Firearms and Toolmarks

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Team Members

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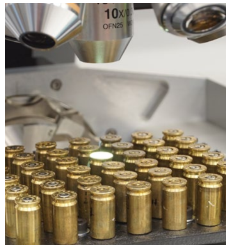
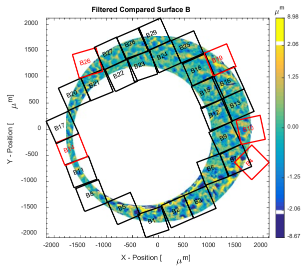
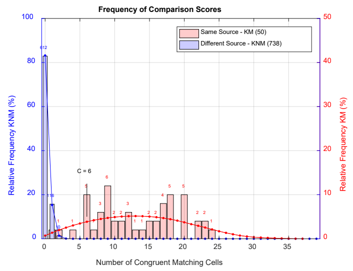






FORENSIC SCIENCES

Agenda

- Firearms and toolmarks overview

  Johannes Soons
- A metrology foundation for firearm and toolmark examination

  Michael Stocker
- Reference Population Database of Firearm Toolmarks (RPDFT)

  Alan Zheng
- Digital preservation of the President John F. Kennedy assassination ballistic artifacts

  Robert Thompson and T. Brian Renegar

Disclaimers

- Certain commercial equipment, instruments, or materials are identified in this presentation to specify the experimental procedure adequately. Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology (NIST), nor is it intended to imply that the materials or equipment identified are necessarily the best available for the purpose.

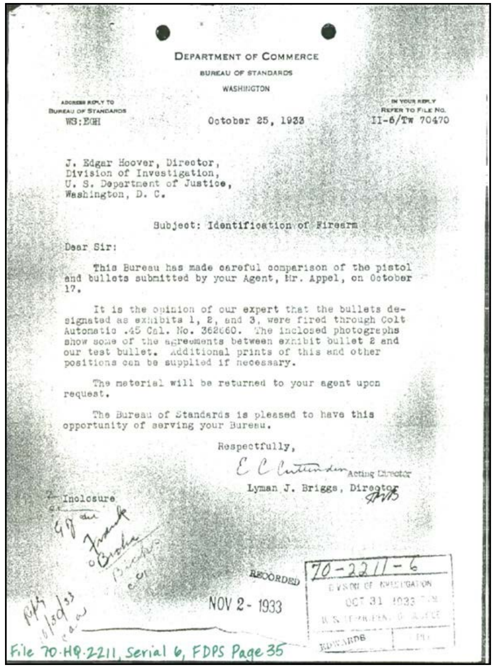
- Points of view in this presentation are mine and do not necessarily represent the official position or policies of NIST.

- This presentation has not been reviewed by the NIST Editorial Review Board.

Forensics@NIST – 1930s

- NIST was the nation's first federal crime lab
- Expertise in firearms and documents helped solve hundreds of crimes
- NIST helped Division of Investigation (FBI) establish its crime lab

NBS's William Souder using a comparison microscope: "one of the nation's best and least known criminologists," The Washington Post, 1954



DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS
WASHINGTON

ADDRESS REPLY TO BUREAU OF STANDARDS
WS:EGH

October 25, 1933

IN YOUR REPLY REFER TO FILE NO.
II-6/Tw 70470

J. Edgar Hoover, Director,
Division of Investigation,
U. S. Department of Justice,
Washington, D. C.

Subject: Identification of Firearm

Dear Sir:

This Bureau has made careful comparison of the pistol and bullets submitted by your Agent, Mr. Appel, on October 17.

It is the opinion of our expert that the bullets designated as exhibits 1, 2, and 3, were fired through Colt Automatic .45 Cal. No. 362660. The inclosed photographs show some of the agreements between exhibit bullet 2 and our test bullet. Additional prints of this and other positions can be supplied if necessary.

The material will be returned to your agent upon request.

The Bureau of Standards is pleased to have this opportunity of serving your Bureau.

Respectfully,

E C Crittenden, Acting Director
Lyman J. Briggs, Director

2 Inclosure

RECORDED 70-2211-6

NOV 2 - 1933

File 70-HQ-2211, Serial 6, FDPS Page 35

1933 letter from the NIST acting director to J. Edgar Hoover reporting a firearm identification

Toolmark identification: forensic science discipline concerned with determining if a toolmark was produced by a particular tool[1]

Firearm "tools"

- Revolver
- Pistol
- Rifle
- Shotgun

Source: SWGGUN

Common toolmark evidence

- Bullet
- Cartridge case
- Magazine

aegisacademy.com

Non-firearm tools

- Screwdriver
- Pry bar
- Wire cutter
- Pliers
- Lock pick

Source: SWGGUN

Common toolmark evidence

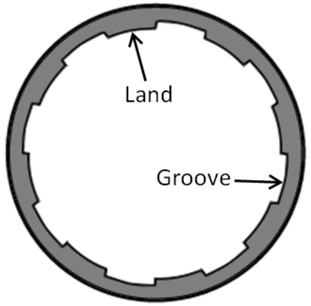
- Lock
- Safe
- Window frame
- Wire

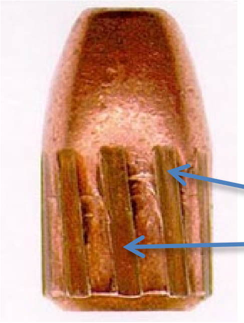
[1]Association of Firearm and Tool Mark Examiners, Glossary, 6th Edition, 2013, www.afte.org

Bullets and cartridge cases: Regions of interest

Bullets have striated (and impressed) toolmarks from the barrel rifling

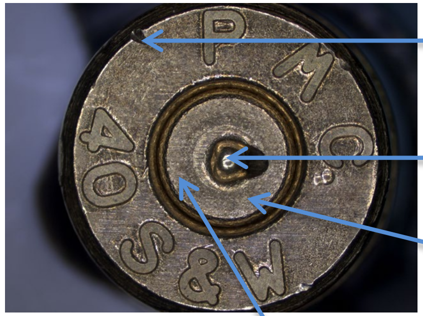
MGM/UA; Centralia College – H. Ebiari





Areas “engraved” by barrel lands

Cases have impressed and striated toolmarks from various sources



Ejector mark

Firing pin impression

Breech face impression

Aperture shear (striae)

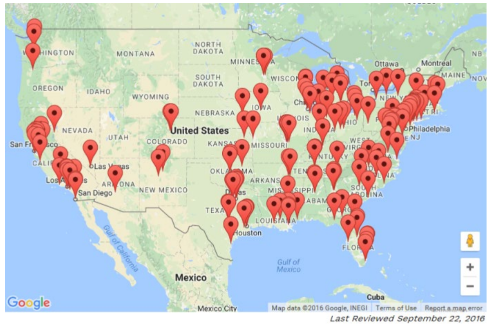
- Magazine marks
- Chamber marks
- Extractor mark

Casings constitute >> 90 % of NIBIN database entries for firearm identification.

