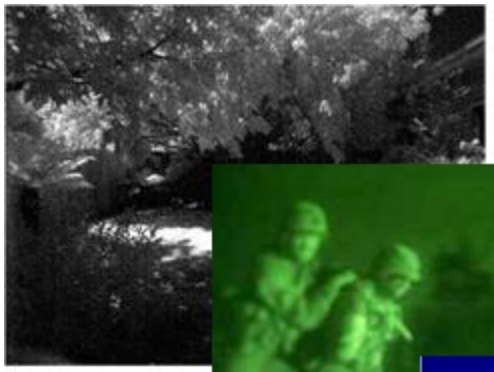
IRID®

Infrared Toolmark Imaging Forensic Applications

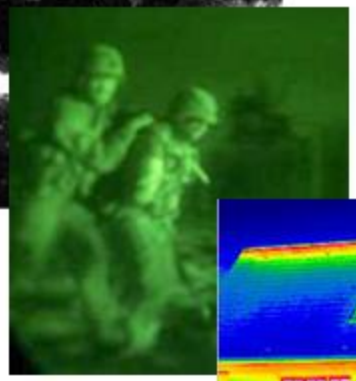
- **Common Origin of Fired Ammunition Components**
- **Authentic or Counterfeit Electronic Components**

Francine Prokoski
President
Infrared Identification Incorporated

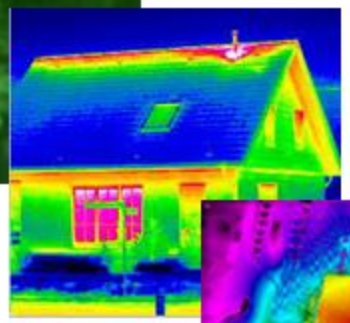
60 Year Development of Infrared Imaging



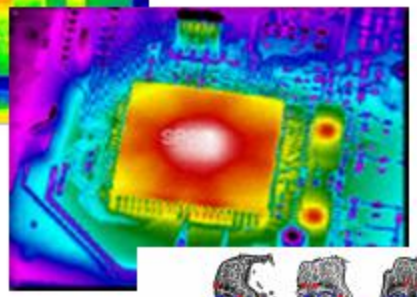
IR Film



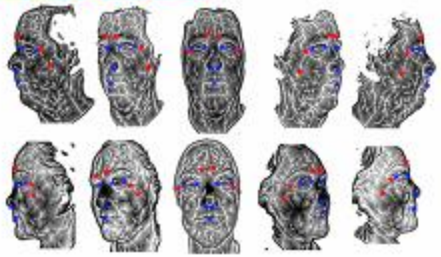
IR Viewers



Analog Cameras



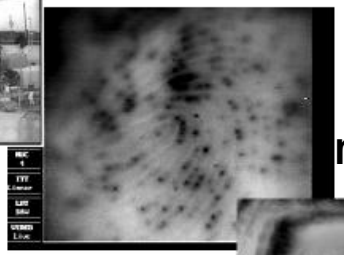
Radiometric
Digital Cameras



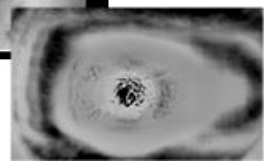
Calibrated
3D/IR Systems

inches

mm



microns



Traditional Infrared Imaging

USES:

Nonilluminated Vision	- Surveillance, Night Driving
Temperature Measurement	- QC, Process Control, Fire Safety, Health Monitoring
Spectral Analysis	- Plume Analysis,Trace Evidence, Camouflage Detection

TECHNICAL ISSUES LIMITING USE:

Small Array Size

Shallow Depth of Focus

Strong Influence of Emissivity on Temperature Measurement

Motion Blur with Uncooled Detectors

NonTraditional Infrared Imaging

USES:

Emissivity Mapping

- Forensic Toolmark Detection & ID
- Industrial NonContact Inspection for Surface Defect at site of Thermal Anomaly
- Medical Assessment of Wound, Incipient Infection, Adverse Reaction to Vaccination

IMPORTANCE OF TECHNICAL ISSUES:

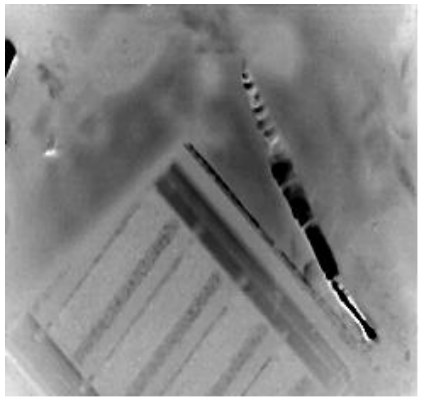
Small Array Size - High Magnification Optics, Small Local Features

Shallow Depth of Focus – CNC-Controlled Range Gated Sequences

Strong Influence of Emissivity – Increases Toolmark Detection

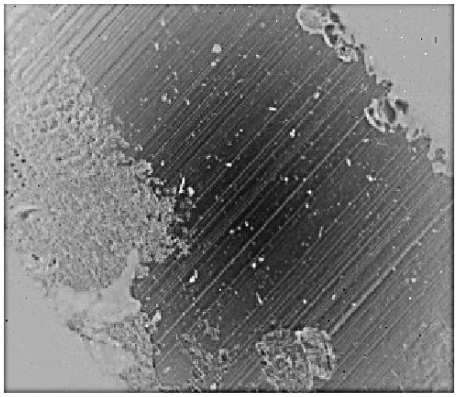
Motion Blur with Uncooled Detectors – Lock-on Toolmark Details

Emissivity Effect: Actual vs. Apparent Temperature



Plastic, Glass, and Metal Surfaces
All at the Same Room Temperature
Appear to Have Highly Detailed
Temperature Variations in IR Images

Variations in Materials
Different Surface Processing



Must Know ε to Calculate Actual Temperature from Apparent Temp

ε is a Measure of Emission Efficiency

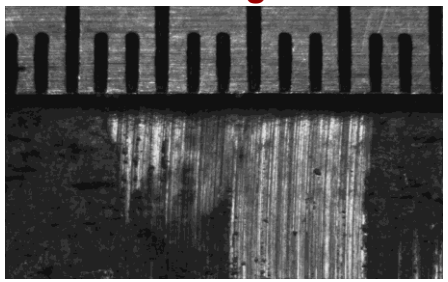
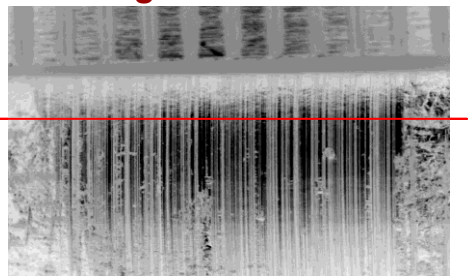
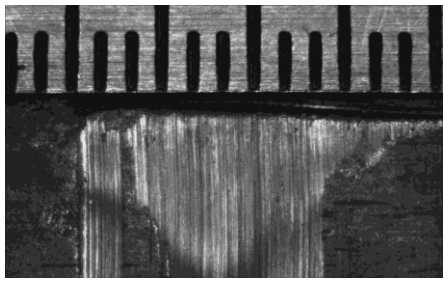
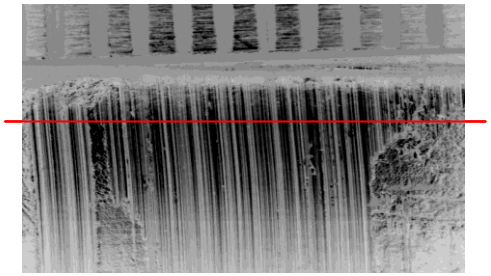
Function of: Distance, Atmosphere, Optics, Spectral Band, Surface Texture, Surface Geometry Relative to Camera, Material Composition, Color, Temperature, etc.

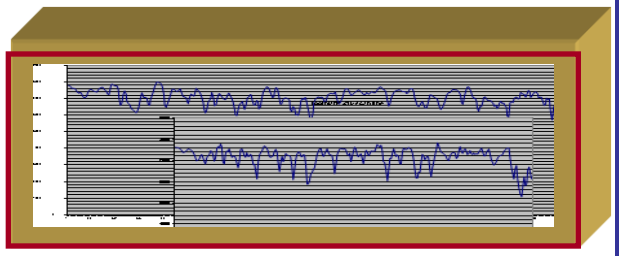
Sample Values: **Polished Aluminum ε= 0.05 (inefficient)**
Human Skin ε= 0.98 (efficient)

Manual Toolmarks

Variations in User's Force, Angle, Path, and Motion Affect Mark
Analysis Must Link Mark to Tool or Mark to Mark
3D Nature of Toolmarks Complicates VL Imaging

Two Different Users Make Impression + Striae Marks with Screwdriver

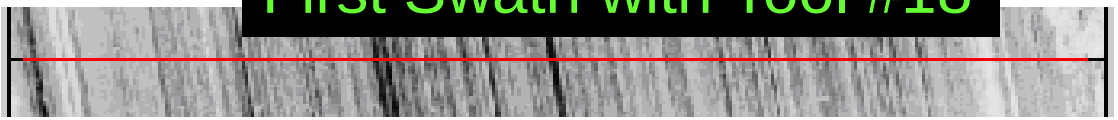
	VL Images	*IR Images with CutLine*	*CutLine Waveform as BarCode*
Ruler in 1/36 inch			
Toolscrape018			
			
Toolscrape218			



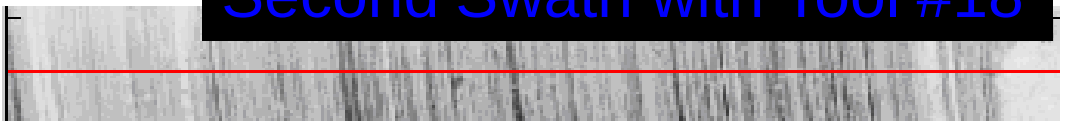
Frequency Domain Comparison of Toolmarks

