Email Cover Letter composed by Chairman John Murdock - Committee for the Advancement of the Science of Firearm and Toolmark Identification
Dated: June 14, 2011

John Paul:

You are receiving this message in your capacity as the RDT&E IWG Executive Secretary. First, thank you for extending the deadline to today, June 14, 2011, for the AFTE Response to the 25 Questions related to firearms and toolmark examinations promulgated by the RDT&E IWG. The AFTE Board of Directors delegated the responsibility of editing and adding to the list of references that you received from SWGGUN on May 20, 2011 to its Committee for the Advancement of the Science of Firearm and Toolmark Identification, which I chair. I have attached what AFTE considers to be appropriate scientific references for each question. This 94 page document is dated June 14, 2011.

Finally, it is important to me that you know the names of the AFTE Members on my committee. They are Brandon Giroux, Luke Haag, Jim Hamby, Andy Smith and Pete Striupaitis. Everyone of us contributed, in many ways, to AFTE's response to your 25 questions. But, we only assembled the references. Those that assemble must never be confused with those that create. The real credit goes to the many men and women who, over the years, have conducted the research that makes AFTE confident that you will find that firearms and toolmark identification, as a forensic specialty, rests on firm scientific underpinnings. We hope that these references will provide you with a better understanding of the research related to our field. If you experience difficulty acquiring any of these references, we will provide them to you.

John Murdock, Chairman

SWGGUN and AFTE Committee for the Advancement of the Science of Firearm and Toolmark Identification's response to 25 foundational firearm and toolmark examination questions received from the Subcommittee on Forensic Science (SoFS), Research, Development, Testing, & Evaluation Interagency Working Group (RDT&E IWG) on April 18, 2011. This response is a compilation of published research which addresses each question.

Foreword to Questions #1 through #9:

Toolmark Identification is an **applied science**. It is congruous with **applied research**, which uses some part of research communities' accumulated theories, knowledge, methods and techniques for a specific commercial or client driven purpose.

Applied science differs from fundamental science. Applied science focuses on practical applications with less emphasis on the most basic scientific principles.

The forensic science discipline of Firearm and Toolmark Identification (FA & TM ID) is derived from validated theories in the physical sciences. Specifically, the origination of toolmarks is based on previously established theories, principles and properties that were adapted in the material and engineering sciences. These essential principles, which can be found in innumerable textbooks, are delineated below, followed by a limited representative reference list:

I. Physical Properties

- A. Pressure
- B. Temperature- Friction & Heat

II. Metallurgical Properties

- A. Plastic Deformation
- B. Stress-Strain Relationships
- C. Failure Mechanics
- D. Forces
  1. Compression
  2. Torsion
  3. Shear
  4. Tensile

The 47 page SWGGUN response was submitted to the SoFS RDT&E IWG on May 20, 2011. This 94 page combined response was submitted on June 14, 2011.

5. Flexure

III. Mechanical Properties- Materials reaction to applied forces

A. Chip Formation Processes & Phenomena/Theory

B. Non-Chip or Chipless Formation Processes & Phenomena/Theory

1. Electro-chemical machining (ECM)

2. Electro-discharge machining (EDM)

3. Laser

IV. Surface Integrity

A. Fatigue/Fracture Mechanics

B. Hardness

C. Heat Transfer

D. Texture-

1. Roughness, Waviness & Lay

2. Metrology- Provides standard of three primary components to describe 3D Surface texture and supplies a quantitative basis for toolmarks.

E. Tribology- Established body of knowledge that explains wear and the random affects of tool wear

Fundamental References:

Brandt D., *Metallurgy Fundamentals*, Goodheart-Wilcox Company Inc., 1985

Ostwald and Munoz, *Manufacturing Processes and Systems*, John Wiley & Sons, Ninth Edition, 1997

Wright R.T., *Processes of Manufacturing*, The Goodheart-Wilcox Co., Inc., 1987

DuVall J.B., *Contemporary Manufacturing Processes*, Goodheart-Wilcox Co., Inc., 1996

Hurd D., Silver M., Bacher A.B., & McLaughlin C.W., *Physical Science*, Prentice-Hall, New Edition, 1993

Salmon, S.C., *Modern Grinding Process Technology*, McGraw-Hill, Inc., 1992

McCarthy WJ and Smith R.E., *Machine Tool Technology*, McKnight & McKnight Publishing, 1968

Ernst and Merchant, *Chip Formation, Friction and Finish*, The Cincinnati Milling Co., Cincinnati, Ohio

De Garmo, E.P., *Materials and Processes in Manufacturing*, The MacMillian Co., 3rd Edition, 1969

De Garmo, E.P., Black, J.T., Kohser, R.A., *Materials & Processing in Manufacturing*, MacMillian Publishing Co., 7th Edition, 1988

Amstead, B.H., Ostwald, P.F., Begeman, M.L., *Manufacturing Processes*, Wiley & Sons, 8th Edition, 1987

Wright, T.R., *Processes of Manufacturing*, Goodheart-Wilcox, 1987

Pollack, H. W., *Materials Science & Metallurgy*, Reston Publications, 1973

Neely, J., *Practical Metallurgy & Materials*, Wiley & Sons, 1979

Crossover References

Biasotti, A., “The Principles of Evidence Evaluation as Applied to Firearms and Tool Mark Identification”, *AFTE Journal*, Volume 9, Number 4, October 1964.

Burrard, G, The Identification of Firearms and Forensic Ballistics, Butler & Tanner 1934, Reprinted Barnes & Company 1962 and Wolfe publishing 1990

Davis, JE, An Introduction to Toolmarks, Firearms and the Striagraph, Charles C. Thomas, 1958

Goddard, Waite, Fisher and Gravelle, *Army Ordnance*, November & December 1925

Gunther J.D., and Gunther C.O., *The Identification of Firearms*, Wiley & Sons, Inc. 1935

Hatcher, J.S., Textbook of Firearms Investigation, Identification and Evidence, Small Arms Technical Publishing Company, 1935

Hatcher Jury & Weller Hatcher, J.S., Jury, F.J. and Weller, J., *Firearm Investigation Identification and Evidence*, The Stackpole Company, 1957.

Mathews, JH, Firearms Identification, Volumes I-III, University of Wisconsin Press, 1962

Peterson, J.L., "Utilizing the Laser for Comparing Tool Striations"; *Journal of the Forensic Science Society*, 57 (14), 1974, pp. 57-62

Vandiver, J.V., "Identification and Use of Toolmark Identification", *Law and Order*, No. 7, 1976

1. What literature documents the scientific domains used to inform the foundations of firearm/toolmark analysis? Have the relevant communities and/or standards setting organizations looked to engineering, material sciences, etc. for experimental design, lessons learned and research which can inform advancing the practice of firearms/toolmark analysis? If so, what references exist to document this crossover of information?

See Fundamental and Crossover References mentioned above.

The history of firearms identification and court acceptance of firearms and toolmark evidence in the United States goes back over 100 years and has been the subject of numerous publications. The following list of references represents a portion of these publications. The last two articles listed represent special contributions made by Kraft in 1931 when he authored a comprehensive two-part summary of the literature produced during the period 1919 through 1930 that dealt with (in part one) “the identification of weapons by means of the projectile and cartridge case” and (in part two) “other questions that may arise in forensic ballistics." Kraft’s critical review of many articles written in German, etc. made them available to many English speaking examiners for the first time. The AFTE Theory of Identification, developed and adopted by the relevant scientific community (AFTE in 1992), has provided the toolmark identification community with a theory defining and describing the approach that examiners have traditionally taken when identifying/individualizing toolmarks.

Buxton, J., “The Science of Ballistics: Judicial Applications”, *American Journal of Police Sciences*, May – June, 1931, 2(3): 211-219

Serhant, J. “The Admissibility of Ballistics in Evidence”, *American Journal of Police Sciences*, May – June, 1931, 2(3): 202-210

Baker, N., “The Campbell Case”, *American Journal of Police Science*, Jan – Feb, 1931, 3(1): 21-31

Inbau, F., “Scientific Evidence in Criminal Cases (Firearms Identification – “Ballistics”)”, *AFTE Journal*, Vol. 13, No. 2, 1981: 281 (Originally appeared in Journal of Police Science, 1933)

Gunther, J.D., and Gunther C.O, “The Identification of Firearms”, Wiley & Sons, Inc. 1935.

Goddard, C. “A History of Firearm Identification”, *AFTE Journal*. Vol. 17, No. 1, 1985, pp. 55 – 68 (Originally printed in Chicago Police Journal, 1936).

FBI, “Firearms Identification”, U.S. Government Printing Office, 1941, pp 17 – 33 “Development and Admissibility of Ballistics and Firearms Evidence”.

Goddard, C., “A History of Firearms Identification to 1930.” *AFTE Journal*, Vol. 31, No. 3, 1999, pp. 225 – 241.

IAI Firearms Sub-Committee - Stanton O. Berg, Chairman, “The History of Firearms Identification”, *Identification News*, June 1965, pp. 5 – 15.

Saferstein, R. “Firearms Identification – Historical Background”, *Forensic Science Handbook – Volume* II, Prentice Hall, 1988, see p. 411 – 415.

Hamby, J., “The History of Firearm and Toolmark Identification”, *AFTE Journal*, Vol. 31, No. 3, 1999, pp. 266-284.

Kraft, B., “Critical Review of Forensic Ballistics – Part I”, *American Journal of Police Science*, Jan-Feb 1931, 2(1), pp. 52 – 66.

Kraft, B., “Critical Review of Forensic Ballistics – Part II”, *American Journal of Police Science*, Mar – Apr, 1931, 2(2), pp. 125 – 142.

Moran, B. and Murdock, J. “Zen and the Art of Motorcycle Maintenance – Contribution to Forensic Science – An Explanation of the Scientific Method” Appendix No. 2 (pp. 234-240) from the article by Grzybowski, R., Miller, J., Moran, B., Murdock, J., Nichols, R., and R. Thompson titled “Firearm/Toolmark Identification: Passing the Reliability Test Under Federal and State Evidentiary Standards” in *AFTE Journal*, Vol. 35, No. 2, Spring 2003, pp. 209-241.

This appendix describes how the classical scientific method is used in firearm and toolmark identification. Column four in the scientific method chart generally describes research of the type summarized by Nichols. It is this research that led directly to the adoption of the AFTE Theory of Identification in 1992.

Biasotti, A.A., (1981) Rifling Methods – A Review and Assessment of the Individual Characteristics Produced., *Association of Firearm and Toolmark Examiners Journal*, Vol. 13, No. 3, pp. 34-61.

The author reviews the various methods of rifling barrels and the types of marks that they produce on bullets.

Biasotti, A., (1981) Bullet Bearing Surface Composition and Rifling (Bore) Conditions as Variables in the Reproduction of Individual Characteristics on Fired Bullets *Association of Firearm and Toolmark Examiners Journal* , Vol. 13, No. 2, pp. 94-102.

The purpose of the experiment described herein is to demonstrate the effects of several of the more significant variables that may contribute towards the reproducibility of identifiable individual characteristics on fired bullets. The author discusses individual characteristics via an examination of various types of bullets (Lubaloy, Golden, and Nyclad) and various conditions of the bore.

Nichols, R.G., “Firearm and Toolmark Identification Criteria: A Review of the Literature”, *Journal of Forensic Sciences*, Vol. 42, No. 3, 1997, pp.446-474.

A review of 34 articles pertaining to the examination of consecutive manufactured tools, identification criteria for firearms and toolmark identification and mathematical and computer models developed for a standard identification.

Nichols, R.G. “Firearm and Toolmark Identification Criteria: A Review of the Literature, Part II”, *Journal of Forensic Sciences*, Vol. 48, No. 2, March 2003, pp 318-327.

An update to a previously published review of articles pertaining to firearm and toolmark identification criteria is presented. In this update, 22 additional articles were reviewed, including works of a general nature, studies critically assessing the theory of consecutive matching striations, empirical studies involving various firearm components, toolmark studies, as well as articles discussing the utility of statistics in the firearms and toolmark identification discipline. These articles have been reviewed in a format to permit others to learn what has been published in the field in an effort to educate interested parties. Further, a discussion of the importance of articulation and communication within the discipline is presented.

Nichols, R.G., Defending the Science of the Firearms and Tool Mark Identification Discipline: Responding to Recent Challenges, *Journal of Forensic Sciences*, Vol. 52, No. 3, May 2007, pp. 586-594.

A compendium of fifty-six (56) references that includes approximately thirty-two (32) articles that describe the examination of consecutively, or nearly consecutively, manufactured firearms components.

Katterwe, H "Modern Approaches for the Examination of Toolmarks and Other Surfaces", *Forensic Science Review*, Volume. 8, Number. 1, Pp. 46-71, June 1996

The author explores the effects of the production of toolmarks on different materials’ surfaces.

Wiercigroch, M., Cheng A. (1997) Chaotic and Stochastic Dynamics of Orthogonal Metal Cutting. *Chaos, Solitons and Fractals*, 8:4, April 1997, pp. 715-726.

The authors explore the effects of the machining processes as it relates to vibration of the machine tools and cutting resistance. It is demonstrated that the result is random material grain sizes.

2. Have studies been conducted at the manufacturing level addressing material uniformity, reproducibility, and the QA/QC procedures of the manufacturer?

Bonfanti, M.S. and DeKinder, "The Influence of Manufacturing Processes on the Identification of Bullets and Cartridge Cases- A Review of the Literature", *Science and Justice*, Volume 39, No. 1, 1999, pp. 3-10.

A compendium of fifty (50) references that describe the examination of consecutively, or nearly consecutively, manufactured firearms components.

Nichols, R.G., "Firearm and Toolmark Identification Criteria: A Review of the Literature", *Journal of Forensic Sciences*, Vol. 42, No. 3, 1997, pp.446-474.

A review of 34 articles pertaining to the examination of consecutive manufactured tools, identification criteria for firearms and toolmark identification and mathematical and computer models developed for a standard identification.

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Nichols, R.G., Defending the Science of the Firearms and Tool Mark Identification Discipline: Responding to Recent Challenges, *Journal of Forensic Sciences*, Vol. 52, No. 3, May 2007, pp. 586-594.

A compendium of fifty-six (56) references that includes approximately thirty-two (32) articles that describe the examination of consecutively, or nearly consecutively, manufactured firearms components.

Springer, E., Toolmark Examinations – A Review of Its Development in the Literature., *Journal of Forensic Sciences*, Vol. 40, No. 6, November 1995, pp.964-8.

A review of forty-seven (47) articles pertaining to toolmark examinations. This includes a history of toolmark examinations, a review of its development from

1900 to present, and addresses the use of automated technology in conducting toolmark examination/ validation .

Coffman, B.C., (2003). Computer Numerical Control (CNC) Production Tooling and Repeatable Characteristics on Ten Remington Model 870 Production Run Breech Bolts. *Association of Firearm and Toolmark Examiners Journal*, 35:1, pp. 49-54.

The authors examine ten shotgun bolt faces, consecutively produced by the same CNC manufacturing machine tool and compare for the presence subclass and individual characteristics. Results of these comparisons found that the manufacturing process used to fabricate these bolts produced subclass characteristics and sufficient individual characteristics to provide uniqueness.

Lopez, Laura and Sally Grew. “Consecutively Machined Ruger Bolt Faces.” *AFTE Journal*, Vol. 32, No. 1, Spring 2000, pp.19 - 24.

This study warns that one should be careful with microscopic marks from a bolt face machined with an end mill. A misidentification is possible unless the identification is made using wear or machining “chatter” marks.

3. What toolmark reproducibility studies have been conducted?

Bachrach B., Jain A., Jung S., and Koons R.D.(2010) A Statistical Validation of the Individuality and Repeatability of Striate Tool Marks: Screwdrivers and Tongue and Groove Pliers. *Journal of Forensic Sciences*, Vol. 55, No. 2, pp 348-357.

> Study that statistically validated the original premise of individuality in Toolmark Identification by analyzing statistical distributions of similar values resulting from the comparison of Known Matches (KM) and Known Non-Matched (KNM) pairs of striated toolmarks. This quantifiable analysis of KM and KNM toolmark similarity distributions showed nearly error-free identifications.

Doelling, B., “Comparison of 4000 Consecutively Fired Steel Jacketed Bullets”, Abstract B58, p. 53 from Proceedings of the AAFS Annual Meeting, Seattle, WA, February 19 - 24, 2001

> Author examined 4000 fired bullets using conventional pattern matching as well as quantitative consecutive matching striation (CMS) techniques

Fadul, T.G., An Empirical Study to Evaluate the Repeatability and Uniqueness of Striations/Impressions Imparted on Consecutively Manufactured Glock EBIS Barrels, *AFTE Journal,* Vol. 43,No. 1, Winter, 201, pp.37-44.

> An empirical study of ten consecutively manufactured Glock barrels containing the Enhanced Bullet Identification System (EBIS). Study consisted of test sets sent to 238 examiners from 150 laboratories in 44 states and 9 countries that were designed to test the examiner’s ability to correctly identify fired bullets to the barrel that fired them. The results from 183 of these examiners produced an error rate of 0.4%. This study validated the repeatability and uniqueness of striated markings in gun barrels, as well as the ability of a competent examiner to reliably identify fired bullets to the barrels that marked them.

Gouwe, J., Hamby, J.E., Norris, S. (2008). Comparison of 10,000 Consecutively Fired Cartridge Cases from a Model 22 Glock .40 S&W Caliber Semiautomatic Pistol. *AFTE Journal*, Vol. 40, No. 1, pp. 57-63.

> Ten thousand (10,000) .40 S&W caliber cartridge cases fired from a Glock, model 22, pistol were compared. All 10,000 fired cases could be identified to each other. This study validates previous durability studies that showed identifiable markings from a tool could persist for a long period of time.

Hamby, J. Identification of Projectiles. *AFTE Journal, Vol.* 6, No. 5/6, Fall 1974, pp 22-24

> Durability study of 501 fired bullets and cartridge cases fired through a worn M16 rifle. The rifle was fired as quickly as the 20 round magazines could be changed

into the rifle. It was possible to identify fired bullet 1 to bullet 501 as well as identifying fired cartridge case 1 to case 501.

Hamby, J.E., Brundage, D., Thorpe, J., The Identification of Bullets Fired from 10 Consecutively Rifled 9mm Ruger Pistol Barrels: A Research Project Involving 507 Participants from 20 Countries. *AFTE Journal, Vol.* 41, Number 2, Fall 2009, pp. 99 – 110.

Ten consecutively rifled RUGER P-85 pistol barrels were obtained from the manufacturer and then test fired to produce known test bullets and 'unknown' bullets for comparison by firearms examiners from around the world. This study is a continuation of one originally designed and reported on by David Brundage. The original study was primarily limited to examiners from nationally accredited laboratories in the United States. For this study, the sets were provided to firearms examiners around the world. The Ruger P85 pistol and the 10 consecutively rifled barrels used for the original study were borrowed from the Illinois State Police. Ammunition was obtained from the Winchester Ammunition Company (A Division of Olin) and 240 tests sets were produced and distributed to forensic scientists and researchers worldwide. A thesis which involved a total of 201 participants including the original 67 reported on by Brundage was published by Hamby and Thorpe in 2001. This paper reports the final conclusions of the research conducted by Brundage, Hamby and Thorpe over a 10 year period.

The total number of participants to date (6-2011) is 561 participants from 21 countries, eight of whom used instrumental analysis to correctly identify the consecutively rifled barrels. Also reported within the research was the examination and identification of the 16,800 fired cartridge cases produced during this experiment.

Kirby, S. "Comparison of 900 Consecutively Fired Bullets and Cartridge Cases from a. 455 Caliber S&W Revolver", *AFTE Journal,* Vol. 33. No. 3, Summer 2001, pp. 113-125.

Durability study of major working edges of a revolver.

Ogihara, Y., et al, "Comparison of 5000 Consecutively Fired Bullets and Cartridge Cases From a 45 Caliber M1911 Pistol", *AFTE Journal*, Vol. 15, No. 3, July 1983, pp. 127-140.

Durability study of test-fired bullets and cartridge cases from a single pistol. It was possible to identify bullet number 1 to number 5000 and cartridge case 1 to number 5000.

Schecter, B., et al. "Extended Firing of a Galil Assault Rifle", *AFTE Journal*, Vol. 24, No. 1, January 1992, pp. 37 – 45.

Authors performed extended firings of a new Galil Assault Rifle firing some 7,100 cartridges. Identifiable ejector marks were successfully compared between case number 9 and number 7,060.

Shem, R. and Striupaitis, P., “Comparison of 501 Consecutively Fired Bullets and Cartridge Cases from a Raven 25 Caliber Raven Pistol”, *AFTE Journal,* Vol. 15, No. 3, July 1983, pp. 109 – 112.

Durability study of major working surfaces of a pistol for the test-fired bullets and cartridge cases. It was possible to identify bullet number 1 to number 501 and cartridge case 1 to number 501.

4. As manufacturing techniques and materials change over time, what studies have been performed to validate or invalidate older foundational studies?

Austin, Peter F., "The Identification of Bullets Fired From High Velocity Rifles with Consecutively Rifled Micro-Groove Barrels", Presented at the Firth International Meeting of Forensic Sciences – University of Toronto, Toronto, Ontario, Canada, June 5 to 11, 1969.

> Author discusses his ability to identify and individualize fired bullets obtained by test firing consecutively rifled micro-groove barrels.

Lutz, M., "Consecutive Revolver Barrels", *AFTE Newsletter,* No.9, Page 24 (1970).

> Author obtained one long revolver barrel, had it cut into two barrels, and then test fired both barrels to determine that it was possible to individualize the fired bullets to their specific barrel.

Matty, W." Raven .25 Automatic Pistol Breech Face Tool Marks". *AFTE Journal*, Vol. 16, No. 3, Fall 1984, pp. 57-60.

> For this study, three consecutively made breechfaces from Raven pistols were compared. The concentric toolmarks on the breechfaces were found to be individual and not subclass.

Lyons, D. J. "The Identification of Consecutively Manufactured Extractors", *AFTE Journal*, Vol. 41, No. 3, Fall 2009, pp.246-256.