Automated comparisons

National Integrated Ballistics Information Network (NIBIN)

- National network administered by the ATF for the acquisition and **search** of firearm toolmark images to solve and prevent crimes
- NIBIN uses proprietary correlation algorithms and criteria
- NIBIN is an investigative search engine. **A high score does not imply an identification**.
- High scoring images are manually compared. Identification requires comparison of the evidence by a forensic examiner.



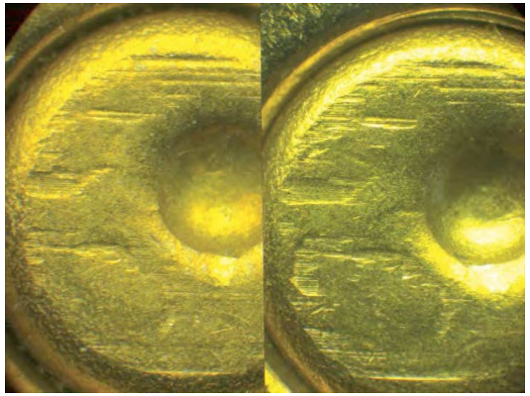
- 220 stations[1]
- 4.2 million ballistic samples[1]
- 45 million images[1]
- 67,000 investigative leads in FY 2019[1]

Casings constitute >> 90 % of NIBIN database entries for firearm identification.

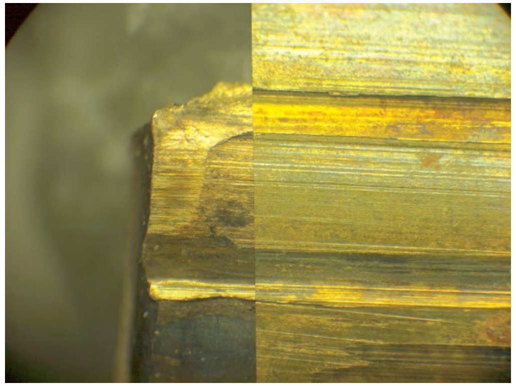
[1] https://www.atf.gov/resource-center/fact-sheet/fact-sheet-national-integrated-ballistic-information-network (accessed October 2020)

Firearm identification – Current practice[1]

Leica



Toolmarks on cartridge cases[2]



Striated toolmarks on bullets[2]

Compare class characteristics - Measurable features that indicate a restricted group source

Compare individualizing toolmarks (subjective):

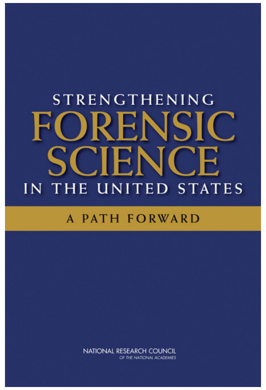
- Does the agreement exceed the best agreement demonstrated between toolmarks from different tools?
- Is the agreement consistent with the agreement demonstrated by toolmarks from the same tool?

Render an opinion:

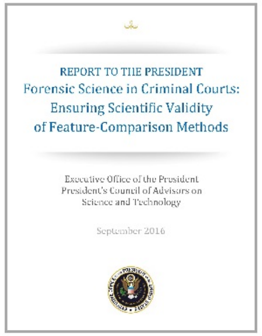
- Identification
- Exclusion
- Inconclusive
- Unsuitable

[1]AFTE Theory of Identification, AFTE Journal – Volume 43, Number 4, Page 287, 2011.
[2]Robert M. Thompson, “Firearm Identification in the Forensic Science Laboratory

Current practice is under scrutiny



- NAS 2009 "..the decision of the toolmark examiner remains a **subjective decision** based on unarticulated standards and **no statistical foundation for estimation of error rates**."



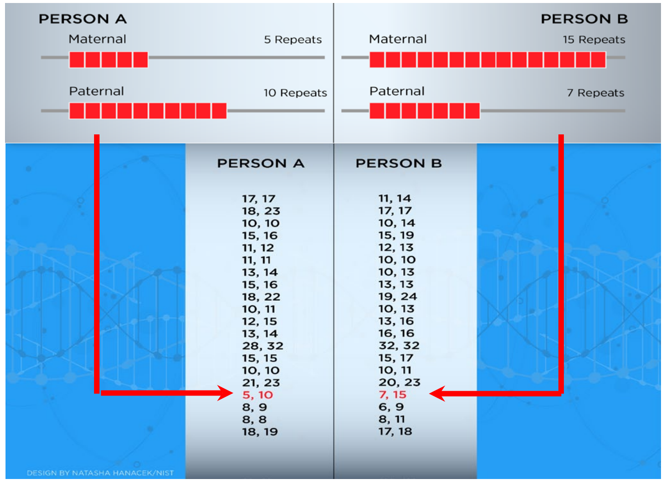
- PCAST 2016: "PCAST finds that firearms analysis currently falls short of the criteria for foundational validity, because there is only a single appropriately designed study to **measure validity and estimate reliability**."
- PCAST 2016: "A second – and more important – direction is … to convert firearms analysis **from a subjective method to an objective method**…"

- The National Research Council, "Strengthening Forensic Science in the United States—A Path Forward", Washington DC, 2009.
- President's Council of Advisors on Science and Technology, "Forensic science in criminal courts: Ensuring scientific validity of feature-comparison methods", Washington DC, 2016.

Toolmarks are not DNA (nor fingerprints)

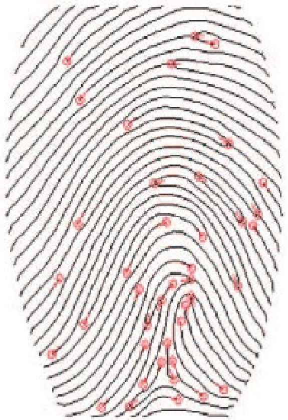
DNA:

- Identification is based on measuring a combination of independent, known, “class” characteristics, i.e., measurable features that indicate a restricted group source
- Population frequencies can be estimated for each feature (independence yields very low random match probability)
- A person’s DNA profile does not change.