Different Person, Same Tool

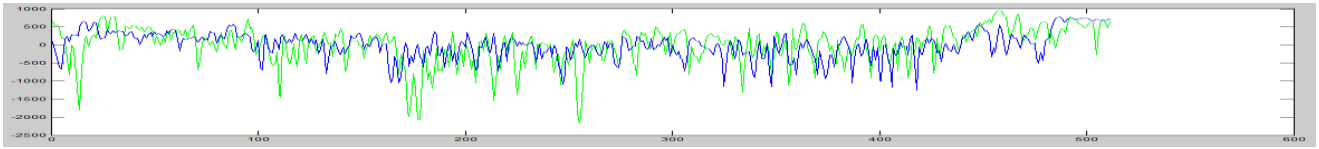
First Swath with Tool #18



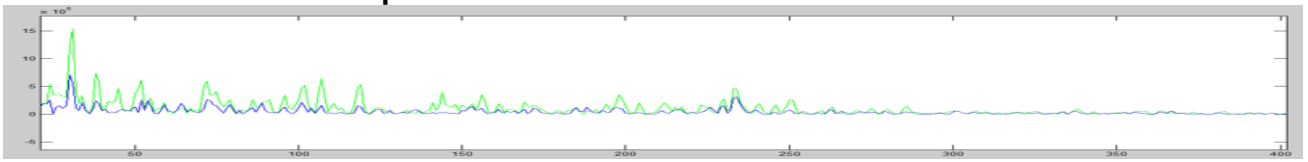
Second Swath with Tool #18



Depth Profiles – Not Aligned



FFT of Depth Profiles – Not Scale Normalized



New Slide

Identification of Manual IR Toolmarks

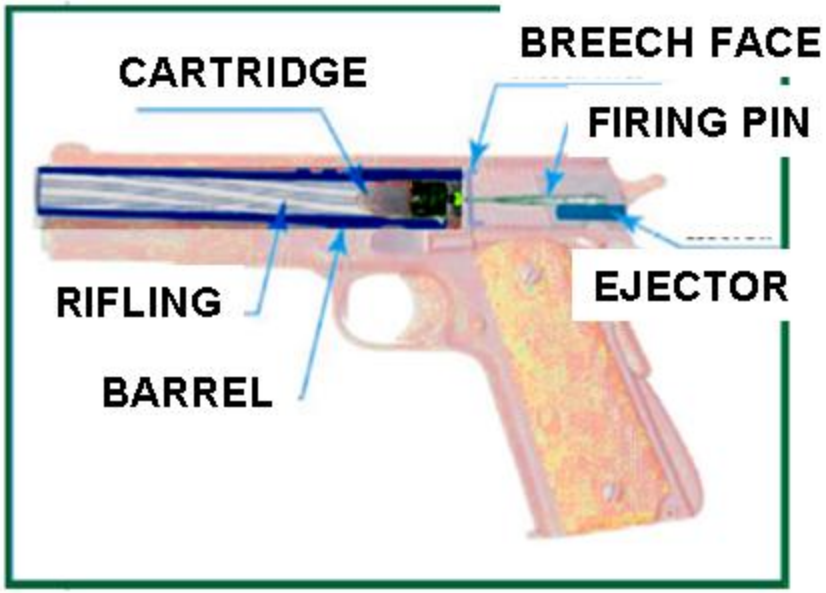
- Magnification is Required to View/Extract Toolmark Features
- Traditional Approach uses Visible Light Imaging
- With Ring or Oblique Light Source
- Light Variations and Artifacts Affect Reliability

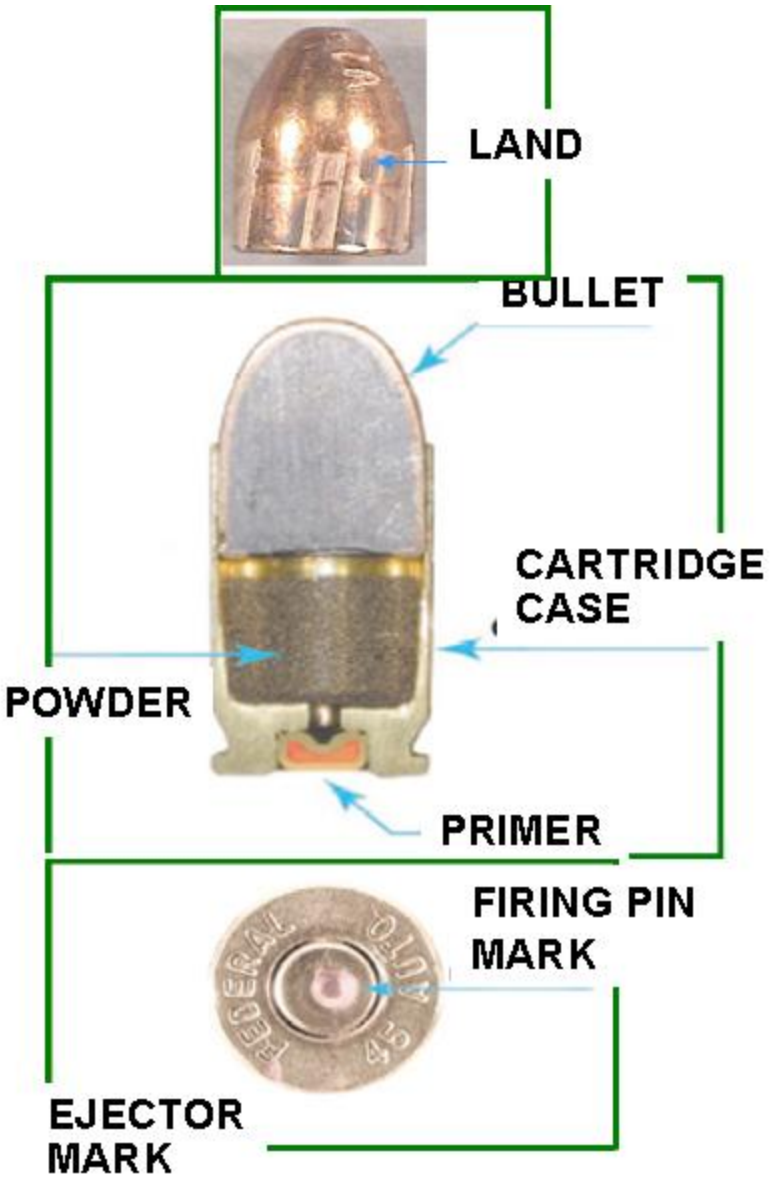
- IR imaging Eliminates Lighting Adjustments and Anomalies
- Greater Image Reliability Allows For Higher Accuracy
- No Illumination Tuning Allows Automated Capture & Comparison

Automated IR Imaging and Matching of 400 Screwdriver Marks Ranked 87% of Siblings in #1 Place vs. 16% for VL Imaging

Automated Toolmark Production

Semiautomatic Hand Gun is Example Of a Manufacturing Process Involving Multiple Actions Leaving Toolmarks

