basal deformation.

This study is comprised of three distinct phases: the creation of bullets with basal deformation, imaging and measuring bullets using the IBIS® BULLETTRAX-3D™ system to visualize the basal damage, and creating and introducing the proposed nomenclature to members of the Firearms and Tool Mark field through a questionnaire.

Phase I of this chapter will delve into the reasoning behind why pistols were chosen over other types of firearms, the distance and media chosen to fire the projectiles upon, the caliber and type of ammunition used in the study, and how these variables affect basal damage.

Phase II of this chapter discusses the types of damage visualized, how they were analyzed and grouped, and the procedure to acquiring a damaged bullet sample using the the IBIS® BULLETTRAX-3D™ system.

Phase III of this chapter addresses a proposed classification system to describe basal damage found on projectiles and the perception of a sample of Firearm and Tool Mark examiners based upon the results of an online survey.

Phase I: Creation of bullets with basal deformation

Setting. The basis of this study was to create projectiles that have incurred basal deformation after having been fired from a firearm. Considering "most shooting cases are on the order of a few feet to ten to twenty yards" (Haag & Haag, 2011, p. 175), the researcher wanted to maintain a distance within zero and sixty feet as the projectile travel distance between the firearm and the intended target. Due to concerns regarding the possible ricochet distances, an optimum distance of 50 feet was chosen. This distance allowed the safety of the researcher to be maintained and resided well within the predetermined sixty foot range. On account of the distance, it was decided that the first part of Phase I of the study would be conducted at an outdoor location. The Midwest City Police Department allowed the researcher to perform the initial portion of their study at their gun range located in Midwest City, Oklahoma.

The second portion of Phase I was completed at the Oklahoma State Bureau of Investigation (OSBI) Forensic Laboratory located in Edmond, OK. The location was chosen due to the proximity of a bullet water recovery tank to the W. Roger Webb Forensic Science Institute at the University of Central Oklahoma (UCO-FSI).

Intervention and Materials. Seeing that the basis of the study was to create basal deformation, it was necessary to create a comprehensive set of results. Haag & Haag (2011) stated that "common materials struck by projectiles include Sheetrock (wallboard), wood, sheet metal (e.g., filing cabinets, vehicles, road signs), asphalt, concrete, construction block/bricks, rubber (e.g., tires), plastic (e.g., truck bed liners, patio furniture), and clothing and other fabrics (e.g., upholstered furniture)" (p. 105). Since this study is concentrating on severe, basal damage, unyielding, and frangible mediums were used. The researcher selected three mediums commonly found in populated areas to be used as targets: wood, metal, and brick. These elements are components of property frequently found in cities, e.g., vehicles, buildings, and barriers.

The wood-type material selected was 7/16 inch oriented strand board (OSB). According to Wardell (2013), oriented strand board is the “most-used sheathing and subflooring material” with as high as 75% of the market share. Dedel (2007) stated, “Many drive-by shootings involve multiple suspects and multiple victims. Using a vehicle allows the shooter to approach the intended target without being noticed and then to speed away before anyone reacts. The vehicle also offers some protection.” For this reason, a driver side door belonging to a 1991 Chevrolet Cheyenne 1500 pickup truck was selected as the metal-type medium. According to Tayabji, S. & Rao, S. (2014), “traffic volumes on the primary highway system, especially in urban areas, have seen tremendous increases over the last 20 years… precast concrete pavement (PCP) technology that provides for accelerated repair and rehabilitation of pavements.” Accordingly, the researcher selected a mixture of 16 inch x 8 inch x 8 inch concrete cinder blocks, as well as, 11.5 inch x 4 inch concrete retaining wall blocks in lieu of the brick-type medium as frangible targets.

Based on the ATF (2015) AFMER, pistols were the most common firearm type manufactured in 2013 compared to revolvers, rifles, shotguns, and miscellaneous firearms. Pistols with calibers between .32 and .38, calibers between .38 and 9mm, and calibers between 9mm and .50 were the cost common; therefore, .380, 9mm, and .45 caliber ammunition has been chosen for the study (p. 1). Sturm, Ruger & Company, Inc. manufactured 324,983 pistols in the .38 caliber category and manufactured 146,426 pistols in the .50 caliber category (p. 3). The Firearms Commerce in the United States Annual Statistical Update stated that there were 3,095,528 handguns imported into the United States in 2013, with 451,657 handguns being imported from Croatia (Clapp 2014). The researcher chose to include American made as well as internationally imported firearms in the study. Since Springfield Armory has been importing Croatian made XD pistols since 2002, this firearm was included in the study. Ultimately, the Ruger LCP 380 ACP, Springfield Armory XD 9mm, and the Ruger P90 .45 ACP were the firearms used in the project (see Figure 3).

Figure 3. Ruger LCP 380 ACP, Springfield Armory XD 9mm, and the Ruger P90 .45 ACP. Adapted from “Bud’s Gun Shop Catalog”, by Bud’s Gun Shop, 2015, https://www.budsgunshop.com/catalog

In small arms ammunition, bullets may be jacketed or unjacketed, most unjacketed bullets are lead, and even jacketed bullets have a plain lead core (Heard, 2008, p. 67). Since there were three mediums and three guns chosen, two types of ammunition were used: jacketed (one 50 round box of Federal brand .380 Auto/ 95 grn/FMJ, one 50 round box of Federal brand 9mm/115grn/FMJ, and one 50 round box of Federal brand .45Auto/230grn/FMJ) and unjacketed (one 50 round box of Ultramax Remanufactured 380ACP/115 grn, one 50 round box of Ultramax Remanufactured 9mm/125 grn, and one 50 round box of Ultramax Remanufactured 45ACP/230 grn) ammunition.

Measurement Instruments. A Shooting Chrony Gamma Master Chronograph was used to measure the muzzle velocity in m/s after each shot and the Ballistic Chrony printer was used to record the acquired velocities.

Data Collection/Procedures. Each box of ammunition was checked for consistency, non-firing markings, or other problematic aberrations prior to arriving at the gun range. 300 Staples® #1, 2-1/4" x 3-1/2" Brown Kraft Coin Envelopes were labeled with the corresponding caliber, jacket, group, and shot number. The backstop was set up with the cinder blocks and retaining wall blocks. The Shooting Chrony chronograph and shooting rest were placed on a table fifty yards from the backstop. The Ruger LCP was loaded with one cartridge of the Federal 380 ACP ammunition and was fired at 90° to the target surface (see Figure 4). The bullet was collected and placed in the appropriate envelope, and the muzzle velocity were verified and recorded. This process was repeated with one cartridge of the Ultramax unjacketed 380 ACP ammunition. The concrete blocks were then arranged so that the angle was 75°. A Federal 380 ACP cartridge was fired, the bullet was collected and placed in the appropriate envelope, and the muzzle velocity were verified and recorded. This was repeated four times for a total of five shots at this angle. The process was then repeated using the Ultramax unjacketed 380 ACP ammunition for a total of five shots at 75°. This entire process was repeated at 60° and 45°. This section was comprised of envelopes numbered one through thirty-two.

Figure 4. Ruger LCP 380 ACP firing at concrete blocks

The angle of the concrete block was reverted to 90° again and the process began for both the jacketed and unjacketed 9mm ammunition so that each type was fired 5 times at 75°, 60°, and 45°. This section was comprised of envelopes numbered thirty-three to sixty-four. When that was complete, the angle of the concrete block was reverted to 90° once again so that the process would repeat for both the jacketed and unjacketed 45 ACP ammunition. This section was comprised of envelopes numbered sixty-five to ninety-six.

After all six types of ammunition were shot at the concrete blocks, the concrete blocks were replaced with the metal truck door. The previous steps were repeated starting with the car door at 90°, then 75°, 60°, and 45° (see Figure 5). This section was comprised of envelopes numbered ninety-seven to 192. After all six types of ammunition were fired at the car door, the door was removed, and the wooden backstop was installed as the last medium. Again, the previous steps were repeated starting with the car door at 90°, then 75°, 60°, and 45°. This section was comprised of envelopes numbered 193 to 282.

Figure 5. Chevrolet Cheyenne driver side door

After completion of firing, the materials and equipment were removed from the firing range. At this point, there are nine distinct groups of fired ammunition (groups A-I); containing thirty-two projectiles each (see Table 1). Each group is subdivided into six sections.

The procedure to create the final group, J, was performed at the OSBI Forensic Laboratory. Three rounds of Federal jacketed 380 ACP ammunition were loaded into the Ruger LCP. Three shots were fired into the water recovery tank, and three bullets were collected and placed into the appropriate envelope. No muzzle velocity was recorded for the second portion of Phase I. The process was repeated for the Ultramax unjacketed 380 ACP ammunition, the jacketed Federal 9mm ammunition, the unjacketed 9mm ammunition, the jacketed 45 ACP ammunition, and finally, the unjacketed 45 ACP ammunition. Once this step was completed, all of the samples were taken back to the UCO-FSI, were photographed, and were stored in a safe, locked area at the UCO-FSI graduate student office.

Phase II: Visualization of damaged bullets with the aid of the IBIS® BULLETTRAX-3D™

Setting. Phase II of the study took place at Forensic Technology WAI Inc. (FTI) headquarters in Côte St-Luc, Quebec, Canada.

Intervention and Materials. The damaged projectiles were sent through FedEx to the FTI headquarters so that the researcher could image the bullet samples using the automated IBIS® BULLETTRAX-3D™ imaging system.

Data Collection/Procedures. Once the researcher arrived at headquarters, she was instructed on how to use the equipment to image and acquire the bullet samples. Once the researcher had been properly trained on using the automated IBIS® BULLETTRAX-3D™ imaging system, select projectiles were loaded into the system one by one (see Figure 6).

Figure 6. IBIS® BULLETTRAX-3D™ Acquisition Station

First, the bullet was inserted into the H2 Magnetic Bullet Holder (see Figure 7). The bullet was placed securely between the support tips using sticky wax. The researcher was careful not to cover any engraved areas with the wax. The alignment gauge was used “to find the optimal vertical position for the bullet relative to the vertical lines” (FTI 2011). The support tips were rotated to ensure the bullet was centered and not wobbly. The bullet holder was then placed into the magnetic socket of the Acquisition Station.

The researcher began the bullet acquisition by creating a case folder in which the bullet acquisitions would be saved, adding a new bullet exhibit to that case, entering the designated “Bullet #” as the “Exhibit Number”, selecting the start and end calibers, number of Land Engraved Areas (LEA), direction of twist, rifling type, and event type.

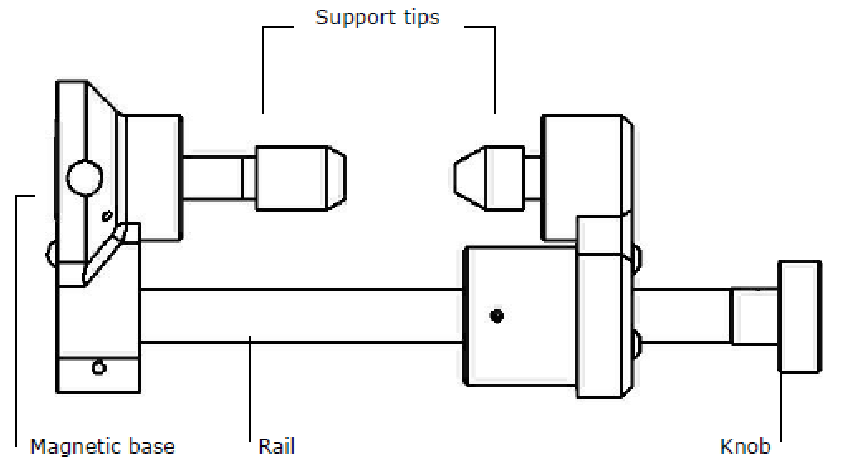

Figure 7. IBIS® BULLETTRAX-3D™ H2 Bullet Holder. Reprinted from IBIS BULLETTRAX-3D 2.3 Training Guide (p. 24), by Forensic Technology WAI Inc, 2011, Côte St-Luc , QC: Forensic Technology WAI Inc.

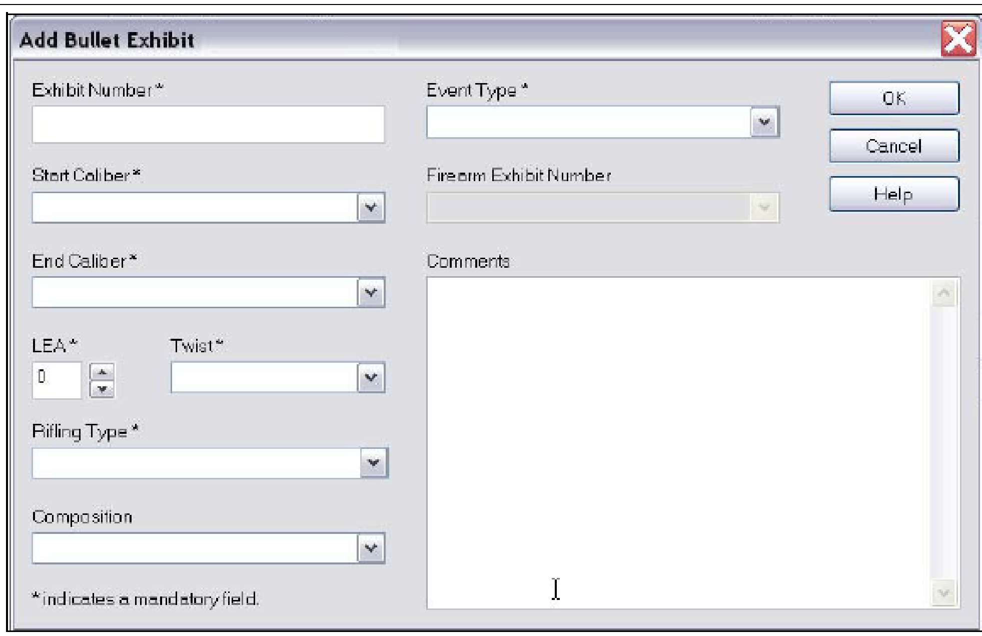

Figure 8. IBIS® BULLETTRAX-3D™ Add Bullet Exhibit Dialog Box. Reprinted from IBIS BULLETTRAX-3D 2.3 Training Guide (p. 24), by Forensic Technology WAI Inc, 2011, Côte St-Luc , QC: Forensic Technology WAI Inc.

The researcher ensured that the bullet surface was perpendicular to the microscope, perpendicular to the Live Image area, and in focus (see Figure 9). The researcher ensured the LEA, was between 0.5cm and 1.0cm “from the right edge of the Live Image area…the top half of the GEA [appeared] in the top section of the Live Image area, and the top shoulder an all the LEAs [appeared] in the middle of the Live Image area” (FTI 2011). Some bullets had petals that were bent backwards so that they were covering the area that needed to be imaged. To remedy this, the researcher used pliers to bend the petals toward the nose of the bullet so that they were no longer blocking the basal portion of the bullet. The researcher ensured that the bearing surface was not damaged by this act.

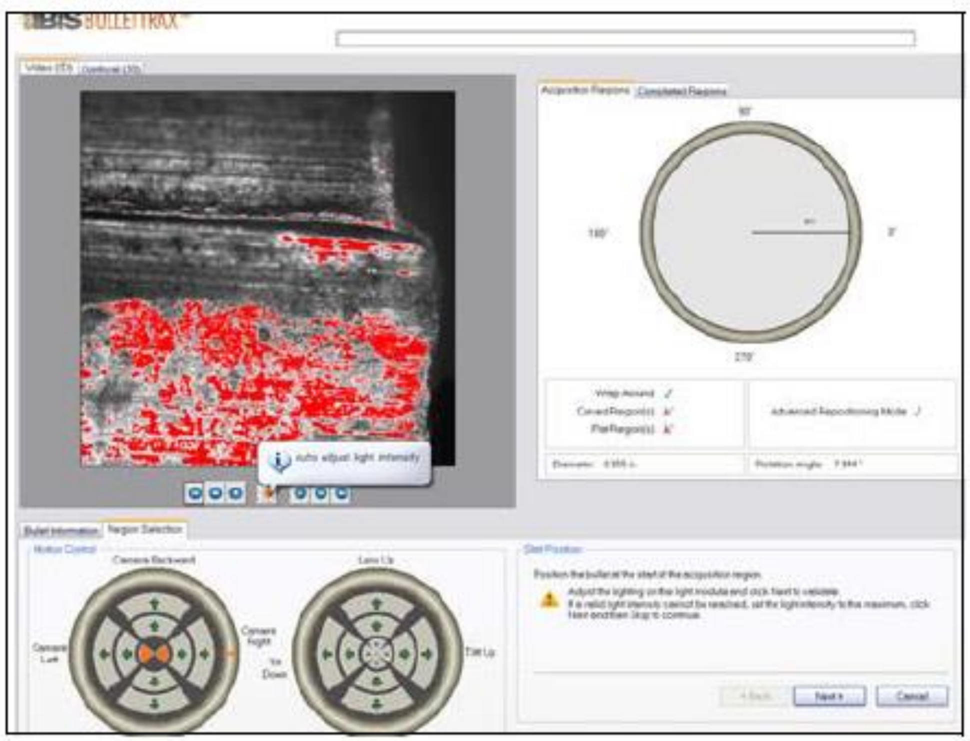

Figure 9. IBIS® BULLETTRAX-3D™ Acquisition Window. Reprinted from IBIS BULLETTRAX-3D 2.3 Training Guide (p. 24), by Forensic Technology WAI Inc, 2011, Côte St-Luc , QC: Forensic Technology WAI Inc.

After the system completed the bullet acquisition, a Validation window appears (see Figure 10). This window allows the researcher to “verify the placement of anchor lines and assign index numbers to LEAs and GEAs” (FTI 2011). Once the researcher is satisfied with the acquisition, the image is saved and the next acquisition is started. After all of the acquisitions were finalized, the data was then correlated to create a standard nomenclature to classify the levels of damage imparted on the bullets. Figures 11 and 12 exemplify a small sample of comparisons using acquired images.