Toolmarks:

- The individualizing features are not known in advance, may change over time, and may not repeat.
- Many different ways in which firearms are manufactured and used, yielding different individualizing features.
- Population data can (currently) only be assessed through comparisons of toolmarks with ground truth.

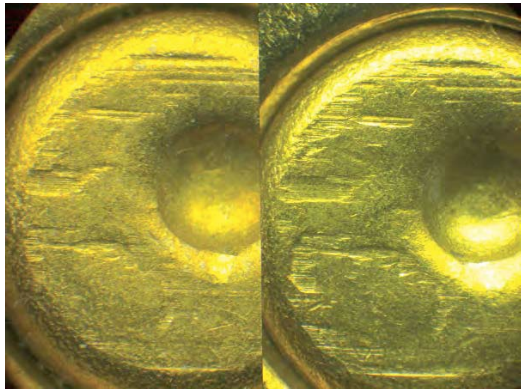


Key challenges

- **A match in class characteristics is far from sufficient for identification**
- **Significant variability in marks observed from the same firearm**
    - Firing conditions (internal ballistics)
    - Sample deformation/fragmentation
    - Firearm use, wear, and maintenance
    - Ammunition component effects
    - Measurement methods
- **Similarities in marks produced by different firearms**
    - Sub-class characteristics (consecutively manufactured firearm components)
    - Ammunition manufacturing effects transferred to firearm evidence
- **No full consensus on objective, quantitative, comparison criteria**
- **No consensus on how to express the weight of evidence (uncertainty)**
- **No comprehensive ground-truth population data**

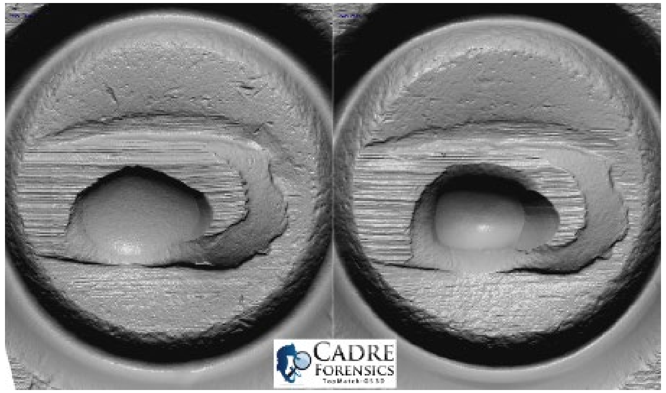
Metrology: From 2D to 3D

2D reflectance microscopy images



Comparison microscopy[1]

3D topography images



Virtual comparison microscopy

Pretty picture, but how accurate is it?

Leica

Advantages:

- Higher reproducibility and focus on actual topography
- Measure once, compare often
- Well suited for numerical analysis

Status:

- Already common for database search
- Virtual comparison microscopy is starting to be used in case work

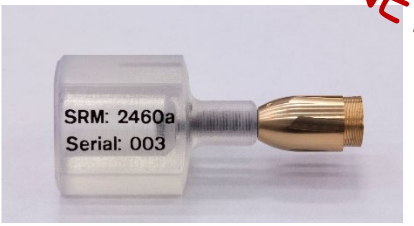
[1]Robert M. Thompson, "Firearm Identification in the Forensic Science Laboratory

Physical standards for measurement traceability and quality control

- Provide SRM bullets and cartridge cases
- Provide reference images for comparison
- Laboratories regularly compare/check their measurements with the reference

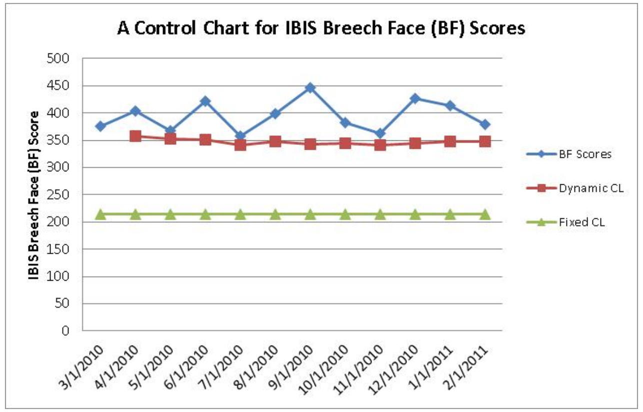
SRM 2460 Standard Bullet

NEW



SRM 2460a
Standard Bullet Replica

Enter measured image into NIBIN



Track similarity score with reference image

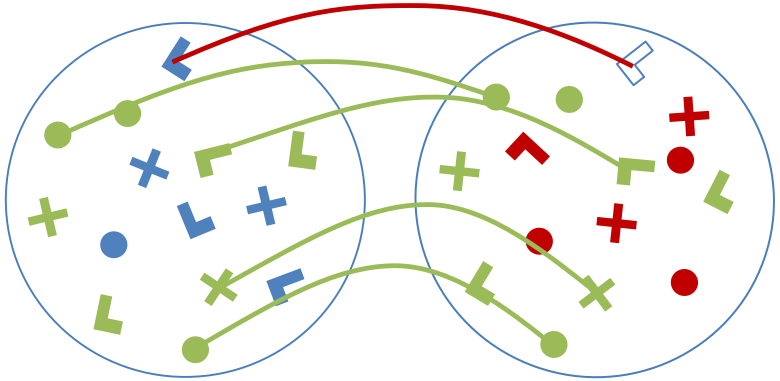
SRM 2461 Standard Cartridge Case

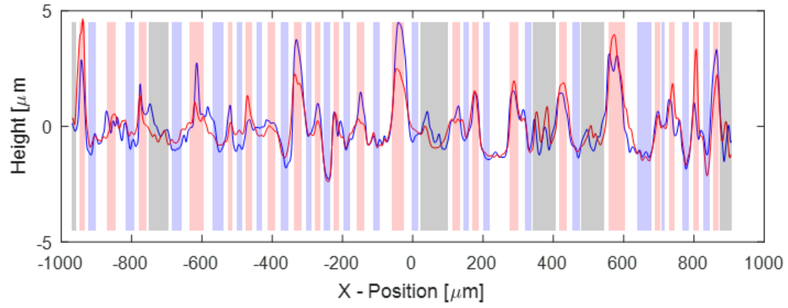
T. Vorburger, et al., “The Second National Ballistics Imaging Comparison (NBIC-2),” J. Res. Natl. Inst. Stand. Technol., 2014.