> Study conducted on ten consecutively manufactured firearm extractors. Firearm and toolmark examiners from different laboratories were given ten sets of cartridge cases marked by these extractors to attempt to make the correct associations between the known and unknown cases. Each examiner also received twelve unknown marked cases in addition to the standards for the ten consecutively manufactured cartridge cases, with each known specimen having at least one unknown specimen associated with it.

Hamby, J.E., Brundage, D., Thorpe, J., "The Identification of Bullets Fired from 10 Consecutively Rifled 9mm Ruger Pistol Barrels: A Research Project Involving 507 Participants from 20 Countries", *AFTE Journal, Vol.* 41, Number 2, Fall 2009, pp. 99 – 110.

> Ten consecutively rifled RUGER P-85 pistol barrels were obtained from the manufacturer and then test fired to produce known test bullets and 'unknown' bullets for comparison by firearms examiners from around the world. This study is a continuation of one originally designed and reported on by David Brundage. The original study was primarily limited to examiners from nationally accredited laboratories in the United States. For this study, the sets were provided to

firearms examiners around the world. The Ruger P85 pistol and the 10 consecutively rifled barrels used for the original study were borrowed from the Illinois State Police. Ammunition was obtained from the Winchester Ammunition Company (A Division of Olin) and 240 tests sets were produced and distributed to forensic scientists and researchers worldwide. A thesis which involved a total of 201 participants including the original 67 reported on by Brundage was published by Hamby and Thorpe in 2001. This paper reports the final conclusions of the research conducted by Brundage, Hamby and Thorpe over a 10 year period.

The total number of participants to date (6-2011) is 561 participants from 21 countries; eight of whom used instrumental analysis to correctly identify the consecutively rifled bullets. Also reported within this research was the examination and identification of the 16,800 fired cartridge cases produced during this experiment. It was possible to individualize fired case number 1 to case 16,800.

Fadul, T.G., "An Empirical Study to Evaluate the Repeatability and Uniqueness of Striations/Impressions Imparted on Consecutively Manufactured Glock EBIS Barrels", *AFTE Journal,* Vol. 43,No. 1, Winter, 201, pp.37-44.

The author details an empirical study of ten consecutively manufactured Glock barrels containing the Enhanced Bullet Identification System (EBIS). Study consisted of test sets sent to 238 examiners from 150 laboratories in 44 states and 9 countries that were designed to test the examiner's ability to correctly identify fired bullets to the barrel that fired them. The results from 183 of these examiners produced an error rate of 0.4%. This study validated the repeatability and uniqueness of striated markings in gun barrels, as well as the ability of a competent examiner to reliably identify fired bullets to the barrels that marked them.

Fadul, T.G., et al "An Empirical Study to Evaluate the Repeatability and Uniqueness of Striations / Impressions in Fired Cartridge Casings Fired in 10 Consecutively Manufactured Slides" (This project was supported by Award NO. 2009-DN-BX-K230 awarded by the National Institute of Justice, Office of Justice Programs, US Department of Justice) Presented at the 42nd Annual Training Seminar of the Association of Firearm and Toolmark Examiners, held in Chicago, IL on May 29th through June 3rd 2011.

The authors conducted this study to improve understanding of the accuracy, reliability, and measurement validity in the firearm and tool mark discipline of forensic science. Participants were firearms examiners throughout the United States. Some 160 test sets were distributed to laboratories in forty-six states and the District of Columbia.

The test sets were designed to determine an examiner's ability to correctly identify cartridge casings fired from 10 consecutively manufactured Ruger slides to test fired cartridge casings fired from the same slides. This empirical study established an error rate of less than 0.1 percent. Durability testing established that the Ruger slides maintained their individual characteristics after multiple firings.

Hamby, J., and Norris, S., "The Examination, Evaluation and Identification of 9mm Caliber Cartridge Cases From 1275 GLOCK Semiautomatic Pistols Manufactured Over an 18 Year Period" Presented at the 42nd Annual Training Seminar of the Association of Firearm and Toolmark Examiners, held in Chicago, IL on May 29th through June 3rd 2011.

Six hundred and seventeen (617) GLOCK pistols, manufactured in 1993 were obtained, test fired and the fired cartridge cases examined, evaluated and identified to each other. This research was the subject of one chapter of a Ph.D. thesis by Hamby at the University of Strathclyde, Glasgow, Scotland.

Over the past 4 ½ years the authors have been examining fired GLOCK cases as part of the GLOCK Manufacturing Facilities Quality Assurance Program. Five hundred and seventy five (575) cases from the original study were combined with 700 fired cases from the current study and evaluated and identified against each other. These examinations, using conventional optical microscopy, and conventional pattern matching techniques resulted in being able to individualize the fired cases. Combining the fired cases – manufactured over an 18 year period – resulted in a total number of examinations totaling over 1,600,000.

5. Have studies been conducted to review the level of similarity between marks produced by consecutively manufactured tools/firearms vs. randomly manufactured tools/firearms?

Stone, R. (2003) How Unique are Impressed Marks, *Association of Firearm and Toolmark Examiners Journal*, 35:4, pp. 376-383.

> This study outlines several theoretical types of impressed toolmark characteristics (point, line, curve, enclosure and three-dimensional) and applies mathematical probability estimates in an attempt to quantify them. It was found that with marks of "reasonable complexity" the odds of the same marks being repeated on another tool were astronomical.

Collins, E.R., (2005) How "Unique" Are Impressed Toolmarks? – An Empirical Study of 20 Worn Hammer Faces, *Association of Firearm and Toolmark Examiners Journal*, 37:4, pp. 252-295.

> This study utilizes 20 worn hammer faces to determine if Stone's (2003) theoretical types of toolmark characteristics model "accurately and consistently represents the occurrence of individualizing effects." This study includes an addendum by Stone which outlines refinements to his original model. The refinements to the original model continue to provide probabilities that are astronomical.

Hamby, J., and Thorpe, J., "The Examination, Evaluation and Identification of 9mm Caliber Cartridge Cases From 617 Model 17 & 19 Semiautomatic Pistols", Association of Firearm and Toolmark Examiners Journal, Vol. 41, No. 4, Fall 2005, pp.310-324.

> Six hundred and seventeen (617) GLOCK pistols, manufactured in 1993 were obtained, test fired and the fired cartridge cases examined, evaluated and identified to each other. This research was the subject of one chapter of a Ph.D. thesis by Hamby at the University of Strathclyde, Glasgow, Scotland.
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> Of the 617 pistols that were test fired, 550 had consecutive serial numbers which would indicate they were manufactured within a short time frame of each other. The others were in different serial number ranges. It was possible to individualize the fired cases to themselves and to the exclusion of the other fired cases.

Howitt D., Tulleners F., "A Calculation of the Theoretical Significance of Matched Bullets", Journal of Forensic Sciences, Volume 53, Number 4, July 2008, Pp.868-875.

> Study that calculated random occurrence probability for the correspondence of impression marks on a subject bullet to a random distribution of similar marks on a suspect bullet of the same type. These calculations produced values that supported previous reported empirical probabilities on consecutive matching

bullet striae and also indicate that larger consecutive matching sequences are extremely unlikely to occur.

Neel M., and Wells M., "A Comprehensive Statistical Analysis of Striated Tool Mark Examinations Part I: Comparing Known Matches and Known Non-Matches", AFTE Journal, Volume 39, (4), Summer 2007, pp. 176-198.

Study of 4000 striated toolmark comparisons concluded that known matches (KM) and known non-matches (KNM's) can be statistically distinguished from one another with 3D toolmarks containing a 1 in 802,919 and 2D toolmarks containing a 1 in 12,090,164 likelihood ratio.

May L., "Identification of Knives, Tools and Instruments" *Journal of Police Science* Vol. 1, No. 3, 1930, pp. 247-248.

The author conducted a pioneering study on striated type toolmarks on numerous cutting tools, especially knives, with working edges containing some type of ground finish. Also, conducted first attempt at a statistical validation in Toolmark Identification; in which, it was calculated that the possibility of the same identifying mark(s) appearing on another tool is approximately 100,000 X 650 (quadrillion).

Brackett, J.W. "A Study of Idealized Striated Marks and their Comparisons using Models." *Journal of the Forensic Science Society*, Vol. 10, No. 1, January, 1970, pp. 27-56.

Comparison of various proposed probability models for striated marks, with an eye toward the development of an automated system. CMS model tended to support empirical work of Biasotti.

Deinet, Werner. "Studies of Models of Striated Marks Generated by Random Processes." *Journal of Forensic Sciences*, Vol. 26 (1), Jan., 1981, pp. 35-50.

Computer-aided studies of the degree of similarity of striated marks are described. Digitized image data on 40 grinding marks were fed into a minicomputer, and the position values of the lines were determined semiautomatically. Idealized models were defined for an objective comparison of striated marks and then applied to the grinding mark data. Necessary conditions of the models were tested by comparing them with actual, measured properties of the marks. Results of the model calculations are presented and the properties of the models discussed.

Stone, R., "How Unique are Impressed Marks," *AFTE Journal*, Vol. 35(4), Fall 2003, pp. 376-383.

This study outlines several theoretical types of impressed toolmark characteristics (point, line, curve, enclosure and three-dimensional) and applies mathematical probability estimates in an attempt to quantify them. It was found that with marks of “reasonable complexity” the odds of the same marks being repeated on another tool were astronomical.

6. What studies review the degree of variability that exists in (a) bullet striations observable from the same firearm; (b) bullet striations from different firearms

Biasotti, A., (1981) Bullet Bearing Surface Composition and Rifling (Bore) Conditions as Variables in the Reproduction of Individual Characteristics on Fired Bullets, *AFTE Journal* , Vol.13, No. 2, pp. 94 – 102.

> The purpose of the experiment described herein is to demonstrate the effects of several of the more significant variables that may contribute towards the reproducibility of identifiable individual characteristics on fired bullets. The author discusses individual characteristics via an examination of various types of bullets (Lubaloy, Golden, and Nyclad) and various conditions of the bore.

Biasotti, A.A., (1959) A Statistical Study of the Individual Characteristics of Fired Bullets, *Journal of Forensic Science*, 4:1, pp. 34-50

Hamby, J. PhD, et al. (2009) "The Identification of Bullets Fired From 10 Consecutively Rifled 9mm Ruger Pistol Barrels: A Research Project Involving 507 Participants from 20 Countries", *AFTE Journal* 41:2 pp. 99 - 110.

> This lengthy undertaking demonstrated that a large number of examiners from numerous countries ranging from trainees to highly experienced examiners could correctly associate fired 9mm bullets with their parent barrels even though the barrels were consecutively rifled with the same broach. If inconclusive answers were included, an error rate of 0.059% was found. The comparisons considered the normal variability in striae patterns that examiners encounter in bullets fired from the same barrel as well as the degree of agreement in individual characteristics necessary to affect an identity of source. Numerous additional published studies for this same purpose and with the same result, i.e.- bullets from consecutively manufactured barrels can be correctly associated with the source barrel by trained examiners. These are listed below in order of appearance in the peer-reviewed literature. Additionally, many of these studies also addressed persistence of matching individual characteristics over repeated firings ranging from hundreds to thousands of rounds representing far more shots than are likely to occur between the use of a firearm in a crime and its subsequent recovery and submission to the crime laboratory.

Hall, E., (1983) Bullet Markings From Consecutively Rifled Shilen DGA Barrels, *AFTE Journal,* 15:1 pp. 33-47

Kirby, S., (1983) Comparison of 900 Consecutively Fired Bullets and Cartridge Cases From a .455 Caliber S&W Revolver, *AFTE Journal,* 15:3, pp. 113-126

Lutz, M., (1970) Consecutive Revolver Barrels, *AFTE Newsletter* #9, Page 24

Matty, W., (1985) A Comparison of Three Individual Barrels Produced From One Button Rifled Barrel Blank, *AFTE Journal*,17:3, pp. 64-69

Miller, J., (2000) An Examination of Two Consecutively Rifled Barrels and A Review of the Literature, *AFTE Journal,* 32:3, pp. 259-270.

Miller, J., (2001) An Examination of the Application of the Conservative Criteria for Identification of Striated Tool Marks Using Bullets Fired From Ten Consecutively Rifled Barrels, *AFTE Journal,* 32:2, pp. 125-132.

Murdock, J., (1981) A General Discussion of Gun Barrel Individuality and an Empirical Assessment of the Individuality of Consecutively Button Rifled .22 Caliber Rifle Barrels, *AFTE Journal*, 13:3, pp. 84-111

Ogihara, Y., Kubota, M., Sanada, M., Fukuda, K., Uchiyama, T., and Hamby, J., (1983) Comparison of 5000 Consecutively Fired Bullets and Cartridge Cases From a .45 Caliber M1911A1 Pistol, *AFTE Journal,* 15:3 pp. 127-140

Roberge, D., Beauchamp, A., (2006) The Use of BulletTrax-3D in a Study of Consecutively Manufactured Barrels, *AFTE Journal* 38:2 pp. 166 – 172.

> Forensic Technology challenged its newest 3D technology, BulletTRAX-3DTM, with a test provided by firearms examiner Evan Thompson of the Washington State Police Crime Laboratory. This test involves 21 pairs of bullets, among which 20 are fired from ten consecutively manufactured 9mm caliber Luger Hi-Point barrels. Each of the ten first pairs of bullets is connected to a distinct known barrel and is labeled from 1 to 10, the remaining 11 pairs being labeled from A to K. The purpose of this test is to correctly match each pair from the first set to a pair in the second set. The relation between both sets is given by a confidential key, which is a set of ten couples, the first element being a digit (1 to 10), the second a letter (in the A-K range). All pairs of bullets in the Thomson test were imaged with BulletTRAX-3DTM. From the correlation scores, the key was found by a process that can easily be automated by software.

Schecter, B., Silverwater, H., and Etzion, M., (1992) Extended Firing of a Galil Assault Rifle, *AFTE Journal,* 24:1, pp. 37-45

Shem, R. and Striupaitis, P., (1983) Comparison of 501 Consecutively Fired Bullets and Cartridge Cases From a .25 Caliber Raven Pistol, *AFTE Journal*, 15:3, pp. 109-112

Skolrood, R. (1975) Comparison of Bullets Fired From Consecutively Rifled Cooey .22 Calibre Barrels, *Canadian Society of Forensic Science Journal*, 8:2, pp. 49-52

Tulleners, F., Giusto, M., Hamiel, J., (1998) Striae Reproducibility of Sectional Cuts of One Thompson Contender Barrel, *AFTE Journal*, 30:1 pp. 62-81.

Tulleners, F. and Hamiel, J., (1999) Sub-Class Characteristics of Sequentially Rifled .38 Special S&W Revolver Barrels, *AFTE Journal*, 31:2, pp. 117-122

Uchiyama, T., “Toolmark Reproducibility on Fired Bullets and Expended Cartridge Cases”, *AFTE Journal, Vol.* 40, No.1, 2008) pp. 3 – 46.

The reproducibility of landmarks, breechface marks and firing pin marks on one hundred successively fired bullets and cartridge cases was examined. Three types of Speer brand, one of Remington brand and one of DFA brand frangible cartridges were fired in a semi-automatic pistol. Remarkable differences were observed in the general appearance of the landmarks, breechface marks and firing pin marks which were impressed on the different brands of cartridges, even when consecutively fired. Identification of the landmarks between bullets from different brands of cartridges was difficult because their general appearance differed greatly. Difference in bullet diameters was found to be a major cause of changes in landmarks among different manufacturer's bullets. Although the depth and number of striations decreased gradually, reproducibility of breechface marks on the primers of cartridges was rather good. The diameter of firing pin indentations also differed among different brands of cartridges. Although the reproducibility of the diameter of circular lines on firing pin indentations was good, the detail in these circular lines fluctuated a great deal. Quantitative CMS was used as a means of critically evaluating and communicating the extent of striated pattern agreement among the rifling impressions on the fired bullets in this study.

7. Do studies exist which examine the wear rates of materials used to manufacture tools/firearms/bullets and cartridge casings and the factors that affect wear?

General comments: The various studies related to the rifling of gun barrels, the visible changes along the interior surface of a rifled gun barrel (largely, but not exclusively due to galling and/or chip formation during the rifling process) are well known to forensic firearms examiners. It is these very reasons that bullets from new, consecutively rifled barrels can usually be discriminated and associated with the parent barrel. This is especially true when the toolmarks from the original drilling process used to form the bore of a gun barrel survive the subsequent steps involved in the rifling process. This situation is apparent to the forensic firearms examiner upon inspection of the bore of a submitted firearm. The random changes that occur over time with use and abuse only stand to enhance the differences between consecutively manufactured barrels. This is also true for other consecutively manufactured tools. These same reasons and phenomena typically apply to the manufacture of the breech faces and breech blocks in firearms with these areas being largely responsible for the subsequent markings imprinted in the heads and primers of fired cartridge cases.

The previously cited studies directed exclusively to bullets fired from consecutively manufactured gun barrels and listed in response to Question 6 apply here and will not be repeated. Some studies that are relevant to tools other than gun barrels are listed below. The classic textbooks on firearms identification address the sources of class and individual characteristics to varying degrees. These texts are listed separately at the end of this response.

Burd, D. and Kirk, P., (1942) Tool Marks: Factors Involved in Their Comparison and Use as Evidence, *Journal of Police Science*, 32:6 pp. 679-686

Burd, D. and Gilmore, A., (1968) Individual and Class Characteristics of Tools, *Journal of Forensic Science*, 13:3 pp. 390-396

Coffman, B., (2003) Computer Numerical Control (CNC) Production Tooling and Repeatable Characteristics on Ten Remington Model 870 Production Run Breech Bolts, *AFTE Journal*, 35:1 pp. 49-54

Haag, L., (2007) The Matching of Cast Bullets to the Moulds that Made Them, *AFTE Journal*, 39:4 pp. 313-322

> This article dealt with consecutively machined bullet moulds, subclass (carryover marks) and individual characteristics produced by galling and chip formation during the machining process. All of these machining marks are reproduced over the entire surface of lead and lead alloy bullets cast in bullet moulds. Those areas and sites that were the consequence of galling and chip formation were obvious upon low power inspection of the surfaces of cast bullets and

represented the individual characteristics that allowed consecutively manufactured moulds to be discriminated.

Hu, J., Chou, K., (2007) Characterizations of cutting tool flank wear-land contact, *Wear*, 263 pp. 1454-1458.

Koshy, P., Dewes, R.C., Aspinwall, D.K., (2002) High speed end milling of hardened ASI D2 tool steel, *Journal of Materials Processing Technology*, 127 pp. 266-273.

This article explores the factors of the machining process that effect tool wear and the resulting surface roughness. Various cutting speeds and tool coatings were used to evaluate the amount of tool wear and resulting surface roughness. The result of this research was wear of a cutting tool regardless of the combination of tool speed and tool coating. The tool wear resulted in a varying degree of surface roughness (individual characteristics) on all samples.

Lopez, L. and Grew, S., (2000) Consecutively Machined Ruger Bolt Faces, *AFTE Journal*, 32:1 pp. 19-24

Matty, W., (1984) Raven .25 Automatic Pistol Breech Face Tool Marks, *AFTE Journal*, 16:3 pp. 57-60

Miller, J., (2001) An Introduction to the Forensic Examination of Tool Marks, *AFTE Journal*, 33:3 pp. 233-248

Rosati C., (2000) Examination of Four Consecutively Manufactured Bunter Tools, *AFTE Journal*, 32:1 pp. 49-50

Classic articles and textbooks dealing with the formation and deposition of class and individual characteristics by firearms and various other tools on contacting surfaces (listed in order of publication).

Mezger O, Heess W, Hasslacher F, (1931) Die Bestimmung des Pistolensystems aus Verfeuerten Hülsen und Geschossen, *Archive für Krimologie* 89 pp.1-32 und 93-116, Verlag von F.O.W. Vogel, Berlin

Mezger, 0., Heess, W., Hasslacher, F., (1931) Determination of the Type of Pistol Employed from an Examination of Fired Bullets and Shells," *Am. J. Police Science* 2:6 pp. 473-500 (1932) 3:2 pp. 124-146

Burrard, G., (1934) *The Identification of Firearms and Forensic Ballistics*, Herbert Jenkins, Ltd., London, England

Gunther, J., (1935) *The Identification of Firearms,* John Wiley, New York

Hatcher, J., (1935) *Textbook of Firearms Investigation, Identification and Evidence,* Small-Arms Technical Publishing Co., Plantersville, SC

Hatcher, J., Jury, F. and Weller, J., (1957) *Firearms Investigation, Identification and Evidence,* Stackpole Publishing, Harrisburg, PA

O'Hara and Osterberg, J., (1949) *An Introduction to Criminalistics*, The Macmillian Co., New York

Kirk, P., (1953) *Crime Investigation*, John Wiley & Sons, New York, London, Sydney, Toronto

Davis, J., (1958) *An Introduction to Tool Marks, Firearms and the Striagraph*, Charles C. Thomas Publishing Co., Springfield, IL

Mathews, J., (1962) *Firearms Identification-3 Volumes*, Charles C. Thomas Publishing Co., Springfield, IL

Saferstein, R., (1977*) Criminalistics: An Introduction to Forensic Science*, Prentice-Hall, Inc., Englewood Cliffs, NJ

De Forest, P. Gaensslen, R and Lee, H., (1983) *Forensic Science-An Introduction to Criminalistics*, McGraw-Hill Publishing Co.

Warlow, T., (1996) *Firearms, the Law and Forensic Ballistics*, Taylor & Francis, London, England & Bristol, PA

8. What research exists that examines the durability of firearms/manufacture tools (screwdrivers, pry bars, hammers, etc.) as a result of wear/tear, care and abuse in relation to conservation of markings and their effects on identification?

The numerous, previously-cited persistence studies involving hundreds to thousands of rounds fired through a variety of firearms also address this question and will not be re-published here. However, the events associated with the discharge of firearms involve heat and pressures seldom, if ever, will prevent individual characteristics from being deposited on fired cartridge cases and engraved on fired bullets.

Bacharach, B. (2009) Statistical Validation on the Individuality of Tool Marks Due to the Effect of Wear, Environment Exposure and Partial Evidence", *NIJ/NCJRS Document #227929*.

> An objective, quantifiable toolmark study on marks imparted onto wires by diagonal cutters. This study examined the effects of wear, environmental conditions and partial toolmark impressions by an automated 3-D system that mathematically correlated results of toolmarks to the tools that produced them. This study validated, and thus strengthened, the foundations of Toolmark Identification.