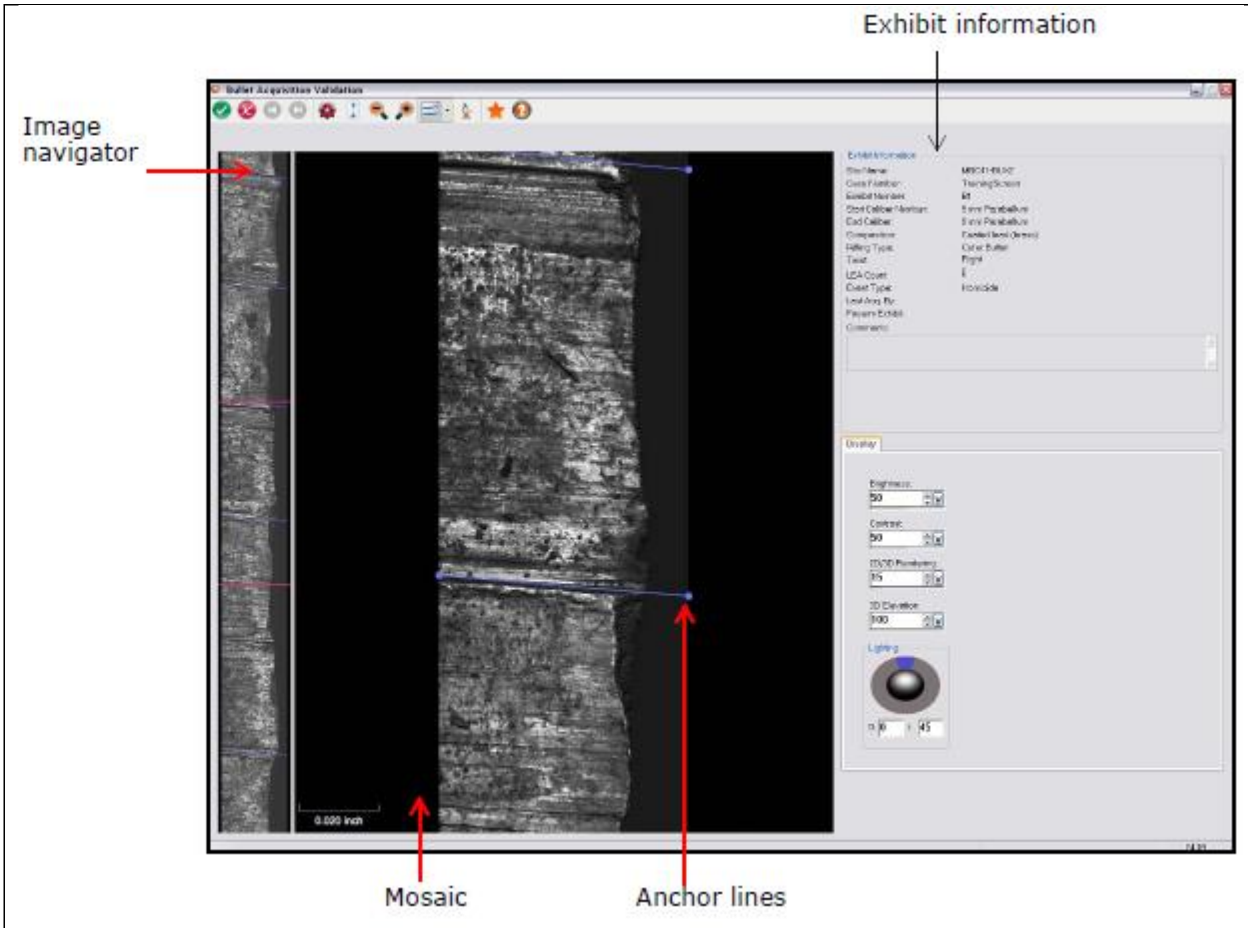

Figure 10. IBIS® BULLETTRAX-3D™ Validation Window. Reprinted from IBIS BULLETTRAX-3D 2.3 Training Guide (p. 24), by Forensic Technology WAI Inc, 2011, Côte St-Luc , QC: Forensic Technology WAI Inc.

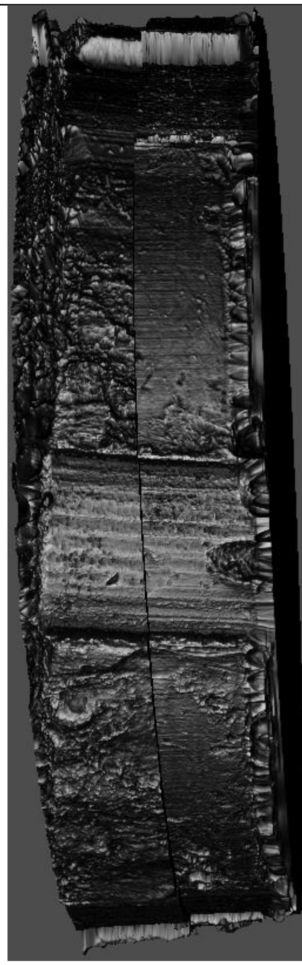

Figure 11. Bullet #19 (unjacketed 380ACP fired upon a cinderblock) compared with Bullet #288 (unjacketed 380 ACP fired into a water tank). D. Roberge (E-mail, July 26, 2013).

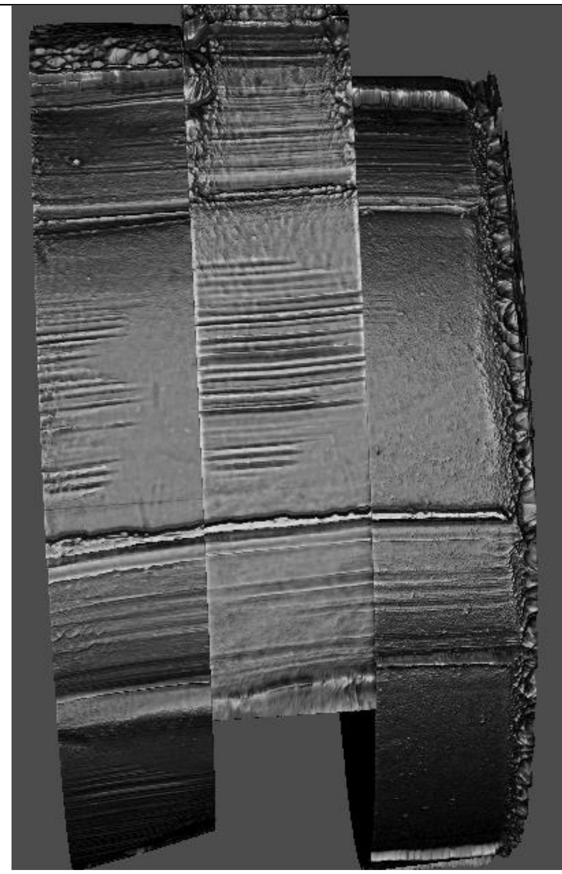

Figure 12. Bullet #205 (jacketed 380ACP fired upon a wood panel) compared with Bullet #110 (jacketed 380 ACP fired upon a metal car door) and Bullet #283 (jacketed 380 ACP fired into a water tank). D. Roberge (E-mail, July 26, 2013).

Phase III: Proposed Classification System

Setting. Phase III is comprised of a questionnaire created on www.surveymonkey.com. The Survey Monkey website, is the "world's leading provider of web-based survey solutions, trusted by millions of companies, organizations and individuals alike to gather the insights they need to make more informed decisions" (Survey Monkey 2015a). This survey was created based on the preliminary nomenclature created from Phase II (see Appendix A).

Sample/Participants. The Association of Firearm and Tool Mark Examiners (AFTE) was formed at the Chicago Police Department Crime Laboratory in 1969 to allow the "presentation of scientific and technical papers, descriptions of new techniques and procedures, review of instrumentation and the solution of common problems encountered in these scientific fields" (AFTE 1999). As of 2010, the association has over 1,000 "members, technical advisors and subscribers that represent over 40 countries from around the world" (AFTE 1999).

Intervention and Materials. Video of select bullets with varying types of damage was recorded and adjusted to be viewable on the Survey Monkey website. Once the video was complete, the questionnaire was created and a test survey was open to FTI employees. After approval from the FTI group, the approval to send out an email blast to current AFTE members was approved. On February 5, 2014, an email blast was sent out as an invitation to participate in the online questionnaire regarding bullet deformation and how the damage affects their identification and analysis (see Appendix B). The videos of the damaged bullet samples were displayed through the Survey Monkey survey, as well as, linked to Youtube.com just in the event that the examiners had technical issues causing them to be unable to view the damaged bullet videos.

Measurement Instruments. The Survey Monkey survey platform allows basic paid users unlimited questions and responses, 24/7 email support, custom logos and colors, skip logic, cross-tabs and filters, and the ability to export data and reports. Skip logic creates a custom path through the survey that varies based on a respondent's answer. Cross-tabs and filters allow survey results to be segmented, allowing hidden trends to be discovered (Survey Monkey 2015b). Due to these attributes, as well as the simplicity of contacting the AFTE members, the Survey Monkey instrument was chosen over paper questionnaires being mailed out to potential respondents. Furthermore, digital surveys are recognized as being more anonymous and having less hassle than their paper counterparts.

Data Collection/Procedures. The survey was open from February 5, 2014 to March, 15, 2015. Once the survey window was closed, the researcher downloaded the data in the available excel and .pdf formats and began to analyze the information.

Data Analysis

The data in relation to the participants who declined consent were not included in this study. The data belonging to those who began the survey and completed the survey at a different time or partially completed were considered in the study analysis.

Limitations and Assumptions. Since it would have been impossible for the study to create every type of basal damage possible, the nomenclature must be clear, but broad enough to define future damage. All automated imaging and analysis had to be completed during the short time allotted at FTI headquarters in Canada. There were no IBIS® BULLETTRAX-3D™ imaging systems in the state of Oklahoma at the time of this research.

This study did not attempt to recreate every type of basal deformation or damage that a bullet could possibly incur. The basis of this study is to create projectiles with a wide range of basal damage so that classes and nomenclature can be produced accordingly. It is under that assumption that all future projectile damage should be able to be classified under these established categories.

Only one possible outcome would have caused the study to be rewritten and redone: if no deformation was incurred on any of the projectiles and/or a low percentage of bullets had basal deformation. The majority of bullets incurred basal deformation; therefore, the early goal of the project was deemed complete, and the project was able to move on to a latter part allowing the researcher to image the damaged bullets and create a proposed nomenclature system.

Moreover, some bullets were so badly damaged, only small pieces and tiny fragments were able to be recovered. These items were still catalogued and photographed, but held no value for perceivable imaging or acquisition.

Delimitations. Due to the amount of resources allotted for this study, bulk ammunition was purchased and used. Because multiple calibers of ammunition are being used in the study, it is not possible to use ammunition that is equal in grain (weight) that is normally commercially produced. It would be possible for the researcher to reload her own ammunition, but this would be more costly and time consuming than the project would allow. Furthermore, since multiple calibers of firearms are being tested, each weapon ejected the projectile at varying velocities and the impacts of the bullets varied even though they were shot at the same distance to the desired surface. This would have been increasingly relevant if a carbine or rifle was used in addition to pistols. Although the addition of rifle ammunition would have broadened the scope of the project, rifle ammunition was thereupon excluded.

The current allotted budget and time period to complete the study imposes restrictions to the scope and comprehensiveness of the study. Surfaces such as bullet resistant glass, tissue and bone simulants, and ballistic vests were unable to be tested, due to their high cost.

CHAPTER 4: RESULTS

Introduction

Based on the data obtained following Phase I and Phase II of the methodology, the researcher generated a preliminary classification system to describe bullet basal deformation. This nomenclature list was used to create the questionnaire found in Phase III.

Phase I Data

The following table encompasses the data obtained from the Phase I methodology (see Table 1).

Table 1. *Phase I data*

Bullet #	Group	Caliber	Jacketing	Brand	Medium	Angle of Impact	Distance (feet)	Muzzle Velocity (m/s)
1	A1	380ACP	Jacketed	Federal	Cinderblock	90	35	861.67
2	A1	380ACP	Unjacketed	Ultramax	Cinderblock	90	50	717.6
3	A2	380ACP	Jacketed	Federal	Cinderblock	75	50	866.65
4	A2	380ACP	Jacketed	Federal	Cinderblock	75	50	849.23
5	A2	380ACP	Jacketed	Federal	Cinderblock	75	50	864.02
6	A2	380ACP	Jacketed	Federal	Cinderblock	75	50	901.13
7	A2	380ACP	Jacketed	Federal	Cinderblock	75	50	889.4
8	A3	380ACP	Unjacketed	Ultramax	Cinderblock	75	50	699.83
9	A3	380ACP	Unjacketed	Ultramax	Cinderblock	75	50	710.01
10	A3	380ACP	Unjacketed	Ultramax	Cinderblock	75	50	696.48
11	A3	380ACP	Unjacketed	Ultramax	Cinderblock	75	50	722.29
12	A3	380ACP	Unjacketed	Ultramax	Cinderblock	75	50	722.2
13	A4	380ACP	Jacketed	Federal	Cinderblock	60	50	878.12
14	A4	380ACP	Jacketed	Federal	Cinderblock	60	50	897.08
15	A4	380ACP	Jacketed	Federal	Cinderblock	60	50	885.96
16	A4	380ACP	Jacketed	Federal	Cinderblock	60	50	877.74
17	A4	380ACP	Jacketed	Federal	Cinderblock	60	50	877.7
18	A5	380ACP	Unjacketed	Ultramax	Cinderblock	60	50	728.03
19	A5	380ACP	Unjacketed	Ultramax	Cinderblock	60	50	717.28
20	A5	380ACP	Unjacketed	Ultramax	Cinderblock	60	50	713.65

21	A5	380ACP	Unjacketed	Ultramax	Cinderblock	60	50	705.7
22	A5	380ACP	Unjacketed	Ultramax	Cinderblock	60	50	715.2
23	A6	380ACP	Jacketed	Federal	Cinderblock	45	50	872.43
24	A6	380ACP	Jacketed	Federal	Cinderblock	45	50	889.35
25	A6	380ACP	Jacketed	Federal	Cinderblock	45	50	880.04
26	A6	380ACP	Jacketed	Federal	Cinderblock	45	50	875.64
27	A6	380ACP	Jacketed	Federal	Cinderblock	45	50	878.3
28	A7	380ACP	Unjacketed	Ultramax	Cinderblock	45	50	706.8
29	A7	380ACP	Unjacketed	Ultramax	Cinderblock	45	50	707.89
30	A7	380ACP	Unjacketed	Ultramax	Cinderblock	45	50	731.5
31	A7	380ACP	Unjacketed	Ultramax	Cinderblock	45	50	698.82
32	A7	380ACP	Unjacketed	Ultramax	Cinderblock	45	50	684.78
33	B1	9mm	Jacketed	Federal	Cinderblock	90	50	1132.6
34	B1	9mm	Unjacketed	Ultramax	Cinderblock	90	50	1039
35	B2	9mm	Jacketed	Federal	Cinderblock	75	50	1052.05
36	B2	9mm	Jacketed	Federal	Cinderblock	75	50	1111.97
37	B2	9mm	Jacketed	Federal	Cinderblock	75	50	1115.97
38	B2	9mm	Jacketed	Federal	Cinderblock	75	50	1110.95
39	B2	9mm	Jacketed	Federal	Cinderblock	75	50	1010.2
40	B3	9mm	Unjacketed	Ultramax	Cinderblock	75	50	1038.25
41	B3	9mm	Unjacketed	Ultramax	Cinderblock	75	50	1046.1
42	B3	9mm	Unjacketed	Ultramax	Cinderblock	75	50	1041.5
43	B3	9mm	Unjacketed	Ultramax	Cinderblock	75	50	1045.6
44	B3	9mm	Unjacketed	Ultramax	Cinderblock	75	50	1039.3
45	B4	9mm	Jacketed	Federal	Cinderblock	60	50	1120.41
46	B4	9mm	Jacketed	Federal	Cinderblock	60	50	1136.8
47	B4	9mm	Jacketed	Federal	Cinderblock	60	50	1121.2
48	B4	9mm	Jacketed	Federal	Cinderblock	60	50	1119.8
49	B4	9mm	Jacketed	Federal	Cinderblock	60	50	1134.7
50	B5	9mm	Unjacketed	Ultramax	Cinderblock	60	50	900.73
51	B5	9mm	Unjacketed	Ultramax	Cinderblock	60	50	884.86
52	B5	9mm	Unjacketed	Ultramax	Cinderblock	60	50	875.77
53	B5	9mm	Unjacketed	Ultramax	Cinderblock	60	50	1042.09
54	B5	9mm	Unjacketed	Ultramax	Cinderblock	60	50	903.49
55	B6	9mm	Jacketed	Federal	Cinderblock	45	50	1128.35
56	B6	9mm	Jacketed	Federal	Cinderblock	45	50	1129.61
57	B6	9mm	Jacketed	Federal	Cinderblock	45	50	1108.61
58	B6	9mm	Jacketed	Federal	Cinderblock	45	50	1111.05
59	B6	9mm	Jacketed	Federal	Cinderblock	45	50	1119.4
60	B7	9mm	Unjacketed	Ultramax	Cinderblock	45	50	1044.43
61	B7	9mm	Unjacketed	Ultramax	Cinderblock	45	50	1044.16

62	B7	9mm	Unjacketed	Ultramax	Cinderblock	45	50	1035.14
63	B7	9mm	Unjacketed	Ultramax	Cinderblock	45	50	1029.77
64	B7	9mm	Unjacketed	Ultramax	Cinderblock	45	50	1037.62
65	C1	45ACP	Jacketed	Federal	Cinderblock	90	50	777.15
66	C1	45ACP	Unjacketed	Ultramax	Cinderblock	90	50	791.48
67	C2	45ACP	Jacketed	Federal	Cinderblock	75	50	768.52
68	C2	45ACP	Jacketed	Federal	Cinderblock	75	50	718.69
69	C2	45ACP	Jacketed	Federal	Cinderblock	75	50	724.71
70	C2	45ACP	Jacketed	Federal	Cinderblock	75	50	728.42
71	C2	45ACP	Jacketed	Federal	Cinderblock	75	50	726.72
72	C3	45ACP	Unjacketed	Ultramax	Cinderblock	75	50	783.13
73	C3	45ACP	Unjacketed	Ultramax	Cinderblock	75	50	796.85
74	C3	45ACP	Unjacketed	Ultramax	Cinderblock	75	50	776.2
75	C3	45ACP	Unjacketed	Ultramax	Cinderblock	75	50	779.25
76	C3	45ACP	Unjacketed	Ultramax	Cinderblock	75	50	801.97
77	C4	45ACP	Jacketed	Federal	Cinderblock	60	50	772.44
78	C4	45ACP	Jacketed	Federal	Cinderblock	60	50	755.52
79	C4	45ACP	Jacketed	Federal	Cinderblock	60	50	737.56
80	C4	45ACP	Jacketed	Federal	Cinderblock	60	50	737.25
81	C4	45ACP	Jacketed	Federal	Cinderblock	60	50	716.14
82	C5	45ACP	Unjacketed	Ultramax	Cinderblock	60	50	778.8
83	C5	45ACP	Unjacketed	Ultramax	Cinderblock	60	50	778.3
84	C5	45ACP	Unjacketed	Ultramax	Cinderblock	60	50	801.38
85	C5	45ACP	Unjacketed	Ultramax	Cinderblock	60	50	787.57
86	C5	45ACP	Unjacketed	Ultramax	Cinderblock	60	50	784.35
87	C6	45ACP	Jacketed	Federal	Cinderblock	45	50	770.67
88	C6	45ACP	Jacketed	Federal	Cinderblock	45	50	738.96
89	C6	45ACP	Jacketed	Federal	Cinderblock	45	50	734.12
90	C6	45ACP	Jacketed	Federal	Cinderblock	45	50	740.86
91	C6	45ACP	Jacketed	Federal	Cinderblock	45	50	719.97
92	C7	45ACP	Unjacketed	Ultramax	Cinderblock	45	50	793.56
93	C7	45ACP	Unjacketed	Ultramax	Cinderblock	45	50	794.8
94	C7	45ACP	Unjacketed	Ultramax	Cinderblock	45	50	781.92
95	C7	45ACP	Unjacketed	Ultramax	Cinderblock	45	50	772.39
96	C7	45ACP	Unjacketed	Ultramax	Cinderblock	45	50	796.48
97	D1	380ACP	Jacketed	Federal	Metal Car Door	90	50	871.55
98	D1	380ACP	Unjacketed	Ultramax	Metal Car Door	90	50	723.29
99	D2	380ACP	Jacketed	Federal	Metal Car Door	75	50	882.6
100	D2	380ACP	Jacketed	Federal	Metal Car Door	75	50	906.94