Objective similarity metrics

Number/Quality of Matching Features

Reference Sample **Questioned Sample**



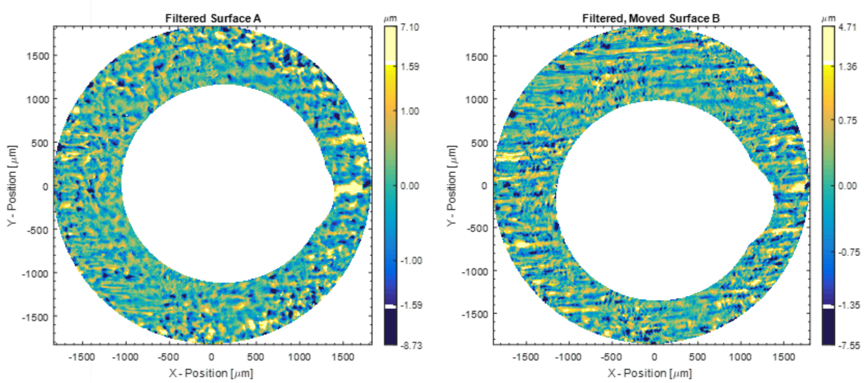


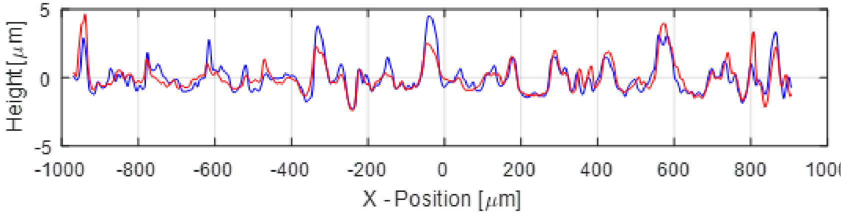
Bullet A
Bullet B

E.g., Congruent Matching Striae (*CMS*)

Area or Profile Similarity (e.g., correlation coefficient)

Reference Sample **Questioned Sample**



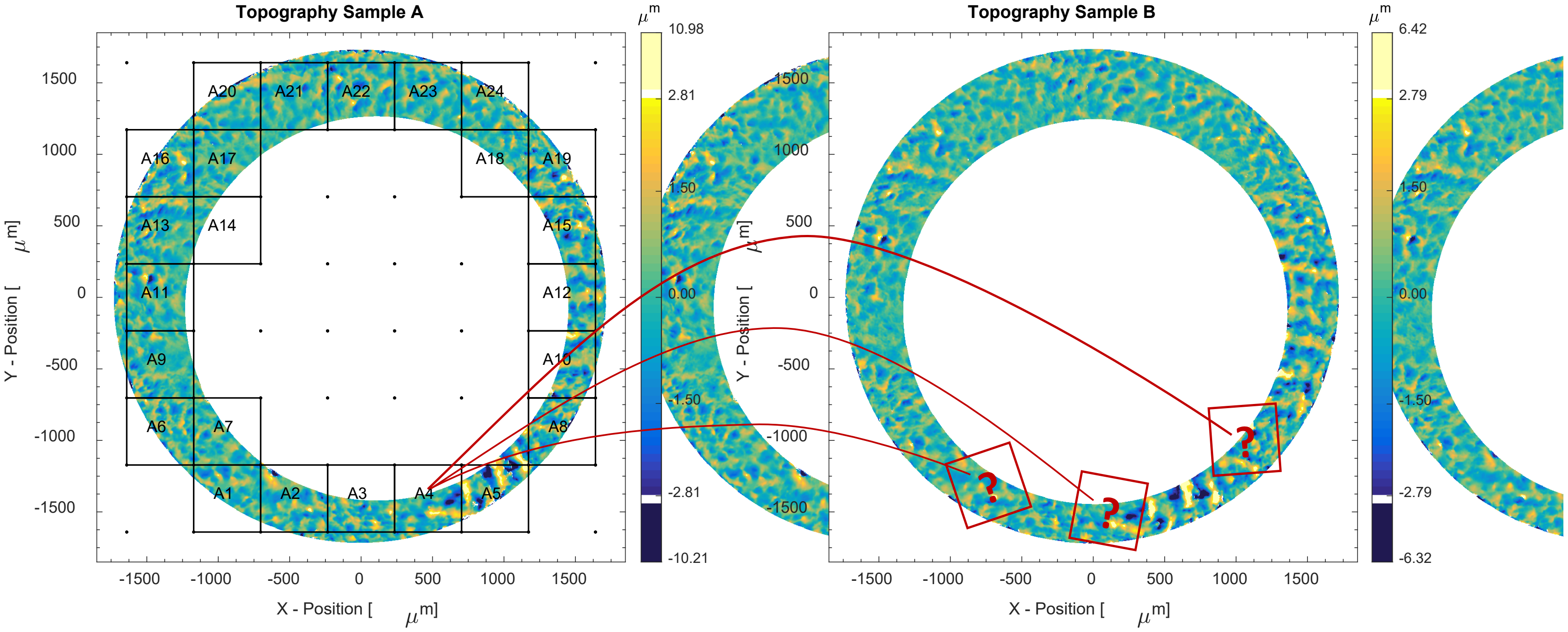


Bullet A
Bullet B

E.g., Pearson correlation coefficient (ACCF) after band-pass filtering and registration

