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; in that, applied science focuses on practical applications with less emphasis on the most basic objects and forces.

The origination of toolmarks in the forensic science discipline of Firearms and Toolmark Identification (FA & TM ID) is derived from the validated theories in the physical sciences. Specifically, the origination of toolmarks in nature is based on previously established theories, principles and properties from the physical sciences that were also earlier adapted in the material, as well as the 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
- C. Force(s)
  1. Compression
  2. Torsion
  3. Shear
  4. Tensile
  5. Flexure

IV. 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

V.) 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.

Biasotti, A.A., (1981) Rifling Methods – A Review and Assessment of the Individual Characteristics Produced., *Association of Firearm and Toolmark Examiners Journal*, Volume 13, Number 3, Pp. 34 – 61.

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* , Volume 13, Number 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.

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.

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.

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., "Firearms and Toolmark Identification Criteria: A Review of the Literature", *Journal of Forensic Sciences*, Volume 42, Number 3, 1997, pp.446-74.

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., 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.

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.

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. *Association of Firearm and Toolmark Examiners 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 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 major working edges of a pistol.

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

Lutz, M., (1970) Consecutive Revolver Barrels . *Association of Firearm and Toolmark Examiners Newsletter* #9, Page 24.

Matty, William. (1984) Raven .25 Automatic Pistol Breech Face Tool Marks. *Association of Firearm and Toolmark Examiners Journal*, 16:3 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. (2009) The Identification of Consecutively Manufactured Extractors, *Association of Firearm and Toolmark Examiners Journal*, 41:3, 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. (2009) The Identification of Bullets Fired from 10 Consecutively Rifled 9mm Ruger Pistol Barrels: A Research Project Involving 507 Participants from 20 Countries. *Association of Firearm and Toolmark Examiners Journal* 41:2 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 [1]. 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 û including the original 67 reported on by Brundage û was published by Hamby and Thorpe in 2001 [2]. This paper reports the final conclusions of the research conducted by Brundage, Hamby and Thorpe over a 10 year period [3, 4].

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.

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, Rocky. (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 marks of "reasonable complexity" that the odds of the same marks being repeated on another tool to be 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.

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 (NKM'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.

> Conducted pioneering study on striated type toolmarks on numerous cutting tools, especially knives, with working edges containing some type of grinded 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 marks of “reasonable complexity” that the odds of the same marks being repeated on another tool to be 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 *Association of Firearm and Toolmark Examiners Journal* , Volume13, Number 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.

Roberge, D., Beauchamp, A., (2006) The Use of BulletTrax-3D in a Study of Consecutively Manufactured Barrels *Association of Firearm and Toolmark Examiners 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 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.

Uchiyama, T., “Toolmark Reproducibility on Fired Bullets and Expended Cartridge Cases”, *Association of Firearm and Toolmark Examiners 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?

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.

> These articles explore 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 r 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.

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?**

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. *Association of Firearm and Toolmark Examiners 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 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 major working edges 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?**

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.

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.

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?

FIREARM BIBLIOGRAPHY

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 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 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 I 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 the groove I 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 I 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 that 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 CMS 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 conservative 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 2) applied the conservative 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 barrel 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 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 which consisted of both bullets and cartridge cases. No false positives or false negatives were reported.

Tulleners, Fred and Mike Guisto. “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 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.

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 cased 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 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.

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 subclass and individual characteristics. Results of these comparisons found that the manufacturing processes used to fabricate these breechfaces produced 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 comprised 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.

> Study of cartridge cases fired from 617 different Glock pistols were 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 along. 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 possible unless ID on wear or 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 cartridge cases, with each known specimen having at least one unknown specimen associated with it.

Study showed that extractors could be distinguished from each other despite that they were consecutively manufactured.

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 encountered.

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 effected 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 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 marks produced by 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.

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 as 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 test was produced 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 class 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.

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 demonstrate 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 tire 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 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.

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.

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 conservative 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.

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.

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 shows conclusively that an objective observer (a machine) detects significant visual differences between KNMs and KMs.

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

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

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.

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.

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.

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

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.

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.

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.

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.

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

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.

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.

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. Further the authors 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.

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.

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 results)? Does research exist which identifies how and which cognitive factors impact the analysis process?

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.

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.

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

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.

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.

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

and

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

These two 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.

and/or

Goddard, "Scientific Identification of Firearms and Bullets", *Journal of Criminal Law and Criminology*, Vol. 17, August 1926, pp 254-263.

Articles discuss the effectiveness of the microscopic comparative method.

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?

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.

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.

AFTE Glossary (1998). Theory of Identification as it Relates to Toolmarks. *AFTE Journal*, vol. 30 (1), 86-88.

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".

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 fired caliber bullets was conducted by using a computer to correlate the KM

and KNM striae groups of these fired test 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.

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

Article describes the examination process of firearms identification beginning with class characteristic agreement and followed by individual characteristic agreement. Using a digital image processor is discussed for 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, are only moderately low.

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

AFTE Glossary (1998). Theory of Identification as it Relates to Toolmarks. *AFTE Journal*, Vol. 30, No. 1, pp. 86-88.

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".

The threshold for identification is applied by individual examiners as described by the AFTE Criteria for Identification. The success or failure of the application can be assessed through scientific outputs or end-products, such as Proficiency and Validity tests (see below).

Miller J., An Examination of the Application of the Conservative Criteria for Identification of Striated Toolmarks Using Bullets Fired from Ten Consecutively Manufactured Rifled Barrels, *AFTE Journal*, Vol. 22, No. 2, Spring 2001, pp. 125-132.

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

None that is known. The AFTE Criteria is intended to be universal, accounting for all known methods of manufacture.

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 #22.

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,
Internet Source: 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%

Reference: Murphy, Doug, Presentation at 2010 AFTE Training Seminar, and listed under Error Rate Documents at www.swggun.org.

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- for short descriptions of each item, 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.

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

No known studies address these specific issues

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

No known studies address these specific issues (22, 23).

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?**

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.