101	D2	380ACP	Jacketed	Federal	Metal Car Door	75	50	891.44
102	D2	380ACP	Jacketed	Federal	Metal Car Door	75	50	924.6
103	D2	380ACP	Jacketed	Federal	Metal Car Door	75	50	926.94
104	D3	380ACP	Unjacketed	Ultramax	Metal Car Door	75	50	698.4
105	D3	380ACP	Unjacketed	Ultramax	Metal Car Door	75	50	707.6
106	D3	380ACP	Unjacketed	Ultramax	Metal Car Door	75	50	718.4
107	D3	380ACP	Unjacketed	Ultramax	Metal Car Door	75	50	715.1
108	D3	380ACP	Unjacketed	Ultramax	Metal Car Door	75	50	712.2
109	D4	380ACP	Jacketed	Federal	Metal Car Door	60	50	899.79
110	D4	380ACP	Jacketed	Federal	Metal Car Door	60	50	901.6
111	D4	380ACP	Jacketed	Federal	Metal Car Door	60	50	895.47
112	D4	380ACP	Jacketed	Federal	Metal Car Door	60	50	934.74
113	D4	380ACP	Jacketed	Federal	Metal Car Door	60	50	895
114	D5	380ACP	Unjacketed	Ultramax	Metal Car Door	60	50	696.85
115	D5	380ACP	Unjacketed	Ultramax	Metal Car Door	60	50	688.09
116	D5	380ACP	Unjacketed	Ultramax	Metal Car Door	60	50	694.21
117	D5	380ACP	Unjacketed	Ultramax	Metal Car Door	60	50	687.4
118	D5	380ACP	Unjacketed	Ultramax	Metal Car Door	60	50	691.51
119	D6	380ACP	Jacketed	Federal	Metal Car Door	45	50	921.09
120	D6	380ACP	Jacketed	Federal	Metal Car Door	45	50	878.3
121	D6	380ACP	Jacketed	Federal	Metal Car Door	45	50	867.4
122	D6	380ACP	Jacketed	Federal	Metal Car Door	45	50	881.2
123	D6	380ACP	Jacketed	Federal	Metal Car Door	45	50	865.75
124	D7	380ACP	Unjacketed	Ultramax	Metal Car Door	45	50	700.64
125	D7	380ACP	Unjacketed	Ultramax	Metal Car Door	45	50	676.18

126	D7	380ACP	Unjacketed	Ultramax	Metal Car Door	45	50	699.8
127	D7	380ACP	Unjacketed	Ultramax	Metal Car Door	45	50	698.29
128	D7	380ACP	Unjacketed	Ultramax	Metal Car Door	45	50	643.77
129	E1	9mm	Jacketed	Federal	Metal Car Door	90	50	1135.12
130	E1	9mm	Unjacketed	Ultramax	Metal Car Door	90	50	1041.37
131	E2	9mm	Jacketed	Federal	Metal Car Door	75	50	1126.25
132	E2	9mm	Jacketed	Federal	Metal Car Door	75	50	1104.36
133	E2	9mm	Jacketed	Federal	Metal Car Door	75	50	1040.12
134	E2	9mm	Jacketed	Federal	Metal Car Door	75	50	1051.05
135	E2	9mm	Jacketed	Federal	Metal Car Door	75	50	1038.16
136	E3	9mm	Unjacketed	Ultramax	Metal Car Door	75	50	1015.34
137	E3	9mm	Unjacketed	Ultramax	Metal Car Door	75	50	1039.6
138	E3	9mm	Unjacketed	Ultramax	Metal Car Door	75	50	1044.2
139	E3	9mm	Unjacketed	Ultramax	Metal Car Door	75	50	1049.1
140	E3	9mm	Unjacketed	Ultramax	Metal Car Door	75	50	1040.5
141	E4	9mm	Jacketed	Federal	Metal Car Door	60	50	1122.49
142	E4	9mm	Jacketed	Federal	Metal Car Door	60	50	1021.68
143	E4	9mm	Jacketed	Federal	Metal Car Door	60	50	1098.7
144	E4	9mm	Jacketed	Federal	Metal Car Door	60	50	1051.1
145	E4	9mm	Jacketed	Federal	Metal Car Door	60	50	1030.47
146	E5	9mm	Unjacketed	Ultramax	Metal Car Door	60	50	1016.28
147	E5	9mm	Unjacketed	Ultramax	Metal Car Door	60	50	1060.07
148	E5	9mm	Unjacketed	Ultramax	Metal Car Door	60	50	967.31
149	E5	9mm	Unjacketed	Ultramax	Metal Car Door	60	50	1030.73
150	E5	9mm	Unjacketed	Ultramax	Metal Car Door	60	50	1024.97

151	E6	9mm	Jacketed	Federal	Metal Car Door	45	50	1122.18
152	E6	9mm	Jacketed	Federal	Metal Car Door	45	50	1137.68
153	E6	9mm	Jacketed	Federal	Metal Car Door	45	50	1124.9
154	E6	9mm	Jacketed	Federal	Metal Car Door	45	50	1122.49
155	E6	9mm	Jacketed	Federal	Metal Car Door	45	50	1127.72
156	E7	9mm	Unjacketed	Ultramax	Metal Car Door	45	50	1025.75
157	E7	9mm	Unjacketed	Ultramax	Metal Car Door	45	50	1035.67
158	E7	9mm	Unjacketed	Ultramax	Metal Car Door	45	50	1030.47
159	E7	9mm	Unjacketed	Ultramax	Metal Car Door	45	50	1021.68
160	E7	9mm	Unjacketed	Ultramax	Metal Car Door	45	50	1029.2
161	F1	45ACP	Jacketed	Federal	Metal Car Door	90	50	756.13
162	F1	45ACP	Unjacketed	Ultramax	Metal Car Door	90	50	793.97
163	F2	45ACP	Jacketed	Federal	Metal Car Door	75	50	757.88
164	F2	45ACP	Jacketed	Federal	Metal Car Door	75	50	746.2
165	F2	45ACP	Jacketed	Federal	Metal Car Door	75	50	754.62
166	F2	45ACP	Jacketed	Federal	Metal Car Door	75	50	718.65
167	F2	45ACP	Jacketed	Federal	Metal Car Door	75	50	749.58
168	F3	45ACP	Unjacketed	Ultramax	Metal Car Door	75	50	797.32
169	F3	45ACP	Unjacketed	Ultramax	Metal Car Door	75	50	791.53
170	F3	45ACP	Unjacketed	Ultramax	Metal Car Door	75	50	778.4
171	F3	45ACP	Unjacketed	Ultramax	Metal Car Door	75	50	795.85
172	F3	45ACP	Unjacketed	Ultramax	Metal Car Door	75	50	783.34
173	F4	45ACP	Jacketed	Federal	Metal Car Door	60	50	758.41
174	F4	45ACP	Jacketed	Federal	Metal Car Door	60	50	753.73
175	F4	45ACP	Jacketed	Federal	Metal Car Door	60	50	756.46

176	F4	45ACP	Jacketed	Federal	Metal Car Door	60	50	722.9
177	F4	45ACP	Jacketed	Federal	Metal Car Door	60	50	716.94
178	F5	45ACP	Unjacketed	Ultramax	Metal Car Door	60	50	788.95
179	F5	45ACP	Unjacketed	Ultramax	Metal Car Door	60	50	781.21
180	F5	45ACP	Unjacketed	Ultramax	Metal Car Door	60	50	801.7
181	F5	45ACP	Unjacketed	Ultramax	Metal Car Door	60	50	776.7
182	F5	45ACP	Unjacketed	Ultramax	Metal Car Door	60	50	781.87
183	F6	45ACP	Jacketed	Federal	Metal Car Door	45	50	735.86
184	F6	45ACP	Jacketed	Federal	Metal Car Door	45	50	759.02
185	F6	45ACP	Jacketed	Federal	Metal Car Door	45	50	737.61
186	F6	45ACP	Jacketed	Federal	Metal Car Door	45	50	742.4
187	F6	45ACP	Jacketed	Federal	Metal Car Door	45	50	727.59
188	F7	45ACP	Unjacketed	Ultramax	Metal Car Door	45	50	783.24
189	F7	45ACP	Unjacketed	Ultramax	Metal Car Door	45	50	771.36
190	F7	45ACP	Unjacketed	Ultramax	Metal Car Door	45	50	788.9
191	F7	45ACP	Unjacketed	Ultramax	Metal Car Door	45	50	784.86
192	F7	45ACP	Unjacketed	Ultramax	Metal Car Door	45	50	791.69
193	G1	380ACP	Jacketed	Federal	Wood Fencing	90	50	899.73
194	G1	380ACP	Unjacketed	Ultramax	Wood Fencing	90	50	698.7
195	G2	380ACP	Jacketed	Federal	Wood Fencing	75	50	884.8
196	G2	380ACP	Jacketed	Federal	Wood Fencing	75	50	884.67
197	G2	380ACP	Jacketed	Federal	Wood Fencing	75	50	908.23
198	G2	380ACP	Jacketed	Federal	Wood Fencing	75	50	905.38
199	G3	380ACP	Unjacketed	Ultramax	Wood Fencing	75	50	698.61
200	G3	380ACP	Unjacketed	Ultramax	Wood Fencing	75	50	691.67

201	G3	380ACP	Unjacketed	Ultramax	Wood Fencing	75	50	708.14
202	G3	380ACP	Unjacketed	Ultramax	Wood Fencing	75	50	706.2
203	G4	380ACP	Jacketed	Federal	Wood Fencing	60	50	874.89
204	G4	380ACP	Jacketed	Federal	Wood Fencing	60	50	887.7
205	G4	380ACP	Jacketed	Federal	Wood Fencing	60	50	908.5
206	G4	380ACP	Jacketed	Federal	Wood Fencing	60	50	901.3
207	G4	380ACP	Jacketed	Federal	Wood Fencing	60	50	884.09
208	G5	380ACP	Unjacketed	Ultramax	Wood Fencing	60	50	697.93
209	G5	380ACP	Unjacketed	Ultramax	Wood Fencing	60	50	702.18
210	G5	380ACP	Unjacketed	Ultramax	Wood Fencing	60	50	706.8
211	G5	380ACP	Unjacketed	Ultramax	Wood Fencing	60	50	701.1
212	G5	380ACP	Unjacketed	Ultramax	Wood Fencing	60	50	711.93
213	G6	380ACP	Jacketed	Federal	Wood Fencing	45	50	886.74
214	G6	380ACP	Jacketed	Federal	Wood Fencing	45	50	922.98
215	G6	380ACP	Jacketed	Federal	Wood Fencing	45	50	908.71
216	G6	380ACP	Jacketed	Federal	Wood Fencing	45	50	899.3
217	G6	380ACP	Jacketed	Federal	Wood Fencing	45	50	906.6
218	G7	380ACP	Unjacketed	Ultramax	Wood Fencing	45	50	679.9
219	G7	380ACP	Unjacketed	Ultramax	Wood Fencing	45	50	681.3
220	G7	380ACP	Unjacketed	Ultramax	Wood Fencing	45	50	695.4
221	G7	380ACP	Unjacketed	Ultramax	Wood Fencing	45	50	679.7
222	G7	380ACP	Unjacketed	Ultramax	Wood Fencing	45	50	697.81
223	H1	9mm	Jacketed	Federal	Wood Fencing	90	50	1148.8
224	H1	9mm	Unjacketed	Ultramax	Wood Fencing	90	50	1040.8
225	H2	9mm	Jacketed	Federal	Wood Fencing	75	50	1130.03

226	H2	9mm	Jacketed	Federal	Wood Fencing	75	50	1141.22
227	H2	9mm	Jacketed	Federal	Wood Fencing	75	50	1147.06
228	H2	9mm	Jacketed	Federal	Wood Fencing	75	50	1128.45
229	H2	9mm	Jacketed	Federal	Wood Fencing	75	50	1139.1
230	H3	9mm	Unjacketed	Ultramax	Wood Fencing	75	50	1033.55
231	H3	9mm	Unjacketed	Ultramax	Wood Fencing	75	50	1041.6
232	H3	9mm	Unjacketed	Ultramax	Wood Fencing	75	50	1036.7
233	H3	9mm	Unjacketed	Ultramax	Wood Fencing	75	50	1040.1
234	H3	9mm	Unjacketed	Ultramax	Wood Fencing	75	50	1048.68
235	H4	9mm	Jacketed	Federal	Wood Fencing	60	50	1032.8
236	H4	9mm	Jacketed	Federal	Wood Fencing	60	50	1056.1
237	H4	9mm	Jacketed	Federal	Wood Fencing	60	50	1083.3
238	H4	9mm	Jacketed	Federal	Wood Fencing	60	50	1022.9
239	H5	9mm	Unjacketed	Ultramax	Wood Fencing	60	50	1011.4
240	H5	9mm	Unjacketed	Ultramax	Wood Fencing	60	50	1032.6
241	H5	9mm	Unjacketed	Ultramax	Wood Fencing	60	50	1006.9
242	H5	9mm	Unjacketed	Ultramax	Wood Fencing	60	50	1020.5
243	H6	9mm	Jacketed	Federal	Wood Fencing	45	50	1133.53
244	H6	9mm	Jacketed	Federal	Wood Fencing	45	50	1117.83
245	H6	9mm	Jacketed	Federal	Wood Fencing	45	50	1127.93
246	H6	9mm	Jacketed	Federal	Wood Fencing	45	50	1104.67
247	H6	9mm	Jacketed	Federal	Wood Fencing	45	50	1118.65
248	H7	9mm	Unjacketed	Ultramax	Wood Fencing	45	50	1048.68
249	H7	9mm	Unjacketed	Ultramax	Wood Fencing	45	50	1060.9
250	H7	9mm	Unjacketed	Ultramax	Wood Fencing	45	50	1041.91

251	H7	9mm	Unjacketed	Ultramax	Wood Fencing	45	50	1051.6
252	H7	9mm	Unjacketed	Ultramax	Wood Fencing	45	50	1032.49
253	I1	45ACP	Jacketed	Federal	Wood Fencing	90	50	766.13
254	I1	45ACP	Unjacketed	Ultramax	Wood Fencing	90	50	789.78
255	I2	45ACP	Jacketed	Federal	Wood Fencing	75	50	765.7
256	I2	45ACP	Jacketed	Federal	Wood Fencing	75	50	759.74
257	I2	45ACP	Jacketed	Federal	Wood Fencing	75	50	752.65
258	I2	45ACP	Jacketed	Federal	Wood Fencing	75	50	757.31
259	I3	45ACP	Unjacketed	Ultramax	Wood Fencing	75	50	788.64
260	I3	45ACP	Unjacketed	Ultramax	Wood Fencing	75	50	790.5
261	I3	45ACP	Unjacketed	Ultramax	Wood Fencing	75	50	798.58
262	I3	45ACP	Unjacketed	Ultramax	Wood Fencing	75	50	783.49
263	I4	45ACP	Jacketed	Federal	Wood Fencing	60	50	753.7
264	I4	45ACP	Jacketed	Federal	Wood Fencing	60	50	731.6
265	I4	45ACP	Jacketed	Federal	Wood Fencing	60	50	751.2
266	I4	45ACP	Jacketed	Federal	Wood Fencing	60	50	740.8
267	I4	45ACP	Jacketed	Federal	Wood Fencing	60	50	756.4
268	I5	45ACP	Unjacketed	Ultramax	Wood Fencing	60	50	732.3
269	I5	45ACP	Unjacketed	Ultramax	Wood Fencing	60	50	770.96
270	I5	45ACP	Unjacketed	Ultramax	Wood Fencing	60	50	802.7
271	I5	45ACP	Unjacketed	Ultramax	Wood Fencing	60	50	781.2
272	I5	45ACP	Unjacketed	Ultramax	Wood Fencing	60	50	774.1
273	I6	45ACP	Jacketed	Federal	Wood Fencing	45	50	745.42
274	I6	45ACP	Jacketed	Federal	Wood Fencing	45	50	750.2
275	I6	45ACP	Jacketed	Federal	Wood Fencing	45	50	742.9

276	I6	45ACP	Jacketed	Federal	Wood Fencing	45	50	746.6
277	I6	45ACP	Jacketed	Federal	Wood Fencing	45	50	748.05
278	I7	45ACP	Unjacketed	Ultramax	Wood Fencing	45	50	786.65
279	I7	45ACP	Unjacketed	Ultramax	Wood Fencing	45	50	782.9
280	I7	45ACP	Unjacketed	Ultramax	Wood Fencing	45	50	784.81
281	I7	45ACP	Unjacketed	Ultramax	Wood Fencing	45	50	785.3
282	I7	45ACP	Unjacketed	Ultramax	Wood Fencing	45	50	787.62
283	J1	380ACP	Jacketed	Federal	Water Tank			
284	J1	380ACP	Jacketed	Federal	Water Tank			
285	J1	380ACP	Jacketed	Federal	Water Tank			
286	J2	380ACP	Unjacketed	Ultramax	Water Tank			
287	J2	380ACP	Unjacketed	Ultramax	Water Tank			
288	J2	380ACP	Unjacketed	Ultramax	Water Tank			
289	J3	9mm	Jacketed	Federal	Water Tank			
290	J3	9mm	Jacketed	Federal	Water Tank			
291	J3	9mm	Jacketed	Federal	Water Tank			
292	J4	9mm	Unjacketed	Ultramax	Water Tank			
293	J4	9mm	Unjacketed	Ultramax	Water Tank			
294	J4	9mm	Unjacketed	Ultramax	Water Tank			
295	J5	45ACP	Jacketed	Federal	Water Tank			
296	J5	45ACP	Jacketed	Federal	Water Tank			
297	J5	45ACP	Jacketed	Federal	Water Tank			
298	J6	45ACP	Unjacketed	Ultramax	Water Tank			
299	J6	45ACP	Unjacketed	Ultramax	Water Tank			
300	J6	45ACP	Unjacketed	Ultramax	Water Tank			

Phase II Data

Proposed Nomenclature.