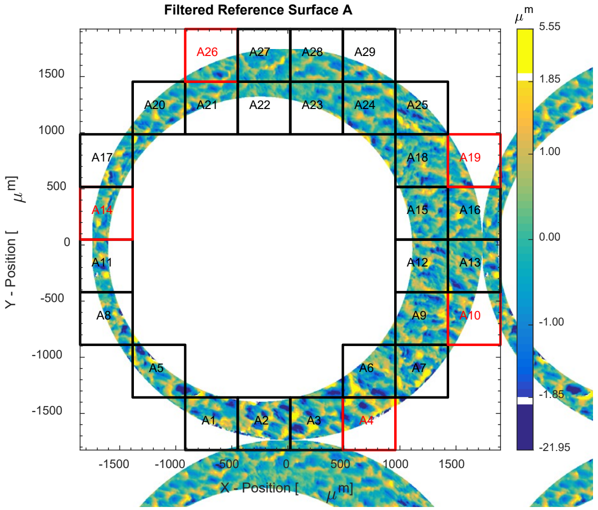
Objective similarity metrics

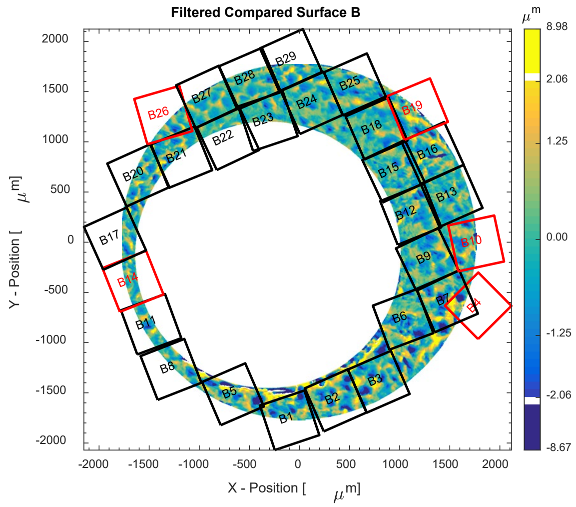
Congruent Matching Cells (CMC)



J. Song, "Proposed NIST Ballistics Identification System (NBIS) using 3D Topography Measurements on Correlation Cells", AFTE Journal, 45 (2), 184-194, 2013.

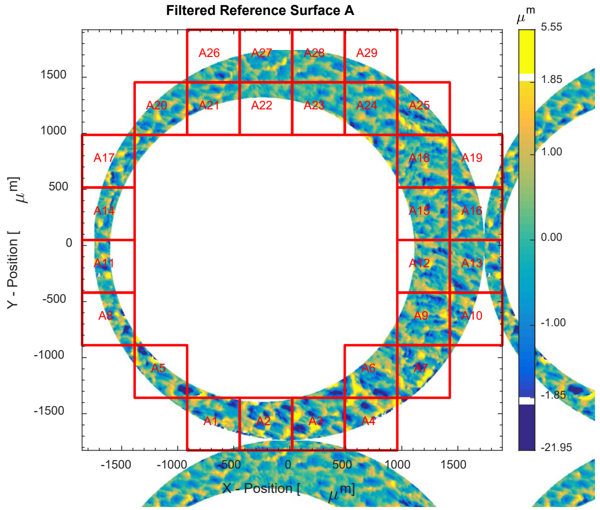
Breech face impressions from the same firearm

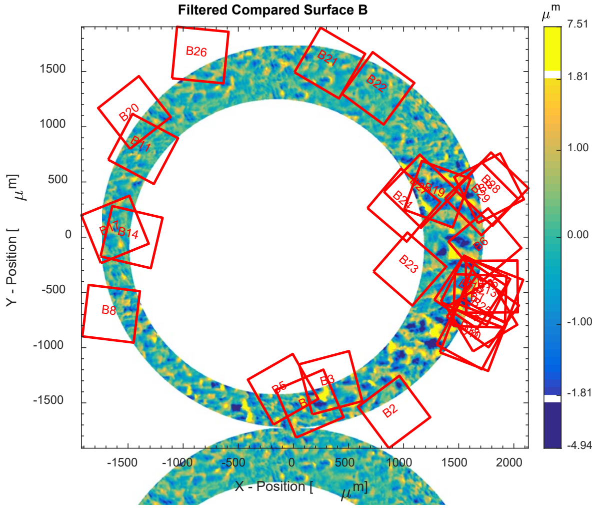




24 CMCs

Breech face impressions from different firearms

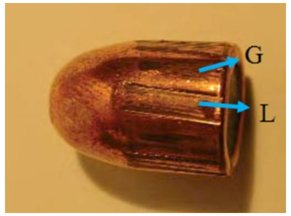




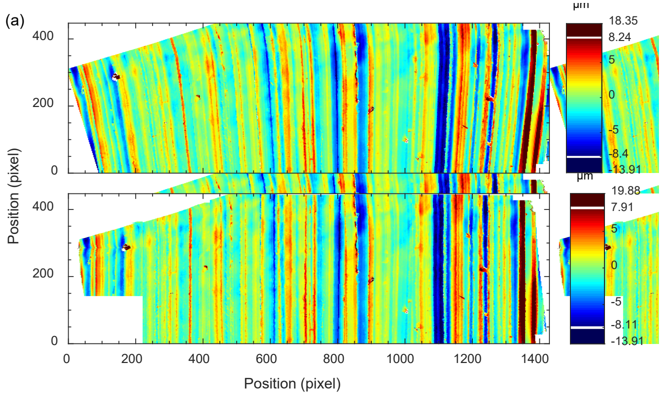
0 CMCs

Objective comparison of deformed bullets

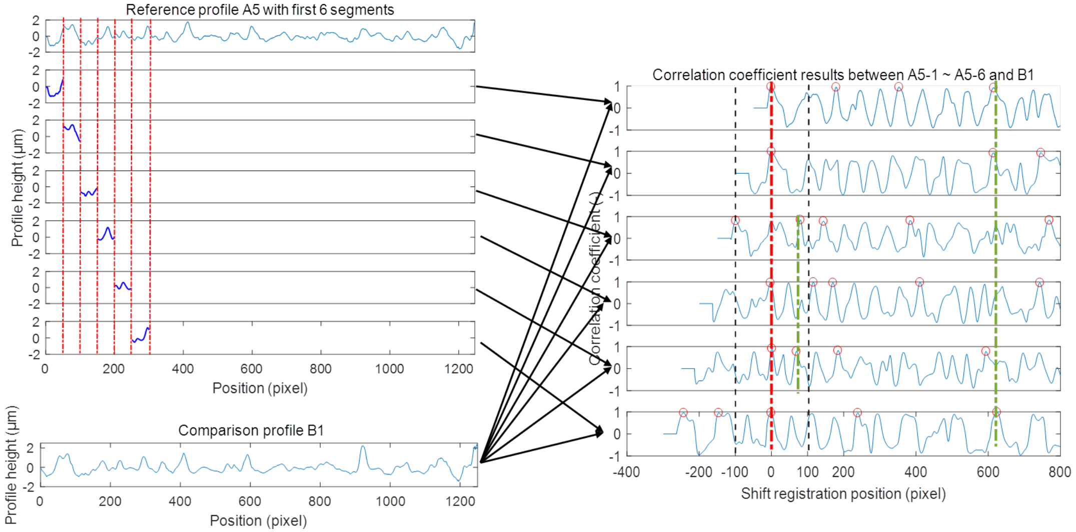
- Profile obtained as weighted average of “straightened” marks
- Application Congruent Matching Profile Segment (CMPS) method
  - Profile equivalent of Congruent Matching Cells (CMC)
  - Low sensitivity to lateral scale variations.