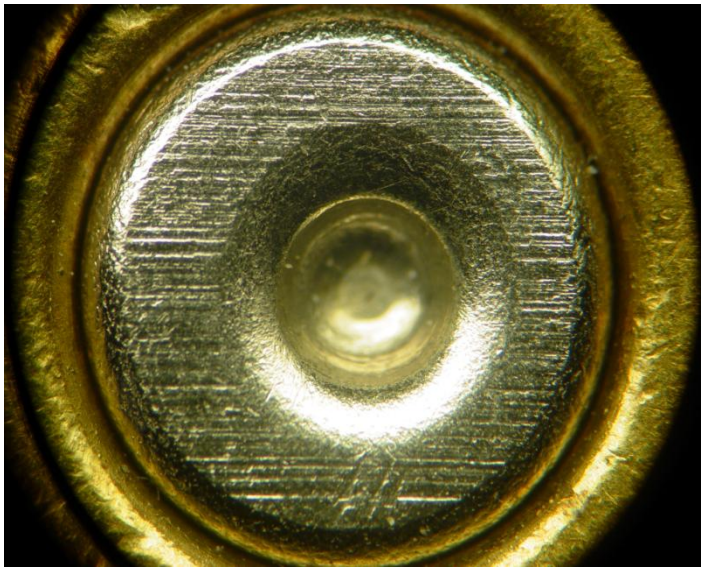




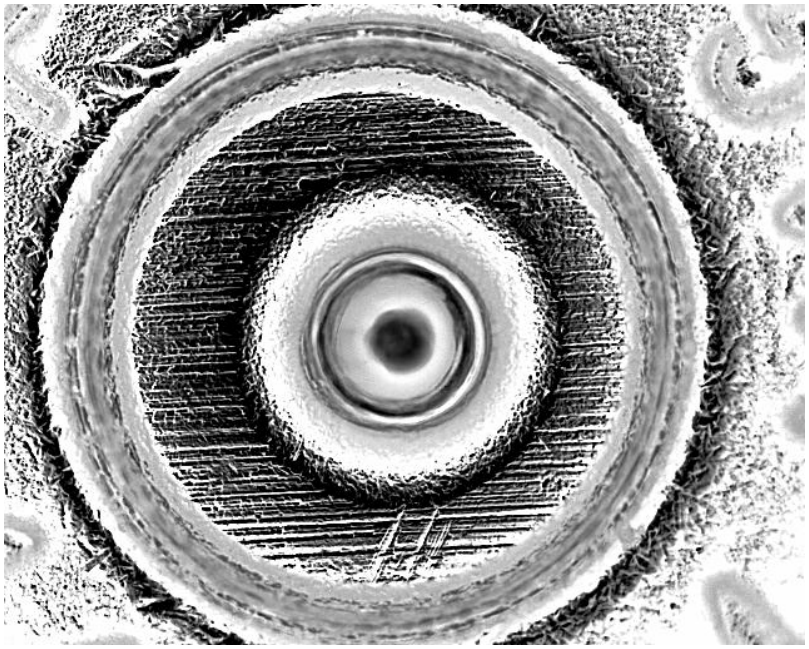
Automated Toolmarks

Primer Area of Magnum .44 cal – casing #18

VL image of breechface Impression



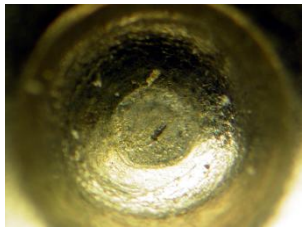
IR Image of breechface Impression



Automated Toolmarks

Firing Pin Details of Magnum .44 cal – caseing #18

VL Image of firing pin impression

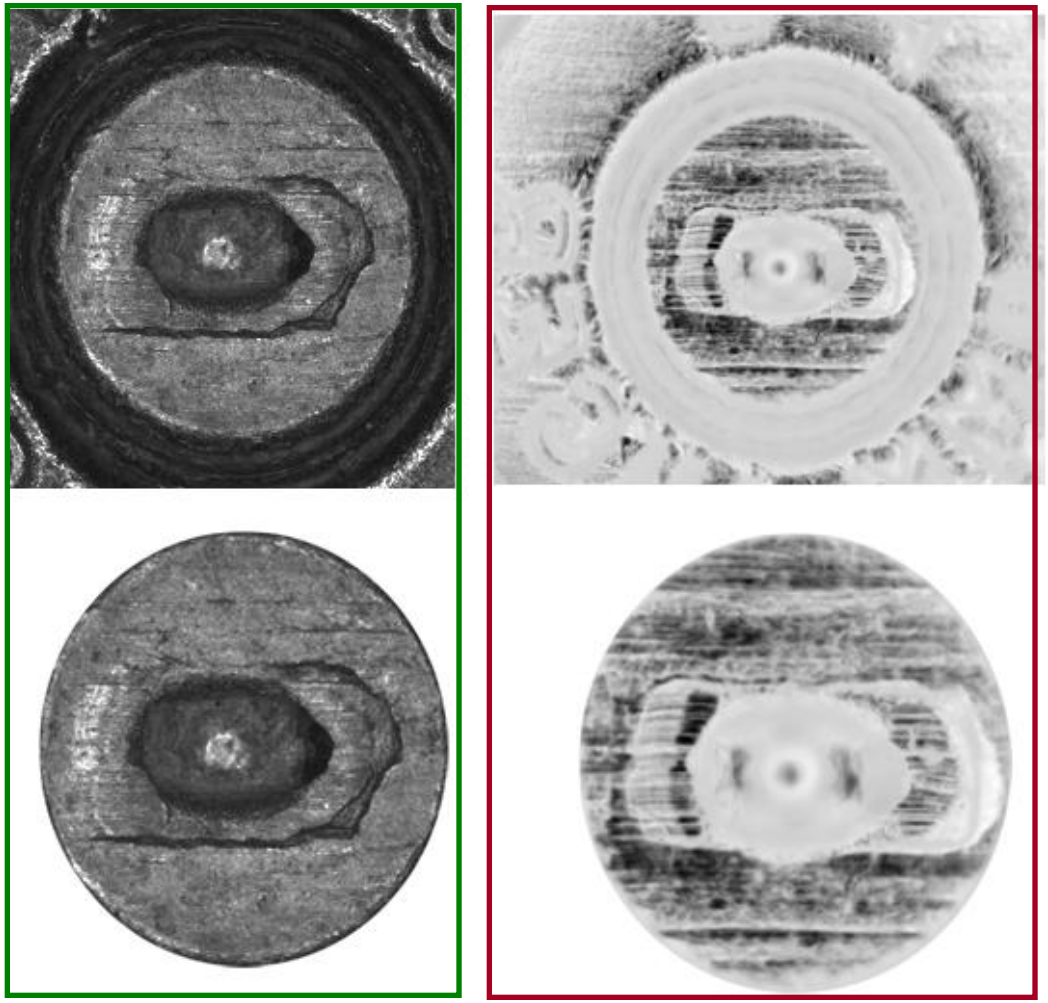


Glock VL and IR Images

Characteristic Primer Shearing Marks from Firing Pin Aperture
Details are More Clear in the IR Images

Whole FOV

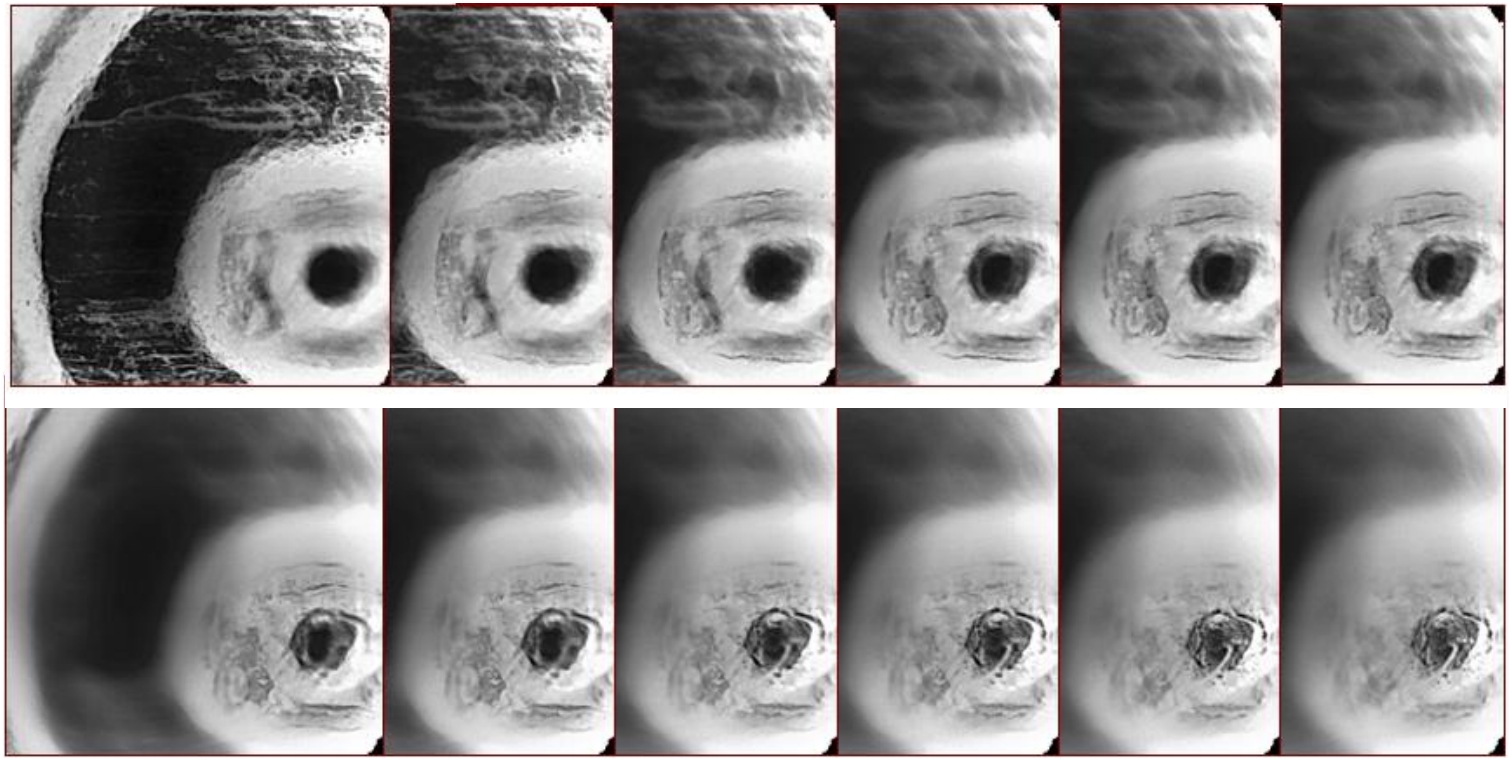
Primers



Technical Issues in Toolmark Analysis

DEPTH OF FOCUS: Very Shallow

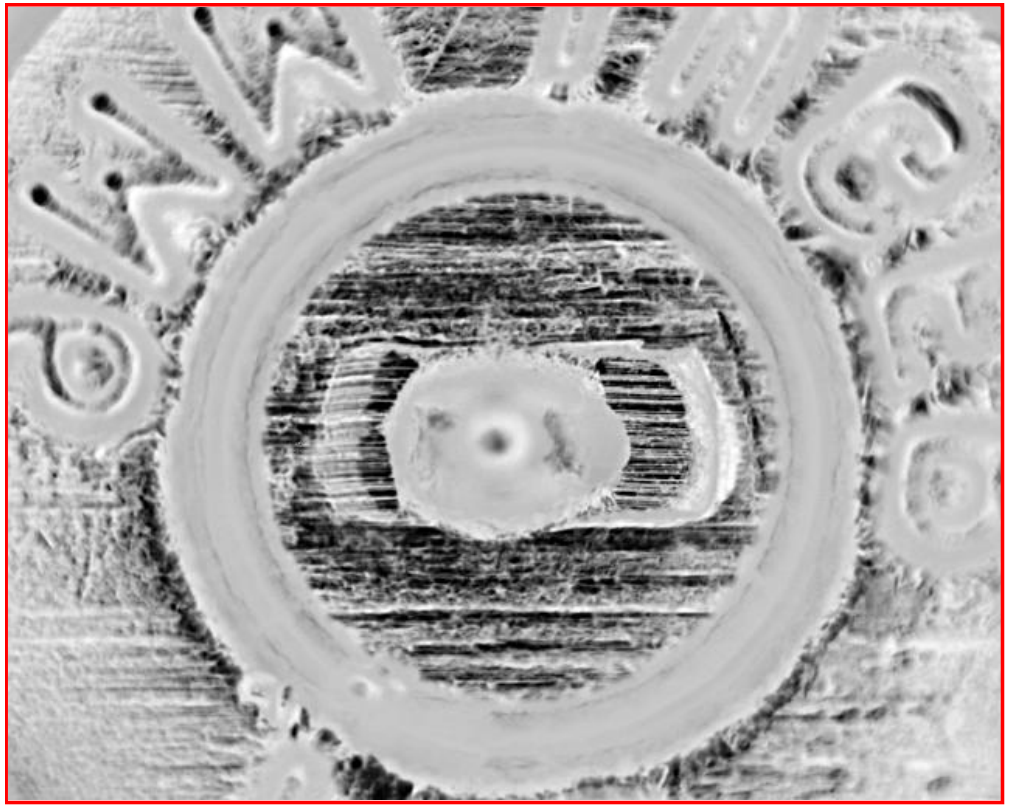
CNC Controls Focus Distance to Provide Precise Range Gating
Synchronization with IR Camera Encodes Depth into Each Frame's Header
3D Rendition of Toolmark Impressions and Striations Can be Formed from 2D Slices



Selected Frames

IR Identification of Glock Casings

Automatic Generation of 1D and 2D BarCodes



Shape of FP Aperture
Relative Position FP Indent
Shearing Striae Left (Bottom)
Shearing Striae Right (Top)
Breechface Impressions
- Within Primer
- Outside Primer