- Scored – A projectile that has been defaced (the surface has been marred)
- Fragmented – The projectile has completely broken into two or more pieces (does not refer to jacket separation).

- Fractured – The projectile has parts that have broken, but have not yet separated from the other parts (this may refer to partial core/jacket impact separation.
- Full core/jacket impact separation – Refers to jacketed projectiles that have had their core completely separated from the inner core.
- Flattened – A portion of the projectile has been flatted or squeezed inwards (this may refer to kidney shaped where the projectile has bent or twisted and the shape of the base is similar to a kidney bean)

Phase III Data

Respondent Background. There were 135 respondents worldwide. Of those who responded, 34.88% have worked as Firearm and Tool Mark Examiners between ten and twenty years (see Figure 7). In addition, 14.5% have worked for over twenty years.

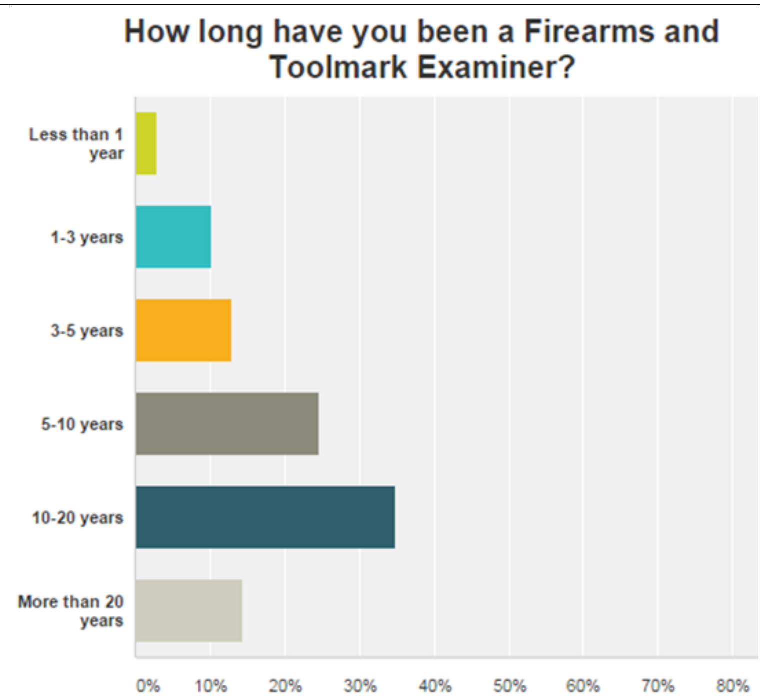

Figure 13. Firearm and Tool Mark Examiner length of employment

Commonly Examined Bullets. 93.4% claimed they examine pristine bullets and 97% examined damaged bullets (see Figure 8). A prodigious amount, 17%, selected other. A overwhelming majority explained that although "fragments" may be considered damaged bullets, it should be in a category or subclass of its own.

The respondents selected Full Metal Jacket, Jacketed Hollow Point, and Total Metal Jacket as the most commonly examined bullet types (see Figure 9). Other compositions that were mistakenly omitted included: black powder ball and nylon coated bullets.

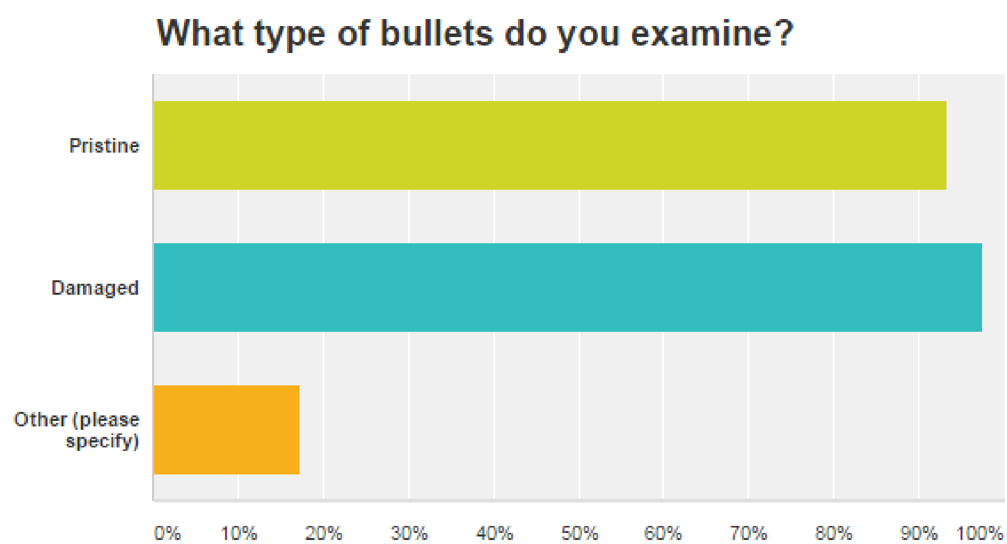

Figure 14. Pristine and Damaged Bullets

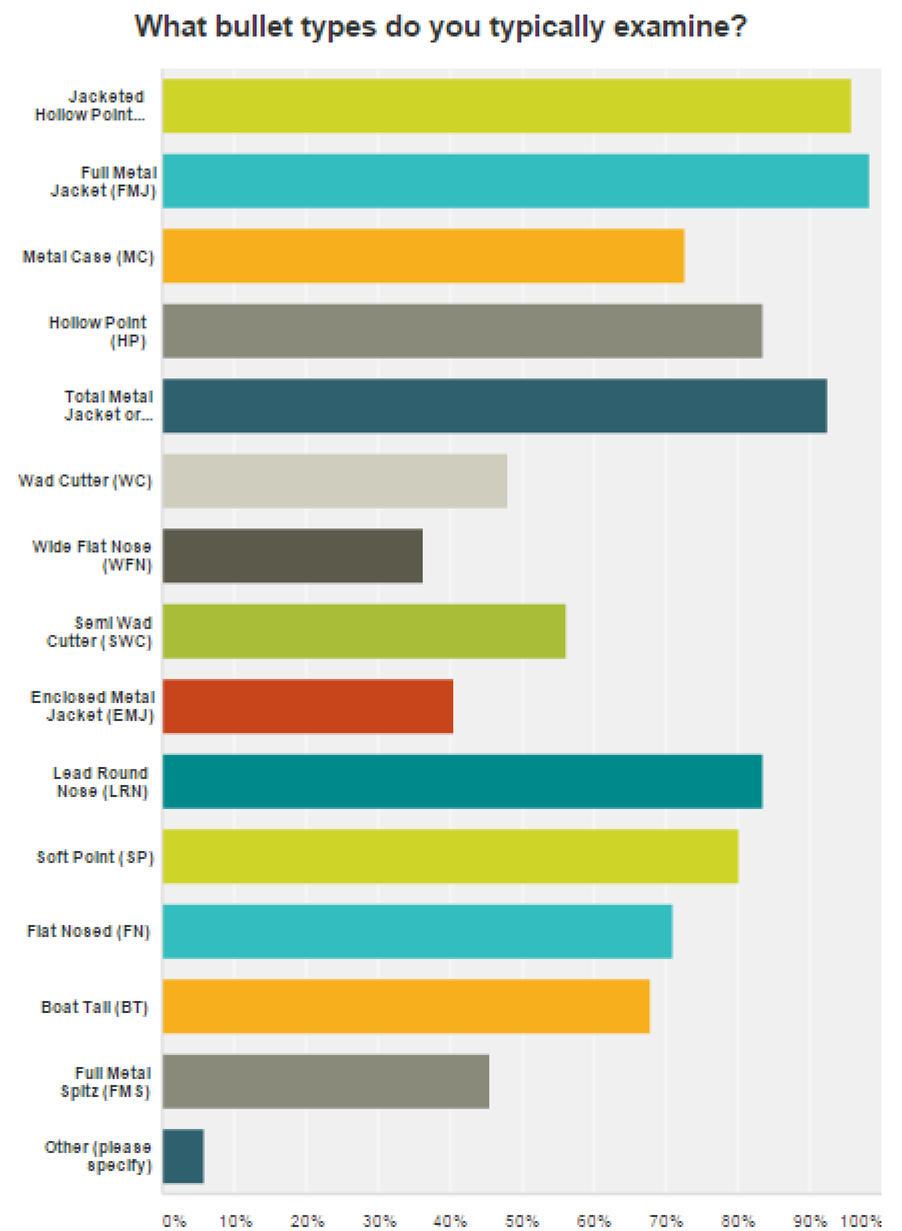

Figure 15. Bullet Composition

The majority of respondents examined bullets that originated from autopsies, crime scenes, and test fires while 67.77% selected “Found” (see Figure 10). One respondent selected other, and clarified that he/she would examine anything else that might have evidentiary value.”

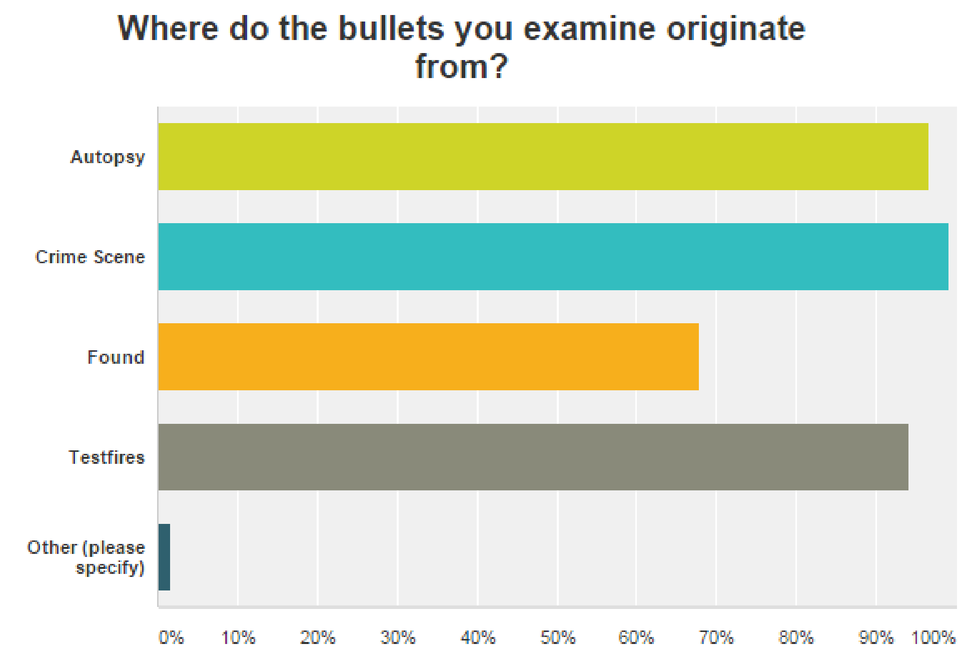

Figure 16. Bullet Origination

When asked, on a scale from never to often "How often are bullets, recovered from bodies, sent in from the medical examiner's office?" 83.5% stated "Often". The previous questions allowed the researcher to gauge general response leading to the determinative question concerning basal damage, 100% responded in the affirmative (see Figure 11).

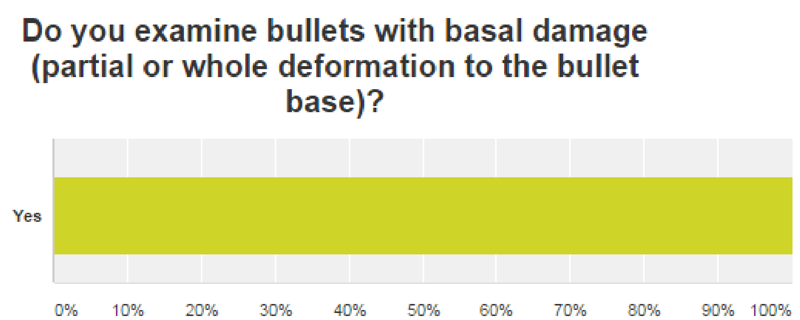

Figure 17. Basal Damage

Basal Damage Nomenclature. The following survey page unveiled six terms created to describe basal deformation and asked the respondent rate the accuracy of the definition by selecting: very inaccurate, somewhat accurate, or very accurate.

- 55.05% selected "Somewhat Accurate" for the definition of "Scored"
- 69.72% selected "Very accurate" for the definition of "Fragmented"
- 50.46% selected "Very accurate" for the definition of "Fractured", while 36.7% selected "somewhat accurate"
- 66.06% selected "Very accurate" for the definition of "Full core/jacket impact separation"
- 62.39% selected "Very accurate" for the definition of "Flattened"
- 49.79% selected "Somewhat accurate" for the definition of "Planar"

A majority of those who rated the definition for "Scored" as inaccurate did not disagree with the definition, but had qualms about the term "Scored" itself. Some stated that the term "Scored" generally indicates a mark left by a single point or extraneous scratches, while terms such as "Abraded", "Marred", "Scraped" or "Wiped" would better suit this definition.

The definition for "Fragmented" was the highest rated definition by the body of respondents. Suggested terms for this definition included "Split" and "Sheared". One examiner stated that "a fired bullet is considered a fragment when any unknown amount of material is missing (meaning, not entirely intact; hence, a fragment)."

Similarly to "Scored", some respondents agreed with the definition for "Fractured", but did not care for the term itself. Several examiners suggested "Torn", while others proposed "Cleft", "Cut", "Separated", "Cracked", and "Split".

Although “Full core/jacket impact separation” had a lower accuracy than “Fragmented”, the researcher believes that the typo in the definition caused the lower rating. Accounting for the comments made by the respondents to adjust the definition to “Refers to jacketed projectiles that have had their jacket completely separated from the inner core”, the “Very Accurate” percentage would have increased to approximately 95%. Others suggested the words “Full” and “Impact” be removed from the term.

Pursuant to previous comments, some respondents inferred that an inaccurate rating for a definition meant that identifications could not be made due to the damage. This was not the intention of the researcher as the purpose of the study is to successfully visualize and analyze damaged bullets. Some respondents recommended terms such as: “Pancaked, “Out of round base”, “Dented”, and “Partially flattened bearing surface”. Others seemed perturbed by the phrase “this may refer to”. Substituting the phrase “this includes” would most likely assuage the situation.

“Planar” was the most disparaged term. Only 29.3% of respondents selected “Very accurate” for this term. The majority preferred “Mushroom”, “Expanded”, “Smashed”, “Petalled”, or anything other than “Planar”. One respondent stated that the term “Planar” implied that the bullet had been completely flattened.

Ultimately, the examiners that selected “Very inaccurate” for the list of definitions were unable acknowledge with the newly created terms and would not discuss the accuracy unless the definition has been discussed with “the entire body of examiners” and that they must first “be generally accepted by the field that uses them”. Terms some respondents suggested that were not described by the preliminary classification included: “Inverted”, “Bellied”, “Obturated”, “Degraded”, “Oxidized”, “Corroded”, “Burnt”, “Melted”, and “Embedded”.

Classification using the given nomenclature. The following fifteen questions allowed examiners to see a 360 degree view of the basal portion of a damaged bullet. They were asked to select as many terms from the given nomenclature that may describe the aforementioned bullet (see Appendix D).

- Bullet 1: Several responded typed “Flattened” in the other field rather than selecting the term. Accounting for these responses, over 85% chose “Flattened” as a descriptor for this bullet.
- Bullet 2: Again, many respondents typed “Flattened”, “Pancaked” and “Mushroomed” in the other field. Accounting for these responses, 73% would have selected the term “Flattened”.
- Bullet 3: Accounting for those who typed “Partial jacket separation” and “Torn jacket” in the “Other” field, 64% selected “Fractured” as one of the descriptors. The general consensus shows that they do not like the term “Fractured”.
- Bullet 4: Accounting for those who typed in the “Other” field, 20% selected “Scored”, 11% selected “Fragmented, 19% selected “Fractured”, 30% selected “Flattened” and 47% selected “Planar” as one of the descriptors. 54% of respondents selected one damage type, 32% chose multiple descriptors, and 13% selected “Other” as their only choice; therefore, 68% of respondents only selected 1 choice. It is possible that some respondents did not understand multiple boxes could be checked. A whopping 14% of respondents described the bullet as “damaged”.

- Bullet 5: Accounting for those who typed in the "Other" field, 42% selected "Scored", 10% selected "Fragmented, 48% selected "Fractured", 58% selected "Flattened" and 39% selected "Planar" as one of the descriptors. Again, 14% described the bullet as "Damaged".
- Bullet 6: Accounting for those who typed "Flattened" in the "Other" field, 56.6% of respondents would have selected "Flattened" as one of the descriptors.
- Bullet 7: Accounting for those who typed in the "Other" field, 31% selected "Scored", 46% selected "Fragmented, 37% selected "Fractured", 50% selected "Flattened" and 23% selected "Planar" as one of the descriptors. 8% of respondents described the bullet as "Damaged" and 14.5% described it as "Deformed".
- Bullet 8: Accounting for those who typed "Mushroomed" in the "Other" field, 82% of respondents would have selected "Planar/Mushroomed" as one of the descriptors.
- Bullet 9: Accounting for those who typed "Mushroomed" in the "Other" field, 61% of respondents would have selected "Planar/Mushroomed" as one of the descriptors. One respondent described it as "Bent".
- Bullet 10: Accounting for those who typed "Flattened" in the "Other" field, 69% of respondents would have selected "Flattened" as one of the descriptors. One respondent described it as having a "Tangential impact".
- Bullet 11: 54% of respondents describe this bullet as "Fragmented" and 21% requested a closer inspection.
- Bullet 12: 55% of respondents describe this bullet as "Scored". Accounting for those who typed "jacket separation" in the "Other" field, 55% of respondents would have

selected “Fractured” as one of the descriptors. Again, 15% of respondents described the bullet as “Damaged”.