Gouwe J., Hamby J.E., Norris, S. (2008). Comparison of 10,000 Consecutively Fired Cartridge Cases from a Model 22 Glock .40 S&W Caliber Semiautomatic Pistol, *AFTE Journal*, 40:1, pp. 57-63.

> Ten thousand (10,000) .40 S&W caliber cartridge cases fired from a Glock, model 22, pistol were compared. All 10,000 fired cases could be identified to each other. This study validates previous durability studies that showed identifiable markings from a tool could persist for a long period of time.

Kirby, S. "Comparison of 900 Consecutively Fired Bullets and Cartridge Cases from a .455 Caliber S&W Revolver", *AFTE Journal,* Vol. 33. No. 3, Summer 2001, pp. 113-125.

> Durability study of major working edges/surfaces of a revolver.

Miller, J. (1998) Cut Nail Manufacturing and Toolmark Identification, *AFTE Journal,* 30:3 pp. 492-498

Miller, J. (1998) Reproducibility of Impressed and Striated Tool Marks: 4d Cut Flooring Nails, *AFTE Journal,* 30:4 pp. 631-638

> These two articles are especially useful in responding to question 8 in that the equipment (tools) used to manufacture cut nails produced both impressed and

striated marks on steel nails that were found to be reproducible and identifiable over lengthy production runs involving tens of thousands of cut nails. The “tools” consisted of shearing machines, cutters and header punches. Although some changes in these toolmarks were observed by the author, nails manufactured after 32,000+ specimens could still be matched to initial samples. Toolmarks on other sites on these nails changed more rapidly but front and end samples ranging from 10,000 to 15,000 units could still be matched on the basis of impressed and striated marks produced during the manufacturing processes. To quote the author, *“Any change in toolmarks left by the cutter or header is so gradual as to allow an identification of toolmarks over a long period of production.”*

Miller, J. (2001) An Introduction to the Forensic Examination of Tool Marks, *AFTE Journal,* 33:3 pp. 233-248

This well-illustrated article with 75 references provides an excellent primer on the subject of toolmarks not produced by firearms. It also addresses the sources of individuality in a wide variety of tool types and how they can be imparted to various receiving surfaces. Finally, and most germane to this question, the author specifically comments on the effects of wear and usage and the persistence of a tool’s individuality [page 244 “Tool Wear”]

Ogihara, Y., et al, “Comparison of 5000 Consecutively Fired Bullets and Cartridge Cases From a 45 Caliber M1911 Pistol”, *AFTE Journal*, Vol. 15, No. 3, July 1983, pp. 127-140.

Durability study of major working edges/surfaces of a pistol.

9. What literature exists that describes the current state and scope of databases related to firearms/bullets/cartridge casings? Have analyses been conducted which define the gaps related to databases in firearms and toolmark research?

Barrett, M., Tajbakhsh, A., Warren, G. (2011) Portable Forensic Ballistics Examination Instrument: Advanced Ballistics Analysis System (ALIAS), *Association of Firearm and Toolmark Examiners Journal* 43:1 pp. 74-78.

> A portable measurement instrument and analysis tool for use by forensic ballistics and firearms examiners that creates, compares and analyses three-dimensional, volumetric models of fired cartridge cases and spent bullets. The technology can measure and examine toolmarks as small as two microns. ALIAS includes computer hardware, an open database infrastructure, a high-precision, Swiss-built, application-specific interferometer with a "six-pac" cartridge case or expended bullet holder (patents pending) and an open software architecture.

De Kinder, J., Tulleners, F., Thiebaut, H. (2004), Reference Ballistic Imaging Database Performance, *Forensic Science International*, 140, pp. 207-215

> These publications point out the limitations of image storage and search systems for fired cartridge cases at the time of these writings. The CALDOJ publication lists 9 issues and areas of concern in attempting to apply this technology to large databases of newly manufactured semi-automatic handguns.
> The combined American-European study by De Kinder, et al. involved 4200 fired cartridge cases from 6 brands of ammunition discharged in 600 model P226 SIG-Sauer 9mm pistols. The authors realized a 72% success rate when the same brand of cartridge case was scanned and entered into the IBIS system with success defined as the correct match appearing in the top 10 candidates. This fell to 21% when different brands of ammunition were scanned and entered in the system.

George, W., (2004) The Validation of the Brasscatcher Portion of the NIBIN/IBIS System Part Two: Fingerprinting Firearms Reality or Fantasy, *Association of Firearm and Toolmark Examiners Journal* 36:4 pp. 289 – 296.

> A study of the Brasscatcher portion of the NIBIN/IBIS system was conducted using a database of 850 cartridge cases fired in Smith & Wesson, .40 S&W caliber pistols. Correlations were generated for entries from Federal, Winchester and Remington brand ammunition and a study to locate the placement of matching cartridge cases initiated. Forensic Technology was able to open the entire database for viewing instead of the normal user field of 20 %. This study provided a real test of the ability of Brasscatcher to identify cartridge cases fired from similar firearms, and addresses the concept of fingerprinting firearms for use in criminal investigations. During this study an additional advantage regarding the second breech face impression image was revealed. The second image is not used for correlation purposes.

Nennstiel R., Rahm J. (2006) A Parameter Study Regarding the IBIS Correlator; *J Forensic Sci.*,51:1 pp. 18-23

Nennstiel R., Rahm J., (2006) An Experience Report Regarding the Performance of the IBIS Correlator, *J Forensic Sci.*, 51:1, pp. 24-30

> The articles by Nennstiel and Rahm provide success rate values for the IBIS technology for bullet and cartridge cases searches. These authors also found that as the database increases the system's success rate decreases.

Tulleners, F., (October 5, 2001) Technical Evaluation: Feasibility of a Ballistics Imaging Database for all New Handgun Sales. *CALDOJ Publication* (a peer reviewed report).

10. What studies, if any, have been designed to attempt to falsify the idea that a specific tool produced a specific mark to the practical exclusion of all others?

The numerous studies of consecutively manufactured tools (gun barrels, semi-automatic pistol slides and breech faces, firing pins, knifes, chisels, screwdrivers, etc.) all address this very issue. A number of these have been previously listed in response to Questions 6, 7 and 8 and will not be republished here. It should not be forgotten or overlooked that the final identification determination in any firearm or toolmark comparison does not include the entire universe of all firearms or tools in existence as the conclusion of Question 10 would suggest. Rather the objective and easily measureable Class Characteristics (caliber and cartridge designation, land and groove count, land and groove widths, direction of twist for firearms; tip shape and width for prying tools, the shape and diameter of the face of a hammer, etc. for tools) that are determined first greatly narrow the potential sources of a fired bullet, a fired cartridge case, a prymark from a crowbar or an impact mark from a hammer, etc.

<u>FIREARM BIBLIOGRAPHY</u>

Bachrach, Ben. "Development of a 3D-Based Automated Firearms Evidence Comparison System." *Journal of Forensic Sciences*, vol. 47 (6), November, 2002, pp. 1253-1264.

> This study reports on a computerized system that calculates correlation coefficients for comparisons of bullet striation patterns using generated 3-D maps of bullet surfaces. Was validated using known matches (KMs) and known non-matches (KNMs), so therefore the system arrives at a conclusion of identification (or not), with an associated probability of error. Highly relevant to our work, because it shows conclusively that an objective observer (a machine) detects significant visual differences between KNMs and KMs.

Biasotti, Alfred A. "A Statistical Study of the Individual Characteristics of Fired Bullets." *Journal of Forensic Sciences*, vol. 4(1), January, 1959, pp. 34-50.

> Validity study in which no more than three consecutively matching striations (CMS) were found on lead bullets fired from different guns and no more than four CMS were found on jacketed bullets fired from different guns.

Brown, C. and W. Bryant. "Consecutively Rifled Gun Barrels Present in Most Crime Labs." *AFTE Journal*, vol. 27 (3), July, 1995, pp. 254-258.

> Study of multi-barreled derringers in which it was assumed that barrels were rifled consecutively. One set of derringer test fires showed some good

correspondence in the groove impressions (gross marks), but showed little correspondence in the land impressions.

Brundage, David J. "The Identification of Consecutively Rifled Gun Barrels." *AFTE Journal*, vol. 30(3), Summer, 1998, pp. 438-444.

Validation study in which ten consecutively broach rifled pistol barrels produced by Ruger were used to used to test the fundamental claim that qualified examiners will rarely, if ever, commit false identifications or false eliminations. Thirty examiners were given the test nationwide and no misidentifications were made.

Bunch, Stephen G. "Consecutive Matching Striation Criteria: A General Critique." *Journal of Forensic Sciences*, vol. 45 (5), Sept. 2000, pp. 955-962.

This paper critiques the Quantitative Consecutive Matching Striation (CMS) approach to toolmark identification. The author discusses the practical and theoretical weaknesses of the approach, argues that it demands a statistical/probabilistic treatment of results - such as the use of Bayesian likelihood ratios - and also suggests much additional research is needed.

DeFrance, Charles S. and Michael VanArsdale. "Validation Study of Electrochemical Rifling." *AFTE Journal*, vol. 35 (1), Winter, 2003, pp. 35-37.

Validation study in which nine examiners participated in the comparison of bullets from electrochemically rifled barrels produced by Smith & Wesson. No misidentifications were made.

Fadul, T.G., "An Empirical Study to Evaluate the Repeatability and Uniqueness of Striations/Impressions Imparted on Consecutively Manufactured Glock EBIS Gun Barrels", *AFTE Journal*, Volume 43, Number 1, Winter 2011, Pp. 37-44.

An empirical study of ten consecutively manufactured Glock barrels containing the Enhanced Bullet Identification System (EBIS). Study consisted of test sets sent to 238 examiners from 150 laboratories in 44 states and 9 countries that were designed to test the examiner's ability to correctly identify fired bullets to the barrel that fired them. The results from 183 of these examiners produced an error rate of 0.4%. This study validated the repeatability and uniqueness of striated markings in gun barrels, as well as the ability of a competent examiner to reliably identify fired bullets to the barrels that marked them.

Freeman, Ray A., "Consecutively Rifled Polygon Barrels," *AFTE Journal*, vol.10 (2), June 978, pp.40-42.

This study documents the comparison of bullets fired through three consecutively manufactured polygon barrels produced by H&K for the Model P9S pistol. It was found that the bullets fired from these barrels could easily be identified to the correct barrel. Additionally, these barrels possessed a fluted chamber. Marks from the fluted chambers were visible on the bullets and could also be used for identification.

Hall, E. "Bullet Markings from Consecutively Rifled Shilen DGA Barrels." *AFTE Journal*, vol. 15(1), Jan., 1983, pp. 33-53.

Study of consecutively button rifled polygonal style barrels. Conclusion implies that there should be no risk of misidentification.

Hamby J. E., Brundage D. J. , Thorpe J. W., "The Identification of Bullets Fired from 10 Consecutively Rifled 9mm Ruger Pistol Barrels: A Research Project Involving 507 Participants from 20 Countries", *AFTE Journal*, Volume 41, Number 2, Spring 2009, pp. 99-110.

Bullets fired from ten (10) consecutively manufactured barrels were correctly identified to the respective barrel that fired them by five hundred-seven (507) firearm examiners from twenty (20) countries. This study validates the underlying theory that: 1) there are identifiable features imparted by a gun on the surfaces of fired bullets that 2) enable a competent firearms examiner to accurately and reliably link them to the barrel that fired them.

Intelligent Automation, Incorporated, "A Statistical Validation of the Individuality of Guns Using High Resolution Topographical Images of Bullets", National Institute of Justice Grant #2006-DN-BX-K030, October, 2010

Study of marks on fired bullets by a topography based (3D) automated system. This study continued the analysis of a previous 2005 NIJ bullet study and validated the original premise of Firearm/Toolmark ID. This study also concluded that 1) the ability to determine that a given bullet was fired from a specific barrel depends on the individual barrel itself and not only on the brand of its manufacture, and 2) the performance of the automated analysis system used in this study is not representative of that of a trained firearms examiner as humans have a remarkable ability to perform pattern matching that is difficult to be replicated in any automated system.

Lomoro, Vincent J. "Class Characteristics of 32 SWL, FIE Titanic Revolvers." *AFTE Journal*, vol. 6 (2), 1974, pp. 18-21.

This paper points out the pitfalls of basing an identification on groove impressions on bullets fired from F.I.E. Titanic Revolvers. Bullets from three different guns were shown to have agreement in the groove impressions, but were found to differ significantly in the land impressions.

Lutz, M. "Consecutive Revolver Barrels." *AFTE Newsletter #9*, Aug., 1970, pp.24-28.

Reported results of the comparison of jacketed and lead bullets fired from two consecutively rifled barrels and that the markings on the bullets were identifiable and unique to the barrel that fired them.

Matty, William. "A Comparison of Three Individual Barrels Produced from One Button-Rifled Barrel Blank." *AFTE Journal*, vol. 17(3), July, 1985, pp. 64-69.

Study of the uniqueness of marks produced on bullets fired from three barrels that were produced from the same rifled barrel blank. Subclass characteristics noted in the groove impressions, but not in the land impressions. Study also notes that over the first few firings the striations on the bullets change significantly.

Miller, Jerry. "An Examination of Two Consecutively Rifled Barrels and a Review of the Literature." *AFTE Journal*, vol. 32 (3), Summer, 2000, pp.259-270.

Study in which bullets were pushed through two consecutively broached.44 caliber barrels and were examined using Biasotti/Murdock conservative quantitative CMS (QCMS) criteria for identifications. No misidentifications.

Miller, Jerry. "Criteria for Identification of Toolmarks, Part II: Single Land Impression Comparisons." *AFTE Journal*, vol. 32 (2), Spring, 2000, pp. 116-131.

This study compares bullets fired by Raven 25 Auto, Lorcin 380 Auto, and Stallard Arms 9mm pistols to specimens in the NIBIN database. This study supports the Biasotti/Murdock QCMS criteria.

Miller, Jerry. "An Examination of the Application of the Conservative Criteria for Identification of Striated Toolmarks Using Bullets Fired from Ten Consecutively Rifled Barrels." *AFTE Journal*, vol. 33 (2), Spring, 2001, pp. 125-132.

Using the bullets from the Brundage Ruger ten barrel test, the author: 1) identified some very minor subclass characteristics but not sufficient to cause a misidentification, and; 2) applied the conservative quantitative CMS criteria which resulted in no misidentifications.

Miller, Jerry and Michael McLean. "Criteria for Identification of Toolmarks." *AFTE Journal*, vol. 30 (1), 1998, pp.15-61.

Using IBIS, the authors compared land impressions of .38 Special jacketed bullets fired from S&W revolvers. Found no CMS counts greater than six (6) for KNMs, using the computer monitor. Using a separate set of test fires and the comparison microscope, no CMS counts greater than four (4) for KNMs were found.

Murdock, John E. “A General Discussion of Gun Barrel Individuality and an Empirical Assessment of the Individuality of Consecutively Button Rifled .22 Caliber Rifle Barrels.” *AFTE Journal*, vol. 13 (3), 1981, pp. 84-95.

This study discusses rifling methods, including the “new” method of button rifling. Examination of nine barrels (three consecutively rifled barrels from three manufacturers) and test fired bullets from each indicated no subclass characteristics. First two bullets fired from each barrel could not be identified to each other which is indicative of rapid change in a new barrel’s interior, which in turn confirms individuality of barrels.

Skolrood, R. W. “Comparison of Bullets fired from Consecutively Rifled Cooey .22 calibre Barrels.”*Canadian Society of Forensic Science*, vol. 8(2), 1975, pp. 49-52.

This paper discusses the potential for broaches to produce reproducible gross marks and that examiners should be wary of these gross marks.

Smith, Erich. “Cartridge Case and Bullet Comparison Validation Study withFirearms Submitted in Casework.” *AFTE Journal*, vol. 37 (2), Spring 2005, pp. 130-135.

This validation study was designed to test the accuracy of examinations by trained firearms examiners who use pattern recognition only (no CMS tabulation) as a method for identification. Eight FBI examiners took the test which consisted of both bullets and cartridge cases. No false positives or false negatives were reported.

Tulleners, Fred and Mike Giusto. “Striae Reproducibility on Sectional Cuts of One Thompson Contender Barrel.” *AFTE Journal*, vol. 30(1), 1998, pp. 62-81.

For this study, a Thompson Center Contender button rifled barrel was sectioned one inch at a time after each test firing. A total of six sections were removed from the barrel. Each sections bullets were compared to each other to see how much the CMS count had changed. Striae on the bullets were found to be significantly altered from one barrel section to the next. The results obtained from adjacent barrel sections were apparently comparable to the results Biasotti obtained from different, uncut barrels. It was also significant that while total line counts differed, the critical observation of CMS generally not exceeding three for known non-matching regimes was very consistent between examiners.

Tulleners, Fred and James Hamiel. “Sub Class Characteristics of Sequentially Rifled .38 Special S&W Revolver Barrels.” *AFTE Journal*, vol. 31 (2), 1999, pp. 117-222.

This article discusses the potential for sub-class characteristics in S&W revolver barrels. The article points out that examiners should be careful when examining the groove impressions on fired bullets from broach rifled barrels.

Bunch, Stephen G. and Douglas P. Murphy. “A Comprehensive Validity Study for the Forensic Examination of Cartridge Cases.” *AFTE Journal*, vol. 35 (2), Spring 2003, pp. 201-203.

> This validity study used 10 consecutively manufactured Glock slides to test the proposition that qualified examiners rarely or never commit false positive or false negative errors in cartridge case exams. FBI examiners participated in this blind study. False positive and false negative rates were 0%.

Coffman, B.C., “ Computer Numerical Control (CNC) Production Tooling and Repeatable Characteristics on Ten Remington Model 870 Production Run Breech Bolts”, *AFTE Journal*, Volume 35, Number 1, Winter 2003, pp. 49-54.

> Ten shotgun bolt faces, consecutively produced by the same CNC manufacturing machine tool, were examined and compared for the presence of subclass and individual characteristics. Results of these comparisons found that the manufacturing process used to fabricate these bolts produced both subclass characteristics and sufficient individual characteristics to provide uniqueness.

Coody, A.C., “Consecutively Manufactured Ruger P-89 Slides”, *AFTE Journal*, Volume 35, Number 2, Spring 2003, pp. 157-160.

> Ten consecutively produced pistol slide breechfaces were examined and compared for the presence of subclass and individual characteristics. Results of these comparisons found that the manufacturing processes used to fabricate these breechfaces produced both subclass characteristics and sufficient individual characteristics to provide uniqueness.

Gouwe J., Hamby J.E., Norris, S., “Comparison of 10,000 Consecutively Fired Cartridge Cases from a Model 22 Glock .40 S&W Caliber Semiautomatic Pistol”, *AFTE Journal*, Volume 40, Number 1, Winter 2008, pp. 57-63.

> Ten thousand (10,000) .40 S&W caliber cartridge cases fired from a Glock, model 22, pistol were compared. All 10,000 fired cases could be identified to each other. This study validates previous durability studies that showed identifiable markings from a tool could persist for a long period of time.

Grooss, Klaus Dieter. “The ‘Hammer-Murderer.’” *AFTE Journal*, vol. 27 (1), 1995, pp. 27-30.

> An actual murder case in Germany that in effect amounted to a blind test of both examiner skill and theoretical validity for cartridge case comparisons. A police officer was suspected of murder, but the lack of clues led to all Walther P5 pistols issued to police in Germany being test fired and compared to the evidence cartridge cases at the BKA lab. An identification occurred with a test-fired cartridge

case from the 3704th pistol. Almost simultaneous events elsewhere proved this conclusion to be accurate. No false identifications occurred.

Hamby J., and Thorpe J., “The Examination, Evaluation and Identification of 9mm Cartridge Cases Fired from 617 Different GLOCK Model 17 & 10 Semiautomatic Pistols”, *AFTE Journal*, Volume 41(4), Fall 2009, Pp. 310-324.

A study of cartridge cases fired from 617 different Glock pistols was conducted utilizing conventional comparative optical microscopy and electronic imaging technology to test the premise of individualization in FA/TM ID. Results of this study validated not only the premise of individualization but also the hypothetical proposition that a competent firearm and toolmark examiner can correctly identify the firearm that fired an ammunition component without committing a misidentification.

Kennington, Robert. “Identification of Cartridge Cases Fired in Different Firearms: ‘Pre-Identified Cartridges.’” *AFTE Journal*, vol. 31(1), 1999, pp. 15-19.

This research discusses the pitfall that toolmarks produced during the manufacturing process of ammunition components pose and that one should be mindful that these marks exist.

Lardizabal, P. “Cartridge Case Study of the HK USP.” *AFTE Journal*, vol. 27 (1), Jan., 1995, pp. 49-51.

This study examined two consecutively manufactured H&K 40 S&W caliber USP breechfaces. Subclass characteristics were identified on the breechface impressions. Test fired bullets from three H&K barrels were also examined and little correspondence was found between signatures from bullets fired from different barrels.

Lopez, Laura and Sally Grew. “Consecutively Machined Ruger Bolt Faces.” *AFTE Journal*, vol. 32 (1), 2000, pp. 19-24.

This study warns that one should be careful with microscopic marks from a boltface machined with an end mill. Misidentification is possible unless the identification is based on wear or individual machining “chatter” marks.

Lyons, D. J., “The Identification of Consecutively Manufactured Extractors”, AFTE Journal, Volume 41, Number 3, Summer, 2009, pp.246-256.

Study conducted on ten consecutively manufactured firearm extractors. Firearm and toolmark examiners from different laboratories were given ten sets of cartridge cases marked by these extractors to attempt to make the correct associations between the known and unknown cases. Each examiner also received twelve unknown marked cases in addition to the standards for the ten

consecutively manufactured extractors, with each known specimen having at least one unknown specimen associated with it. Study showed that extractors could be distinguished from each other despite the fact they were consecutively manufactured and had subclass toolmarks on some surfaces.

Matty, William. “Raven .25 Automatic Pistol Breech Face Tool Marks.” *AFTE Journal*, vol. 16 (3), 1984, pp. 57-60.

For this study, three consecutively made breechfaces from Raven pistols were compared. The concentric toolmarks on the breechfaces were found to be individual and not subclass.