FP Indent Details
Anomalous Marks
- Within Primer
- Outside Primer

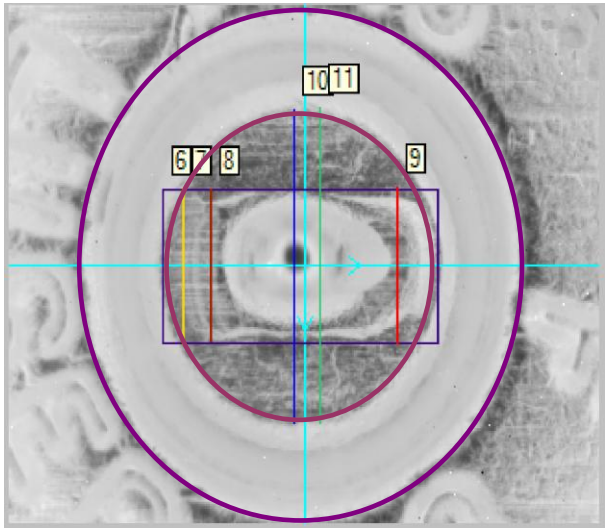
IR Quality Control Monitoring of Glock Firearm

Define Standard Orientation; Reference Landmarks

Axes Reference Inner and Outer Primer Edge Circles
Center is Center of Rotation
FP Aperture Rectangle is Horizontal with FP Drag to Right

CutLines 7 8 and 9 Characterize Shearing Marks
CutLines 10 and 11 Locate Breach Marks Outside and FP Indent Within Rectangle

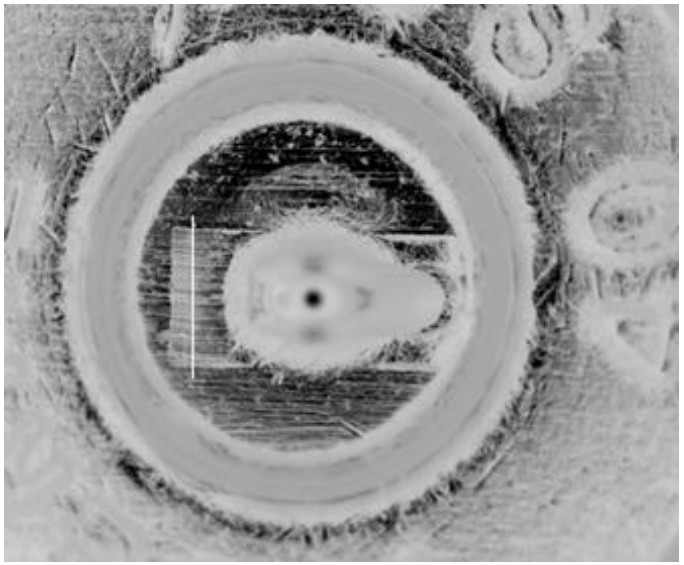
MEASUREMENTS Compared to Standard:
Circularity of CC and primer
Aperture Size & Position
FP Indent Location
CutLine Waveforms:
Breach & Shearing

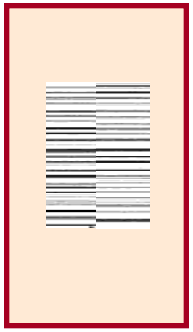


Casing Identification by Primer Sheering Code

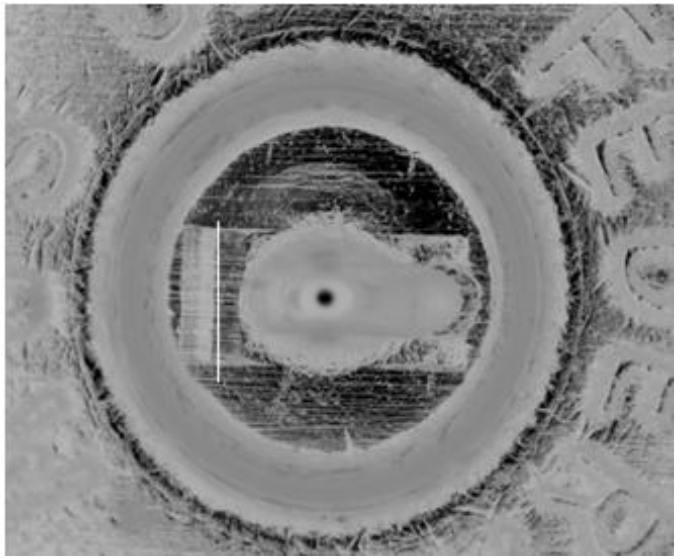
Sibling Glock Casings

CC388 f075





CC304 f053



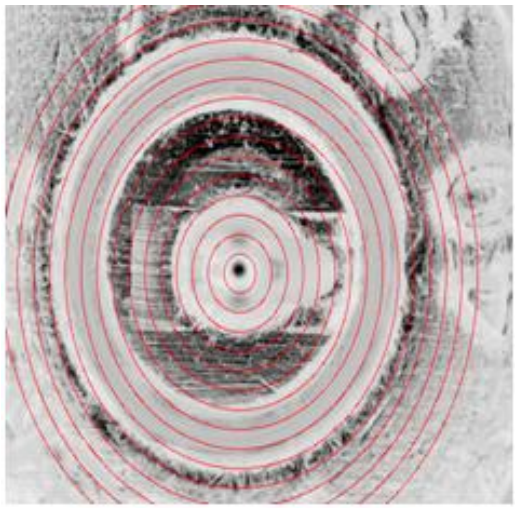
Compare 1D BarCodes from Vertical CutLines through Primer Sheering

Greyscale Variations Ignored

Striae Locations are Compared

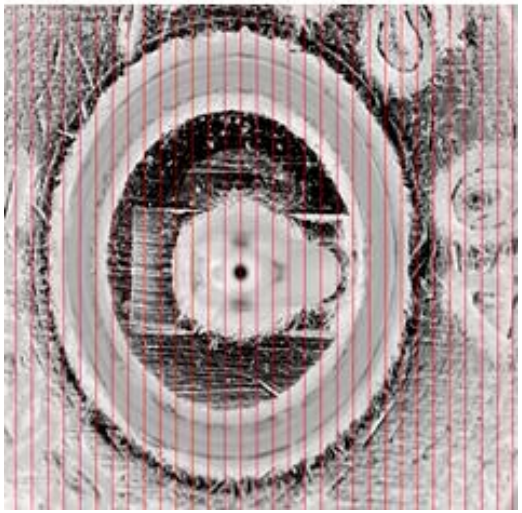
Strongest 1D Match Test
96% Siblings Ranked #1

CutLine Patterns Selected by Part Design



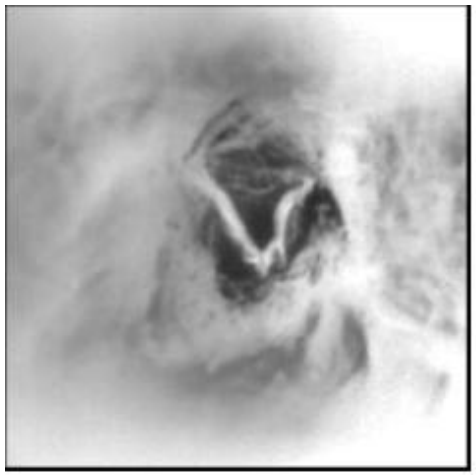
Use of Multiple CutLines Improves Matching
Chose CutLine Density to Cover Production

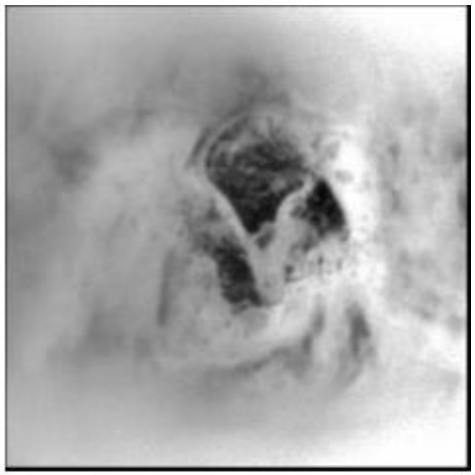
Concentric Rings about FP Center
Compensates for Imprecise Rotation Correction
Better Fit to Primer Shearing Curvature
Set of Concentric CutLines Produces 2D BarCode



Linear Vertical CutLines
Equal-spaced Shifted through FP Center
Sensitive to Rotation Correction
Set of CutLine Waveforms Produces 2D BarCode