- Bullet 13: 84% of respondents described this bullet as being “Pristine”.
- Bullet 14: 55% of respondents described this bullet as being “Scored” while 75% of respondents described this bullet as being “Flattened”.
- Bullet 15: 81% of respondents describe this bullet as “Flattened”.

CHAPTER 5: DISCUSSION

Introduction

The purpose of this study was to create a classification system for basal deformation. To begin, damage was created on the basal portion of different types of bullets using varying targets. The data obtained from this research may allow examiners to have a reference regarding what damage could be incurred upon bullets, of differing calibers and metal composition, when each bullet hits specific surfaces of differing resistance and texture. The proposed nomenclature allows examiners to expand their terminology and facilitate productive discussion.

Discussion of Findings

Examiners look at the critical features of a bullet; including the ogive, bearing surface, and the base to make the determination if they believe that class, subclass, or individual characteristics exist on the item of evidence. It is difficult to gather conclusions about evidence prior to having performed any testing or firing. Based on research and personal experience with damaged projectiles, the following categories may be used as nomenclature for base deformation of bullets:

- <u>Abraded</u> – A projectile that has been defaced (the surface has been marred, scraped or scored)
- <u>Sheared</u> – The projectile has fragmented and completely broken into two or more pieces (does not refer to complete jacket separation).
- <u>Torn</u> – The projectile has parts that have broken and fractured, but have not yet separated from the other parts (this includes cracking, splitting, and partial core/jacket impact separation).

- Full core/jacket separation – Refers to jacketed projectiles that have had their jacket completely separated from the inner core.
- Flattened – A portion of the projectile has been flatted or squeezed inwards (this includes kidney bean shaped and pancaked).

Implications of the Limitations on Present and Future Research

If this study were to have unlimited funding and time, the researcher would be inclined to examine every firearm type, firearm manufacturer, firearm, caliber, ammunition manufacturer, grain, cartridge type, firing type, target medium, angle, distance, and atmospheric condition, along with other variables. Even with these assets, the researcher would not be able to recreate every deformation or damage that could ever be caused to a bullet for such an expansive and expensive study.

Recommendations for Future Research

Test with different distances (closer and further), different calibers (rifle, revolver, and possibly machine gun), different types of ammunition (such as hollow point and frangible ammunition), and more mediums (softer mediums like tissue or harder ones like bone).

Practical Application of Results

At the conclusion of this study, examiners will have an open dialogue to discuss the future of the Firearm and Tool Mark field. If they are able to come to a similar consensus regarding basal deformation nomenclature, manual and automatic bullet image acquisition and analyzation will be enhanced and modernized.

Conclusion

A standardized nomenclature for specific types of damage will make examiners more comfortable with the items of evidence they are examining and with this knowledge, the examiners have an opportunity to have more confidence in the decision whether or not to accept and analyze items of evidence that have basal damage.

Currently, examiners are hesitant to use specified definitions in their casework. They prefer to describe basal damage using broad words like “deformation” and “damage” and acquire pictures for any additional detail. Their apparent apprehension towards change may actually be an indicator of the true fear regarding their certifications, testimony, and reputation.

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APPENDICES

Appendix A: Survey

UCO Bullet Survey 2014

Introduction

The Forensic Science Institute at University of Central Oklahoma is conducting a study on types of damage commonly seen on bullet surfaces and how that damage affects the identification and analysis of the bullets.

This research study is designed to create a methodology to classify the level of deformation to the bullet base (basal damage) on sample bullets. The survey should take about 20 minutes to complete and will run until March 15. There will be no compensation or direct benefit to completing the survey.

You will be asked a series of questions regarding bullet deformation and will be shown embedded .mp4 videos of damaged bullets. If you are unable to view them, please email the researchers for assistance.

All information given is optional and any personal information given will be kept confidential. Please email the researchers (UCOBulletStudy@gmail.com) or contact the UCO IRB (irb@uco.edu or (405-974-5497) with any questions or concerns.

* 1. By completing the test, you are consenting to be a part of this study and allowing the researchers to utilize data regarding your test.

○ I consent.

○ I decline.

* 2. What type of bullets do you examine?

☐ Pristine

☐ Damaged

☐ Other (please specify)

* 3. What bullet types do you typically examine?

- ☐ Jacketed Hollow Point (JHP)
- ☐ Full Metal Jacket (FMJ)
- ☐ Metal Case (MC)
- ☐ Hollow Point (HP)
- ☐ Total Metal Jacket or Encased-Core Full Jacket (TMJ)
- ☐ Wad Cutter (WC)
- ☐ Wide Flat Nose (WFN)
- ☐ Semi Wad Cutter (SWC)
- ☐ Enclosed Metal Jacket (EMJ)
- ☐ Lead Round Nose (LRN)
- ☐ Soft Point (SP)
- ☐ Flat Nosed (FN)
- ☐ Boat Tail (BT)
- ☐ Full Metal Spitz (FMS)
- ☐ Other (please specify)

* 4. Where do the bullets you examine originate from?

- ☐ Autopsy
- ☐ Crime Scene
- ☐ Found
- ☐ Testfires
- ☐ Other (please specify)

* 5. How often are bullets, recovered from bodies, sent in from the medical examiner's office?

	Never	Rarely	Sometimes	Often
Frequency	○	○	○	○

Other (please specify)

* 6. Do you examine bullets with basal damage (partial or whole deformation to the bullet base)?

- ○ Yes
- ○ No

Other (please specify)

UCO Bullet Survey 2014

The following definitions have been created for bullets with basal deformation.

1) Scored – A projectile that has been defaced (the surface has been marred)

2) Fragmented – The projectile has completely broken into two or more pieces (does not refer to jacket separation).

3) Fractured – The projectile has parts that have broken, but have not yet separated from the other parts (this may refer to partial core/jacket impact separation)

4) Full core/jacket impact separation – Refers to jacketed projectiles that have had their core completely separated from the inner core

5) Flattened – A portion of the projectile has been flatted or squeezed inwards (this may refer to kidney shaped where the projectile has bent or twisted and the shape of the base is similar to a kidney bean)

6) Planar – The projectile has impacted the surface so that the bearing surface, or petals, have bent back towards the base of the projectile (this may refer to the mushroom shape)

* 7. How accurate is the definition for Scored?

	Very Inaccurate	Somewhat Accurate	Very Accurate
Accuracy	○	○	○

Other (please specify)

* 8. How accurate is the definition for Fragmented?

	Very Inaccurate	Somewhat Accurate	Very Accurate
Accuracy	○	○	○

Other (please specify)

* 9. How accurate is the definition for Fractured?

	Very Inaccurate	Somewhat Accurate	Very Accurate
Accuracy	○	○	○

Other (please specify)

* 10. How accurate is the definition for Full core/jacket impact separation?

	Very Inaccurate	Somewhat Accurate	Very Accurate
Accuracy	○	○	○

Other (please specify)

* 11. How accurate is the definition for Flattened?

	Very Inaccurate	Somewhat Accurate	Very Accurate
Accuracy	○	○	○

Other (please specify)

* 12. How accurate is the definition for Planar?

	Very Inaccurate	Somewhat Accurate	Very Accurate
Accuracy	○	○	○

Other (please specify)

* 13. Are you aware of any other bullet type with basal damage that has not been described here?

○ No

○ Yes (please specify)

UCO Bullet Survey 2014

The following pages depict images of fired bullets. There will be embedded .mp4 videos. If you are unable to view the embedded videos or the Youtube.com videos, please email the researchers at UCOBulletStudy@gmail.com for assistance.

Please select the descriptions you would use to categorize the bullet. Please click next to continue.

UCO Bullet Survey 2014

<embed src="https://s3.amazonaws.com/UCOBulletSurvey2014/Q01.mp4" width="480" height="285" autoplay="false" controller="true" cache="true" loop="true" bgcolor="#000000" pluginspage="http://www.apple.com/quicktime/download/"></embed>

http://www.youtube.com/watch?v=3xud5uNjiCE

* 14. What description(s) would you use to categorize the bullet?

☐ Pristine

☐ Scored – A projectile that has been defaced (the surface has been marred)

☐ Fragmented – The projectile has completely broken into two or more pieces (does not refer to jacket separation).

☐ Fractured – The projectile has parts that have broken, but have not yet separated from the other parts (this may refer to partial core/jacket impact separation)

☐ Full core/jacket impact separation – Refers to jacketed projectiles that have had their core completely separated from the inner core

☐ Flattened – A portion of the projectile has been flatted or squeezed inwards (this may refer to kidney shaped where the projectile has bent or twisted and the shape of the base is similar to a kidney bean)

☐ Planar – The projectile has impacted the surface so that the bearing surface, or petals, have bent back towards the base of the projectile (this may refer to the mushroom shape)

☐ Other (please specify)

* 15. Would you examine this item of evidence?

○ Yes

○ No (please elaborate)

* 16. What description(s) would you use to categorize the bullet?

☐ Pristine

☐ Scored – A projectile that has been defaced (the surface has been marred)

☐ Fragmented – The projectile has completely broken into two or more pieces (does not refer to jacket separation).

☐ Fractured – The projectile has parts that have broken, but have not yet separated from the other parts (this may refer to partial core/jacket impact separation)

☐ Full core/jacket impact separation – Refers to jacketed projectiles that have had their core completely separated from the inner core

☐ Flattened – A portion of the projectile has been flatted or squeezed inwards (this may refer to kidney shaped where the projectile has bent or twisted and the shape of the base is similar to a kidney bean)

☐ Planar – The projectile has impacted the surface so that the bearing surface, or petals, have bent back towards the base of the projectile (this may refer to the mushroom shape)

☐ Other (please specify)

* 17. Would you examine this item of evidence?

○ Yes

○ No (please elaborate)

* 18. What description(s) would you use to categorize the bullet?

☐ Pristine

☐ Scored – A projectile that has been defaced (the surface has been marred)

☐ Fragmented – The projectile has completely broken into two or more pieces (does not refer to jacket separation).

☐ Fractured – The projectile has parts that have broken, but have not yet separated from the other parts (this may refer to partial core/jacket impact separation)

☐ Full core/jacket impact separation – Refers to jacketed projectiles that have had their core completely separated from the inner core

☐ Flattened – A portion of the projectile has been flatted or squeezed inwards (this may refer to kidney shaped where the projectile has bent or twisted and the shape of the base is similar to a kidney bean)

☐ Planar – The projectile has impacted the surface so that the bearing surface, or petals, have bent back towards the base of the projectile (this may refer to the mushroom shape)

☐ Other (please specify)

* 19. Would you examine this item of evidence?

○ Yes

○ No (please elaborate)

* 20. What description(s) would you use to categorize the bullet?

☐ Pristine

☐ Scored – A projectile that has been defaced (the surface has been marred)

☐ Fragmented – The projectile has completely broken into two or more pieces (does not refer to jacket separation).

☐ Fractured – The projectile has parts that have broken, but have not yet separated from the other parts (this may refer to partial core/jacket impact separation)

☐ Full core/jacket impact separation – Refers to jacketed projectiles that have had their core completely separated from the inner core

☐ Flattened – A portion of the projectile has been flatted or squeezed inwards (this may refer to kidney shaped where the projectile has bent or twisted and the shape of the base is similar to a kidney bean)

☐ Planar – The projectile has impacted the surface so that the bearing surface, or petals, have bent back towards the base of the projectile (this may refer to the mushroom shape)

☐ Other (please specify)

* 21. Would you examine this item of evidence?

○ Yes

○ No (please elaborate)

* 22. What description(s) would you use to categorize the bullet?

☐ Pristine

☐ Scored – A projectile that has been defaced (the surface has been marred)

☐ Fragmented – The projectile has completely broken into two or more pieces (does not refer to jacket separation).

☐ Fractured – The projectile has parts that have broken, but have not yet separated from the other parts (this may refer to partial core/jacket impact separation)

☐ Full core/jacket impact separation – Refers to jacketed projectiles that have had their core completely separated from the inner core

☐ Flattened – A portion of the projectile has been flatted or squeezed inwards (this may refer to kidney shaped where the projectile has bent or twisted and the shape of the base is similar to a kidney bean)

☐ Planar – The projectile has impacted the surface so that the bearing surface, or petals, have bent back towards the base of the projectile (this may refer to the mushroom shape)

☐ Other (please specify)

* 23. Would you examine this item of evidence?

○ Yes

○ No (please elaborate)

* 24. What description(s) would you use to categorize the bullet?

☐ Pristine

☐ Scored – A projectile that has been defaced (the surface has been marred)

☐ Fragmented – The projectile has completely broken into two or more pieces (does not refer to jacket separation).

☐ Fractured – The projectile has parts that have broken, but have not yet separated from the other parts (this may refer to partial core/jacket impact separation)

☐ Full core/jacket impact separation – Refers to jacketed projectiles that have had their core completely separated from the inner core

☐ Flattened – A portion of the projectile has been flatted or squeezed inwards (this may refer to kidney shaped where the projectile has bent or twisted and the shape of the base is similar to a kidney bean)

☐ Planar – The projectile has impacted the surface so that the bearing surface, or petals, have bent back towards the base of the projectile (this may refer to the mushroom shape)

☐ Other (please specify)

* 25. Would you examine this item of evidence?

○ Yes

○ No (please elaborate)

* 26. What description(s) would you use to categorize the bullet?

☐ Pristine

☐ Scored – A projectile that has been defaced (the surface has been marred)

☐ Fragmented – The projectile has completely broken into two or more pieces (does not refer to jacket separation).

☐ Fractured – The projectile has parts that have broken, but have not yet separated from the other parts (this may refer to partial core/jacket impact separation)

☐ Full core/jacket impact separation – Refers to jacketed projectiles that have had their core completely separated from the inner core

☐ Flattened – A portion of the projectile has been flatted or squeezed inwards (this may refer to kidney shaped where the projectile has bent or twisted and the shape of the base is similar to a kidney bean)

☐ Planar – The projectile has impacted the surface so that the bearing surface, or petals, have bent back towards the base of the projectile (this may refer to the mushroom shape)

☐ Other (please specify)

* 27. Would you examine this item of evidence?

○ Yes

○ No (please elaborate)

* 28. What description(s) would you use to categorize the bullet?

☐ Pristine

☐ Scored – A projectile that has been defaced (the surface has been marred)

☐ Fragmented – The projectile has completely broken into two or more pieces (does not refer to jacket separation).

☐ Fractured – The projectile has parts that have broken, but have not yet separated from the other parts (this may refer to partial core/jacket impact separation)

☐ Full core/jacket impact separation – Refers to jacketed projectiles that have had their core completely separated from the inner core

☐ Flattened – A portion of the projectile has been flatted or squeezed inwards (this may refer to kidney shaped where the projectile has bent or twisted and the shape of the base is similar to a kidney bean)

☐ Planar – The projectile has impacted the surface so that the bearing surface, or petals, have bent back towards the base of the projectile (this may refer to the mushroom shape)

☐ Other (please specify)

* 29. Would you examine this item of evidence?

○ Yes

○ No (please elaborate)

* 30. What description(s) would you use to categorize the bullet?

☐ Pristine

☐ Scored – A projectile that has been defaced (the surface has been marred)

☐ Fragmented – The projectile has completely broken into two or more pieces (does not refer to jacket separation).

☐ Fractured – The projectile has parts that have broken, but have not yet separated from the other parts (this may refer to partial core/jacket impact separation)

☐ Full core/jacket impact separation – Refers to jacketed projectiles that have had their core completely separated from the inner core

☐ Flattened – A portion of the projectile has been flatted or squeezed inwards (this may refer to kidney shaped where the projectile has bent or twisted and the shape of the base is similar to a kidney bean)

☐ Planar – The projectile has impacted the surface so that the bearing surface, or petals, have bent back towards the base of the projectile (this may refer to the mushroom shape)

☐ Other (please specify)

* 31. Would you examine this item of evidence?

○ Yes

○ No (please elaborate)

* 32. What description(s) would you use to categorize the bullet?

☐ Pristine

☐ Scored – A projectile that has been defaced (the surface has been marred)

☐ Fragmented – The projectile has completely broken into two or more pieces (does not refer to jacket separation).

☐ Fractured – The projectile has parts that have broken, but have not yet separated from the other parts (this may refer to partial core/jacket impact separation)

☐ Full core/jacket impact separation – Refers to jacketed projectiles that have had their core completely separated from the inner core

☐ Flattened – A portion of the projectile has been flatted or squeezed inwards (this may refer to kidney shaped where the projectile has bent or twisted and the shape of the base is similar to a kidney bean)

☐ Planar – The projectile has impacted the surface so that the bearing surface, or petals, have bent back towards the base of the projectile (this may refer to the mushroom shape)

☐ Other (please specify)

* 33. Would you examine this item of evidence?

○ Yes

○ No (please elaborate)

* 34. What description(s) would you use to categorize the bullet?

☐ Pristine

☐ Scored – A projectile that has been defaced (the surface has been marred)

☐ Fragmented – The projectile has completely broken into two or more pieces (does not refer to jacket separation).

☐ Fractured – The projectile has parts that have broken, but have not yet separated from the other parts (this may refer to partial core/jacket impact separation)

☐ Full core/jacket impact separation – Refers to jacketed projectiles that have had their core completely separated from the inner core

☐ Flattened – A portion of the projectile has been flatted or squeezed inwards (this may refer to kidney shaped where the projectile has bent or twisted and the shape of the base is similar to a kidney bean)

☐ Planar – The projectile has impacted the surface so that the bearing surface, or petals, have bent back towards the base of the projectile (this may refer to the mushroom shape)

☐ Other (please specify)

* 35. Would you examine this item of evidence?

○ Yes

○ No (please elaborate)

* 36. What description(s) would you use to categorize the bullet?

☐ Pristine

☐ Scored – A projectile that has been defaced (the surface has been marred)

☐ Fragmented – The projectile has completely broken into two or more pieces (does not refer to jacket separation).

☐ Fractured – The projectile has parts that have broken, but have not yet separated from the other parts (this may refer to partial core/jacket impact separation)

☐ Full core/jacket impact separation – Refers to jacketed projectiles that have had their core completely separated from the inner core

☐ Flattened – A portion of the projectile has been flatted or squeezed inwards (this may refer to kidney shaped where the projectile has bent or twisted and the shape of the base is similar to a kidney bean)

☐ Planar – The projectile has impacted the surface so that the bearing surface, or petals, have bent back towards the base of the projectile (this may refer to the mushroom shape)

☐ Other (please specify)

* 37. Would you examine this item of evidence?

○ Yes

○ No (please elaborate)

* 38. What description(s) would you use to categorize the bullet?