Matty, William and Torrey Johnson. “A Comparison of Manufacturing Marks on Smith & Wesson Firing Pins.” *Journal of AFTE*, vol. 16 (3), 1984, pp. 51-56.

This study examined the concentric marks produced by Smith & Wesson firing pins. Subclass characteristics were found. These subclass marks are a result of the lathe mounted cutter being much harder than the firing pins and thus marks can be reproduced; however, using the areas of the firing pins that show wear can be used for identification.

Rosati, Carlo. “Examination of Four Consecutively Manufactured Bunter Tools.” *AFTE Journal*, vol. 32 (1), 2000, pp. 49-50.

For this study, four bunters produced by Electrical Discharge Machining (EDM) used by Remington for .45 Auto cartridge case manufacture were used to determine if this process was random in nature. Confirms random nature of marks from EDM process on headstamp characters.

Saribey, A. Y., Hannam A. G., Tarimci C., “An Investigation into Whether or Not the Class and Individual Characteristics of Five Turkish Manufactured Pistols Change During Extensive Firing”, Journal of Forensic Sciences, Volume 54, Number (5), September 2009, pp.1068-1072.

Conducted statistical durability study of fired cartridge cases from five different pistols. Each pistol had at least 1000 cartridge cases fired in them with every 250th case compared to the first fired case. Although there were noted changes in individual and some class characteristics, these wear changes were not statistically significant based on standard deviation measurements. This study statistically validated previous durability studies.

Thompson, Evan. “Phoenix Arms (Raven) Breechface Toolmarks.” *AFTE Journal*, vol. 26 (2), 1994, pp. 134-135.

This is a follow-up study of the Matty article on Raven breechfaces. Four breechfaces from Phoenix pistols (formerly Raven) were compared to determine the nature of their marks. As in the Matty article, the breechfaces were found to possess unique identifying marks.

Thompson, Evan. “False Breechface ID’s.” *AFTE Journal*, vol. 28 (2), April, 1996, pp. 95-96.

This study examines the manufacturing process of Lorcin pistol breechfaces. Of noteworthiness is the fact that Lorcin breechfaces are stamped and then painted over, not machined. False identifications could be possible if the only marks considered are from the breechface. Also noted was the fact that paint on breechfaces has a tendency to chip off and that one should not solely rely on the breechface impression as a means for identification.

Uchiyama, T. “Similarity among Breech Face Marks Fired from Guns with Close Serial Numbers.” *AFTE Journal*, Vol. 18, No. 3, 1986, pp. 15-52.

This study examined the breechface marks produced by Browning Baby, Raven P-25 and Titan pistols. Subclass characteristic were found to be significant on the breechface of each of these pistol models and examiners should use caution when encountering them.

TOOLMARK BIBLIOGRAPHY

Chumbly, L. Scott, et al, “Validation of Tool Mark Comparisons Obtained Using a Quantitative, Comparative, Statistical Algorithm” Journal of Forensic Sciences, Volume 55, Number 4, July 2010, Pp. 953-961.

A statistical analysis and computational algorithm for comparing pairs of toolmarks by profilometry data was conducted. Toolmarks produced by 50 sequentially made screwdrivers, at selected fixed angles, were analyzed both empirically by practicing examiners and by the established computational algorithms. The results of these comparisons, as well as a subsequent blind study with the practicing examiners, showed scores of good agreement between the algorithm and human experts. It was also noted that in some of the examination phases, examiner performance was much better than the algorithm.

Bachrach B., Jain A., Jung S., and Koons R.D., “A Statistical Validation of the Individuality and Repeatability of Striate Tool Marks: Screwdrivers and Tongue and Groove Pliers”, *Journal of Forensic Sciences*, Volume 55, Number 2, March 2010, pp 348-357.

Study that statistically validated the original premise of individuality in Toolmark Identification by analyzing statistical distributions of similar values resulting from the comparison of Known Matches (KM) and Known Non-Matched (KNM) pairs of striated toolmarks. This quantifiable analysis of KM and KNM toolmark similarity distributions showed nearly error-free identifications.

Bacharach, B., “Statistical Validation on the Individuality of Tool Marks Due to the Effect of Wear, Environment Exposure and Partial Evidence”, *NIJ/NCJRS Document #227929*, August, 2009.

An objective, quantifiable toolmark study on marks imparted onto wires by diagonal cutters. This study examined the effects of wear, environmental conditions and partial toolmark impressions by an automated 3-D system that mathematically correlated results of toolmarks to the tools that produced them. This study validated, and thus strengthened, the foundations of Toolmark Identification.

Burd, David Q. and Allen E. Gilmore. “Individual and Class Characteristics of Tools.” *Journal of Forensic Sciences*, Vol. 13 (3), July, 1968, pp. 390-396.

This article discusses tools made from molds, such as die stamps and die forgings, and the possibility of confusing class marks as individual marks.

Butcher, S. and D. Pugh. “A Study of Marks made by Bolt Cutters.” *Journal of the Forensic Science Society*, Vol. 15 (2), April 1975, pp. 115-126.

This study examines test marks made by ten consecutively made bolt cutters and ten randomly selected bolt cutters with ground working surfaces. The study determined that no more than 29% matching stria for known non-matches and between 87% and 93% matching stria for known matches. Implication: no risk of misidentification.

Cassidy, F. “Examination of Toolmarks from Sequentially Manufactured Tongue and Groove Pliers.” *Journal of Forensic Sciences*, vol. 25 (4), Oct., 1980, pp. 796-809.

This study examines the individuality of striated marks produced by consecutively broach cut tongue and groove pliers. Examination of the jaw teeth and their test marks revealed no subclass marks and that the striated marks produced are individual to the tool that made them.

Clow, Charles M. “Cartilage Stabbing with Consecutively Manufactured Knives: A Response to Ramirez v. State of Florida.” *AFTE Journal*, vol. 37 (2), Spring, 2005, pp. 86-116.

This study utilized ten consecutively manufactured knives used in a stabbing motion to determine if the marks produced were unique and if marks were reproducible and identifiable in pig cartilage. Marks were found to be unique. Marks reproduced and were found to be potentially identifiable in cartilage.

Eckerman, Stephanie J. “A Study of Consecutively Manufactured Chisels.” *AFTE Journal*, vol. 34 (4), Fall 2002, pp. 379-390.

In this study, consecutively belt sanded chisels were examined for the possibility of subclass marks. The marks were found to be individual to each chisel.

Flynn, Emmett M. "Toolmark Identification." *Journal of Forensic Sciences*, vol. 2 (1), Jan., 1957, pp. 95-106.

In this study, Chicago Police Crime Lab examined 100 consecutively made chisels finished with a grinding process. 5050 total comparisons made. No misidentifications.

Giroux B. N., "Empirical and Validity Study: Consecutively Manufactured Screwdrivers", AFTE Journal, Volume 41, Number 2, Spring 2009, pp. 153-158.

The fundamental propositions of Toolmark Identification were tested with an empirical and validation study of five consecutively manufactured screwdrivers. The empirical study compared the machining marks imparted on the working surfaces of these screwdrivers to toolmark specimens produced by these screwdrivers. Eight qualified examiners at the FBI Laboratory participated in a blind validation study where eighty comparisons were conducted on the toolmarks produced by these screwdrivers. The results of this blind validity study resulted in no mis-identifications and one mis-elimination.

Hall, J. "Consecutive cuts made by bolt cutters and their effect on identification." *AFTE Journal*, vol. 24 (3), July, 1992, pp. 260-272.

This study showed that consecutive cuts in lead with bolt cutters are identifiable, showing that lead is a suitable material for test marks. Cuts in shackles may or may not change the tool, depending upon the hardness of the shackle.

Hornsby, B. "MCC Bolt Cutters." *AFTE Journal*, vol. 21 (3), July, 1989, p. 508.

This study randomly selected bolt cutters from the same production run. The working surfaces of the bolt cutters were produced through milling and tumbling. The study concluded that, test marks produced by these bolt cutters were unique to the tool that made them.

Jordan, Tom. "Individual Characteristics on Copper Insulated Wire." *AFTE Journal*, Vol. 14 (1), 1982, pp. 53-56.

Using 3 to 6 inch sections of #12 insulated copper wire, this study revealed that the drawing marks are unique to the tool that produced them during manufacture.

Lee, Susan E. "Examination of Consecutively Manufactured Slotted Screwdrivers." *AFTE Journal*, vol. 35 (1), Winter, 2003, pp. 66-70.

This study used five consecutively made screwdrivers to test the reproducibility of marks produced at various angles with both pushing and pulling motions. Each screwdriver's marks were found to be individual to tool that produced them.

Miller, Jerry and G. Beach, "Toolmarks: Examining the Possibility of Subclass Characteristics," AFTE Journal, Vol. 37 (4), Fall 2005, pp. 296-345.

This study utilizes consecutively manufactured diagonal cutting pliers, slip joint pliers, center punches, cold chisels and beveled wood chisels to determine if these tools possess subclass characteristics and individual characteristics. In all cases, except the center punches, subclass characteristics and individual characteristics were observed. The grinding process used to finish the punches produce individual characteristics only. The remaining tools produce marks that are easily identified based on individual characteristics or a combination of subclass and individual characteristics which are easily discernible.

Miller, Jerry. "Cut Nail Manufacturing and Toolmark Identification." *AFTE Journal*, Vol. 30 (3), Summer 1998, pp. 492-498.

This study discusses the cut nail manufacturing process and a study was conducted in which 32,000 + nails were identified to the tools that made them.

Murdock, John E. "The Individuality of Tool Marks Produced by Desk Staplers." *AFTE Journal*, Vol. 6 (5), 1974. pp. 23-39.

This study found that Pilot brand staplers produced individual marks on staples, while Swingline brand staplers produced only subclass marks. The manufacturers used different manufacturing methods which was the reason for the differing types of marks.

Reitz, J. "An Unusual Toolmark Identification case." *AFTE Journal*, vol. 7 (3), Dec., 1975, pp. 40-43.

Consecutively ground and randomly selected twist drill bits were studied. Results show no risk of misidentification. The grinding process caused no subclass influence.

Thompson, Evan and R. Wyant, "Knife Identification Project (KIP)," *AFTE Journal*, Vol. 35 (4), Fall 2003, pp. 366 – 370.

This study utilizes ten consecutively manufactured knives produced by the Benchmade Knife Corporation to produce a test to evaluate the uniqueness of striated toolmarks. One hundred and forty tests were distributed at the 2002 AFTE Training Seminar. One hundred and three examiners submitted results for inclusion in the study. Of the possible 1,030 possible answers, 1,022 were correct

(8 incorrect answers). The error rate for this study was calculated to be 0.776 percent.

Tuira, Y.J. “Tire Stabbing with Consecutively Manufactured Knives.” *AFTE Journal*, Vol. 14 (1), 1982, pp. 50-52.

Two consecutively made Buck knives were thrust into inflated tires and the toolmarks compared. The toolmarks were found to be significantly different.

Van Dijk, T.M. “Steel Marking Stamps: Their Individuality at the Time of Manufacture.” *Journal of the Forensic Science Society,* Vol. 25 (4), July/Aug, 1985, pp. 243-253.

Fifty steel marking stamps made from the same hob (die) were examined for subclass marks. Unique defects from the hobbing process could be used to correctly identify each stamp.

Watson, D. “The Identification of Toolmarks Produced From Consecutively Manufactured Knife Blades in Soft Plastics.” *AFTE Journal*, vol. 10 (3), September, 1978, pp. 43-45.

This article discusses the uniqueness of two consecutively manufactured knives. No carryover was found to exist between the two knives.

Watson, Donald J., “The Identification of Consecutively Manufactured Crimping Dies,” AFTE Journal, vol. 10, September 1978, pp. 19-21.

This study documents the manufacturing process of crimping dies and the results of the comparison of two consecutively manufactured crimping dies. It was found that the crimping dies bore no “carry-over” effects and that lead seals crimped with these dies could be identified back to their source.

11. What research exists that has examined the minimum set of skills a practitioner should possess in order to perform a specific task (e.g. pattern recognition and aptitude versus education)?

Minimum Qualifications for Firearm and Toolmark Examiner Trainees (4/20/2006). *Scientific Working Group for Firearms and Toolmarks*. http://www.swggun.org/swg/index.php?option=com_content&view=article&id=30:minimum-qualifications-for-firearm-and-toolmark-examiner-trainees&catid=10:guidelines-adopted&Itemid=6

This document is a guideline that addresses the minimum education requirements for individuals seeking employment as a firearm and toolmark examiner.

The Association of Firearm and Tool Mark (AFTE) Training manual.

The ATF National Firearms Training Academy (NFEA) -minimum educational qualifications requirements

National Forensic Science Technology Center (NFSTC)- Firearm Examiner Training Program

12. Are there any studies that use digital imaging to either validate or invalidate the basic tenets of firearm and toolmark comparisons? If so, what automated methods exist and how can they be refined?

Chew, Wei et al (2010). Striation Density for Predicting The Identifiability of Fired Bullets With Automated Inspection Systems. *Journal of Forensic Sciences*, Vol. 55, No. 5, 1222-1226.

Deinet, Werner. (1981). "Studies of Models of Striated Marks Generated by Random Processes." *Journal of Forensic Sciences*, Vol. 26 (1), pp. 35-50.

> The author uses computer-aided studies of the degree of similarity of striated marks. He produced digitized images of 40 grinding marks which were entered into a computer wherein position values were defined and idealized models were defined for an objective comparison of striated marks.

Evans, Paul & Smith, Clifton. (2004). "Validation of the Linescan Imaging Technique for Imaging Cylindrical Forensic Ballistics Specimens." AFTE Journal, Vol 36, No 4. pp 275-280.

> Abstract: The imaging of cylindrical surfaces of forensic ballistics specimens with an area camera system requires the geometric registration of a number of different images in order to effect a 360° view of its surface. This view is very difficult to achieve in terms of consistent spatial resolution. A line-scan imaging technique utilising an area array camera producing images of rotating ballistics specimens is described. A discussion of the validity of the technique to use the images for the identification of firearms is presented. The 2-D planar images of complete 3-D cylindrical surfaces produced by the linescan technique have a geometric format that is particularly suited to morphological image processing and the production of image databases.

Geradts, Zeno, et al. (2001). "Pilot Investigation of Automatic Comparison of Striation Marks with Structured Light." SPIE Proceedings Paper, Vol 4232. pp 49-56

> Abstract: We have developed and tested an algorithm that can compare striation marks that are acquired with a standard camera and sidelight as well as 3D-information acquired with structured light. With six different screwdrivers test marks have been made with an angle of 45 degrees to the surface. These striation marks are moulded with gray silicon casting material. Then these marks are digitized with the structured light approach and with side light. For the structured light approach, it appeared that there are artifacts and variations in the image due to the number of stripes in the LCD projections and the camera resolution. We have compensated for these variations by averaging the lines over an area that is selected by the user. In the method that has been used for averaging, the slopes of the striae are followed. This method is also used for side light images to compensate for variations in the striation mark. In this research,

signatures of the tool marks are calculated then compared with a database of signatures by calculating the standard deviation of the difference. For the limited test set of six striation marks made with six different screwdrivers, the algorithm was able to distinguish the global shape of the screwdriver and the depth information itself. Since the images acquired with structured light contain more information on the toolmark itself, the correlation results were better than with side light images.

Intelligent Automation, Incorporated (October, 2010). A Statistical Validation of the Individuality of Guns Using High Resolution Topographical Images of Bullets. *National Institute of Justice Grant #2006-DN-BX-K030*.

Study of marks on fired bullets by a topography based (3D) automated system. This study continued the analysis of a previous 2005 NIJ bullet study and validated the original premise of Firearm/Toolmark ID. This study also concluded that 1) the ability to determine that a given bullet was fired from a specific barrel depends on the individual barrel itself and not only on the brand of its manufacture, and 2) the performance of the automated analysis system used in this study is not representative of that of a trained firearms examiner as humans have a remarkable ability to perform pattern matching that is difficult to be replicated in any automated system.

Leon, Fernando. (2006). "Automated Comparison of Firearm Bullets." Forensic Science International, Vol 156. pp 40-50.

Abstract: Fired bullets bear striation marks that can be thought of as a ''fingerprint'' left by the firearm. This new comparison approach is based on an automated extraction of a ''signature'' encompassing the relevant marks from an image. To this end, multiple pictures of the bullet are recorded first by using different illumination patterns, and a high quality image is generated by means of fusion techniques. After a preprocessing, the image intensities are filtered along the striations direction, yielding a compact representation of the marks. A non-linear filter selects the striae of interest. The actual comparison takes place by cross correlating the signatures obtained this way. Finally, an assessment strategy is proposed to objectively evaluate the performance of the system. As demonstrated with an image database of real bullets, the proposed approach outperforms a state-of-the-art commercial system.

Miller, J., McLean, M. (1998). Criteria for Identification of Toolmarks. *AFTE Journal*, Vol. 30, No.1, pp.15-61.

Using IBIS, the authors compared land impressions of .38 Special jacketed bullets fired from S&W revolvers. Found no CMS counts greater than six (6) for KNMs, using the computer monitor. Using a separate set of testfires and the comparison microscope, no CMS counts greater than four (4) for KNMs were found.

Miller, J. (2000). Criteria for Identification of Toolmarks, Part II: Single Land Impression Comparisons. *AFTE Journal*, vol. 32 (2), Pp.116-131.

This study compares bullets fired by Raven 25 Auto, Lorcin 380 Auto, and Stallard Arms 9mm pistols to specimens in the NIBIN database. This study supports the Biasotti/Murdock Quantitative Conservative Matching Striae (QCMS) criteria.

Smith, C. L. (2002). Linescan Imaging of Ballistics Projectile Markings for Identification. *Security Technology Proceedings, 36th Annual International Carnahan Conference*, pp. 216 – 222.

The identification of firearms from forensic ballistics specimens is an exacting and intensive activity performed by specialists with extensive experience. The introduction of imaging technology to assist the identification process of firearms has enhanced the ability of forensic ballisticians to conduct analyses of these specimens for identification. The characteristic markings on the cartridge and projectile of a bullet fired from a gun can be recognised as a fingerprint for identification of the firearm. Forensic ballistics imaging has the capacity to produce high-resolution digital images of cartridge cases and projectiles for matching of crime scene specimens to test specimens. Projectile bullets fired through the barrel of a gun will exhibit extremely fine striation markings, some of which are derived from minute irregularities in the barrel produced during the manufacturing process. The examination of these striations on the land marks and groove marks of the projectile is difficult using conventional optical microscopy. However, digital imaging techniques have the potential to detect the presence of striations on ballistics specimens for identification matching. This paper describes a linescan imaging technique to examine the striation markings on the land marks and groove marks of projectiles for positive identification. The paper discusses the application of the technique to cylindrical forensic ballistics specimens, and the potential of the technique for image matching. Digital images of land marks and groove marks of projectiles produced by the line scan technique are presented, and analyses of the images are conducted.

Smith, C.L. and Cross, J.M. (1995). “Optical Imaging Techniques for Ballistics Specimens to Identify Firearms.” IEEE Proceedings: 29th Annual International Carnahan Conference on Security Technology. pp 275-289.

Abstract: Characteristic markings on the cartridge and projectile of a bullet are produced when a gun is fired. Over thirty different features within these markings can be distinguished, which in combination produce a “fingerprint” for identification of a firearm. This paper describes an investigation into the development of an imaging system which can store, analyze, retrieve, and match high resolution digital images of cartridge cases. A computerized imaging system for ballistics identification will produce efficiencies in time and personnel, and permit a more precise audit of firearms within a country. The project has produced good quality high resolution digitized images of cartridge cases. The development of the optical system to optimize image quality has been crucial for the image identification phase. By classifying cartridge image attributes, it is possible to store the unique “signatures” of cartridge cases for identification. Appropriate image processing provides the signatures for the image library. The FIREBALL forensic ballistics interactive database incorporates a graphics user interface (GUI) to obtain precise ballistics metrics of cartridge case class characteristics. This project will significantly improve the effectiveness and efficiency of ballistics records and assist the tracing of firearms used in criminal activities by law enforcement agencies.

Smith, C.L. (2006). “Profiling Toolmarks on Forensic Ballistics Specimens: An Experimental Approach.” IEEE Proceedings: 40th Annual International Carnahan Conference on Security and Technology. pp 281-286.

Abstract: This paper will discuss an experimental approach for matching toolmark images from the linescan technique and measurements from the profilometry technique of surface mapping. By relating the topography of a region on the surface of a cartridge case and projectile to that region on the unwrapped image from the linescan technique, a potential match may be developed. The application of depth profiling of imperfections on the projectiles and cartridges from the firing of a weapon has the potential to map unique markings on the ballistics specimens from crime scene firearms. The paper will show depth profiles of land marks and groove marks of projectiles, and firing pin marks and breach face marks on cartridges as examples supporting the potential for the profiling technique.

Zographos, A., et al. (1997). “Ballistics Identification Using Line-Scan Imaging Techniques.” IEEE Proceedings: 31st Annual International Carnahan Conference on Security Technology. pp 82-87.

Abstract: A new line-scan imaging technique, well-suited to the inspection of ballistics specimens, is presented. The proposed system addresses a number of problems associated with the imaging of cartridge cases when conventional inspection techniques are used. This particular paper deals exclusively with imaging of the cylindrical surface of cartridge cases. Imaging of the firing pin marks on the end of the case is not considered. Results obtained so far from a prototype system are presented. It should be noted that this technique is still very much in its experimental phase and that as yet it has not been fully investigated for this forensic ballistics application.

Zhihu Huang; Jinsong Leng. (2010). “An Online Ballistics Imaging System for Firearm Identification.” IEEE - 2nd International Conference on Signal Processing Systems, Vol 2. pp 68-72.

Abstract: Since the traditional ballistics imaging system is dependent upon the expertise and experience of end-user, an intelligent ballistics imaging system is highly demanded to overcome the drawbacks of traditional techniques. This paper aims to develop a novel ballistics imaging system so as to combine the traditional functions with new features such as the line-scan image module, the characteristics extraction module, and the intelligent image processing module. With the help of these features, the new system can identify firearm more efficiently and effectively than the traditional techniques.