Identification by 2D Firing Pin Code



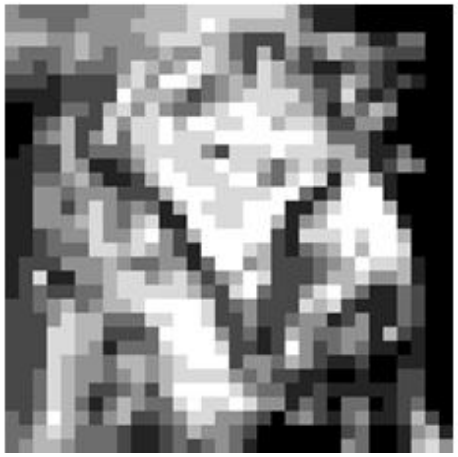


Sibling Casings

FP IR Image Frames
@ Specified Focus

CC 085 FP and Barcode

CC 084 FP and Barcode

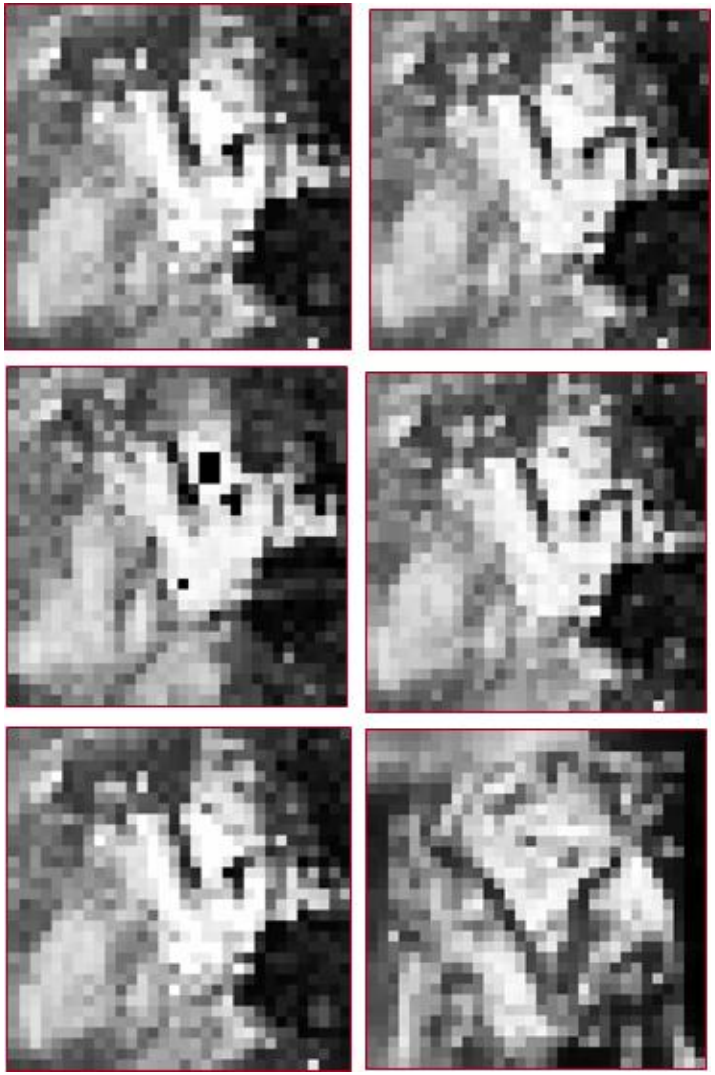


2D Barcode Format

Align & Difference

94% Correlation
Within 1 grey level

Reliability of Self-Generated Toolmark Codes



FP CC091 **Re-Scans**
Barcode Correlation **99.6%**

FP CC090 CC091 **Siblings**
Barcode Correlation **98.5%**

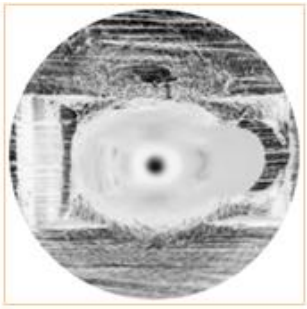
FP CC091 CC085 **Non-Siblings**
Barcode Correlation **24.5%**

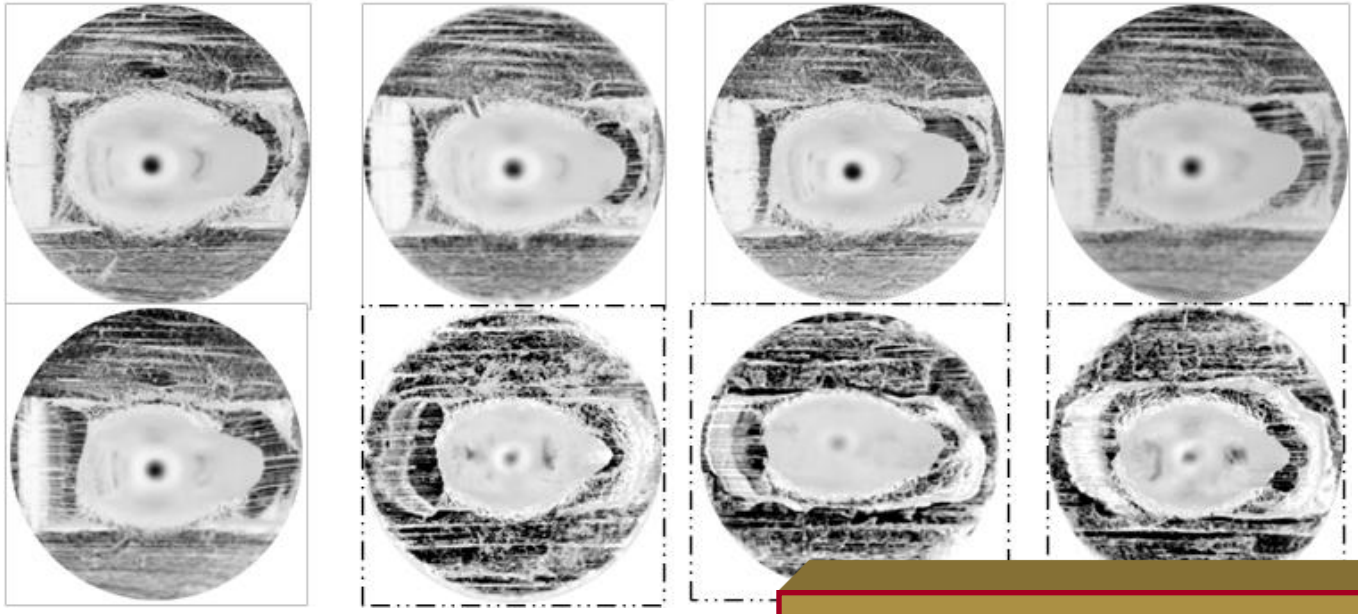
Self-Generated IR Barcodes Provide Accurate Identification Of Toolmarks

Evaluating Match Value Algorithm

Match Value Combining FP and Sheering Comparison Results Against 600 CCs

		tan is Target			silver is Sibling				
	TOP EIGHT MATCHES FOR TARGET								
	WITH POSITION OF SIBLINGS FROM OBSERVATION								
Rank		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Template	1072	1159	1164	1092	1160	1079	617	629	611
FeatureCount	10518	10549	10194	10436	9928	10815	10507	10651	10293
MatchCount	10518	3838	3695	3740	3345	3052	2791	2819	2664
MatchValue	1.000	0.357	0.356	0.352	0.330	0.276	0.260	0.259	0.253





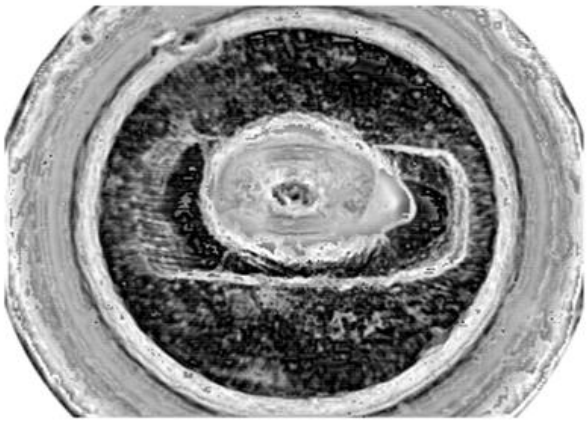
Match Value Ranked All Siblings In Top Positions for 600 CCs

Glock Toolmarks on Primer

VL with oblique visible light illumination

NIR with NIR illumination

IR with no illumination



Passive IR imaging generates more highly detailed Toolmarks
With greater repeatability than visible light or near IR imaging

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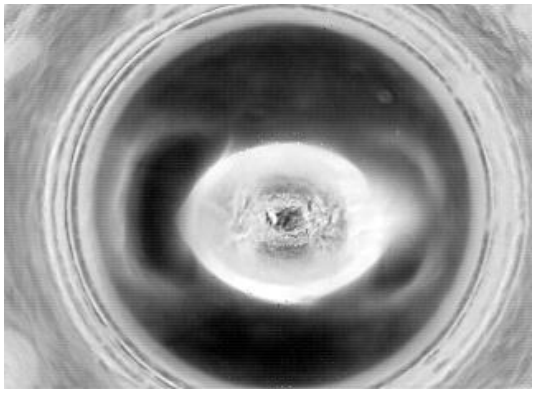
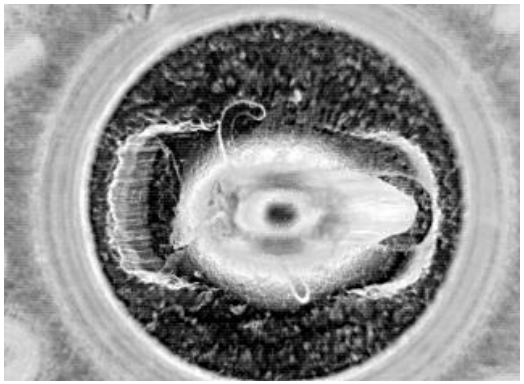
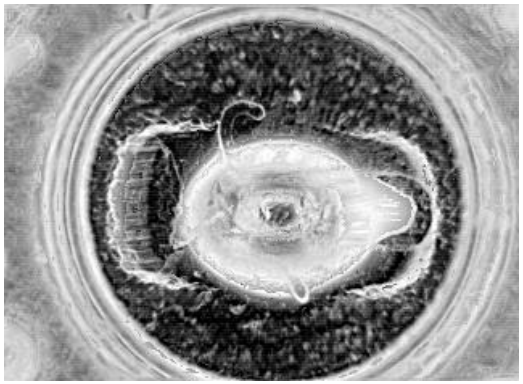
CC #15 fired from Glock 9mm
Imaged with a 500 frame IR sequence:

Frame 272 has deepest firing pin impression features in focus
Frame 315 has primer sheering marks in focus
Fusion of the two frames is used to search reference database for a match

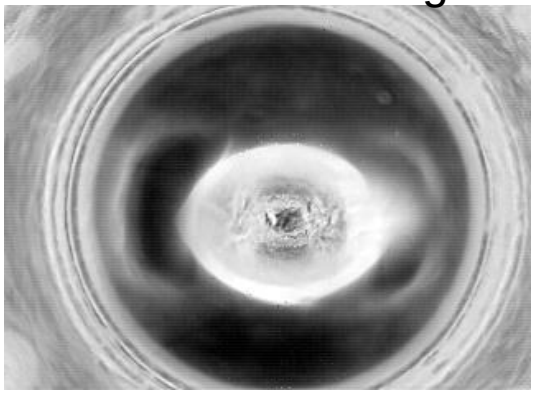
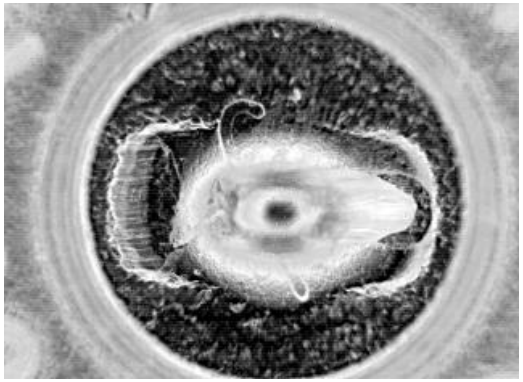
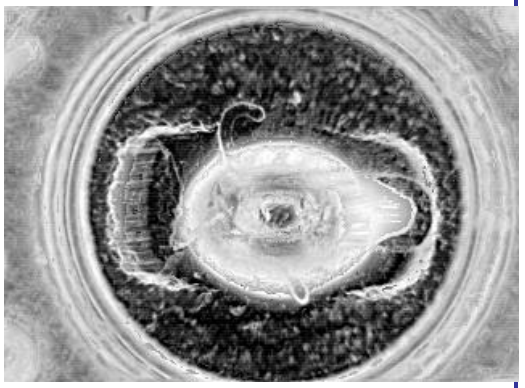