“Straightening” of striated marks



Split reference profile into segments and evaluate the congruency of the profile segment registration positions



Z. Chen, et al., “Fired bullet signature correlation using the Congruent Matching Profile Segments (CMPS) method, Forensic Science International, 305, (2019).
Z. Chen, et al., “Pilot study on deformed bullet correlation,” Forensic Science International, 306, (2020).

Feasibility study on the objective comparison of breech face impressions for inoperable firearms

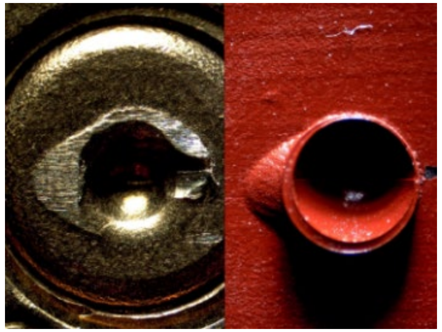
Challenge: Test fires cannot be obtained from inoperable firearms

- Cast firearm breech face surface
- Objective comparison (CMC) of cast with “evidence” cartridge case.

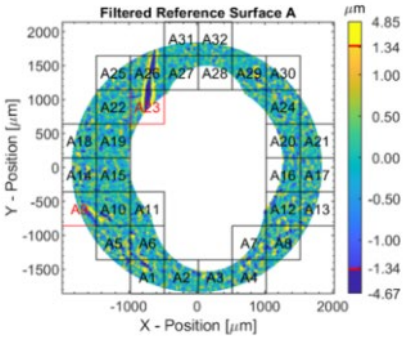
https://www.pewpewtactical.com/reasons-guns-fail/