Zhihu Huang; Jinsong Leng. (2010). "A Novel Binarization Algorithm for Ballistics Imaging Systems." IEEE – 3rd International Congress on Image and Signal Processing, Vol. 3. pp 1287 – 1291.

Abstract: The identification of ballistics specimens from imaging systems is of paramount importance in criminal investigation. Binarization plays a key role in preprocess of recognizing cartridges in the ballistic imaging systems. Unfortunately, it is very difficult to get the satisfactory binary image using existing binary algorithms. In this paper, we utilize the global and local thresholds to enhance the image binarization. Importantly, we present a novel criterion for effectively detecting edges in the images. Comprehensive experiments have been conducted over sample ballistic images. The empirical results demonstrate the proposed method can provide a better solution than existing binary algorithms.

13. What literature documents the automated methods of comparison that exist for firearms/toolmarks examination, how they are being applied to the examination process, and any potential shortcomings.

Bachrach, B. (2002). Development of a 3D-Based Automated Firearms Evidence Comparison System. *Journal of Forensic Sciences*, vol. 47 (6), 1253-1264.

> Abstract: This study reports on a computerized system that calculates correlation coefficients for comparisons of bullet striation patterns using generated 3-D maps of bullet surfaces. Was validated using known matches (KMs) and known non-matches (KNMs), so therefore the system arrives at a conclusion of identification (or not), with an associated probability of error. Highly relevant to our work, because it shows conclusively that an objective observer (a machine) detects significant visual differences between KNMs and KMs.

Bachrach, B. (et al). (2010). "A Statistical Validation of the Individuality and Repeatablity of Striated Tool Marks: Screwdrivers and Tongue and Groove Pliers." Journal of Forensic Sciences, Vol 55, No. 2. pp 348-357.

> Abstract: Tool mark identification relies on the premise that microscopic imperfections on a tool's working surface are sufficiently unique and faithfully transferred to enable a one-to-one association between a tool and the tool marks it creates. This paper presents a study undertaken to assess the validity of this premise. As part of this study, sets of striated tool marks were created under different conditions and on different media. The topography of these tool marks was acquired and the degree of similarity between them was quantified using well-defined metrics. An analysis of the resulting matching and nonmatching similarity distributions shows nearly error-free identification under most conditions. These results provide substantial support for the validity of the premise of tool mark identification. Because the approach taken in this study relies on a quantifiable similarity metric, the results have greater repeatability and objectivity than those obtained using less precise measures of similarity.

Blackwell, R.J., and Framan E.P. (1980). "Automated Firearms Identification System (AFIDS): Phase I. AFTE Journal, Vol. 12, No. 4. pp 11-37. *(Reprinted in AFTE Journal – original article was prepared by the authors of the Jet Propulsion Laboratory for the Applications Technology Office, National Aeronautics and Space Administration)*

> Abstract: Items critical to the future development of an automated firearms identification system (AFIDS) have been examined, with the following results: 1. Types of objective data, that can be utilized to help establish a more factual basis for determining identity and nonidentity between pairs of fired bullets, have been identified. 2. A simulation study has indicated that randomly produced line, similar in nature to the individual striations on a fired bullet, can be modeled and that random sequences, when compared to each other, have predictable relationships., 3. A schematic diagram of the general concept for AFIDS has

been developed and individual elements of this system have been briefly tested for feasibility., Future implementation of such a proposed system will depend on such factors as speed, utility, projected total cost and user requirements for growth. The success of the proposed system, when operational, would depend heavily on existing firearms examiners.

Chu, Wei, et al. (2010). Pilot Study of Automated Bullet Signature Identification Based on Topography Measurements and Correlations. J Forensic Sci, Vol 55, No 2, 1-7.

Abstract: The authors outline a procedure for automated bullet signature identification based on topography measurements using confocal microscopy and correlation calculation. The correlation results show a 9.3% higher accuracy rate compared with a currently used commercial system based on optical reflection.

De Kinder, Jan and Bonfanti, Monica. (1999). "Automated Comparisons of Bullet Striations Based on 3D Topography." Forensic Science International, Vol 101. pp 85-93.

Abstract: A system capable of comparing the signatures on bullets in the field of firearms identification is presented. It is based on the recording of the topography of a bullet using laser profilometry. A procedure to derive a one-dimensional array of characteristics out of the recorded data is presented. These so-called feature vectors are compared with similar quantities from other bullets using a correlation technique. Good results were obtained for weapons leaving well-defined characteristics.

Dongguang, L. (2006). Ballistics Projectile Image Analysis for Firearm Identification. *IEEE Transactions on Image Processing*, Vol 15, No. 10, 2857-2865.

Abstract: The author proposes a new analytic system based on the fast Fourier transform for identifying projectile specimens by the line-scan imaging technique. His paper develops optical, photonic, and mechanical techniques to map the topography of the surfaces of projectiles for the purpose of identification.

Dongguang, L.. (2009). "Ballistics Image Processing and Analysis for Firearms Identification." Image Processing. Chapter 9, pp 141-174. ISBN: 978-953-307-026-1.

A chapter in the book "Image Processing" in which the author discusses line-scan imaging techniques of firearm related evidence (bullet and cartridge cases) coupled with a new analytic technique of Fast Fourier Transform. The system gives an approach for projectile capturing, storing, and automatic analysis and makes a significant contribution towards the efficient and precise identification of projectiles.

Jacque-Mann, M. and Espinoza, E. (1992). “Firearms Examination by Scanning Electron Microscopy: Observations and an Update on Current and Future Approaches.” AFTE Journal, Vol. 24, No. 3. pp 294-303.

Abstract: The use of scanning electron microscopy (SEM) in the examination of firearms evidence was introduced in the literature over twenty years ago. Due to cost and convenience factors, however, scanning electron microscopy has remained largely inaccessible and therefore under-exploited in the firearms community. We will review the significant advantages of SEM in the examination of firearms evidence and present information on recent and future improvements in methodology which make this approach more attractive and available to forensic laboratories.

Jones, B.C., Press, M., and Guerci, J.R. (1998). “Decision Fusion Based Automated Drill Bit Correlator.” SPIE Conference on Investigation and Forensic Science Technologies: SPIE, Vol. 3576. pp 253-263.

Abstract: This paper describes a recent study conducted to investigate the reproducibility of toolmarks left by drill bits. This paper focuses on the automated analysis aspect of the study, and particularly the advantages of using decision fusion methods in the comparisons. To enable the study to encompass a large number of samples, existing technology was adapted to the task of automatically comparing the test impressions. Advanced forensic pattern recognition algorithms that had been developed for the comparison of ballistic evidence in the *DRUGFIRETM* system were modified for use in this test. The results of the decision fusion architecture closely matched those obtained by expert visual examination. The study, aided by the improved pattern recognition algorithm, showed that drill bit impressions do contain reproducible marks. In a blind test, the DRUGFIRE pattern recognition algorithm, enhanced with the decision fusion architecture, consistently identified the correct bit as the source of the test impressions.

Miller, J. (2000). Criteria for Identification of Toolmarks, Part II: Single Land Impression Comparisons. *AFTE Journal*, vol. 32 (2), 116-131.

Abstract: This study compares bullets fired by Raven 25 Auto, Lorcin 380 Auto, and Stallard Arms 9mm pistols to specimens in the NIBIN database. This study supports the Biasotti/Murdock Quantitative Conservative Matching Stiae (QCMS) criteria.

Senin, Nicola, et al. (2006). “Three-Dimensional Surface Topography Acquisition and Analysis for Firearm Identification.” Journal of Forensic Sciences, Vol. 51, No. 2. pp 282-295.

Abstract: In the last decade, computer-based systems for the comparison of microscopic firearms evidence have been the subject of considerable research

work because of their expected capability of supporting the firearms examiner through the automated analysis of large amounts of evidence. The Integrated Ballistics Identification System, which is based on a two-dimensional representation of the specimen surface, has been widely adopted in forensic laboratories worldwide. More recently, some attempts to develop systems based on three-dimensional (3D) representations of the specimen surface have been made, both in the literature and as industrial products, such as BulletTRAX-3D, but fundamental limitations in achieving fully automated identification remain. This work analyzes the advantages and disadvantages of a 3D-based approach by proposing an approach and a prototype system for firearms evidence comparison that is based on the acquisition and analysis of the 3D surface topography of specimens, with particular reference to cartridge cases. The concept of 3D virtual comparison microscope is introduced, whose purpose is not to provide fully automated identification, but to show how the availability of 3D shape information can provide a whole new set of verification means, some of them being described and discussed in this work, specifically, visual enhancement tools and quantitative measurement of shape properties, for supporting, not replacing, the firearm examiner in reaching the final decision.

Smith, C. and Li, Dongguang. (2008) “Intelligent Imaging of Forensic Ballistics Specimens for ID.” IEEE Proceedings: Congress on Image and Signal Processing, Vol 3. pp 37-41.

Abstract: The paper describes some of important technologies in firearm identification using forensic ballistics specimens. The mapping of micro-surfaces on regions on the specimens for comparison to establish identification according to the precision of measurement of the features has been proposed. The physical techniques of linescan, laser depth proofing, and photonic 3D topography can be developed into future tools for forensic ballisticians for identification of cartridge cases and projectiles.

Uchiyama, Tsueno. (1988). “Automatic Comparison Model of Land Marks.” AFTE Journal, Vol. 20, No. 3. pp 252-258.

Abstract: In the comparison of fired bullets, examiners compare the contour of the bullet surfaces using a comparison microscope. There can be much information on the surfaces of fired bullets that is related to the gun bore surface through which bullets are fired. However, one cannot expect that all of the bore surface characteristics will be reproducibly transferred; even on consecutively fired bullets it may not be possible. Also, there are always many extraneous markings on fired bullet surfaces which are not representative of the gun bore surface and which the examiner must learn to distinguish and ignore as useless information. Usuall*y,* a comparison microscope examination of a pair of fired bullets requires more than 20 minutes before the examiner can form an opinion as to identity or non-identity. In some cases, such an examination requires up to one week. In this paper, the bullet comparison process conducted by the

examiner was analyzed in order to see if any of this manual process could be replaced or assisted by the use of a computer.

Uchiyama, Tsueno. (1993). “Automated Landmark Identification System.” AFTE Journal, Vol 25, No. 3. pp 172-196.

Abstract: We have developed the Automated Landmark Identification System (ALIS). This system handles the images of the striae in the landmarks on fired bullets through a CCD camera. First, image processor calculate the histogram of intensity of an image from the CCD camera. Then a personal computer converts the histogram data into "bar code" like stripes. These "bar code" and histogram data are compared to any other similarly recorded and stored data. In comparison process, the data of the landmark with the narrower width is moved from left to right, and the percent match of striae, sum of square between histograms of image data and sum of depth of matching striae are calculated for each shift in position. The maximum number of consecutively matched striae is also counted for each shift in position. From the fluctuating pattern of these calculated parameters, the reliability of the positive conclusion can be calculated.

14. What studies exist regarding the use of databases to facilitate an automated approach to analysis?

Bachrach, B. (2000). “Ballistic Matching Using 3D Images of Bullets and Cartridge Cases: Project Summary.” National Institute of Justice Grant Award Number 97-LB-VX-0008.

> Abstract/Results of Study: To determine the feasibility of using 3D information from a bullet’s surface to improve the matching rate of existing automated search and retrieval systems, it was required to develop and implement all the elements of an acquisition component. Furthermore, this particular acquisition component would operate based on 3D captured data, as opposed to 2D captured data. Together with the acquisition component, a preliminary version of a correlation component was developed in order to verify the usefulness of the 3D captured data. The complete automated search and retrieval system was tested through a number of independent evaluations. Among these evaluations, we have performed a number of so-called “blind tests.” For these blind tests, we were provided with control bullets from different guns (i.e., we were told which gun fired each of the “control bullets”), and with questioned bullets. The task was to identify which gun fired each of the questioned bullets based on the data obtained from the control bullets. In all cases the system was able to perform in a very satisfactory manner, making very few mistakes in the identification of which gun fired each of the questioned bullets. As a direct result of the research done under this project we have developed a fully functional prototype of the 3D ballistic analysis system (named SCICLOPs).

Baldwin, D., Morris, M., Bajic, S., Zhou, Z., Kreise, M. J. (April 2004). Statistical Tools for Forensic Analysis of Toolmarks. *Ames Laboratory, USDOE Office of Science*, IS-5160.

> Recovery and comparison of toolmarks, footprint impressions, and fractured surfaces connected to a crime scene are of great importance in forensic science. The purpose of this project is to provide statistical tools for the validation of the proposition that particular manufacturing processes produce marks on the work-product (or tool) that are substantially different from tool to tool. The approach to validation involves the collection of digital images of toolmarks produced by various tool manufacturing methods on produced work-products and the development of statistical methods for data reduction and analysis of the images. The developed statistical methods provide a means to objectively calculate a "degree of association" between matches of similarly produced toolmarks. The basis for statistical method development relies on "discriminating criteria" that examiners use to identify features and spatial relationships in their analysis of forensic samples. The developed data reduction algorithms utilize the same rules used by examiners for classification and association of toolmarks.

Banno, Atsuhiko, et al. (2004). Three Dimensional Visualization and Comparison of Impressions on Fired Bullets. *Forensic Science International*, 140, pp 233-240.

In this study, the authors focused on 3D geometric data of landmark impressions on fired bullets for identification. They presented an algorithm for a shape comparison of impressions on bullets. They were concerned only with visualization and comparison and not identification. However, the authors feel the most important future work regarding this method is the identification phase which would require the comparison of numerous pairs of bullets to determine the rigid threshold.

Banno, Atsuhiko. (2004). “Estimation of Bullet Striation Similarity Using Neural Networks.” Journal of Forensic Sciences, Vol 49, No 3. pp 1-5.

Abstract: A new method that searches for similar striation patterns using neural networks is described. Neural networks have been developed based on the human brain, which is good at pattern recognition. Therefore, neural networks would be expected to be effective in identifying striated toolmarks on bullets. The neural networks used in this study deal with binary signals derived from striation images. This signal plays a significant role in identification, because this signal is the key to the individuality of the striations. The neural network searches a database for similar striations by means of these binary signals. The neural network used here is a multilayer network consisting of 96 neurons in the input layer, 15 neurons in the middle, and one neuron in the output layer. Two signals are inputted into the network and a score is estimated based on the similarity of these signals. For this purpose, the network is assigned to a previous earning. To initially test the validity of the procedure, the network identifies artificial patterns that are randomly produced on a personal computer. The results were acceptable and showed robustness for the deformation of patterns. Moreover, with ten unidentified bullets and ten database bullets, the network consistently was able to select the correct pair.

Bolton-King, Rachel S. et. al. (2010). What are the Prospects of 3D Profiling Systems Applied to Firearms and Toolmark Identification? *AFTE Journal*, Vol 42, No 1, 23 – 33.

This article concluded that focus-variation microscopy has potentially the most promising approach for a forensic laboratory instrument, in terms of functionality and 3D imaging performance, and is worthy of further investigation.

De Kinder, Jan, et al. (1998). “Surface Topology of Bullet Striations: An Innovating Technique.” AFTE Journal, Vol. 30, No. 2. pp 294-299.

Abstract: Laser topography is presented as a way to obtain characteristic information of the striation marks on bullets. A profilometer, equipped with a translational and rotational stage, is used tor this purpose. Using the translational stage, the parameters of the system were optimized and one groove on a 9mm

Para bullet was studied. The correspondence between our results and light microscopy is shown. The first results of measurements of the whole circumference of a bullet using the rotational stage promise a potential application in the field of firearms and tool marks identification.

De Kinder, Jan. (2002). “Ballistic Fingerprinting Databases.” Science & Justice, Vol 42, No. 4. pp 197-203

Abstract: This article discusses a number of questions regarding the setting up of ballistic fingerprinting databases, consisting of ammunition components fired by all the firearms held in legal possession. These questions can be classified into three categories--the efficiency of the database, forensic issues, and practical issues to be dealt with. The current New York State legislation is used as an illustration of the choices to be made when setting up a ballistic fingerprinting database. Three important arguments are formulated against the installation of a ballistic fingerprinting database.

Demoli, N. et al. (2004). Toolmarks Identification using SEM Images in an Optoelectronic Correlator *Device. Optik*, Vol 115, No. 11, pp. 487-492.

The authors propose a method for identifying toolmarks by utilizing an optoelectronic correlator device as a possible solution. The effectiveness of the proposed approach is demonstrated by the results of the identification of marks on wires by lap joint pliers. Since this method combines fast optical processing and digital image information, the proposed method can be automated.

George, W. (2004). “A Validation of the Brasscatcher Portion of the NIBIN/IBIS System.” AFTE Journal, Vol. 36, No. 4. pp 286-288.

Abstract: A study was conducted using over 500 cartridge casings fired in Smith & Wesson½ .40 S&W caliber pistols and entered into the BRASSCATCHER portion of IBIS. Entries were made using Remington½ and Federal½ ammunition and the study examined the ability of IBIS to match these cartridge casings. The results of this study raise the issue of limiting the viewable correlation results to the top 20% of the entries in the database

George, W. (2004). “The Validation of the Brasscatcher Portion of the NIBIN/IBIS System Part Two: Fingerprinting Firearms Reality or Fantasy.” AFTE Journal, Vol. 36, No. 4. pp 289-296.

Abstract: A study of the Brasscatcher portion of the NIBIN/IBIS system was conducted using a database of 850 cartridge cases fired in Smith & Wesson .40 S&W caliber pistols. Correlations were generated for entries from Federal, Winchester and Remington brand ammunition and a study to locate the placement of matching cartridge cases initiated. Forensic Technology was able to open the entire database for viewing instead of the normal user field of 20 %.

This study provided a real test of the ability of Brasscatcher to identify cartridge cases fired from similar firearms, and addresses the concept of fingerprinting firearms for use in criminal investigations. During this study an additional advantage regarding the second breech face impression image was revealed. The second image is not used for correlation purposes.

Geradts, Zeno, et al. (1994). A New Approach to Automatic Comparison of Striation Marks. *Journal of Forensic Sciences*, Vol. 39, No 4, pp. 974-980.

The authors created a database for toolmarks named TRAX using a PC. The database is filled with video images and administrative data about the toolmarks. The authors also developed an algorithm for the automatic comparison of digitized striation patterns. The system works well for deep and complete striation marks which will be implemented in TRAX.

Geradts, Z. et al. (1999). “Pattern Recognition in a Database of Cartridge Cases.” SPIE Proceedings: Investigation and Forensic Science Technologies, Vol. 3576. pp 104-115.

Abstract: On the market several systems exist for collecting spent ammunition for forensic investigation. These databases store images of cartridge cases and the marks on them. The research in this paper is focused on the different methods of feature selection and pattern recognition that can be used for comparison. For automatic comparison of these images it is necessary to extract firstly the useful parts of the images. On databases of 2000 images several preprocessing steps have been tested and compared. The results and methods, which have been implemented, are presented.

Giverts P., Springer E., and Argaman U., Using the IBIS for the Examination of Bullets Fired from Polygonally Barreled Guns Such as the Glock Pistol, *AFTE Journal,* Volume 36, Number 3, Summer 2004, pp 226-229.

Polygonally rifled barreled handguns have enjoyed much popularity and have become widespread in recent years. However, as of now, the IBISÖ is not too efficient in searching polygonal bullets. Thus, there is now all the more need for one to be able to successfully handle, in the IBISÖ, bullets fired from such. This paper describes and suggests a possible solution for enabling the IBISÖ to successfully handle such bullets.

Kong, Jun, et al. (2003). A Firearm Identification System Based on Neural Network. AI 2003: Advances in Artificial Intelligence; *Lecture Notes in Computer Science*, Vol. 2903, pp.315-326.

The authors present a firearm identification system based on Self-Organizing Feature map (SOFM) neural network. The experiments performed showed the model proposed has high performance and robustness by integrating the SOFM neural network and the decision-making strategy. The model also will make a significant contribution towards the further processing, such as the more efficient and precise identification of cartridge cases by combination with more characteristics on cartridge case images.

Kong, Jun, et al. (2004). An Automatic Analysis System for Firearm Identification Based on Ballistics Projectiles. Rough Sets and Current Trends in Computing; *Lecture Notes in Computer Science*, Vol 3066, Pp. 653-658.

Over 30 different features within the marks left on bullets and projectiles can be distinguished which in combination produce a "fingerprint." The authors present a means of automatically analyzing features within a firearm "fingerprint" where it is possible to identify not only the type and model of a firearm, but also each individual weapon. A new analytic system based on fast Fourier transform (FFT) for identifying the projectile specimens digitized using the line-scan imaging technique. Experimental results show that the proposed system has the ability of efficient and precise analysis and identification for projectiles specimens.

Kou, Chenyuan and Tung, Cheng-Tan. (1994). "FISOFM: Firearms Identification Based on SOFM Model of Neural Network." Proceedings – Institute of Electrical and Electronics Engineers – 28th Annual International Carnahan Conference on Security Technology. pp 120-125.

Abstract*:* Firearms Identification (F1) has been getting serious and tremendous in crime investigation for the last two decades. We propose a solution to FI in Neural Network (NN) technology. There are lots of methods have been using in FI such as extractor mark, breach mark, ejector mark, and chambering mark identification, etc. We choose the chambering mark identification as our method in this research. It is the simple and useful method for crime investigation. Because of the principle of tool mark, we may identify the firearms. The chambering mark needs to be scanned, preprocessed, segmented, described, reduced and enhanced the noise pattern, and will be recognized its individual characteristic via the Self Organizing Feature Map(S0FM) model of NN. It really eases the burden of Forensic Laboratory's technicians, because they do not need to Identify the tool mark via microscope, instead of using Neural Network technology of Artificial Intelligence to identify firearms.

Peterson, J.L., (1974). Utilizing the Laser for Comparing Tool Striations. *Journal of Forensic Sciences*., Vol. 14, No 1, pp. 57-62.

The author describes a method for examining the contour of striated tool marks by focusing laser light on the tool striations moving at a constant rate. The graphical representations of the reflected light may be used to compare tool marks without utilizing a comparison microscope, however the author determined that the system would require refinement prior to its regular utilization in a forensic science laboratory.

Robinson, M. et al. (1998). "Ballistics Imaging – Latest Developments." IEEE Proceedings: 32nd Annual International Carnahan Conference on Security Technology. Pp 181-183.