Firearm/Ammunition combinations that produce breechface impressions may use fusion of three frames for database searching
Firing pin impressions are not fused with other feature frames in the case of Firearms whose firing pin position & orientation are not fixed

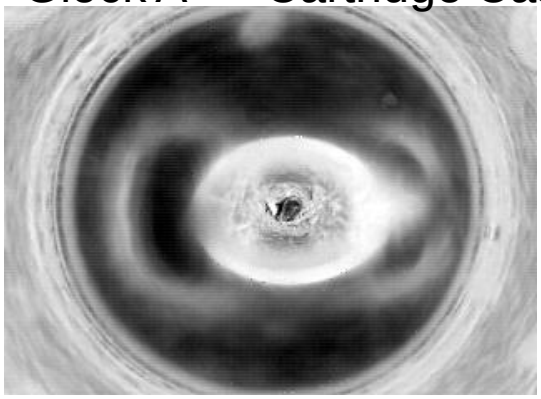
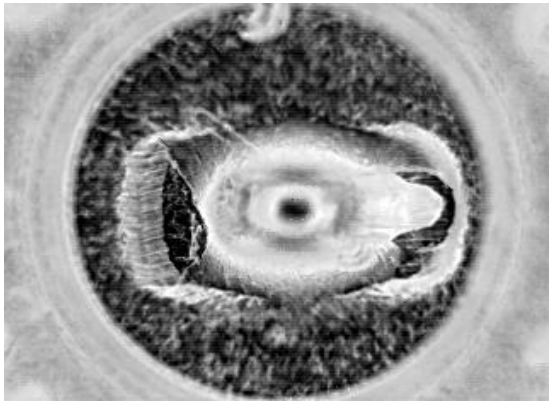
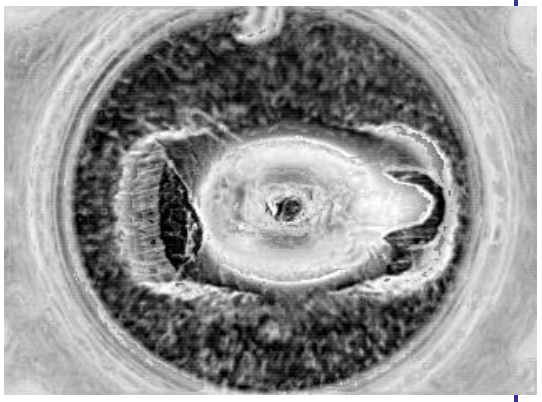
22

FPI, Primer Sheering, and Fused Frames from Sibling Casings fired from the same Glock

Glock A Cartridge Case #15

Glock A Cartridge Case #14

Comparison of Thermal IR Toolmark Images of
Firing Pin Impressions and Primer Shearing Marks on
Two Cartridge Cases fired from the same Glock

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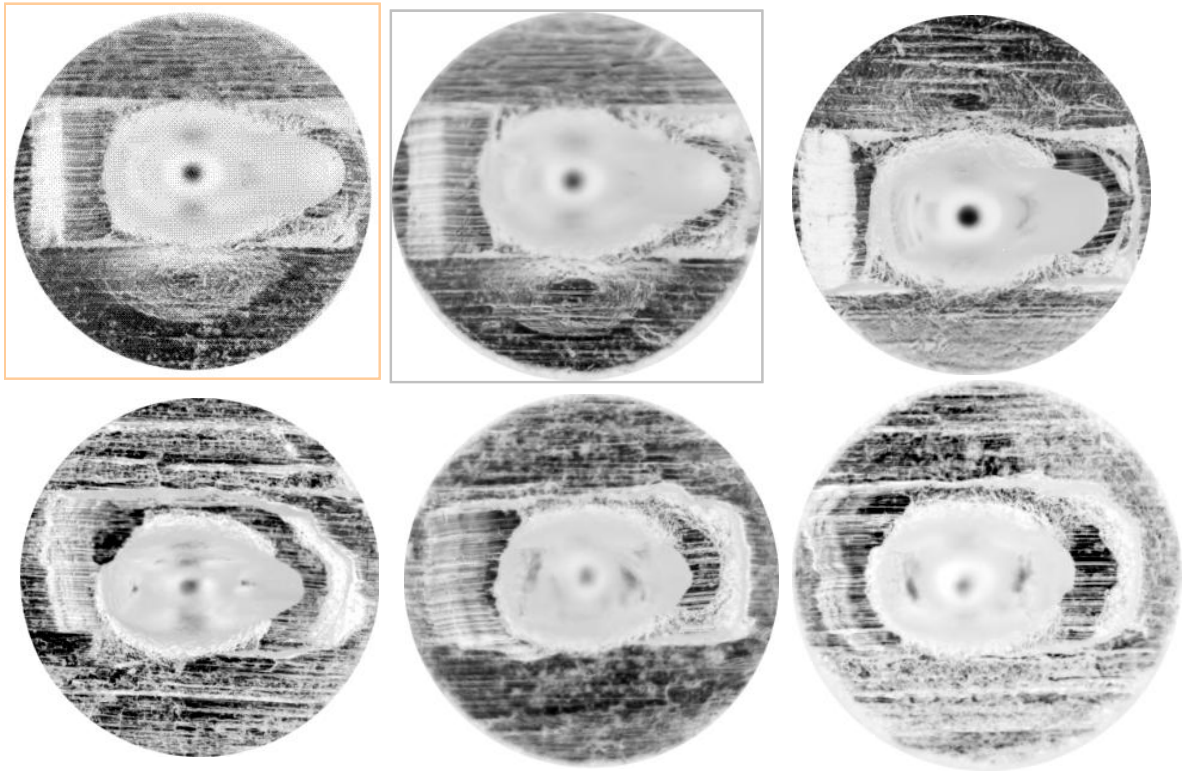
IR2IR Automated Comparisons of 262 Glock CC

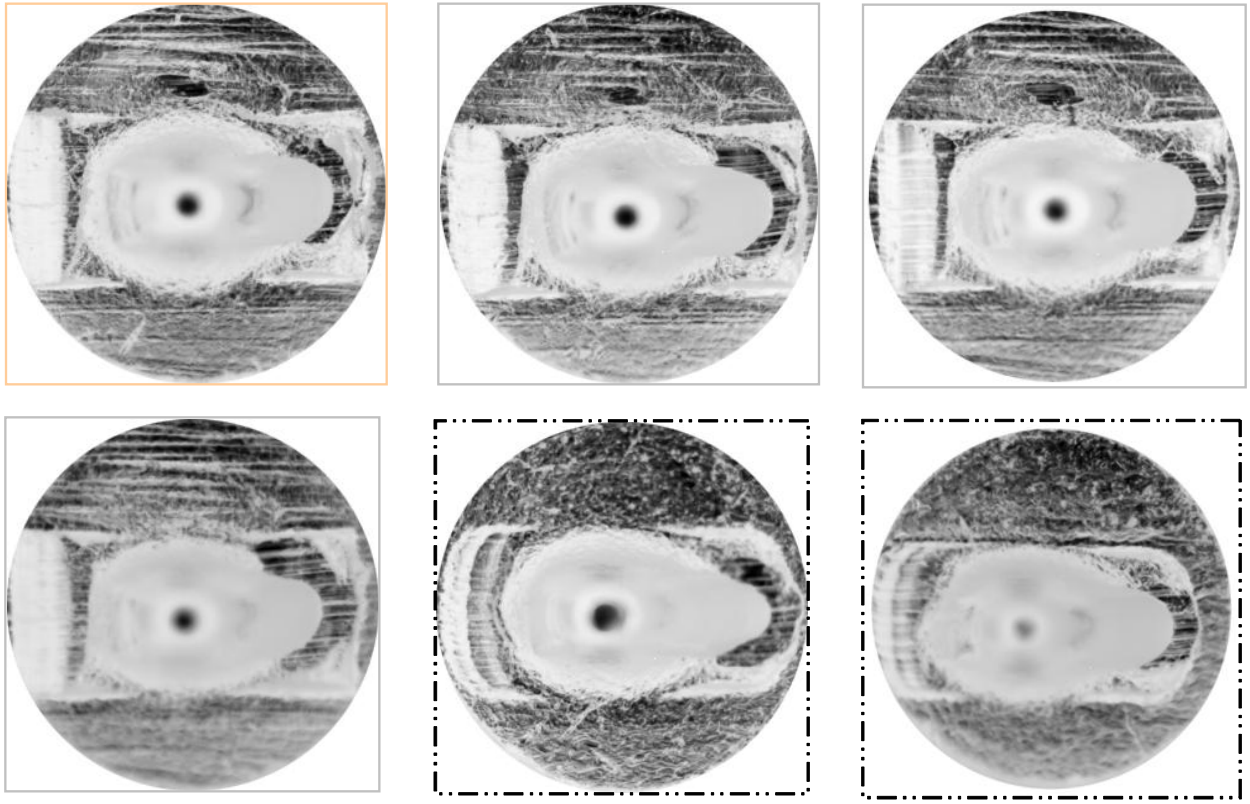
TOP MATCHES TO CC1006 INCLUDE ITS 1 SIBLING IN RANK #1 WITH MATCH VALUE 0.315

	tan is Target		silver is Sibling					
	TOP EIGHT MATCHES FOR TARGET							
	WITH POSITION OF SIBLINGS FROM OBSERVATION							
Rank		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Template	1006	1063	1092	260	254	213	266	243	278
FeatureCount	9982	10937	10436	11699	11629	11757	10895	11370	11195
MatchCount	9982	3550	2699	2677	2669	2634	2561	2538	2519
MatchValue	1.000	0.315	0.253	0.217	0.218	0.212	0.228	0.214	0.216



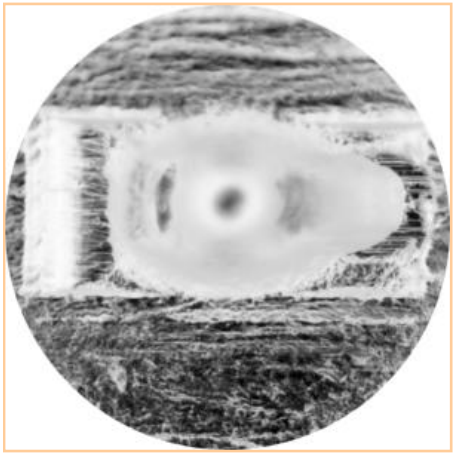
TOP MATCHES TO CC1159 INCLUDE ITS 3 SIBLINGS IN RANK #1,2,3 WITH MATCH VALUES FROM 0.259 to 0.427