Casting of breech face surface

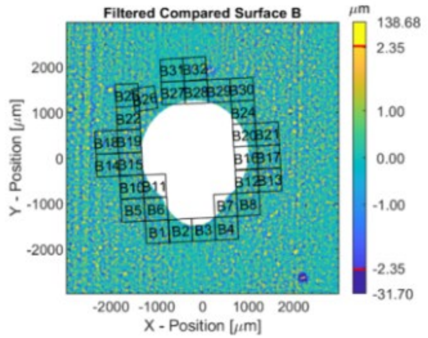
Test Fire Cast



Test Fire

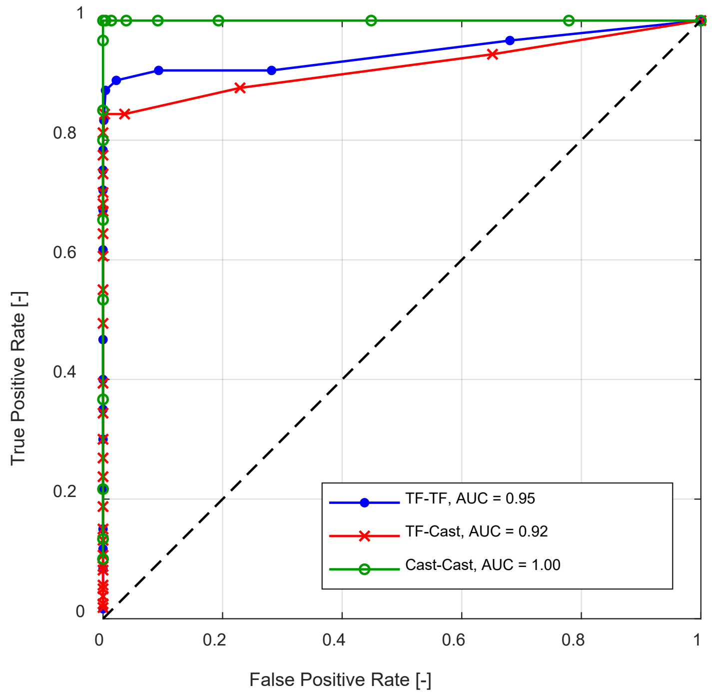


Cast



Comparison of ROC curves

Consecutively manufactured slides



NIST Ballistics Toolmark Research Database

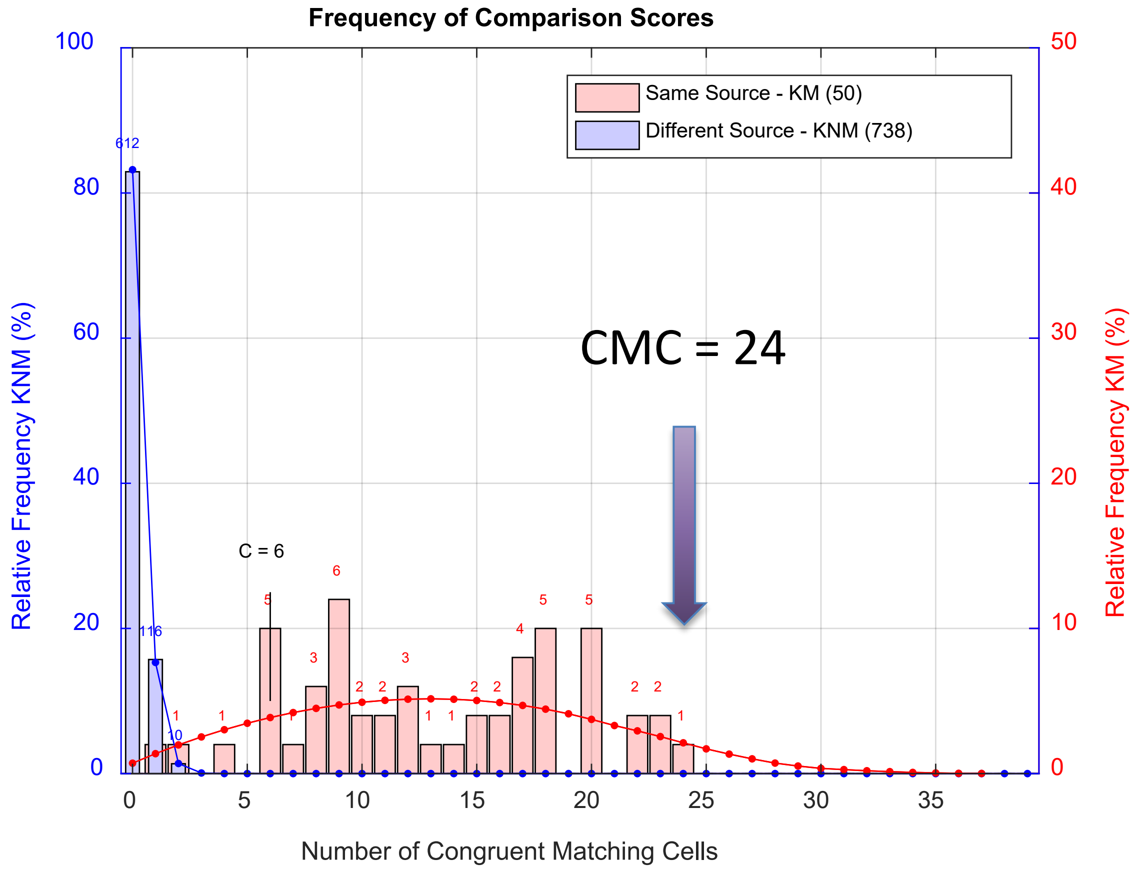
National Institute of Justice

www.nist.gov/forensics/ballisticsdb

Open-access research database of firearm toolmarks on bullets and cartridge cases:

- Firearms representing major class/subclass characteristics
- Consecutively manufactured firearm components
- Firearm firing many rounds (persistence/decay)
- Firearm firing different ammunition brands
- Firearms known to present identification challenges

Characterizing the Weight of the Evidence



- Characterize score distributions for "relevant" known matching and known non-matching comparisons
- Characterize the weight of evidence:
  - Error rates
  - Likelihood ratio
  - ….

J.F. Song, et al., "Estimating Error Rates for Firearm Evidence Identifications in Forensic Science," Forensic Science International, 284, (2018).
J.F. Song, et al., "Evaluating Likelihood Ratio (LR) for firearm evidence identifications in forensic science based on the Congruent Matching Cells (CMC) method, 317,(2020).

Reference Population Database of Firearm Toolmarks

RPDFT

Netherlands Forensic Institute
Ministry of Justice and Security

Infrastructure for weight of evidence estimation:

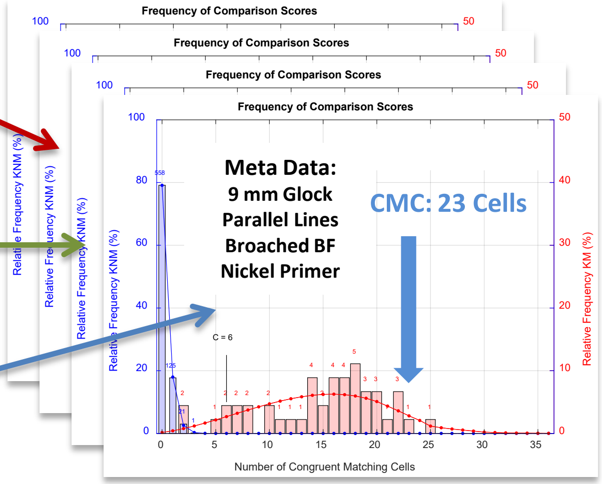
- Database of ground-truth toolmark images indexed by meta data
- Database of (multiple) comparison scores indexed by meta data

Indexed reference toolmark images

Comparison method 1 → Comparison Results 1

Comparison Method 2 → Comparison Results 2

Comparison Method 3 → Comparison Results 3



Scenario:

- Forensic lab submits meta data and comparison score(s)
- System generates statistical distribution of scores relevant to meta data
- Statistical distributions are used to calculate the weight of evidence

NIST Contributions

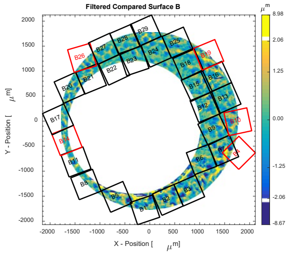
- Characterization and improvement of measurement methods
- Physical and documentary standards

OSAC
Organization of Scientific Area Committees for Forensic Science

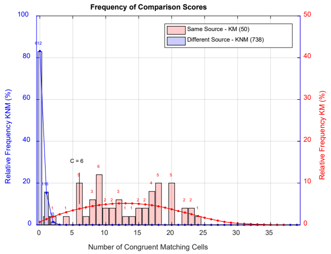
- Research and population databases

www.nist.gov/forensics/ballisticsdb

NIST Ballistics Toolmark Research Database



- Development and evaluation of objective comparison methods
- Estimation of the weight of the evidence.



RPDFT

Firearm and Toolmark Identification

Challenges:

- No consensus on "best" comparison metric(s)
- No consensus on "best" processing parameters
- Human skill/expertise is difficult to mimic (subclass)
- Large variability in same-source pattern similarity (firearm, ammo, time)
- Evaluation and expression of weight of evidence is still a **<u>major</u>** challenge.

Outlook:

- Significant and promising research efforts
- Results are finding their way into standards, products, and forensic labs
- 3D metrology and virtual comparison microscopy are now applied in both search and 1-1 case work
- Application of computer aided techniques to 1-1 case work comparisons is still a few years out.

Thank You

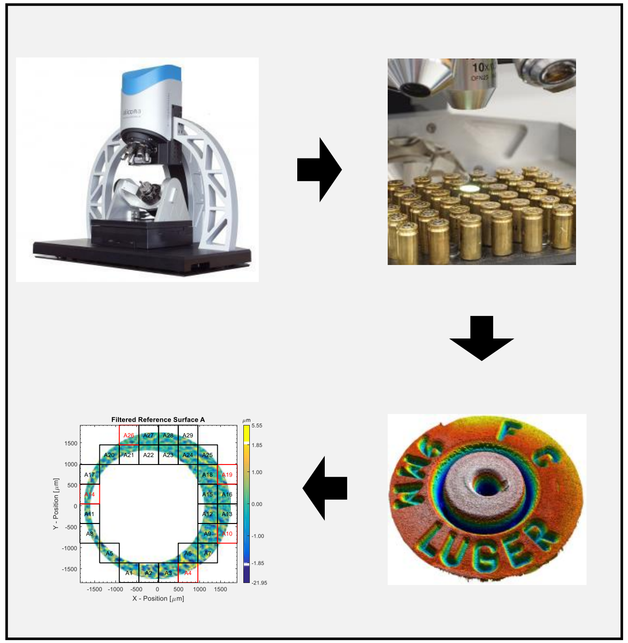
soons@nist.gov

Susan Ballou, Zhe Chen, Maria Nadal, Brian Renegar, Robert Ramotowski, Harry Song, John Song, Michael Stocker, Robert Thompson, Ted Vorburger, James Yen, Clarence Zarobila, Nien-Fan Zhang, Xiaoyu Alan Zheng