Abstract: This paper outlines the latest developments concerning a forensic imaging system that uses a CCTV camera in a line-scan mode for the inspection of bullet specimens placed on a rotating platform. Specifically, line-scan images obtained from the cylindrical sides of fired rounds including both projectiles and cartridge cases plus firing pin marks are discussed. Ultimately, it is anticipated that this research will lead to the development of a forensic imaging application from which a data base can be built to automatically match different bullet specimens in much the same way as a fingerprint data base is operated.

Smith, C. (1997). "Fireball: A Forensic Ballistics Imaging System." Institute of Electrical and Electronic Engineers Proceedings: 31st Annual International Carnahan Conference on Security Technology. pp 64-70.

Abstract: Characteristic markings on the cartridge and projectile of a bullet are produced when a gun is fired. Over thirty different features within these markings can be distinguished, which in combination produce a "fingerprint" for identification of a firearm. This paper will describe an investigation into the development of an imaging system for Police Services which can store, analyse, retrieve, and match high resolution digital images of cartridge cases. A computerised imaging system for ballistics identification will produce efficiencies in time and personnel, and permit a more precise audit of firearms within a country. The project has produced good quality high resolution digitised images of cartridge cases for the identification function. The development of the optical system to optimise image quality has been crucial for the image identification phase. By classifying cartridge image attributes, it is possible to store the unique "signatures" of cartridge cases for identification. Appropriate image processing provides the signatures for the image library. The Fireball forensic ballistics interactive database incorporates a Graphics User Interface (GUI) to obtain precise ballistics metrics of cartridge case class characteristics. Features of the Fireball forensic ballistics database will be presented, together with a description of the major applications of this ballistics imaging system.

Thompson, R., et al. (1996). "Computerized Image Analysis for Firearms Identification; The Integragted Ballistic Identification System (IBIS) BRASSCATCHER Performance Study." AFTE Journal, Vol. 28, No. 3. pp 194-203

Abstract: The Bureau of Alcohol, Tobacco and Firearms (ATF) San Francisco Laboratory Center has conducted a Performance Study of the IBIS BRASSCATCHER hardware and software used in acquiring and correlating breech face and firing pin impressions on expended cartridge casings. Pairs of casings from over 200 pistols representing .25, .380, 9mm, .45 calibers were

correlated. There was no microscopic pre-screening of the cartridge casings prior to selection for testing. The correct "twin" casing was found in the first position of ranked scores between 58 to 78 percent of the time, and 74 to 93 percent of the time in the top five positions. The correct "twin" casing was found in the first position 94 percent of the time for a Glock 9mm caliber pistol database. Visual subjective estimations of cartridge casing "matchability" show that images judged "good" and "fair" in quality constituted the bulk of "first position " matches selected by the computer. However, a sizeable number of "poor" quality images of matching casings were still found in the top scoring position.

Uchiyama T., Toolmark Reproducibility on Fired Bullets and Expended Cartridge Cases, *AFTE JournaL,* Volume 40, No. 1, Winter, 2008, pp. 3-46

The reproducibility of landmarks, breechface marks and firing pin marks on one hundred successively fired bullets and cartridge cases were examined. Three types of Speer brand, one of Remington brand and one of DFA brand frangible cartridges were fired in a semi-automatic pistol. Remarkable differences were observed in the general appearance of the landmarks, breechface marks and firing pin marks which were impressed on the different brands of cartridges, even when consecutively fired. Identification of the landmarks between bullets from different brands of cartridges was difficult because their general appearance differed greatly. Difference in bullet diameters was found to be a major cause of changes in landmarks among different manufacturer's bullets. Although the depth and number of striations decreased gradually, reproducibility of breechface marks on the primers of cartridges was rather good. The diameter of firing pin indentations also differed among different brands of cartridges. Although the reproducibility of the diameter of circular lines on firing pin indentations was good, the detail in these circular lines fluctuated a great deal. Quantitative CMS was used as a means of critically evaluating and communicating the extent of striated pattern agreement among the rifling impressions on the fired bullets in this study.

15. Does research exist that supports the "comparative" nature of firearms/toolmarks examinations versus "blind" analysis of known and unknown (e.g. documentation of features and then comparing the resuls)? Does research exist which identifies how and which cognitive factors impact the analysis process?

Balthazard, V. (2004). "Identification of Projectiles from Firearms." AFTE Journal, Vol. 36, No. 3. Pp 219-225. (REPRINT from Identification de Projectiles d'Armes a Feu. Archives d'Anthropologie Criminelle. Vol. 28 (1913), pp 421-433.

> Foundational article in the field of firearm and tool mark identification in which the author establishes the general criteria and procedure/processes for determining an identification between two items. The author uses photography as his method of determining an identification as this article predates the advent of the comparison microscope.

Bunch, S. (et al). (2009). "Is a Match Really a Match? A Primer on the Procedures and Validity of Firearm and Toolmark Identification." Forensic Science Communications, Vol. 11, No. 3. pp 1-10.

> Abstract: The science of firearm and toolmark identification has been a core element in forensic science since the early 20th century. Although the core principles remain the same, the current methodology uses validated standard operating procedures (SOPs) framed around a sound quality assurance system. In addition to reviewing the standard procedure the FBI Laboratory uses to examine and identify firearms and toolmarks, we discuss the scientific foundation for firearm and toolmark identification, the identification criterion for a "match," and future research needs in the science.

Burd, D. and Kirk, P. (1942). "Tool Marks. Factors Involved in Their Comparison and Use as Evidence." Journal of Criminal Law and Criminology, Vol. 32, No. 6. pp 679-686.

> Text from Article: Comparison of tool marks as an aid in the solution of crime is a well known and widely used procedure which is generally considered as yielding valid court evidence. It is true; nevertheless, that much misapprehension exists as to the individuality of such marks and the probability of repetition of a mark by more than one tool. Such misapprehension as exists has undoubtedly arisen in part from a lack of careful study of the factors which influence the character of the marks left by a tool, and which must be considered in the identification of such marks. In view of the great difficulty of obtaining at any time an absolutely perfect match of the striations making up a tool mark of the friction type, it is of crucial importance to determine what degree of identity must be established before it can be stated that two marks were made by the same tool.

Gunther, C. O. (1932). "Markings on Bullets and Shells Fired from Small Arms. Mechanical Engineering, Vol. 54. pp 341-345.

AND

Gunther, C. O. (1930). “Markings on Bullets and Shells Fired from Small Arms. Mechanical Engineering, Vol. 52. pp 107-118 and 1065-1069.

AND

Gunther, C.O. (1932). “Principles of Firearms Identification: Further Analysis of Accidentical Characteristics.” Army Ordnance, Vol. 13. pp 40-43.

AND

Gunther, C.O. (1932). “Principles of Firearms Identification: Fingerprinting Ordnance in the War on Crime.” Army Ordnance, Vol. 12. pp 339-340.

In this series of articles the author explores the application of science to firearm and toolmark examination. He establishes the processes of comparison of evidence from both a class and individual basis. He further describes the techniques of photography and microscopy and how to utilize these techniques during a comparison examination. These articles are foundational for the field of firearm and toolmark identification.

Itiel E. Dror, Christophe Champod, Glenn Langenburg, David Charlton, Heloise Hunt, Robert Rosenthal, Cognitive issues in fingerprint analysis: Inter- and intra-expert consistency and the effect of a ‘target’ comparison

Deciding whether two fingerprint marks originate from the same source requires examination and comparison of their features. Many cognitive factors play a major role in such information processing. In this paper we examined the consistency (both between- and within-experts) in the analysis of latent marks, and whether the presence of a ‘target’ comparison print affects this analysis. Our findings showed that the context of a comparison print affected analysis of the latent mark, possibly influencing allocation of attention, visual search, and threshold for determining a ‘signal’. We also found that even without the context of the comparison print there was still a lack of consistency in analysing latent marks. Not only was this reflected by inconsistency between different experts, but the same experts at different times were inconsistent with their own analysis. However, the characterization of these inconsistencies depends on the standard and definition of what constitutes inconsistent. Furthermore, these effects were not uniform; the lack of consistency varied across fingerprints and experts. We propose solutions to mediate variability in the analysis of friction ridge skin.

Kellett, PM, Individualization: Principles and Procedures in Criminalistics Laboratory Director, San Bernardino County Sheriff's Department, CA

The author's stated purpose in writing this text is to identify and discuss first principles common to all comparisons and individualizations. The material presented grew out of “Forensic Identification” taught at Ontario Police College. The author writes in a style suitable for students, trial attorneys and criminalists. The book is well-referenced (128 footnotes) and contains an index.

Osterburg, James W. (1969). “The Evaluation of Physical Evidence in Criminalistics: Subjective or Objective Process?” Journal of Criminal Law and Criminology, Vol. 60, No. 1. pp 97-101.

> The author discusses the role statistics might play in establishing identify/identification as well as the current state of firearms identification in determining when individualization has occurred.

Thornton, J. (1979). “The Validity of Firearms Evidence.” AFTE Journal, Vol. 11, No. 2. pp 16-19. (Reprint from Forum July/August 1978).

> The author discusses the nature of the comparison process in firearms identification. He further delves into the concept of objective criteria for the practice of firearms identification. He establishes what processes are objective and what processes are subjective in the comparison of two items of evidence.

Tuthill, H., and George, G. (1994). Principles and Procedures in Criminalistics, *Lightening Powder Company*

> This book not only defines the steps of Analysis, Comparison and Evaluation of fingerprint evidence, but defines these steps for all types of physical evidence. The principles of comparison are discussed in the concepts of uniqueness and individualization of physical evidence, with a section devoted to fingerprints. Other topics are ethical and moral considerations, class and individual characteristics, degrees of opinions, and expert witness testimony.

16. What studies exist which compare one toolmark analytical method to another?

Biasotti, A. (1959). A Statistical Study of the Individual Characteristics of Fired Bullets. *Journal of Forensic Sciences*, vol. 4 (1), 34-50.

Validity study in which no more than three consecutively matching striations (CMS) were found on lead bullets fired from different guns and no more than four CMS were found on jacketed bullets fired from different guns.

Bunch, Stephen G. "Consecutive Matching Striation Criteria: A General Critique." *Journal of Forensic Sciences*, Vol. 45 (5), Sept. 2000, pp. 955-962.

This paper critiques the Consecutive Matching Striation (CMS) approach to toolmark identification. The author discusses the practical and theoretical weaknesses of the approach, argues that it demands a statistical/probabilistic treatment of results - such as the use of Bayesian likelihood ratios - and also suggests much additional research is needed.

Burrard, G, The Identification of Firearms and Forensic Ballistics, Herbert Jenkins, Ltd., London, 1934, Reprinted Barnes & Company 1962 and Wolfe publishing 1990.

This textbook discusses and highlights the reliability of the microscopic comparative method.

Chumbly, L. Scott, et al, "Validation of Tool Mark Comparisons Obtained Using a Quantitative, Comparative, Statistical Algorithm" Journal of Forensic Sciences, Volume 55, Number 4, July 2010, pp. 953-961.

A statistical analysis and computational algorithm for comparing pairs of toolmarks by profilometry data was conducted. Toolmarks produced by 50 sequentially made screwdrivers, at selected fixed angles, were analyzed both empirically by practicing examiners and by the established computational algorithms. The results of these comparisons, as well as a subsequent blind study with the practicing examiners, showed scores of good agreement between the algorithm and human experts. It was also noted that in some of the examination phases, examiner performance was much better than the algorithm.

Gunther, J.D., and Gunther, C.O., *The Identification of Firearms*, Wiley & Sons, Inc. 1935.

This textbook discusses and highlights the reliability of the microscopic comparative method.

Matthews, J. Howard. Firearms Identification: Volume I, II, and III, University of Wisconsin Press 1962.

These three textbooks discuss and highlight the reliability of the microscopic comparative method.

Goddard, C.H., "Scientific Identification of Firearms and Bullets", *Journal of Criminal Law and Criminology*, Vol. 16, No. 2, August 1926, pp 254-263.

This article discusses the effectiveness of the microscopic comparative method.

Moran, B. (2003). "Toolmark Criteria for Identification: Pattern Match, CMS, or Bayesian?" AFTE Journal, Vol. 35, No. 4. pp 359-360. *(Reprint from INTERfaces, Vol. 28, Nov-Dec 2001. pp 9-10.)*

Abstract: The purpose of this discussion is to 1.) open a dialogue with both our Bayesian and non-Bayesian colleagues in the British Forensic Science Service on the topic of approaches to criteria for identification and conclusion giving in toolmark (and firearm) identification, 2.) to solicit some specific examples to the practical use of Bayes Rule in toolmark identification cases and 3.) to solicit feedback on more objective approaches to the interpretation of striated toolmarks such as consecutive matching striae (CMS).

Biasotti, A. and Murdock, J. (1984). "Criteria for Identification or State of the Art of Firearms and Toolmark Identification." AFTE Journal, Vol. 16, No. 4. pp 16-24

Authors lay out the current state of firearms identification and what is required to determine an identification. They also discuss the practical certainty of an identification vs. an absolute identification. The authors lay a foundational framework for more objective criteria in the formulation of an identification conclusion.

Miller, J. (2001). "An Examination of the Application of the Conservative Criteria for Identification of Striated Toolmarks Using Bullets Fired from Ten Consecutively Rifled Barrels." AFTE Journal, Vol. 33, No. 2. pp 125-132.

Abstract: The possibility of the reproduction of subclass characteristics between fired bullets is most likely to occur from barrels that are consecutively rifled. An evaluation of bullets fired from ten consecutively rifled barrels is made using the previously proposed conservative criteria for identification of striated toolmarks. The influence of any subclass characteristics on an identification and the validity of using the conservative criteria for identification as a criteria to determine an identification is examined.

Moran, B. (2001). "The Application of Numerical Criteria for Identification in Casework Involving Magazine Marks and Land Impressions." AFTE Journal, Vol. 33, No. 3. pp 41 – 46.

Abstract: This paper addresses the evaluation of magazine marks and the magazine surfaces that produce them with regard to potential for subclass and individualizing characteristics. It also describes the practical use of numerical criteria in the evaluation of striated toolmarks in routine casework (magazine marks and rifling impressions) and it's significance in providing objective criteria for examining striated toolmarks having limited information such as magazine marks on fired cartridge cases.

Nichols, R. (2003). "Consecutive Matching Striations (CMS): Its Definition, Study and Application in the Discipline of Firearms and Tool Mark Identification." AFTE Journal, Vol. 35, No. 3. pp 298-306.

Abstract: The concept of consecutive matching striations (CMS) has been met with aggressive opposition and suspicion within the discipline of firearms and tool mark identification. It is believed that this is due to a lack of a fuller understanding as to its definition and application within the field. The purpose of this paper is to help resolve some of the persistent issues that critics of CMS have consistently presented throughout the years. To fulfill that purpose, this paper will articulate a definition of CMS that helps to demonstrate that it is not in conflict with what has been referred to as the traditional pattern matching approach, but is simply a means of describing the observed pattern. In addition, the paper will critically evaluate and summarize those articles that have had as their basis the intent to invalidate the conservative minimum criteria for identification. Finally, this article will address frequently expressed concerns in an effort to put them to a final rest.

17. What research has been completed, if any, to determine if a threshold exists to assess when there is sufficient data to complete an examination?

AFTE Criteria For Identification Committee Report: "Theory of Identification, Range of Striae Comparison Reports and Modified Glossary Definitions-an AFTE Criteria For Identification Committee Report", *AFTE Journal*, Vol. 24, No. 3, July 1992, pp. 336-340.

> Nichols (see Question 2 for Nichols Part I and Part II references) has summarized the scientific studies that allow us, assuming no subclass influence, to predict that: 1) the working surfaces of different tools produce discernibly different toolmarks even though some quality/quantity of microscopic agreement may be present (these toolmarks are referred to as known non-matches) and; 2) toolmarks produced by the same tool working surface (referred to as known matches) can be identified with one another and exhibit a greater quality/quantity of microscopic agreement than known non-matching toolmarks.
>
> The references summarized by Nichols are examples of the extensive testing done in this area. As a result of these studies, AFTE formulated and adopted a Theory of Identification to explain the basic theory that allows opinions of common origin to be made in toolmark comparisons. The AFTE Theory of Identification, adopted in 1992, states:
>
> 1. The theory of identification as it pertains to the comparison of toolmarks enables opinions of common origin to be made when the unique surface contours of two toolmarks are in "sufficient agreement".
>
> 2. This "sufficient agreement" is related to the significant duplication of random toolmarks as evidence by a pattern or combination of patterns of surface contours. Significance is determined by the comparative examination of two or more sets of surface contour patterns comprised of individual peaks, ridges and furrows. Specifically, the relative height or depth, width, curvature and special relationship of the individual peaks, ridges and furrows within one set of surface contours are defined and compared to the corresponding features in the second set of surface contours. Agreement is significant when it exceeds the best agreement demonstrated between toolmarks known to have been produced by different tools and is consistent with agreement demonstrated by toolmarks known to have been produced by the same tool. The statement that "sufficient agreement" exists between two toolmarks means that the agreement is of a quantity and quality that the

likelihood another tool could have made the marks is so remote as to be considered a practical impossibility.

3. Currently the interpretation of individualization/identification is subjective in nature, founded on scientific principles and based on the examiner's training and experience.

In accordance with the AFTE Theory of Identification, and a commitment to standardization, AFTE has developed a specific range of conclusions possible when comparing toolmarks. As adopted in 1992, the range of conclusions was preceded by: "The examiner is encouraged to report the objective observations that support the findings of toolmark examinations. The examiner should be conservative when reporting the significance of these observations." These two statements were designed to give the examiner license to explain his or her reasoning for reaching his or her conclusions. These conclusions are based on a specific comparison of individual characteristics, having eliminated any possibility of subclass influence. They are:

1. **Identification**: Agreement of a combination of individual characteristics and all discernible class characteristics where the extent of agreement exceeds that which can occur in the comparison of toolmarks made by different tools and is consistent with the agreement demonstrated by toolmarks known to have been produced by the same tool.

2. **Inconclusive:**

   a. Some agreement of individual characteristics and all discernible class characteristics, but insufficient for an identification.

   b. Agreement of all discernible class characteristics without agreement or disagreement of individual characteristics due to an absence, insufficiency, or lack of reproducibility.

   c. Agreement of all discernable class characteristics and disagreement of individual characteristics, but insufficient for an elimination.

3. **Elimination:** Significant disagreement of discernible class characteristics and/or individual characteristics.

4. **Unsuitable**: Unsuitable for examination.

It is important to note that the word “inconclusive” does not have to be included in a laboratory report. Each of the subcategories under Inconclusive above were designed to stand alone, as conclusive findings. The word “inconclusive” was chosen simply because the three associative evidence statements, a), b), and c) are findings less conclusive than Identification.

Biasotti, A. (1959). A Statistical Study of the Individual Characteristics of Fired Bullets. *Journal of Forensic Sciences*, vol. 4 (1), 34-50.

Validity study in which no more than three consecutively matching striations (CMS) were found on lead bullets fired from different guns and no more than four CMS were found on jacketed bullets fired from different guns.

Burrard, G. (1934). The Identification of Firearms and Forensic Ballistics. Herbert Jenkins, London.

The Gutteridge case is described where 1375 revolvers of the same make/model were compared with the suspect revolver. Six of the 1375 had similar irregular indentations on the breechfaces. Test firings from these six were distinctly different from each other and from the toolmarks on the “crime” cartridge case, which matched test firings from the suspect revolver.

Miller J., and McLean M., Criteria for Identification of Toolmarks, *AFTE Journal,* Vol. 30, No. 1, Winter 1998, pp. 15-61.

Miller J., Criteria for Identification of Toolmarks, Part II, *AFTE Journal*, Vol. 32, No. 2, Spring 2000, pp. 116-131.

Miller J. and Neel M., Criteria for Identification of Toolmarks, Part III, *AFTE Journal*, Vol. 36, No. 1, Winter 2004, pp. 7-38.

Extensive three-part study on striated toolmarks contained on various caliber fired bullets was conducted by using a computer to correlate the KM and KNM striae groups of these test-fired specimens. These studies validated Biasotti’s previous work that concluded consecutiveness of matching striae is more reliable than percent of matching striae. Additionally, these studies support the conclusions made by examiners using the conservative quantitative consecutive matching striae criteria authored by Biasotti and Murdock in 1997.

Smith, Erich. “Cartridge Case and Bullet Comparison Validation Study with Firearms Submitted in Casework.” AFTE Journal, vol. 37 (2), Spring 2005, pp. 130-135.

This validation study was designed to test the accuracy of examinations by trained firearms examiners who use pattern recognition as a method for identification. Eight FBI examiners took the test that consisted of both bullets and cartridge cases. No false positives or false negatives were reported.

Uchiyama T. (1988). A Criterion for Land Mark Identification. *AFTE Journal*, Vol. 20, No. 3, 236-251.

This article describes the examination process of firearms identification beginning with class characteristic agreement and followed by individual characteristic agreement. The use of a digital image processor is discussed as a viable counting method of lines on a bullet.

Uchiyama T. (1988). A Criterion for Land Mark Identification Using Rare Marks. *AFTE Journal*, Vol. 20, No. 3, 260-268.

In this paper, an example is presented for making a judgment of identity based on rare marks appearing on metal jacketed bullets. The significance level of the calculated probability estimates using this model is only moderately low.

18. What research has been completed, if any, to determine the threshold for identification (individualization)?

<u>STRIATED TOOLMARKS:</u>

Quantitative Consecutive Matching Striae (CMS) Theory

There are a number of scientists in the firearm/toolmark identification community who have specifically researched the individuality of striated toolmarks based on the quantity of consecutively matching striae. These scientists approached this through the use of theoretical, mathematical, and empirical studies. By doing this, the examiner is able, from data gathered using the scientific method, to assign measurable weight to the qualitative component described in the AFTE Theory of Identification. This allows the examiner to supplement his/her training and experience with data that is scientifically defensible. The following references validate this approach:

GENERAL

1959 – Biasotti, A., A Statistical Study of the Individual Characteristics of Fired Bullets. Journal of Forensic Sciences. 1959 Jan; 4(1): 34-50.