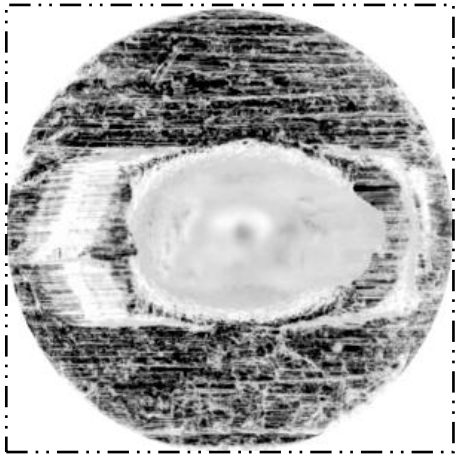
	TOP EIGHT MATCHES FOR TARGET								
	WITH POSITION OF SIBLINGS FROM OBSERVATION								
Rank		1	2	3	4	5	6	7	8
Template	1159	1092	1072	1160	1089	1102	255	1100	256
FeatureCount	10549	10436	10518	9928	9959	9549	10597	9886	10786
MatchCount	10549	4532	3862	2636	2580	2458	2704	2520	2740
MatchValue	1.000	0.427	0.360	0.259	0.253	0.250	0.250	0.249	0.248

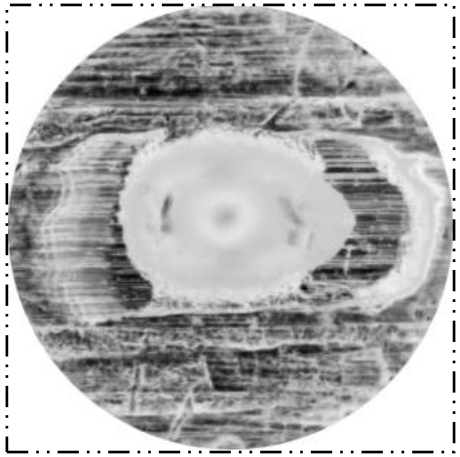


TOP MATCHES TO CC1016 FIND NO MATCH VALUES ABOVE 0.232
CONCLUSION IT HAS NO SIBLINGS IS CORRECT

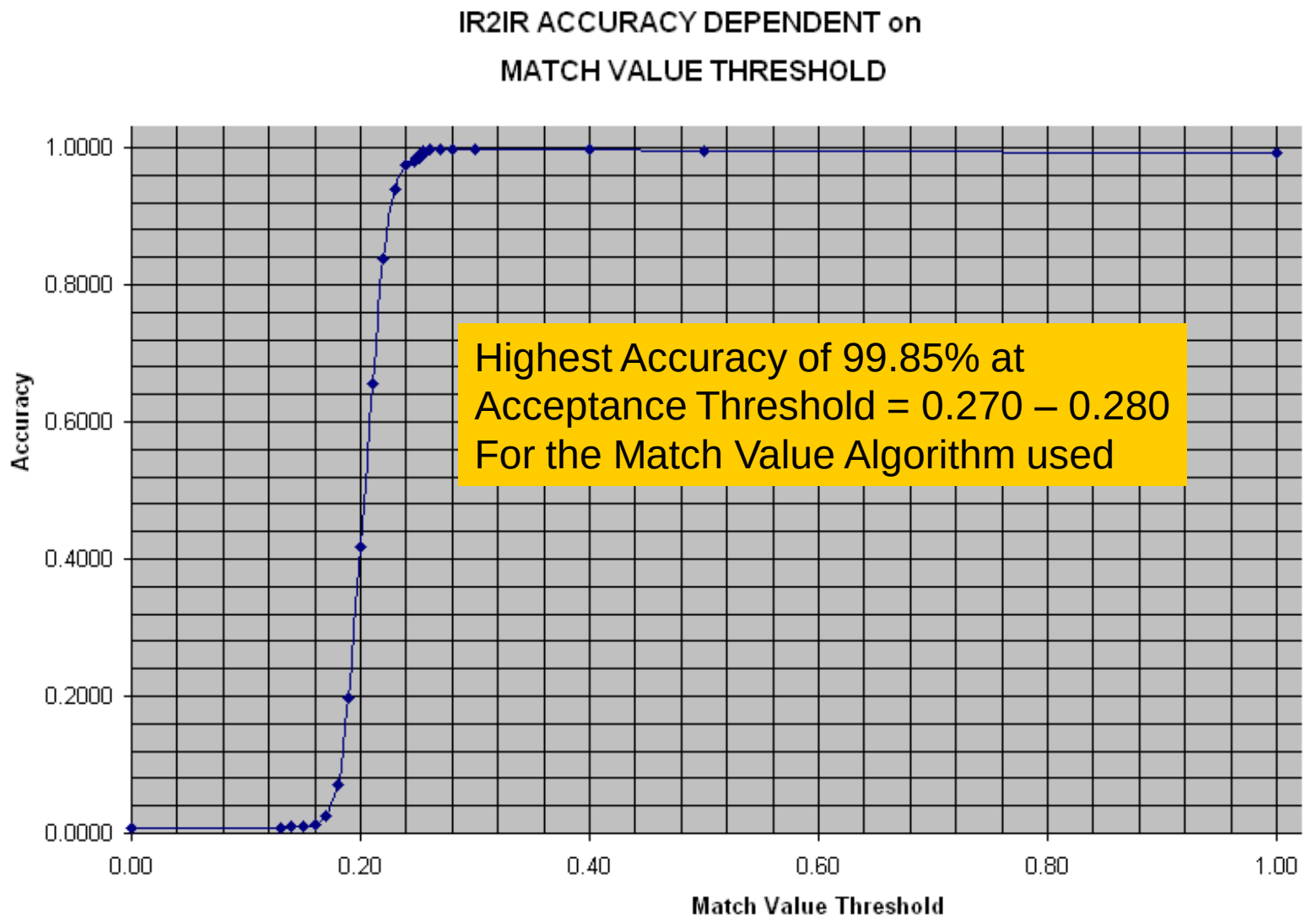
		tan is Target			silver is Sibling				
	TOP EIGHT MATCHES FOR TARGET								
	WITH POSITION OF SIBLINGS FROM OBSERVATION								
Rank		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Template	1016	632	234	266	260	1079	214	605	638
FeatureCount	10225	11476	11474	10895	11699	10815	12154	10688	10803
MatchCount	10225	2769	2697	2612	2586	2576	2578	2560	2532
MatchValue	1.000	0.232	0.226	0.233	0.211	0.232	0.199	0.234	0.228