☐ Pristine

☐ Scored – A projectile that has been defaced (the surface has been marred)

☐ Fragmented – The projectile has completely broken into two or more pieces (does not refer to jacket separation).

☐ Fractured – The projectile has parts that have broken, but have not yet separated from the other parts (this may refer to partial core/jacket impact separation)

☐ Full core/jacket impact separation – Refers to jacketed projectiles that have had their core completely separated from the inner core

☐ Flattened – A portion of the projectile has been flatted or squeezed inwards (this may refer to kidney shaped where the projectile has bent or twisted and the shape of the base is similar to a kidney bean)

☐ Planar – The projectile has impacted the surface so that the bearing surface, or petals, have bent back towards the base of the projectile (this may refer to the mushroom shape)

☐ Other (please specify)

* 39. Would you examine this item of evidence?

○ Yes

○ No (please elaborate)

*** 40. What description(s) would you use to categorize the bullet?**

- ☐ Pristine
- ☐ Scored – A projectile that has been defaced (the surface has been marred)
- ☐ Fragmented – The projectile has completely broken into two or more pieces (does not refer to jacket separation).
- ☐ Fractured – The projectile has parts that have broken, but have not yet separated from the other parts (this may refer to partial core/jacket impact separation)
- ☐ Full core/jacket impact separation – Refers to jacketed projectiles that have had their core completely separated from the inner core
- ☐ Flattened – A portion of the projectile has been flatted or squeezed inwards (this may refer to kidney shaped where the projectile has bent or twisted and the shape of the base is similar to a kidney bean)
- ☐ Planar – The projectile has impacted the surface so that the bearing surface, or petals, have bent back towards the base of the projectile (this may refer to the mushroom shape)
- ☐ Other (please specify)

*** 41. Would you examine this item of evidence?**

- ○ Yes
- ○ No (please elaborate)

* 42. What description(s) would you use to categorize the bullet?

- ☐ Pristine
- ☐ Scored – A projectile that has been defaced (the surface has been marred)
- ☐ Fragmented – The projectile has completely broken into two or more pieces (does not refer to jacket separation).
- ☐ Fractured – The projectile has parts that have broken, but have not yet separated from the other parts (this may refer to partial core/jacket impact separation)
- ☐ Full core/jacket impact separation – Refers to jacketed projectiles that have had their core completely separated from the inner core
- ☐ Flattened – A portion of the projectile has been flatted or squeezed inwards (this may refer to kidney shaped where the projectile has bent or twisted and the shape of the base is similar to a kidney bean)
- ☐ Planar – The projectile has impacted the surface so that the bearing surface, or petals, have bent back towards the base of the projectile (this may refer to the mushroom shape)
- ☐ Other (please specify)

* 43. Would you examine this item of evidence?

- ○ Yes
- ○ No (please elaborate)

44. How long have you been a Firearms and Toolmark Examiner?

- ○ Less than 1 year
- ○ 1-3 years
- ○ 3-5 years
- ○ 5-10 years
- ○ 10-20 years
- ○ More than 20 years

N/A (please specify title/job fuction)

45. Is your organization public or private?

- ○ Public
- ○ Private

46. If you would like to be contacted with the results of this survey, please include your information below. Please be advised that any confidential information will be maintained and will not be distributed nor listed in the results of this research.

Each field in this section is optional.

Name:

Agency:

City/Town:

State: -- select state --

Country:

Email Address:

Phone Number:

47. Do you have any suggestions for this survey or for future surveys?

If you have any questions or concerns, please contact the researchers at UCOBulletSurvey@gmail.com or the UCO IRB at irb@uco.edu or (405) 974-5497 with questions about research participation.

Appendix B: Recruitment Announcements and Consent Form

Dear AFTE Members,

This is an invitation for participation in a new research study. The Forensic Science Institute at University of Central Oklahoma is conducting a study on types of damage commonly seen on bullet surfaces and how that damage affects the identification and analysis of the bullets.

This research study is designed to create a methodology to classify the level of deformation to the bullet base (basal damage) on sample bullets. The survey should take about 20 minutes to complete and will run until March 15. If you would like to participate, please proceed to the following link: www.surveymonkey.com/s/UCOBulletSurvey

All information given is optional and individual responses will be kept confidential. By completing the survey, you are consenting to be a part of this study and allowing the researchers to utilize data for analysis. Please email the researchers with any questions or concerns.

Thank you for your time,

Thao Warme and Deion Christophe
UCOBulletSurvey@gmail.com
dchristophe@uco.edu

SurveyMonkey, Inc [US] https://www.surveymonkey.com/r/?sm=sqsAk4OEyT2alEm4oORGNC

UNIVERSITY OF CENTRAL OKLAHOMA
Forensic Science Institute

UCO Bullet Survey 2014

Introduction

The Forensic Science Institute at University of Central Oklahoma is conducting a study on types of damage commonly seen on bullet surfaces and how that damage affects the identification and analysis of the bullets.

This research study is designed to create a methodology to classify the level of deformation to the bullet base (basal damage) on sample bullets. The survey should take about 20 minutes to complete and will run until March 15. There will be no compensation or direct benefit to completing the survey.

You will be asked a series of questions regarding bullet deformation and will be shown embedded .mp4 videos of damaged bullets. If you are unable to view them, please email the researchers for assistance.

All information given is optional and any personal information given will be kept confidential. Please email the researchers (UCOBulletStudy@gmail.com) or contact the UCO IRB (irb@uco.edu or (405-974-5497) with any questions or concerns.

*** 1. By completing the test, you are consenting to be a part of this study and allowing the researchers to utilize data regarding your test.**

- ○ I consent.
- ○ I decline.

Appendix C: Institutional Review Board Approval Letter

February 4, 2014 IRB Application #: 14003

Proposal Title: The Classification and Analysis of Damaged Bullets

Type of Review: Initial-Expedited

Investigators:

Ms. Thao Phung Warme

Mr. Deion Christophe

Forensic Science Institute

Campus Box 203

University of Central Oklahoma

Edmond, OK 73034

Dear Ms. Warme and Mr. Christophe:

Re: Application for IRB Review of Research Involving Human Subjects

We have received your materials for your application. The UCO IRB has determined that the above named application is APPROVED BY EXPEDITED REVIEW. The Board has provided expedited review under 45 CFR 46.110, for research involving no more that minimal risk and research category 7.

Date of Approval: 2/4/2014

Date of Approval Expiration: 2/3/2015

If applicable, informed consent (and HIPAA authorization) must be obtained from subjects or their legally authorized representatives and documented prior to research involvement. A stamped, approved copy of the informed consent form will be sent to you via campus mail. The IRB-approved consent form and process must be used. While this project is approved for the period noted above, any modification to the procedures and/or consent form must be approved prior to incorporation into the study. A written request is needed to initiate the amendment process. You will be contacted in writing prior to the approval expiration to determine if a continuing review is needed, which must be obtained before the anniversary date. Notification of the completion of the project must be sent to the IRB office in writing and all records must be retained and available for audit for at least 3 years after the research has ended.

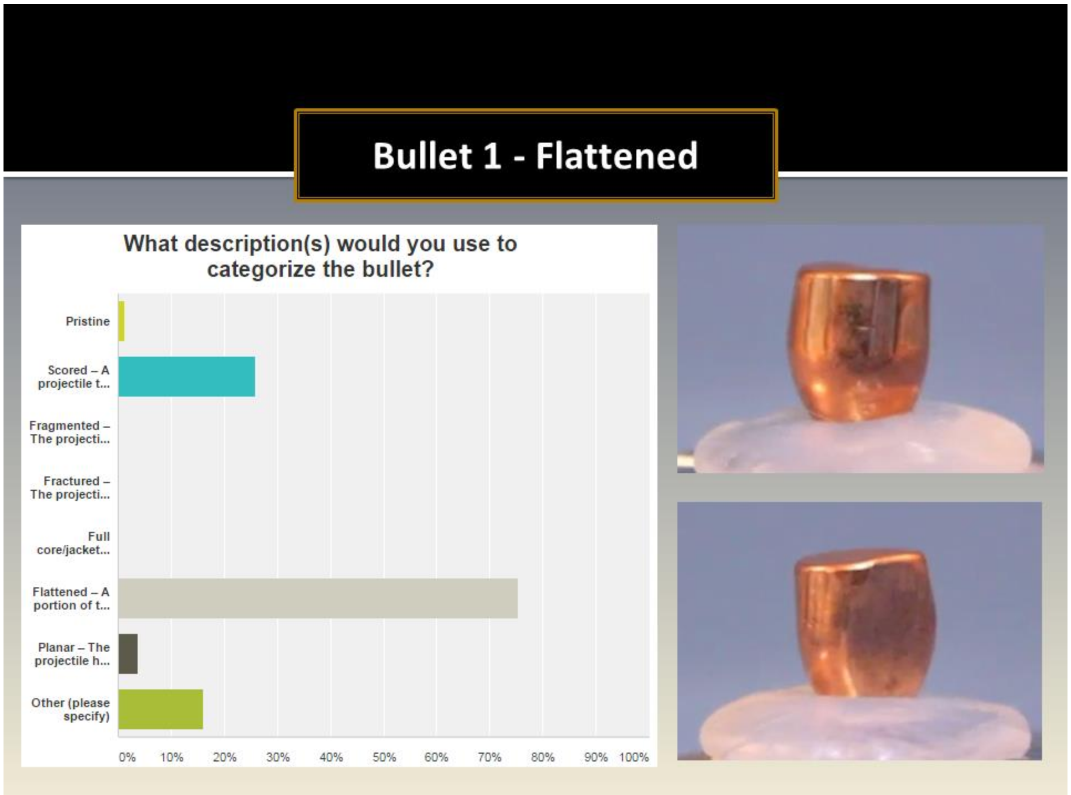
It is the responsibility of the investigators to promptly report to the IRB any serious or unexpected adverse events or unanticipated problems that may be a risk to the subjects.

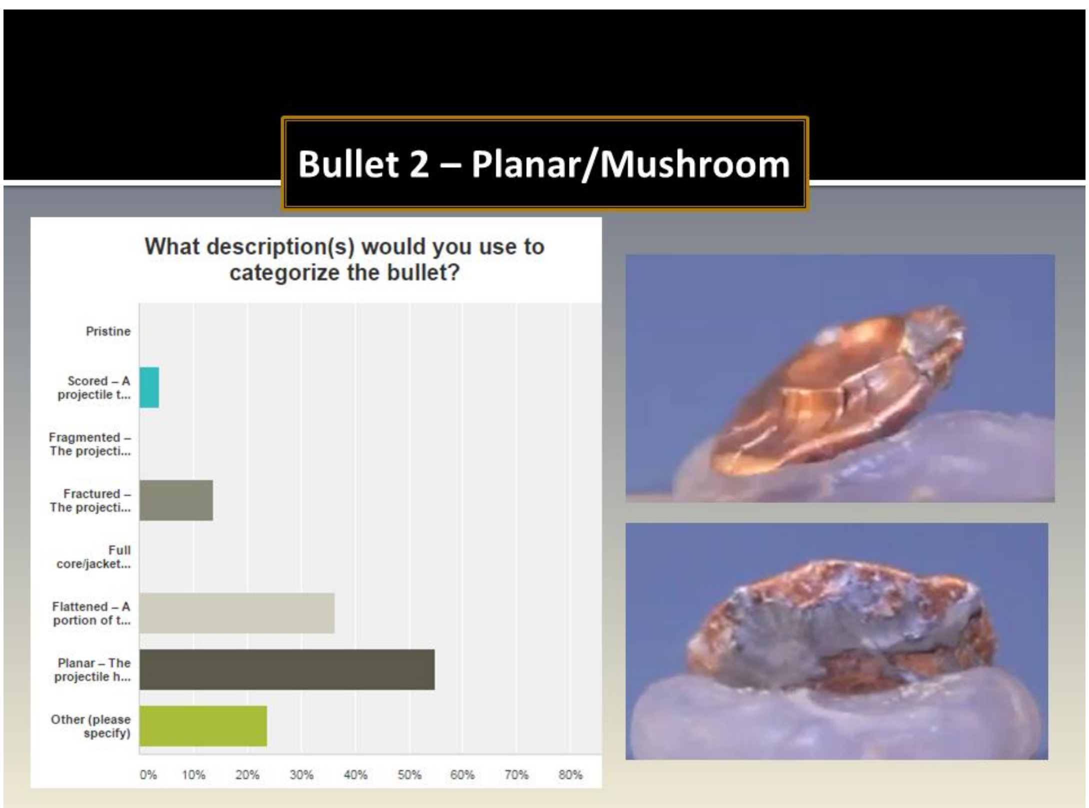
On behalf of the UCO IRB, I wish you the best of luck with your research project. If our office can be of any further assistance, please do not hesitate to contact us.

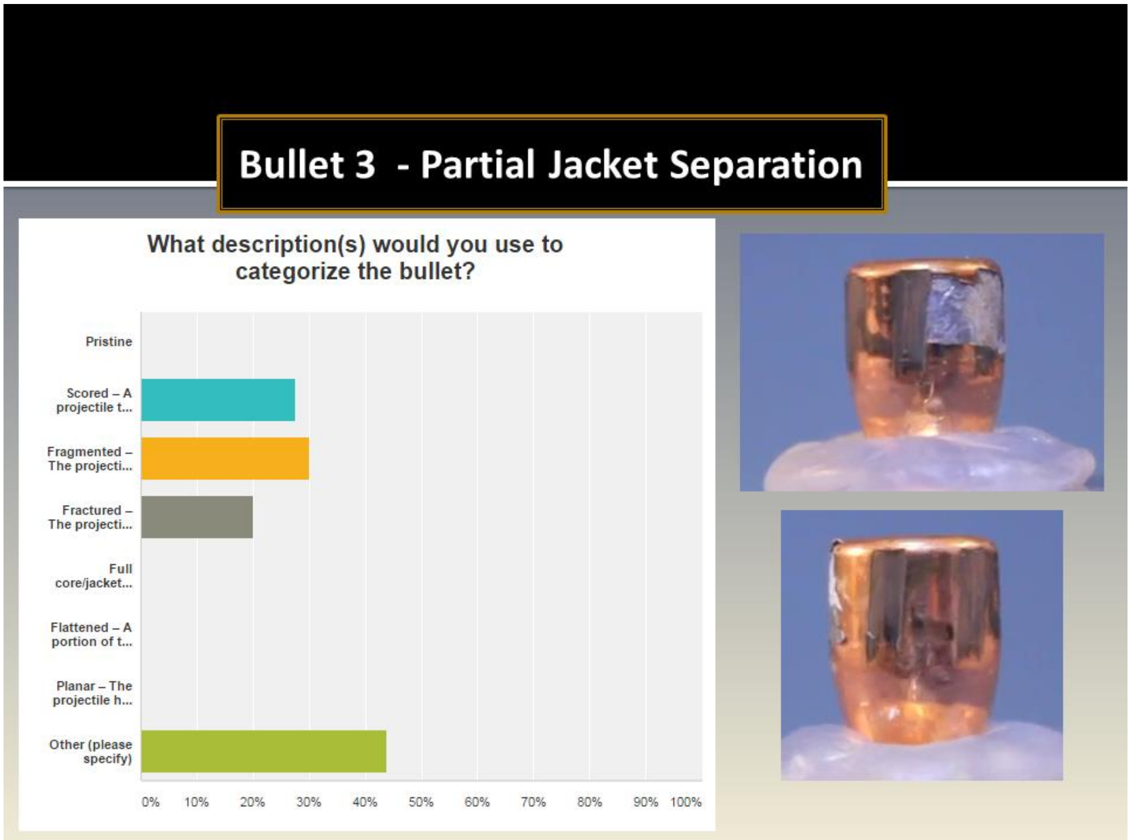
Sincerely,

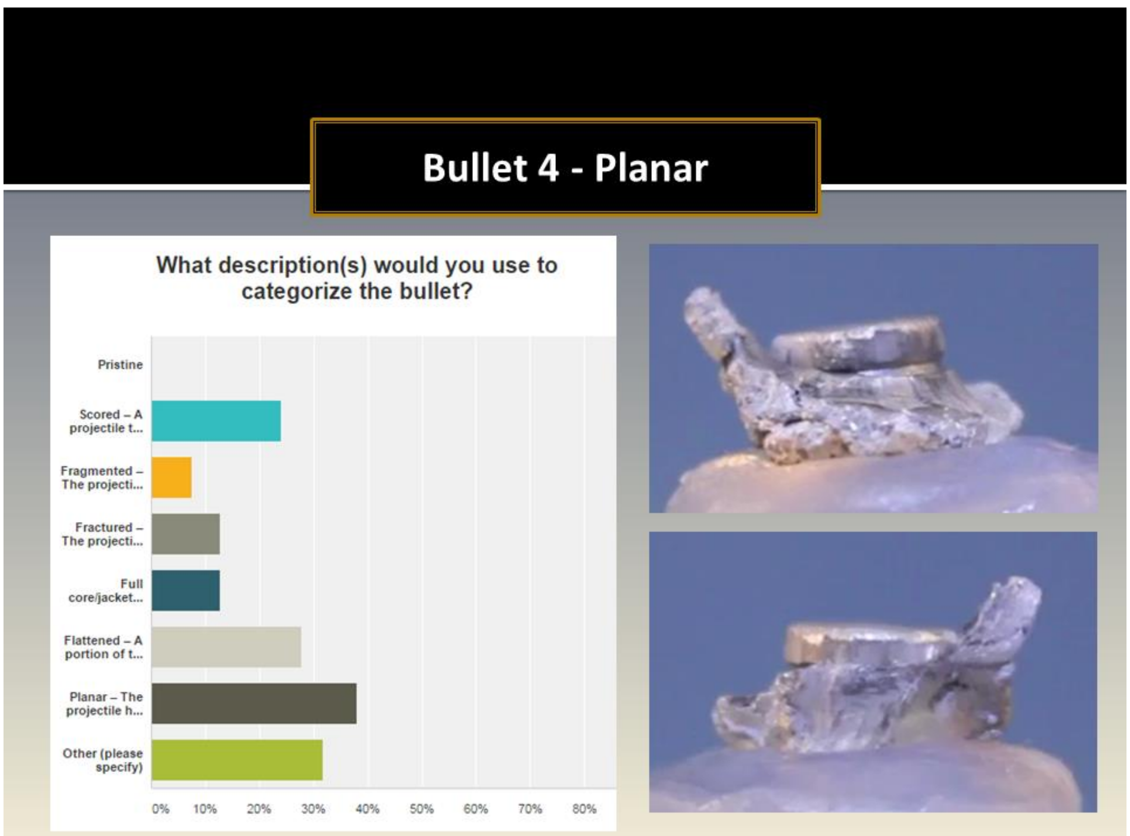
Jill A. Devenport, Ph.D.
Chair, Institutional Review Board
Director of Research Compliance
Campus Box 159
University of Central Oklahoma
Edmond, OK 73034
405-974-5479
jdevenport@uco.edu