> This paper summarizes the study of the probability of occurrence of consecutive matching striae in land impressions from fired bullets in both match and nonmatch positions reported by the author in 1955. The findings are based on the author's research conducted between 1951 and 1955. Biasotti concluded that, "The most significant point of the data collected is the fact that 3 consecutive matching lines for lead bullets and 4 consecutive matching lines for metal-cased bullets appears to be the dividing line between data for same and different guns; and therefore, these critical series form the base line upon which the data for bullets from the same gun can be differentiated from the data for different guns." Therefore, approximately 3 - 4 consecutive matching striae appeared to be the threshold number between a known match and known non-match.

MATHEMATICAL MODELS

1970 – Brackett, J., A Study of Idealized Striated Marks and Their Comparison Using Models. Journal of the Forensic Science Society. 1970; 10(1): 27-56.

> Brackett published his study of various mathematical models that could be applied to the study of "idealized" striated marks including geometric models, number-based models, random number outcome models, and random number replica models. His purpose was to develop a theoretical basis for striated mark analysis that could be developed into mechanical (empirical) models that could

be compared to toolmarks in order to obtain sufficient information to establish objective criteria for identity between two sets of toolmarks. He discovered from these different models that the development of a random number table was quite reliable in representing a striated toolmark model. Although his ideal striations were devoid of width, his work is significant in that he demonstrated the concept of consecutiveness alone to be a very powerful tool in deciphering coincidence from common associations. His ideal mathematical striated marks model was described as “tedious”, but it closely supported the empirical study of consecutive matching striae conducted by and reported in 1959 by Biasotti. The author suggested that such models could be more practically used with the assistance of computers in the future.

1980 – Blackwell, R., Framan, E. Automated Firearms Identification System (AFIDS): Phase I. AFTE Journal 1980 Oct; 12(4): 11-37.

Blackwell and Framan published their research into the development of automated firearms identification systems. In their concern for establishing applicable criteria for developing computerized systems that could be objectively and reliably “utilized to help establish a more factual basis for determining identity and nonidentity between two pairs of fired bullets”, the authors researched the literature. The results of this effort revealed that there was little in the literature that provided such objective criteria that could provide a “universal factual basis for establishing identity of a firearm” with the exception of the work of Biasotti reported in 1959. They observed “Biasotti has conducted research which could prove very useful to future developments in firearm identification”. To investigate this possibility, the authors conducted a simulation study of striated marks by applying Brackett’s formulas and models, which they found reliable, and in agreement with each other. Results of their work were found to be in general agreement with the results of Biasotti’s empirical studies described in 1959. They observed in the simulation study that “the results substantiated Biasotti’s hypothesis and regardless of the phase relationship of one sequence with the other, the chance occurrence of consecutive matching lines exceeding those proposed by Biasotti did not occur.”

1981 – Deinet, W., Studies of Models of Striated Marks Generated by Random Processes. Journal of Forensic Sciences 1981 Jan; 26(1): 35-50.

Dienet described his use of computer-aided studies of the degree of similarity of striated markings. Dienet addressed the problem that “a high degree of similarity between two sets of marks is not sufficient to identify a tool if it is highly probable that the similarity may occur by chance”. With this in mind, Dienet defined this problem in the form of the following question: “Given two patterns that are similar to a certain degree, what is the probability that such a similarity, or an even greater one, occurs at random?" He attempted to answer this question by constructing models based on assumptions that: "1) random processes generate the patterns on the tools; 2) different patterns on tools produced by the same machine are independent; and 3) the probability of the occurrence of a line is independent of its position". His paper described the calculation of probability of random occurrence of matches using actual striated toolmarks using blades of 20 shears that were ground to produce random imperfections that were then used to produce toolmarks in lead. Two sets of marks were produced with each tool and a 1.2 mm portion of each pattern was photographed and scanned into the computer. The images were prepared and evaluated with respect to line position. The "Digitized image data on 40 grinding marks were fed into a minicomputer, and the position values of the lines were determined semi-automatically." Idealized models were defined for an objective comparison of striated marks and then applied to the grinding mark data. Necessary conditions of the models were tested by comparing them with actual measured properties of the marks. Three different probability theory models were examined including combinatorial model, a renewal theory model, and binomial function fit model. The results of the model calculations were presented and the properties of the models were discussed. Each model presented certain strengths and weaknesses in fulfilling the above three requirements but were not entirely ideal. However, he also concluded that "numerical values computed with the aid of models permit an evaluation of the degree of similarity" and "for automation of pattern comparisons a preselection is possible, but any probability-related statements require additional studies and examinations"

1988 – Uchiyama, T., A Criterion for Land Mark Identification. AFTE Journal 1988 Jul; 20(3): 236-251.

Uchiyama sought to develop criteria for identification of land impressions using probability theory and also developed a significance level associated with this approach. This was developed because of his observations that neither the total number of matching striae nor the percentage of matching striae was sufficient to establish identity. His significance level approach provided an evaluation of goodness of fit and primarily provided the probability of an accidental or random match of striae. He developed the probability equation based on actual fired bullets. Using his significance level of evaluation he observed that consecutiveness of matching striae played a principle part in indicating the identity of bullets fired from the same gun.

1992 – Uchiyama, T., The Probability of Corresponding Striae in Toolmarks. AFTE Journal 1992 Jul; 24(3): 273-290.

Uchiyama's study provides an estimate of the maximum number of consecutively corresponding lines that might be expected given the considerations of: 1) striae density; 2) critical coincidence ratio (CCR – a method of quantitatively representing how well two lines match relative to width, a range of zero to 1 with 1 being a perfect match); and 3) striae width. He developed a computer model to generate and compare striated toolmarks using these considerations. His model demonstrated that when the widths of lines were varied (as might be expected in actual striated toolmarks), the number of coincidental consecutive matching striae decreased with increasing deviations in striae width. From this experimentation he demonstrated that the additional influence of line width, in the critical evaluation of consecutive agreement, had significant additional influence on the maximum number of matching consecutive striae. When the conditions of his variables were such that the coefficient of variation for striae width was 0.9 and the CCR value was 0.8, the maximum number of coincidental consecutive matching striae was approximately 3 – 4. These results of a maximum of 3 to 4 consecutive lines that would represent a known nonmatch very closely agreed with Biasotti's original empirical work.

1997 – Biasotti, A., Murdock, J., in Faigman DL, Kaye DK, Saks MJ, Sanders J, editors. Modern Scientific Evidence: The Law and Science of Expert Testimony. St. Paul: West, 1997 – Chapter 23, Firearms and Toolmark Identification

This work includes, for the first time, a proposed conservative numerical criterion based on counting runs of consecutive matching striae. The purpose of this proposal was to offer a standard that could be used to distinguish between a striated toolmark identification and non-identification. The developed conservative quantitative criteria is as follows:

- In three dimensional toolmarks when at least two different groups of at least three consecutive matching striae appear in the same relative position, or one group of six consecutive matching striae are in agreement in an evidence toolmark compared to a test toolmark.
- In two dimensional toolmarks when at least two groups of at least five consecutive matching striae appear in the same relative position, or one group of eight consecutive matching striae are in agreement in an evidence toolmark.
- For these criteria to apply, however, the possibility of subclass characteristics must be ruled out.

Since this chapter was first published in 1997, there have been a number of studies which have included an evaluation, using quantitative consecutive matching striae, of the numerical criteria for the identification of striated toolmarks proposed above by Biasotti and Murdock. No known non-matching (two or three dimensional) toolmarks were found in these studies which exhibited agreement in excess of the proposed Biasotti-Murdock criteria. These studies, as well as a description of a survey and training in the use of quantitative CMS as a criterion for the identification of striated toolmarks are described on pages 702 through 707 of the following reference:

> Biasotti, A., Murdock, J., Moran, B., Firearms and Toolmark Identification. Chapter 35, Vol.4, pp 645-723 in Modern Scientific Evidence: The Law and Science of Expert Testimony (Faigman DL, Kay DK, Saks MJ, Sanders, J, Chen EK., eds, 2009-2010), St. Paul: Thompson-West.

A footnote on pages 681 through 685 in the above reference discusses the consideration of subclass toolmark influence. Toolmarks of any kind cannot be identified if subclass influence is present.

<u>IMPRESSED TOOLMARKS</u>:

Biasotti, A., Murdock, J., Moran, B., Firearms and Toolmark Identification. Chapter 35, Vol.4, pp 645-723 in Modern Scientific Evidence: The Law and Science of Expert Testimony (Faigman DL, Kay DK, Saks MJ, Sanders, J, Chen EK., eds, 2009-2010), St. Paul: Thompson-West.

> Research conducted thus far by Biasotti, Murdock, and Moran, indicates that the practical probabilities limits in known non-matches for impression toolmarks similar to those found for striated toolmarks. Some progress has been made in developing quantitative criteria for the identification of compression toolmarks. Following Stone's publication of a theoretical model for the mathematical evaluation of well defined types of impressed toolmarks, Collins used and evaluated Stone's model while performing an empirical study of twenty worn hammer faces. His preliminary results show that combinations of even low numbers of simple impressed defects are, on a practical level, quite discriminating. However, more research is needed involving very fine, high density, randomly distributed individual impression characteristics, viewed two dimensionally, before definitive practical probability limits can be stated confidently.

Stone, R. "How Unique are Impressed Toolmarks?" *AFTE Journal*. Vol. 35, No. 4, Fall 2003. pp. 376-383.

> The comparison model developed by Stone offers a springboard upon which those interested in studying the occurrence of impressed contours and establishing the basis for a quantifiable identification criterion of impressed toolmarks may now do so.

Collins, E. “How Unique are Impressed Toolmarks: An Empirical Study of 20 Worn Hammer Faces.” *AFTE Journal*. Vol. 37, No. 4, Fall 2005. pp. 252-295.

Collins tested the validity of Stone’s theories on the statistical uniqueness of impressed toolmarks through the empirical examination of the defects observed on the faces of twenty hammers that had been subjected to various degrees of wear and abuse through normal use. These examinations were carried out under controlled conditions that would simulate those used in practical casework. The results of this study led to a re-evaluation of Stone’s work and a modification of related formulae. The revised formulae were used to calculate practical but conservative probabilities associated with impressed toolmarks using the data collected from the hammers in the study.

19. Does research exist which demonstrates that criteria for identifications (individualization) vary with method of manufacture or type of tool?

The AFTE Theory of Identification, adopted by AFTE in 1992, is intended to be universal, accounting for all known methods of manufacture.

Biasotti, A.A., “Statistical Analysis of Bullet Comparison (Preliminary, Unpublished, Report for Masters Thesis)”, prepared for Criminology 299 course, University of California Berkeley, June 1, 1951.

In this report, Biasotti described how the purpose of his research was to arrive at a concept of probability for bullet comparison based on the relative frequency of occurrence of common characteristics (e.g. consecutive series of matching lines) between bullets fired from the same gun and bullets fired from similar guns of the same caliber. He went on to describe how 1) the purpose of his study was to give the Criminalist some basis for establishing what constitutes a match and what degree of probability can be attached and 2) the relative frequency of occurrence of consecutive series as will be compiled in this study could be used directly as empirical findings without deriving any concept of probability; but if this were done, the data would apply only to the particular type of gun and ammunition used in this particular study. Then similar studies would have to be conducted for every gun of different manufacture of the same caliber and for every different type of ammunition to be significant. Biasotti completed his Masters thesis, “Bullet Comparison – A Study of Fired Bullets, Statistically Analyszed, “ in February 1955 and published his findings in the Journal of Forensic Sciences, Vol 4., No. 1, Jan. 1 1959, pp. 34-50.

In 1997, forty six years after stating in his 1951 student progress report, Biasotti (in collaboration with John Murdock) decided that sufficient research had been done on both firearms and non-firearms toolmakrs to justify publishing the conservative quantitative criteria for striated toolmarks. (Listed under Question 18). The criteria was published in reference (A) below and remains the same in the current edition of Modern Scientific Evidence (reference (B) below).

(A) Biasotti, A., Murdock, J., Chapter 23, “Firearms and Toolmark Identification” from Modern Scientific Evidence: The Law and Science of Expert Testimony, Vol. 2, West Pub. Co., 1997, pp. 124-155; and (B) Biasotti, A., Murdock, J., Moran, B., Firearms and Toolmark Identification. Chapter 35, Vol.4, pp 645-723 in Modern Scientific Evidence: The Law and Science of Expert Testimony (Faigman DL, Kay DK, Saks MJ, Sanders, J, Chen EK., eds, 2009-2010), St. Paul: Thompson-West.

20. What studies have been performed to determine error rates in firearm and toolmark analyses? What studies have been performed to determine examiner error rates? What research exists which identifies rates for misidentifications and false exclusions?

See responses to Question #21.

21. Do studies exist which demonstrate how often false negatives (e.g. a non-match is declared, when they match) are reported?

Error rates in actual casework are difficult to assess due to a lack of "ground truth." Proficiency tests are not administered in a consistent, controlled manner but do provide a large amount of data. **Validity tests** employ various levels of blindness and control, but are usually designed to create a "worst case scenario" in which consecutively machined firearms and tools are used.

Proficiency Tests

Crime Laboratory Proficiency Testing Results, 1978*1991, II: Resolving Questions of Common Origin, *Journal of Forensic* Sciences, Vol. 40, No. 6, Nov. 1995, pp.1009-29.

> Article examined the origins of crime laboratory proficiency testing and the performance of laboratories in the identification and classification of common types of physical evidence. Part II reviews laboratory proficiency in determining if two or more evidence samples shared a common source. Parts I and II together review the results of 175 separate tests issued to crime laboratories over the period 1978 to 1991.

CTS 1978 - 1991, Stephen Bunch summary and slight revision of Peterson & Markham F/T results.
Internet Source: www.swggun.org/resources/admissibility/prof_test results081603.pdf

Proficiency Test Results from Peterson and Markham Article - **Firearms**
Source: "Crime Laboratory Proficiency Test Results, 1978-1991, II: Resolving Questions of Common Origin," *Journal of Forensic Sciences*, Vol. 40, No. 6, November 1995, pp. 1009 -1029. (12 separate tests involving between 42 and 173 laboratories.)

From Table 8, page 1019:
Total comparisons = 2106
False identifications = 12
False eliminations = 17
True identification conclusions = 905
True elimination conclusions = 954
True identifications judged inconclusive = 43
True eliminations judged inconclusive = 175
Total true identifications = 905 + 43 + 17 = 965
Total true eliminations = 954 + 175 + 12 = 1141
Total identification conclusions offered = 905 + 12 = 917
Total elimination conclusions offered = 954 + 17 = 971
Total inconclusives = 43 + 175 = 218

Data Analysis – Firearms
Test Sensitivity = true IDs offered/true IDs = 905/965 = 93.78%
Test Specificity = true eliminations offered/true eliminations = 954/1141 = 83.61%

False positive error rate (false or mis-identifications) = false positive responses/total true eliminations = 12/1141 = **1.05%**
False negative error rate (false or mis-eliminations) = false negative responses/total true identifications = 17/965 = **1.76%**
Inconclusive rate = 218/2106 = 10.35%

Proficiency Test Results from Peterson and Markham article - **Toolmarks**
Source: "Crime Laboratory Proficiency Test Results, 1978-1991, II: Resolving Questions of Common Origin," *Journal of Forensic Sciences*, Vol. 40, No. 6, November 1995, pp. 1009 - 1029. (12 separate tests involving between 72 and 163 laboratories.)

From Table 13, page 1024:
Total comparisons = 1961
False identifications = 30
False eliminations = 44
True identification conclusions = 646
True elimination conclusions = 755 + 53 + 44 = 852
True identifications judged inconclusive = 83 + 48 = 131
True eliminations judged inconclusive = 258
Total true identifications = 646 + 44 + 48 = 821
Total true eliminations = 852 + 30 + 258 = 1140
Total identification conclusions offered = 646 + 30 = 676
Total elimination conclusions offered = 852 + 44 = 896
Total inconclusives = 83 +258 + 48 = 389

Under toolmarks, the authors include a category of "unjustified exclusions." An example: two wires cut by different areas on the cutting edge of a single pair of wire cutters was marked by a participant as an elimination. While this mistake would be understandable if one merely considers microscopic correspondence and ignores the larger picture, it was properly categorized as an unjustified exclusion, and counted here as a false negative. In other cases, however, the responses were correct from a scientific perspective (only false positives and false negatives matter), but incorrect from a training and quality assurance perspective. For my purposes, the scientific propositions trump quality assurance considerations, and thus the remaining "unjustified exclusions" were counted as correct responses.

CTS 1992 – 2005, F/T results revisions by Douglas Murphy, Presentation at 2010 AFTE Training Seminar (also at www.swggun.org/resources/docs/CTSErrorRates.pdf)

CTS Error Rates: 1992 – 2005
- Firearms False Positive = 1.5%
- Firearms False Negative = 0.5%
- Toolmark False Positive = 1.7%
- Toolmark False Negative = 1.6%

The two preceding summaries were produced by applying standard error rate calculation methods to results reported by CTS, to include false positive and false negative rates, sensitivity and specificity.

Validity Tests

Teale, *Popular Science Monthly*, February 1932, p.213

> The author reports on studies by Calvin Goddard of markings produced by six consecutively manufactured firing pins and four consecutively manufactured gun barrels. These studies appear to be the first documented attempt to test the firearm examiner's ability to distinguish between consecutively manufactured tools. This is the traditional "worst case scenario" testing that has been conducted by firearm and toolmark examiners to validate the ability to individualize tools. With regard to the firing pin study, Teale relates the following: "To prove his case, Col. Goddard told me he sent to the factory where for the suspect's gun was manufactured and obtained half a dozen firing pins made on the same machine one after another" and "the differences are apparent in the confirmation of the tips of six firing pins made successively on the same machine. Contact with the cartridge caps will leave identifying imprints." With regard to the study of markings produced on consecutively manufactured gun barrels, Teale notes that "Not long ago at the Springfield Armory, in Massachusetts, bullets were fired through four rifles that had been made one after the other on the same machine. The Markings on the bullets were so different that each bullet could be traced to the gun that fired it."

A short description of each of the following articles, see the SWGGUN ARK, Error Rates and Power Point slide #62 in SWGGUN ARK- Appendix I.
Internet Source:
www.swggun.org/swg/index.php?option=com_content&view=article&id=6:error-rate-resources&catid=9:ark&Itemid=18

Brundage, David J. "The Identification of Consecutively Rifled Gun Barrels." *AFTE Journal*, Vol. 30, No. 3, Summer, 1998, pp. 438-444.

DeFrance, Charles S. and Michael VanArsdale. "Validation Study of Electrochemical Rifling." *AFTE Journal*, Vol. 35, No. 1, Winter, 2003, pp. 35-37.

Fadul, T.G., "An Empirical Study to Evaluate the Repeatability and Uniqueness of Striations/Impressions Imparted on Consecutively Manufactured Glock EBIS Gun Barrels", *AFTE Journal*, Volume 43, Number 1, Winter 2011, Pp. 37-44.

Hamby J. E., Brundage D. J. , Thorpe J. W., "The Identification of Bullets Fired from 10 Consecutively Rifled 9mm Ruger Pistol Barrels: A Research Project Involving 507 Participants from 20 Countries", *AFTE Journal*, Volume 41, Number 2, Spring 2009, pp. 99-110.

Smith E., "Cartridge Case and Bullet Comparison Validation Study with Firearms Submitted in Casework." *AFTE Journal*, vol. 37 (2), Spring 2005, pp.130-135.

Bunch, S.G. and Murphy D.P.. "A Comprehensive Validity Study for the Forensic Examination of Cartridge Cases." *AFTE Journal*, Vol. 35, No. 2, Spring 2003, pp. 201-203.

Giroux B. N., "Empirical and Validity Study: Consecutively Manufactured Screwdrivers", *AFTE Journal*, Volume 41, Number 2, Spring, 2009, Pp. 153-158.

Lyons, D. J., "The Identification of Consecutively Manufactured Extractors", *AFTE Journal*, Volume 41, Number 3, Summer, 2009, Pp.246-256.

Thompson, Evan and R. Wyant, "Knife Identification Project (KIP)," *AFTE Journal*, Vol. 35 (4), Fall 2003, Pp. 366 – 370.

Christensen AM, Sylvester AD., Physical Matches of Bone, Shell and Tooth Fragments: A Validation Study. *Journal of Forensic Sciences*, 2008;53, Pp.694-698

Orench, Jose A., "A Validation Study of Fracture Matching Metal Specimens Failed in Tension," AFTE Journal, vol. 37 (2), Spring 2005, pp. 142-149.

Grzybowski, R., Miller, J., Moran, B., Murdock, J., Nichols, R., and R. Thompson. "Firearm/Toolmark Identification: Passing the Reliability Test Under Federal and State Evidentiary Standards." *AFTE Journal*, vol. 35 (2), Spring 2003, pp. 209-241.

There is a particularly good discussion, with references listed below, of error rate on page 216 through 230 of this article. This description includes reported summaries of firearm and non-firearm proficiency tests, what is done in most forensic laboratories to ensure that the results of individual cases are correct as reported, and the error rate of individual examiners.

References for above article:

Biasotti, A., Murdock, J., Moran, B., Firearms and Toolmark Identification. Chapter 35, Vol.4, pp 645-723 in Modern Scientific Evidence: The Law and Science of Expert Testimony (Faigman DL, Kay DK, Saks MJ, Sanders, J, Chen EK., eds, 2009-2010), St. Paul: Thompson-West.

Moenssens, A., "Meeting the Daubert Challenge to Handwriting Evidence – Preparing for a Daubert Hearing", abstract of a talk given at the Second Annual Symposium on the Forensic Examination of Questioned Documents at Albany, N.Y. on June 18, 1999. (see www.forensic-evidence.com) An earlier version of this also appears in the October, 1999 issue of the *Forensic Science Communications*, a peer reviewed quarterly journal published on the Internet by FBI Laboratory personnel (see http://www.fbi.gov/programs/lab/fsc/current/index.htm)

Peterson, J., and Markham, P., “Crime laboratory testing results, 1978 – 1991, II: Resolving Questions of Common Origin.” Journal of Forensic Science, 1995: 40(6): 1009-1029.

22. Are there studies in toolmarks that identify what information/circumstances may bias an examiner's conclusion?

Refer to answer under Question 23.