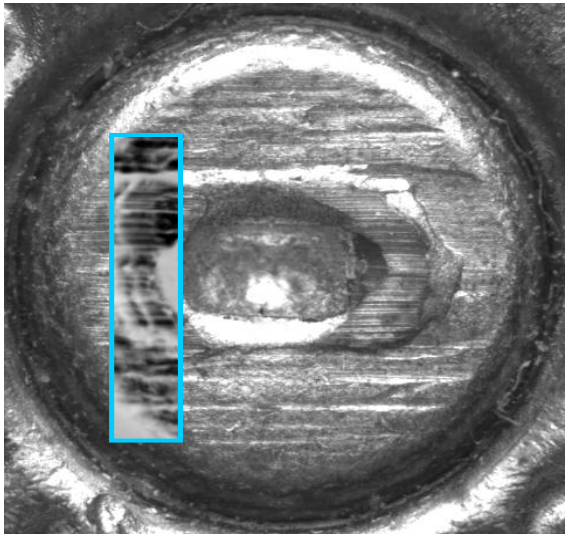


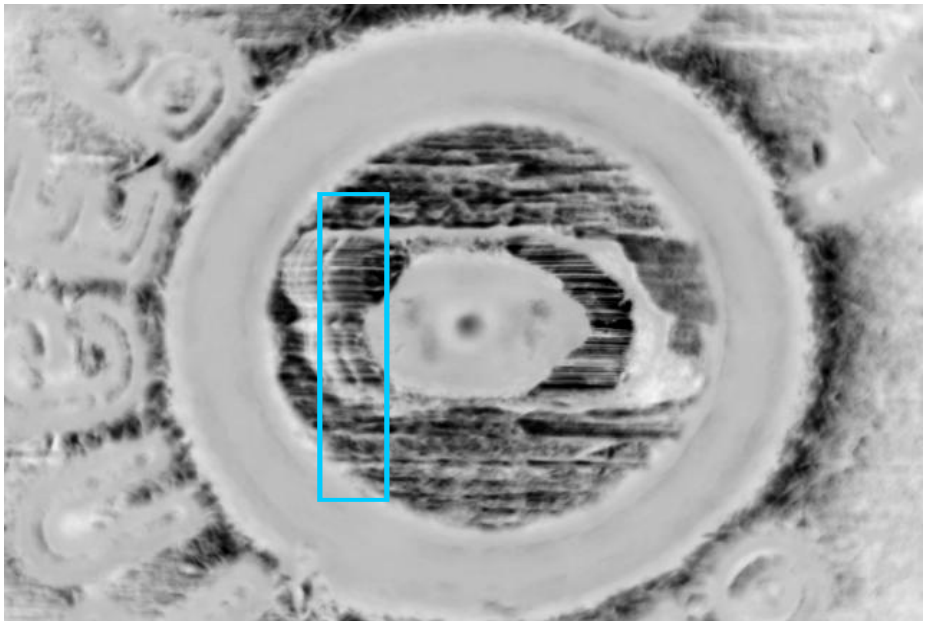
Performance of Match Value Algorithm



Examiner Cross-Spectral Review

Glock Sheering and BreechFace Marks in Corresponding VL and IR Images





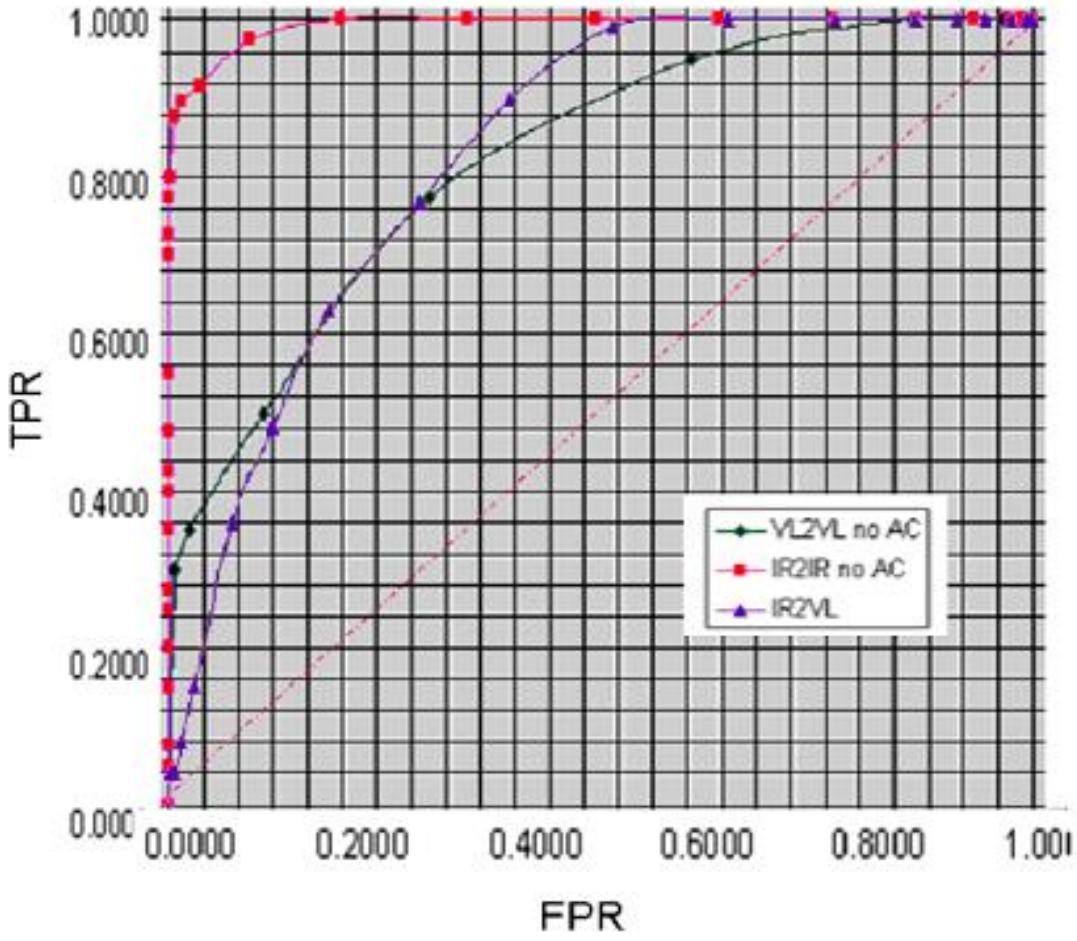
Segment cut from IR image overlaid on VL image demonstrates Similarity of Breechface and Primer Sheering Toolmarks in VL and IR

and

Simplicity of Manual Cross-spectral comparison In spite of VL Lighting Artifact and Different Resolution: Primer Diameters: 380 VL 320 IR

ROC Comparison of Cartridge Case Matching Based on BreechFace and Sheering Marks

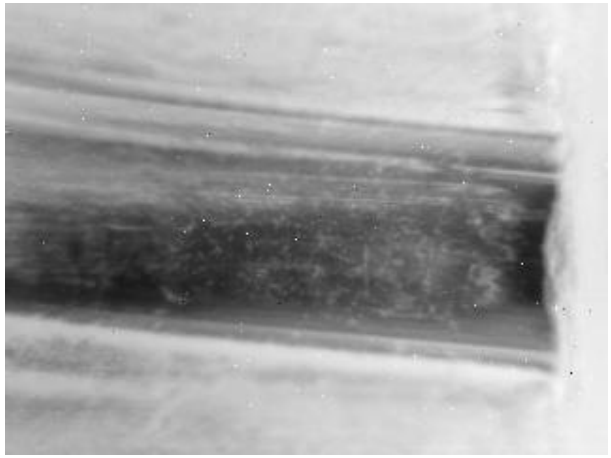
Accuracy of Matching as a Function of Image Spectra:
IR-IR **VL-VL** and Cross-Spectral **IR-VL**



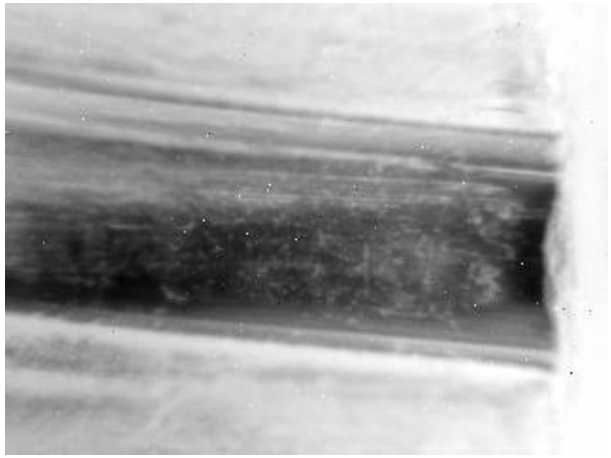
IR-ID of Damaged Bullets

FlashCorrelation of IR Bullet Sequences:

- Same-Sequence Framewise Self-Correlation Measures Rotation Stability
- Two-Sequence Framewise Cross-Correlation Detects Suspected Siblings and Synchronizes Sequences



Bullet #1 Frame #1



Bullet #1 Frame #1529

Bullet #2 Frame#516

Bullet #2 Frame #516+1529

IR Image Sequences of Damaged Bullets

Visual Image

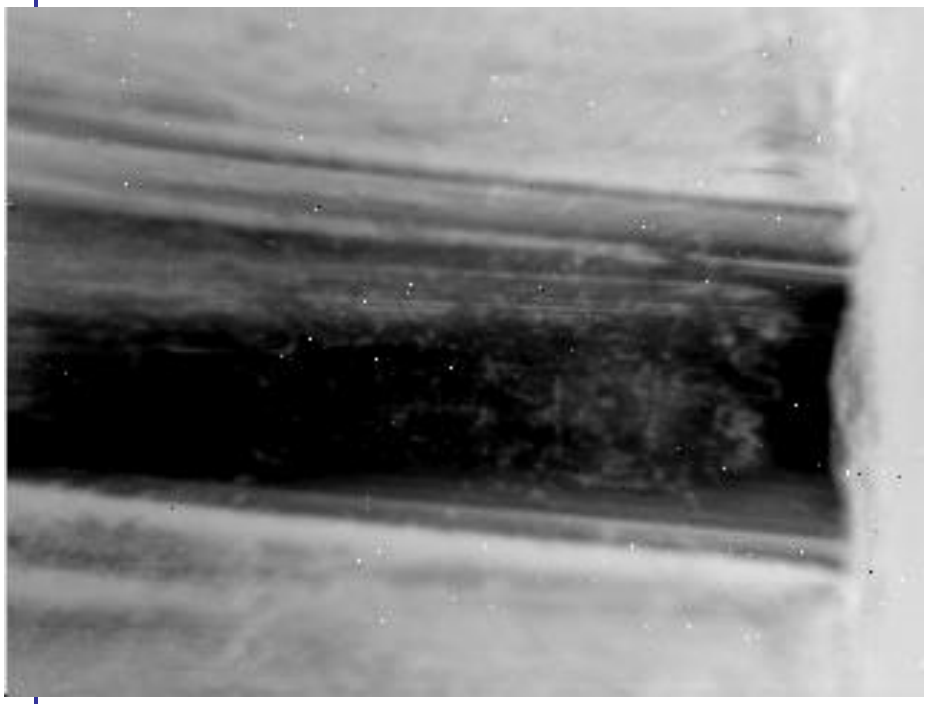
Bullet #1

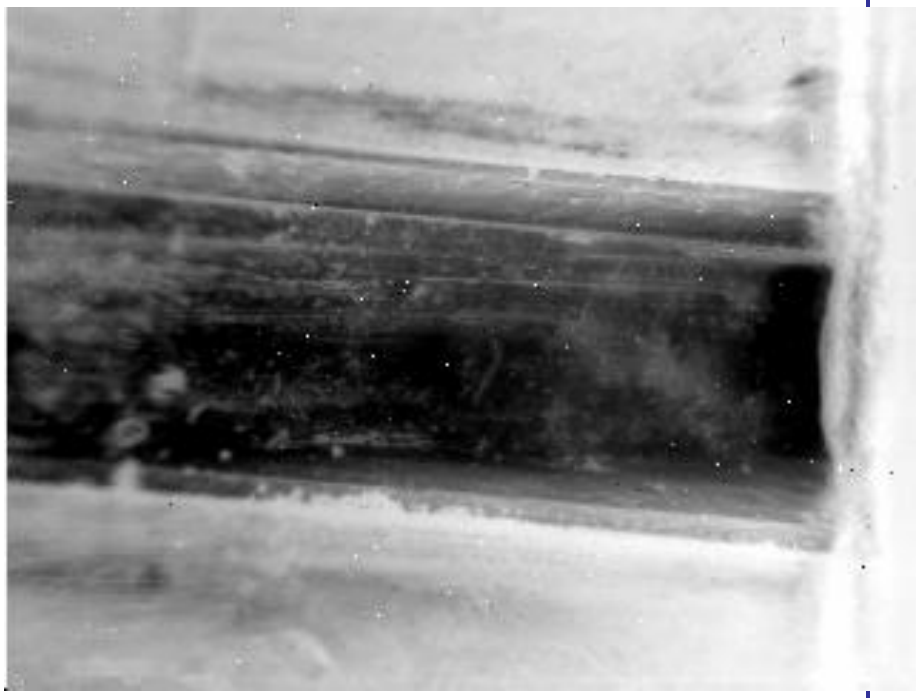
Visual Image

Bullet #2

SigSauer 40 Speer S&W

30 sec imaging per 360°





Bullet #1

Bullet #2

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Conclusion

- Thermal IR Imaging is Characterized by Emissivity Effects and Shallow Depth of Focus
- Range Gated Emissivity Maps Provide Reliable 3D Models and Extended-Focus 2D Images
- Which have been found to produce high-accuracy ID of Firearms-Induced Toolmarks
- Using fully Automated Image Capture and Compare

Questions?

Thank you!

Francine Prokoski, President

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