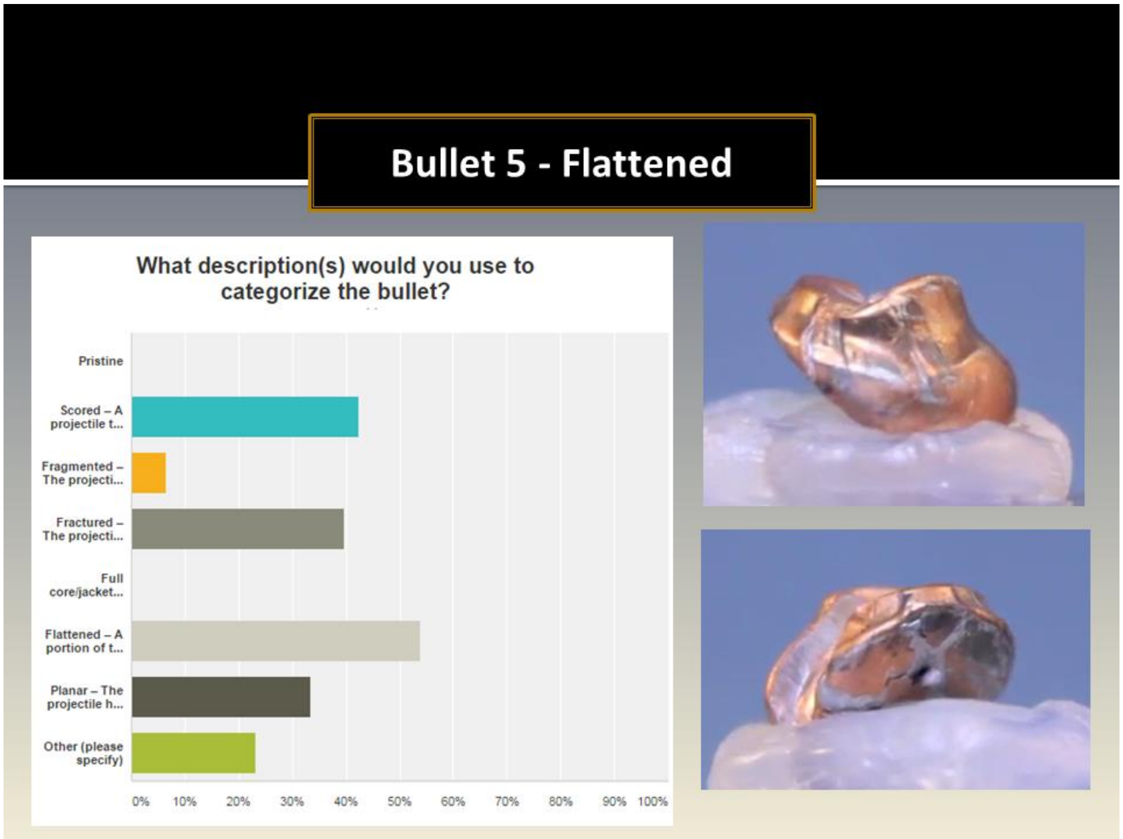
Appendix D: Classification Using the Given Nomenclature

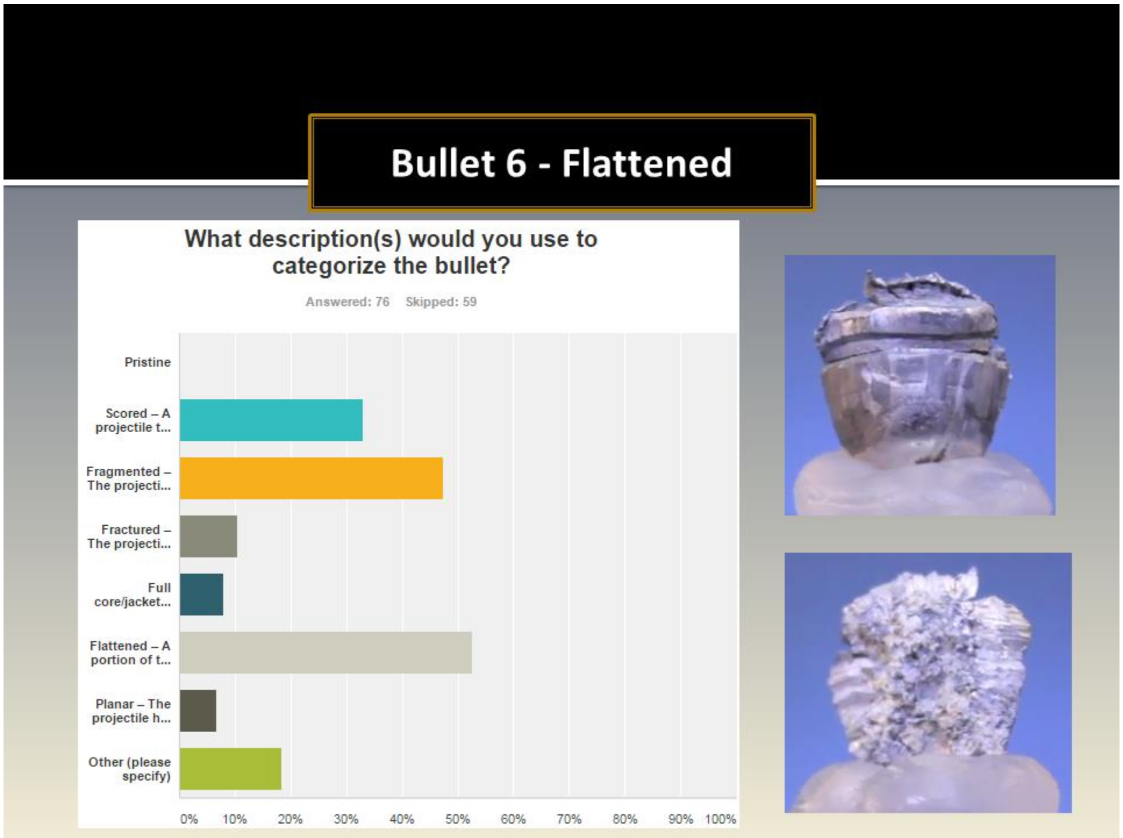


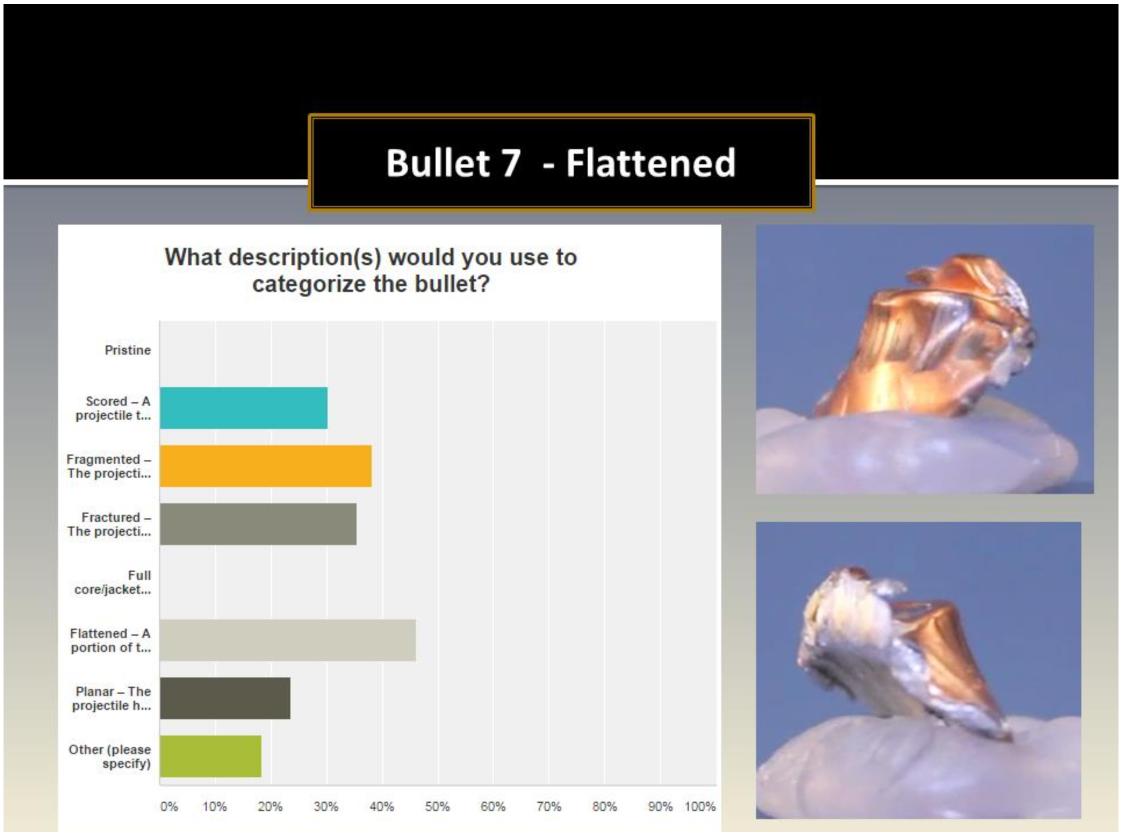


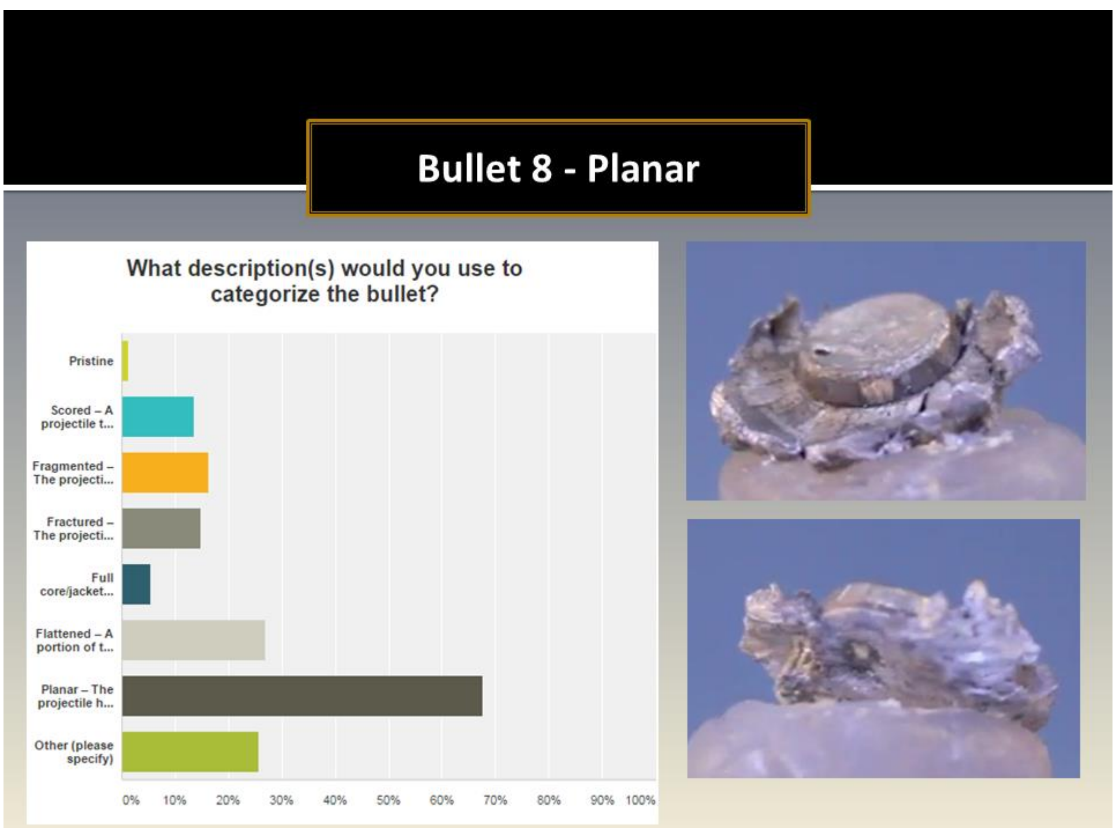

Bullet 3 - Partial Jacket Separation
What description(s) would you use to categorize the bullet?
Pristine
Scored – A projectile t...
Fragmented – The projecti...
Fractured – The projecti...
Full core/jacket...
Flattened – A portion of t...
Planar – The projectile h...
Other (please specify)
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

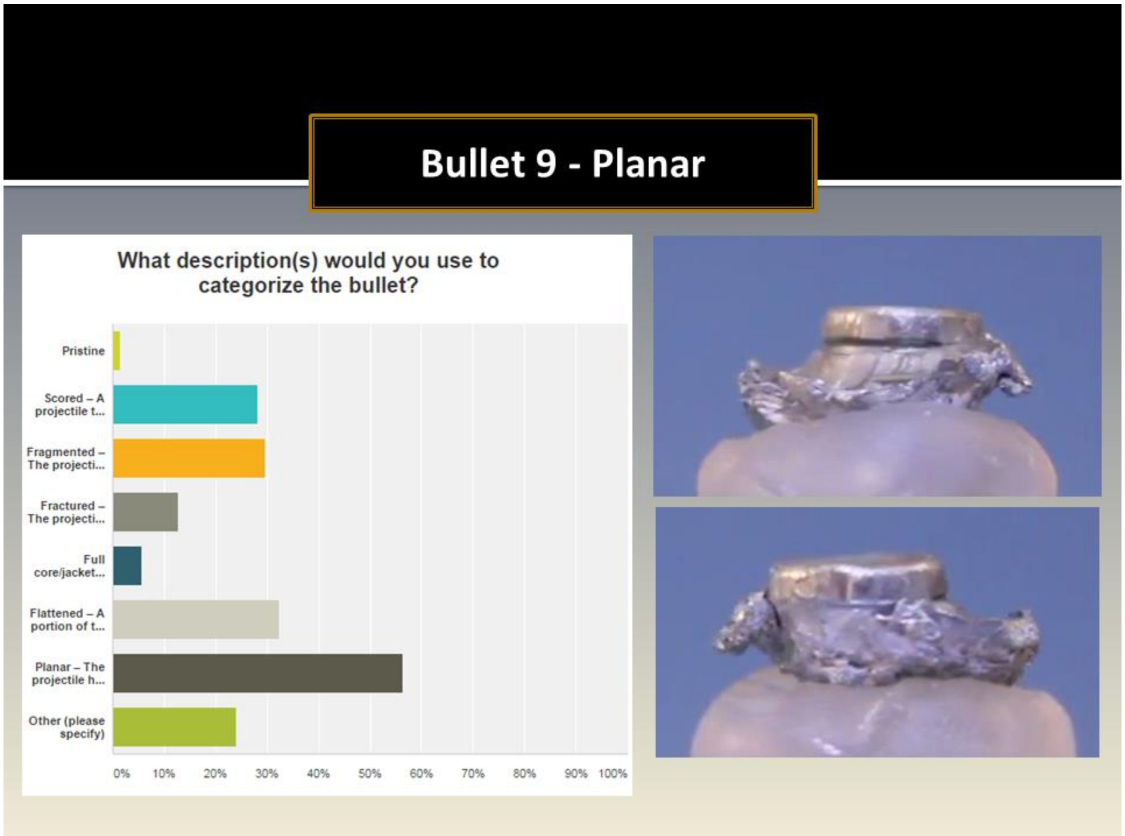

Bullet 4 - Planar
What description(s) would you use to categorize the bullet?
Pristine
Scored – A projectile t...
Fragmented – The projecti...
Fractured – The projecti...
Full core/jacket...
Flattened – A portion of t...
Planar – The projectile h...
Other (please specify)
0% 10% 20% 30% 40% 50% 60% 70% 80%

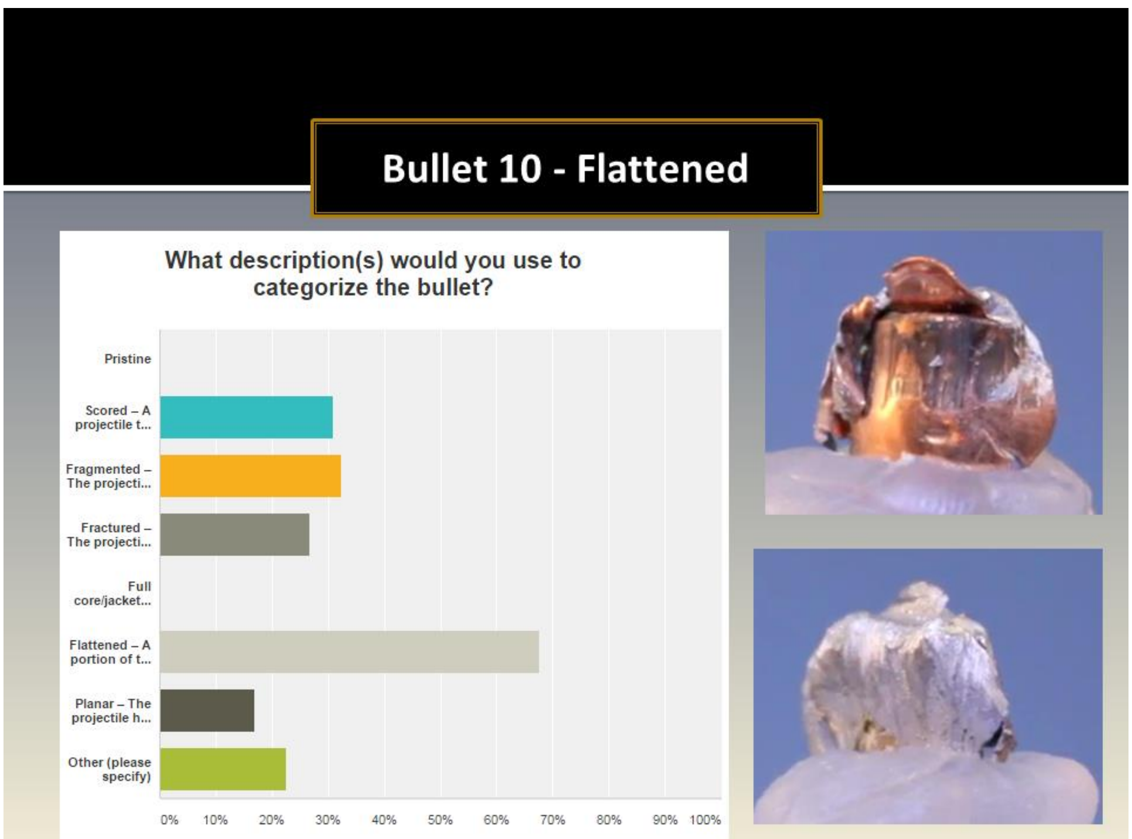

Bullet 5 - Flattened
What description(s) would you use to categorize the bullet?
Pristine
Scored – A projectile t...
Fragmented – The projecti...
Fractured – The projecti...
Full core/jacket...
Flattened – A portion of t...
Planar – The projectile h...
Other (please specify)
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