23. Are there specific studies showing a difference in rate of inconclusive versus conclusive as a result of "contextual bias" information?

The following articles largely deal with fingerprints. But, to answer questions 22 & 23, this is the best information we have due to the close similarity to how fingerprint examiners and firearm examiners perform their tasks. These articles deal with fingerprints, but the types of influences present to a fingerprint examiner can generally be characterized as the same for a firearm examiner; however, please do not assume that if firearm and toolmark examiners were faced with the same induced biases that similar mistakes would occur. No such studies have been conducted for firearms and toolmark evidence, but they probably should be conducted.

Budowle, B., et al. (2009). "A Perspective on Errors, Bias, and Interpretation in the Forensic Sciences, and Direction for Continuing Advancement." Journal of Forensic Sciences, Vol. 54, No. 4. Pp 798-809.

> Abstract: The forensic sciences are under review more so than ever before. Such review is necessary and healthy and should be a continuous process. It identifies areas for improvement in quality practices and services. The issues surrounding error, i.e., measurement error, human error, contextual bias, and confirmatory bias, and interpretation are discussed. Infrastructure is already in place to support reliability. However, more definition and clarity of terms and interpretation would facilitate communication and understanding. Material improvement across the disciplines should be sought through national programs in education and training, focused on science, the scientific method, statistics, and ethics. To provide direction for advancing the forensic sciences a list of recommendations ranging from further documentation to new research and validation to education and to accreditation is provided for consideration. The list is a starting point for discussion that could foster further thought and input in developing an overarching strategic plan for enhancing the forensic sciences.

Koehler, J. "Fingerprint Error Rates and Proficiency Tests:What They Are and Why They Matter." Citation: 59 Hastings L.J. 1077 2007-2008.

> Introduction text of article: When a fingerprint examiner declares a match between a print from a known source and a latent print recovered from a crime scene,' his word may seal a defendant's fate like no other form of evidence save, perhaps, DNA**.** At trial the fingerprint examiner will offer little in the way of data, statistical tests, or uncertainty. Instead, he will say that latent print could only have been made by the source of the known print, that he is 100% certain, that he has never erred, and that the method he used to make this and other identifications has an error rate of zero.' In recent years, the broader scientific community has objected to this form of testimony. Critics charge that fingerprint analysis lacks an empirical foundation and that examiners make exaggerated claims that are likely to mislead jurors.

Dror, I., Charlton, D., and Peron, A., "Contextual Information Renders Experts Vulnerable to Making Erroneous Identification", Forensic Science International 2006, 156: 74-78.

> Abstract: We investigated whether experts can objectively focus on feature information in fingerprints without being misled by extraneous information, such as context. We took fingerprints that have previously been examined and assessed by latent print experts to make positive identification of suspects. Then we presented these same fingerprints again, to the same experts, but gave a context that suggested that they were a no-match, and hence the suspects could not be identified.Within this new context, most of the fingerprint experts made different judgements, thus contradicting their own previous identification decisions. Cognitive aspects involved in biometric identification can explain why experts are vulnerable to make erroneous identifications.

Dror, I., Charlton, D., Hind, S. and Peron, A., "When Emotions Get the Better of Us: The Effect of Contextual Top-Down Processing on Matching Fingerprints", Applied Cognitive Psychology 2005, 19: 799-809.

> Abstract: Twenty-seven participants made a total of 2,484 judgments whether a pair of fingerprints matched or not. A quarter of the trials acted as a control condition. The rest of the trials included top-down influences aimed at biasing the participants to find a match. These manipulations included emotional background stories of crimes and explicitly disturbing photographs from crime scenes, as well as subliminal messages. The data revealed that participants were affected by the top-down manipulations and as a result were more likely to make match judgments. However, the increased likelihood of making match judgments was limited to ambiguous fingerprints. The top-down manipulations were not able to contradict clear non-matching fingerprints. Hence, such contextual information actively biases the ways gaps are filled, but was not sufficient to override clear bottom-up information.

Dror, I. and Rosenthal, R., "Meta-analytically Quantifying the Reliability and Biasability of Forensic Experts", Journal of Forensic Science July 2008, 53(4): 900-903.

> Abstract: In this paper we employ meta-analytic procedures and estimate effect sizes indexing the degree of reliability and biasability of forensic experts. The data are based on within-expert comparisons, whereby the same expert unknowingly makes judgments on the same data at different times. This allows us to take robust measurements and conduct analyses that compare variances within the same experts, and thus to carefully quantify the degree of consistency and objectivity that underlie expert performance and decision making. To achieve consistency, experts must be reliable, at least in the very basic sense that an expert makes the same decision when the same data are presented in the same circumstances, and thus be consistent with themselves. To achieve objectivity, experts must focus only on the data and ignore irrelevant information, and thus be unbiasable by extraneous context. The analyses show that experts are not

totally reliable nor are they unbiasable. These findings are based on the fingerprint expert’s decision making, but because this domain is so well established, they apply equally well (if not more) to all other less established forensic domains.

Dror, I. and Charlton, D. “Why Experts Make Errors”, Journal of Forensic Identification 2006, 56(4): 600-616.

Abstract: Expert latent fingerprint examiners were presented with fingerprints taken from real criminal cases. Half of the prints had been previously judged as individualizations and the other half as exclusions. We re-presented the same prints to the same experts who had judged them previously, but provided biasing contextual information in both the individualizations and exclusions. A control set of individualizations and exclusions was also re-presented as part of the study. The control set had no biasing contextual information associated with it. Each expert examined a total of eight past decisions. Two-thirds of the experts made inconsistent decisions. The findings are discussed in terms of psychological and cognitive vulnerabilities.

Dutton, G. (1998) “The Importance of Being Impartial.” AFTE Journal 30(3): 523-526.

Text from Article: Most firearm examiners around the globe are paid their wage by their respective governments, whether this is at a local, state, or federal authority. Although this means examiners work for the prosecution "side" in the investigation of crime, it does not mean that the evidence examiners give should be weighted towards the prosecution case. The testimony as expert witnesses must be absolutely impartial. The firearms examiner that is not impartial is doing the field a great disservice and subject to possible ramifications from the AFTE code of ethics.

Gianelli, P. (2007). “Confirmation Bias.” Criminal Justice, Vol. 22. pp 60-61.

The author discusses the concepts of motivational and cognitive bias and how it relates to forensic examinations.

Hodge, E. (1988). “Guarding Against Error.” AFTE Journal, Vol. 20, No. 3. pp 290-293.

The author discusses potential errors and omissions in casework. He further discusses five ways to reduce error: training, case organization, the removal of psychological pressures, checking your work, and using the partner system.

Koppl, R. and Whitman, G. (2010). “Rational Bias in Forensic Science.” Law, Probability & Risk, Vol. 9. pp 69-90.

Abstract: The current organization of forensic science induces biases in the conduct of forensic science even if forensic scientists are perfectly rational. Assuming forensic examiners are flawless Bayesian statisticians helps us to

identify structural sources of error that we might otherwise have undervalued or missed altogether. Specifically, forensic examiners' conclusions are affected not just by objective test results but also by two subjective factors: their prior beliefs about a suspect's likely guilt or innocence and the relative importance they attach to convicting the guilty rather than the innocent. The authorities—police and prosecutors—implicitly convey information to forensic examiners by their very decision to submit samples for testing. This information induces the examiners to update their prior beliefs in a manner that results in a greater tendency to provide testimony that incriminates the defendant. Forensic results are in a sense 'contaminated' by the prosecution and thus do not provide jurors with an independent source of information. Structural reforms to address such problems of rational bias include independence from law enforcement, blind proficiency testing and separation of test from interpretation.

Paust, J. (1978). "Dum-Dum Bullets, Law, and 'Objective' Scientific Research: The Need for a Configurative Approach to Decision", Jurimetrics, Vol. 18. pp 68-278.

Text from Article: An examination of an article in *Science* magazine by Kenneth Hammond and Leonard Adelman on "Science, Values, and Human Judgment" seems to demonstrate, contrary to the views of its authors, that science, values and bias are necessarily integrated. In an attempt to "objectify" some recent research on the societal characteristics of hollow-point (or "dum-dum") handgun bullets, Messrs. Hammond and Adelman have defined and applied a seriously flawed, one-sided approach to decisions about weapons effects. They have allowed hidden choice points (about values, bias, what should be measured and how it should be measured) to impair their attempts at scientific research, objective inquiry and unprejudiced conclusions. In short, the values and biases of the scientists have been built into the definitional framework for their scientific inquiry and, thus, into the quantified results.

Risinger, D., Saks, M., Thompson, W., and Rosenthal, R. (2002). "The Daubert/Kuhmo Implications of Observer Effects in Forensic Science: Hidden Problems of Expectation and Suggestion", California Law Review January 2002, 90(1):1-56.

The authors discuss the concept of observer effects in general as well as in forensic science as a whole. They also discuss ways in which to reduce observer effects.

24. Does research exist which uses class characteristics to describe the relative rarity of source firearms based on the population of firearms that can be estimated?

No. Although the FBI has a General Rifling Characteristics (GRC) database, it is intended as an investigative tool and does not include population information.

25. What statistical research has been conducted and applied to firearm and toolmark examinations? What statistical models for firearms and toolmarks have been published?

The following 14 articles have been abstracted elsewhere in this document in the response to other questions:

Neel, Michael (et al.), A Comprehensive Statistical Analysis of Striated Tool Mark Examinations Part 1: Comparing Known Matches and Known Non-Matches, *AFTE Journal*, Volume 39, No. 3, Summer, 2007, pp 174-196

Faden, D. (et al.), Statistical Confirmation of Empirical Observations, *AFTE Journal*, Volume 39, Number 3, Summer 2007, 211-220

Bachrach, Ben. "Development of a 3D-Based Automated Firearms Evidence Comparison System." *Journal of Forensic Sciences*, Vol. 47, No. 6, November, 2002, pp. 1253-1264.

Biasotti, Alfred A. "A Statistical Study of the Individual Characteristics of Fired Bullets." *Journal of Forensic Sciences*, Vol. 4, No. 1, January, 1959, pp. 34-50.

Intelligent Automation, Incorporated, "A Statistical Validation of the Individuality of Guns Using High Resolution Topographical Images of Bullets", *National Institute of Justice* Grant #2006-DN-BX-K030, October, 2010

Howitt D., Tulleners F., "A Calculation of the Theoretical Significance of Matched Bullets," Journal of Forensic Sciences, Volume 53, Number 4, July 2008, pp. 868-875.

Neel M., and Wells M., "A Comprehensive Statistical Analysis of Striated Tool Mark Examinations Part I: Comparing Known Matches and Known Non-Matches", AFTE Journal, Volume 39, No. 4, Summer 2007, pp. 176-198.

May L., "Identification of Knives, Tools and Instruments", *Journal of Police Science* , Volume 1, No. 3, 1930, pp. 247-248.

Deinet, Werner. "Studies of Models of Striated Marks Generated by Random Processes." *Journal of Forensic Sciences*, Vol. 26 (1), Jan., 1981, pp. 35-50.

Stone, Rocky, "How Unique are Impressed Marks," *AFTE Journal*, Vol. 35, No.4, Fall 2003, pp. 376-383.

Collins, Eric R., "How "Unique" Are Impressed Toolmarks? – An Empirical Study of 20 Worn Hammer Faces," *AFTE Journal*, Vol. 37 (4), Fall 2005, pp. 252-295.

Chumbly, L. Scott, et al, “Validation of Tool Mark Comparisons Obtained Using a Quantitative, Comparative, Statistical Algorithm” *Journal of Forensic Sciences*, Volume 55, Number 4, July 2010, pp. 953-961.

Bachrach B., Jain A., Jung S., and Koons R.D., “A Statistical Validation of the Individuality and Repeatability of Striate Tool Marks: Screwdrivers and Tongue and Groove Pliers”, *Journal of Forensic Sciences*, Volume 55, Number 2, March 2010, pp 348-357.

Bacharach, B., “Statistical Validation on the Individuality of Tool Marks Due to the Effect of Wear, Environment Exposure and Partial Evidence”, NIJ/NCJRS Document #227929, August, 2009.

Wever, G., et al. (2011). “A Comprehensive Statistical Analysis of Striated Tool Mark Examinations Part 2: Comparing Known Matches and Known Non-Matches using Likelihood Ratios.” AFTE Journal, Vol. 43, No. 2. pp 137-145.

> Abstract: A potential model for increasing the objectivity in the interpretation of toolmarks is explored using consecutively matching striae (CMS) and Bayesian inference. Given the nature of the data, standard statistical thinking suggests that Bayesian inference is likely to be the most powerful method of interpretation. The unavoidable paucity of data for high CMS runs for the known non-match condition is handled using a small advance in modelling. The resulting likelihood ratios show some, but incomplete separation between the known match and known non-match conditions. Although promising, the resulting incomplete separation between known match and known non-match is thought to represent limitations of the CMS summary of the complete pattern and limitations of the modeling used.

Buckleton, J., et al. (2005). “An Exploratory Bayesian Model for Firearm and Tool Mark Interpretation.” AFTE Journal, Vol. 37, No. 4. pp 352-361.

> Abstract: An exploratory Bayesian model for the interpretation of striated tool marks has been developed. This model is based on a consecutive matching striae (CMS) summary of the visual image of a striated tool mark comparison. The results of applying this model to two data sets are encouraging.

Champod, C., et al. (2003). “Firearm and Tool Marks Identification: The Bayesian Approach.” AFTE Journal, Vol. 35, No. 3. pp 307-316.

> Abstract: We have read with interest the paper written recently by Bruce Moran in the AFTE Journal and the exchange of letters in INTERface. The author is a respected commentator in the field of firearm and tool mark examination. He challenges readers to demonstrate the practical applicability of Bayes theorem in firearms and tool mark examination. Mr Moran discusses an «objective» criterion such as consecutive matching striae (CMS) and it’s applicability to firearms and

tool marks examination. Notably he suggests the adoption of the consecutive matching striae numerical criterion for identification which (in the author's words) "establishes a clear threshold between identification and non-identification in striated tool marks, because it is based on scientific principles and sound empirical research". He also declares that "Bayes theorem is not appropriate as an effective means to interpret the identification science".

Deinet, W., et al. (2007). "Comments on the Application of Theoretical Probablity Models including Bayes Theorem in Forensic Science Relating Firearm and Tool Marks," AFTE Journal, Vol. 39, No. 1. Pp 4-7.

Abstract: The comparison of firearm and tool marks is of great importance in forensic science. Examiners magnify the marks using a microscope and decide, on the basis of their experience, whether the degree of similarity is sufficient for an identification. One aim of scientific research is to develop probability models to make objective and reproducible results possible. In this paper comments are made on the application of Bayes' rule. Additionally, the extent to which an objective description of forensic science evidence is possible by the application of probability models is discussed.

Taroni, F., et al. (1996). "Statistics: A Future in Tool Marks Comparison?" AFTE Journal, Vol. 28, No. 4. pp 222-232.

This article discusses the uses of statistics and the possible use of statistics by the field of Firearm and Toolmark Identification.

Deschenes, M., et al. (1995). "Statistics and Tool Marks Comparisons." AFTE Journal, Vol. 27, No. 2. pp 140-141.

This paper suggests how statistics can be utilized in toolmark comparisons but also the limitations of using them.

Biedermann, A., Bozza, A., and Taroni, F. (2008). "Decision Theoretic Properties of Forensic Identification: Underlying Logic and Argumentative Implications." Forensic Science International, Vol. 177. pp 120-132.

Abstract: The field of forensic science has profited from recent advances in the elicitation of various kinds probabilistic data. These provide the basis for implementing probabilistic inference procedures (e.g., in terms of likelihood ratios) that address the task of discriminating among competing target propositions. There is ongoing discussion, however, whether forensic identification, that is, a conclusion that associates a potential source (such as an individual or object) with a given item of scientific evidence (e.g., a biological stain or a tool mark), can, if ever, be based on purely probabilistic argument. With regard to this issue, the present paper proposes to analyze the process of forensic identification from a decision theoretic point of view. Existing probabilistic inference procedures are used therein as an integral part. The idea underlying the proposed analyses is that inference and decision are connected in the sense that the former is the point of departure for the latter. As such the approach forms a coordinated whole, that is a framework also known in the context as ‘full Bayesian (decision) approach’. This study points out that, as a logical extension to purely probabilistic reasoning, a decision theoretic conceptualization of forensic identification allows the content and structure of arguments to be examined from a reasonably distinct perspective and common fallacious interpretations to be avoided.

Meyers, C. (2002). “Some Basic Bullet Striae Considerations.” AFTE Journal, Vol. 34, No. 2, pp 158-160.

Abstract: The purpose of this paper is to review some of the basics of striae formation on fired bullets and the often present problems in their replication and subsequent attempts at quantification. Methods of quantifying bullet striae along with a slightly different view of percent match will be mentioned.

Stone, R. (2004). “A Probabilistic Model of Fractures in Brittle Metals.” AFTE Journal, Vol. 36, No. 4. pp 297-301.

Abstract: The examination and comparison of fracture evidence has often fallen within the purview of firearm/toolmark examiners. Little has been published concerning the individuality or probabilistic examination of this type of evidence. Traditionally, examinations have been based on “common sense” and the “feeling” or “assumption” that “two things that match this well couldn’t have originated from separate objects or separate breaks”. This study will focus on how such two and three dimensional fractures form in brittle metals and will present derived mathematical probability models for them. It also presents a model that, with validation, would allow examiners to quantify such fractures in actual casework.

Claytor, L.K., and Davis, A.L. “A Valdiation of Fracture Matching Through the Microscopic Examination of the Fractured Surfaces of Hacksaw Blades.” AFTE Journal, Vol. 42, No. 4. pp. 323-332.

Abstract: During a fracture, an object separates into two or more parts; fracture matching is the association of those surfaces to each other. Forensic fracture matching relies on the principle that no two objects fracture identically. The authors hope to further support this principle by studying the topography of fractured hacksaw blades. Two consecutively manufactured hacksaw blades were each fractured eleven times and inter-compared. Two hundred fifty-three topographical comparisons were conducted between 44 fractured edges; each fracture produced two surfaces discernable from any other. In addition, a series of proficiency style tests were made from consecutively manufactured blades and

sent to participants throughout the United States and abroad. A total of 66 answer sheets were returned, providing 330 test results for evaluation. A comprehensive list of 49 references is included.

Uchiyama, T. (1992). “The Probability of Corresponding Striae in Toolmarks.” AFTE Journal, Vol. 24. No. 3. pp 273-290.

Abstract: Two significant and practical corresponding relationships used to compare and determine the common origin of striated toolmarks are the number and quality of corresponding striae. It is essential to know how many striae can correspond by chance in order to determine the discriminating power of these relationships. The probability of chance correspondence (i.e., % match), and the maximum number of consecutively matched striae was estimated for variation in the density of the striae, the critical coincidence ratio (CCR), and the width of the striae of the marks compared. The critical coincidence ratio is a measure of how each specific striae compared is counted as corresponding or not corresponding. The results generated by this simulator study will be used to evaluate the discriminating power of these relationships and allow the implementation of effective and efficient automated systems applied to the comparison of real striated toolmarks. Automated comparison systems applied to real striated toolmarks (ie., fired bullets) will in turn allow comparisons on a scale sufficient to establish and validate objective criteria for the comparison of striated toolmarks to determine common origin.

Kaye, D. (2010). “Probability and Individuality in Forensic Science Evidence.” Brooklyn Law Review, Vol. 75, No. 4, pp. 1163-1185

Abstract: Day in and day out, the testimony of criminalists reflects the paradigm of positive, uniquely specific identification of fingerprints, DNA profiles, bullets, handwriting, and other trace evidence. Commentators from other disciplines have called for a “paradigm shift” that would replace talk of individualization with statements of probabilities or would exclude certain testimony pending better research on the ability of analysts to perform as claimed. With rare exceptions, however, the courts have failed to perceive the gap between optimistic theory and hard proof, and they have accepted weak forms of validation. Now that Congress has called on the National Academy of Sciences to “disseminate best practices and guidelines concerning the . . . analysis of forensic evidence,” a new opportunity to reassess the long-entrenched claims of individualization is at hand. This essay seeks to contribute to such a reassessment by examining the arguments of two of the most powerful critics of this aspect of forensic science, Professors Michael Saks and Jay Koehler. The “individualization fallacy” they describe implicates issues in philosophy, logic, mathematics, psychology, and statistics. This essay argues that contrary to one possible reading of their work, there is no rule of logic or ontology that prevents individualization and that testimony as to uniqueness is acceptable in some situations. It suggests a

combination of evidentiary rules and practices to avoid the excesses of the current form of testimony.

Kirk, P. and Kingston, C. (1964). "Evidence Evaluation and Problems in General Criminalistics." Journal of Forensic Sciences, Vol. 9, No. 4. Pp 434-444.

Authors discuss the ideas of objectivity and subjectivity and the role statistics plays in forming the foundation of identification conclusions. Although the articles addresses more general criminalistics issues, firearms identification fits within the broad range of topics being discussed.

Biasotti, A. (1964). "The Principles of Evidence Evaluation as Applied to Firearms and Tool Mark Identification." Journal of Forensic Sciences, Vol. 9, No. 4. pp 428-433.

The author discusses the current state of firearm and toolmark identification by a review of the literature. He also addresses the issue of more objective standards in the field to form a conclusion of identification. The author discusses probability and statistical models as a possible approach to more objective standards.

Gunther J.D., and Gunther C.O, "The Identification of Firearms", Wiley & Sons, Inc. 1935. pp 33-36.

The authors discuss a basic probability model for determining the individuality of a firearm. They looked at the random chances of particular individual / accidental characteristics in determining how "unique" a particular firearm signature was. They also discuss the concepts of a mark being so unique that it will be differentiated from all other firearms.

Hatcher, J., Jury, F., and Weller, J. "Firearms Investigation Identification and Evidence." Small-Arms Technical Publishing Company, 1935. (reprint 2006 – Ray Riling Arms Books Company) pp 376-381.

The authors discuss basic concepts and ideas of probability models being used in firearms identification to determine how likely a particular firearm was responsible for firing a particular bullet / cartridge case. They base their discussion in this text on the theory of probabilities and clearly state that their estimates of a numerical probability is strictly theoretical.