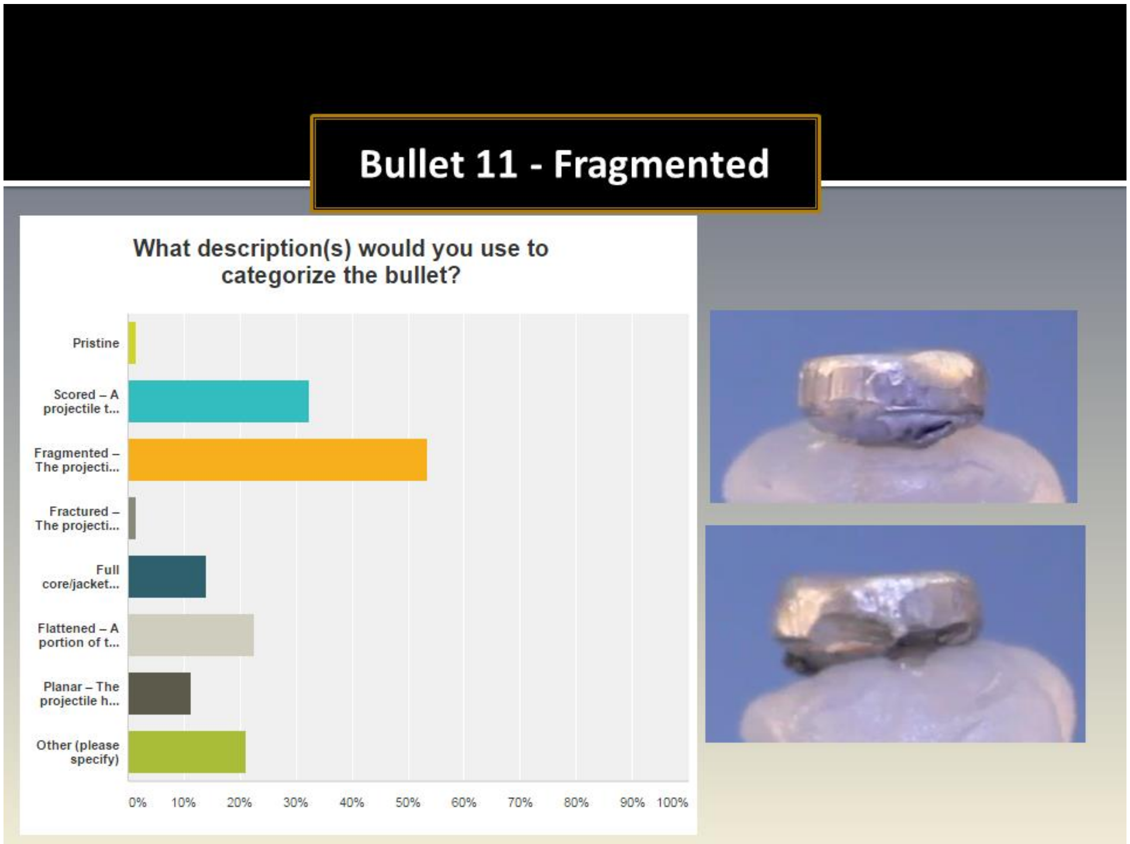

Bullet 6 - Flattened
What description(s) would you use to categorize the bullet?
Answered: 76 Skipped: 59
Pristine
Scored – A projectile t...
Fragmented – The projecti...
Fractured – The projecti...
Full core/jacket...
Flattened – A portion of t...
Planar – The projectile h...
Other (please specify)
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

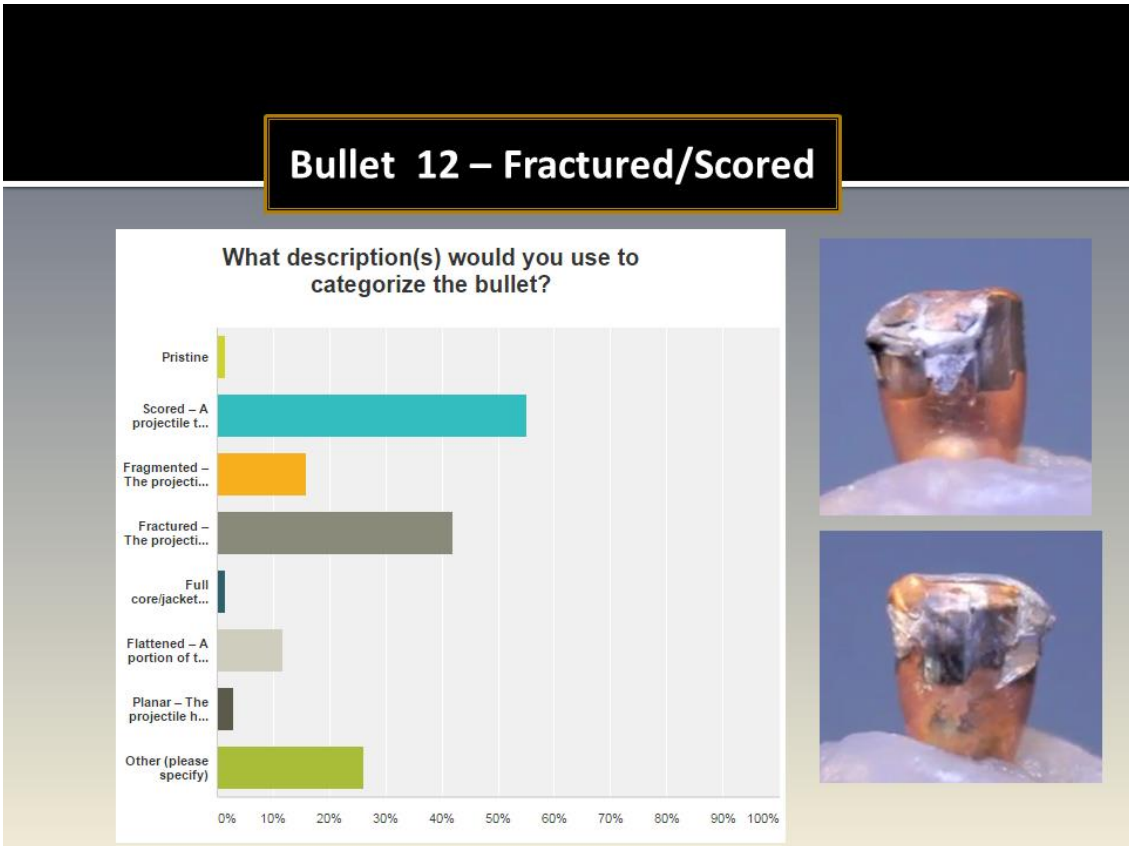

Bullet 7 - Flattened
What description(s) would you use to categorize the bullet?
Pristine
Scored – A projectile t...
Fragmented – The projecti...
Fractured – The projecti...
Full core/jacket...
Flattened – A portion of t...
Planar – The projectile h...
Other (please specify)
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

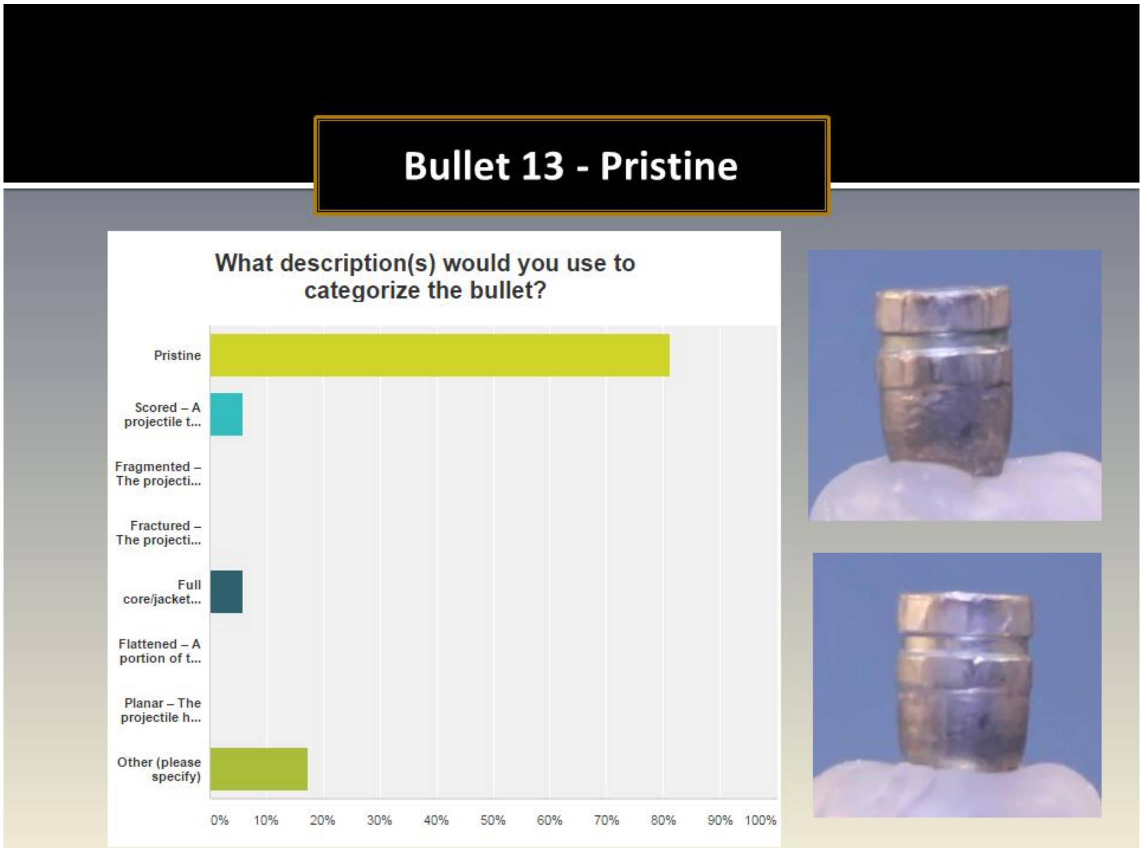

Bullet 8 - Planar
What description(s) would you use to categorize the bullet?
Pristine
Scored – A projectile t...
Fragmented – The projecti...
Fractured – The projecti...
Full core/jacket...
Flattened – A portion of t...
Planar – The projectile h...
Other (please specify)
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

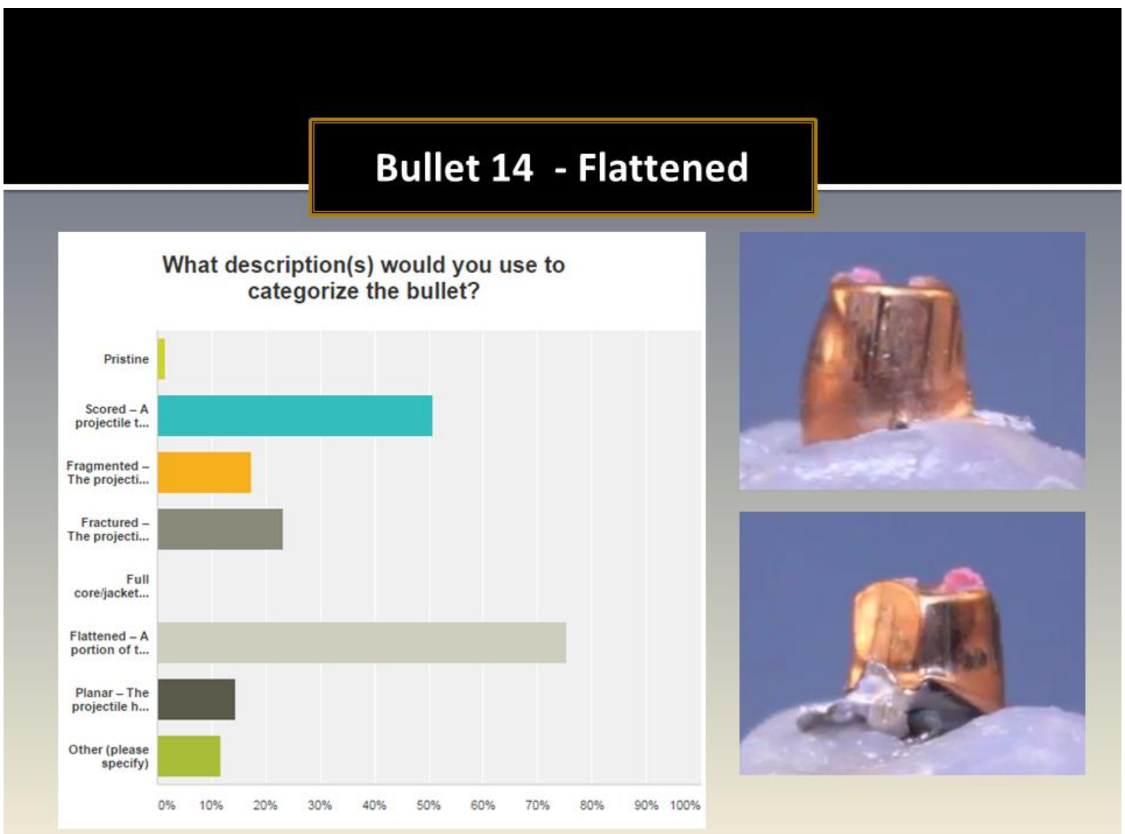

Bullet 9 - Planar
What description(s) would you use to categorize the bullet?
Pristine
Scored – A projectile t...
Fragmented – The projecti...
Fractured – The projecti...
Full core/jacket...
Flattened – A portion of t...
Planar – The projectile h...
Other (please specify)
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

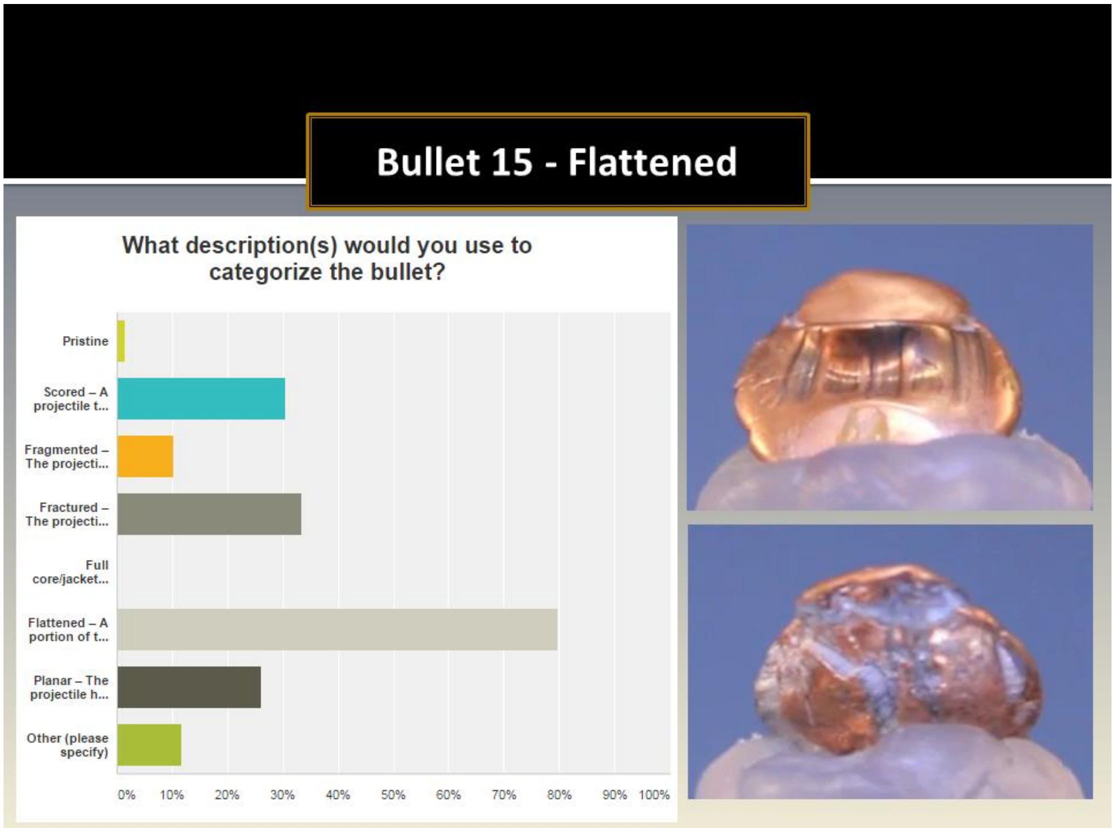

Bullet 10 - Flattened
What description(s) would you use to categorize the bullet?
Pristine
Scored – A projectile t...
Fragmented – The projecti...
Fractured – The projecti...
Full core/jacket...
Flattened – A portion of t...
Planar – The projectile h...
Other (please specify)
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%


Bullet 11 - Fragmented
What description(s) would you use to categorize the bullet?
Pristine
Scored – A projectile t...
Fragmented – The projecti...
Fractured – The projecti...
Full core/jacket...
Flattened – A portion of t...
Planar – The projectile h...
Other (please specify)
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%


Bullet 12 – Fractured/Scored
What description(s) would you use to categorize the bullet?
Pristine
Scored – A projectile t...
Fragmented – The projecti...
Fractured – The projecti...
Full core/jacket...
Flattened – A portion of t...
Planar – The projectile h...
Other (please specify)
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%


Bullet 13 - Pristine
What description(s) would you use to categorize the bullet?
Pristine
Scored – A projectile t...
Fragmented – The projecti...
Fractured – The projecti...
Full core/jacket...
Flattened – A portion of t...
Planar – The projectile h...
Other (please specify)
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%


Bullet 14 - Flattened
What description(s) would you use to categorize the bullet?
Pristine
Scored – A projectile t...
Fragmented – The projecti...
Fractured – The projecti...
Full core/jacket...
Flattened – A portion of t...
Planar – The projectile h...
Other (please specify)
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%


Bullet 15 - Flattened
What description(s) would you use to categorize the bullet?
Pristine
Scored – A projectile t...
Fragmented – The projecti...
Fractured – The projecti...
Full core/jacket...
Flattened – A portion of t...
Planar – The projectile h...
Other (please specify)
0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%