A Metrology Foundation for 3D Ballistic Imaging

2D

3D



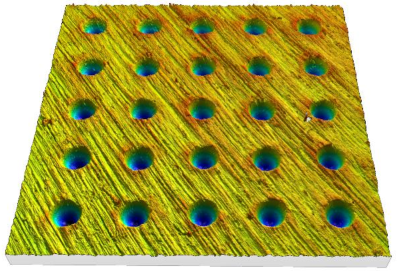
Introducing objectivity by focusing on actual surface topography

1. Higher reproducibility
2. Suitable for numerical analysis
3. Measure once and compare often

NIST FORENSIC SCIENCES

Goals

- Facilitate successful implementation, from purchase to process control, of 3D ballistic imaging equipment in forensic laboratories, ultimately improving the quality of 3D surface topography data.
- Introduce reference standards for the application of 3D optical surface topography measurement to firearm toolmark analysis to provide accuracy and traceability.
- Introduce performance specifications and measurement/quality assurance protocols to standardize terminology and measurement practices

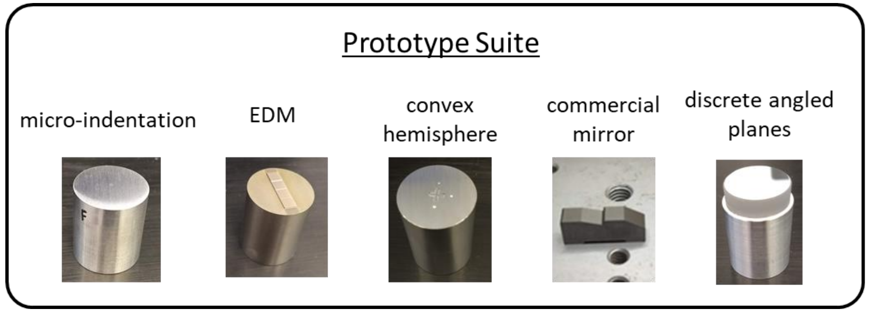


Motivation

Current SRM cartridge case and bullets

- Perfect artifacts for quality control
- Sensitive to various instrument parameters
- Can determine when something is wrong
- Does not provide a means to fix the problem
- Does not provide easy way to demonstrate traceability

New Proposed Prototype Suite



- Provide means to verify instrument specifications
- Provides a means to address individual error sources (you can fix the problems)
- Provides direct traceability path to SI unit of length

Instrument Survey

<u>3D Surface Topography Microscope Manufacturers:</u>

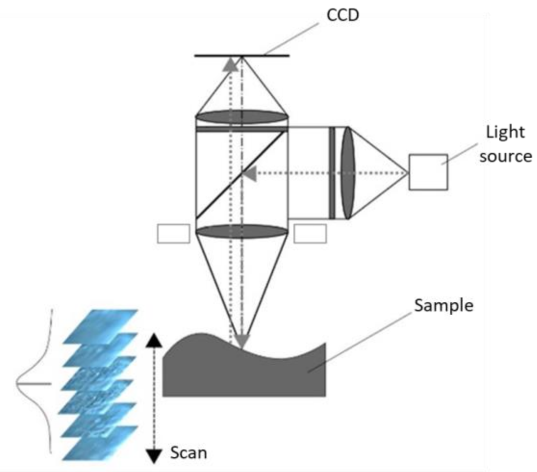
1. Alicona / FV
2. Nanofocus/Conf
3. Sensofar / FV & Conf & Int
4. Evofinder / FV & PS
5. Gelsight/Photometric Stereo
6. Zygo / Int
7. Bruker / Int
8. Balscan / FV & PS
9. ALIAS / Int

Focus Variation - FV **Confocal Microscopy** - Conf

Photometric Stereo - PS **Interferometric** - Int

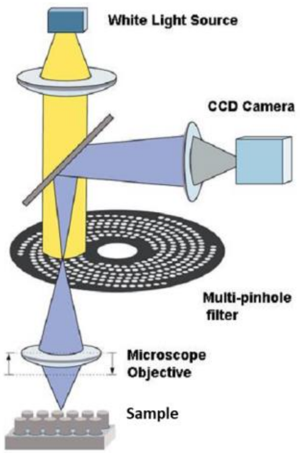
3D Topography Methods

Focus Variation

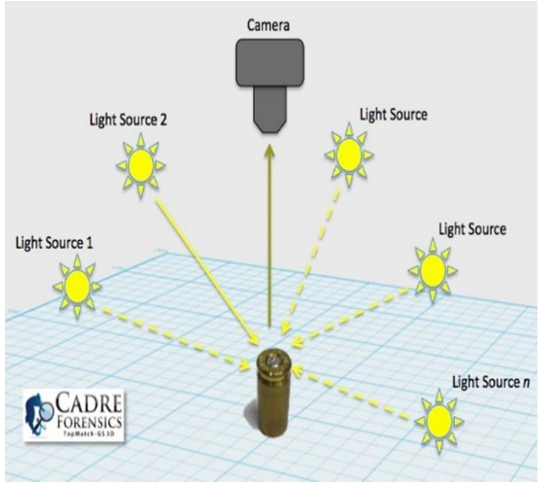


(Diagram from ISO 25178 Part 606)

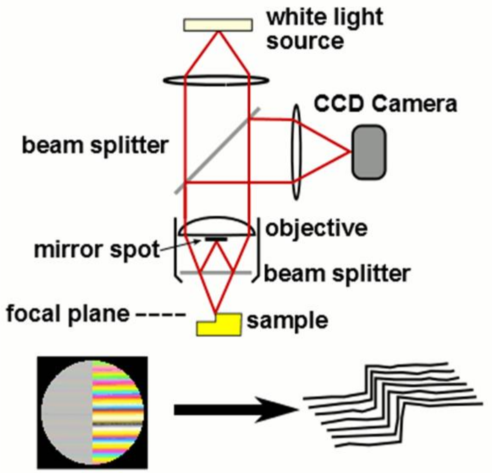
Confocal Microscopy



Photometric Stereo



Interferometric



Commercial Products

Alicona

Lateral and Vertical Calibration Standard

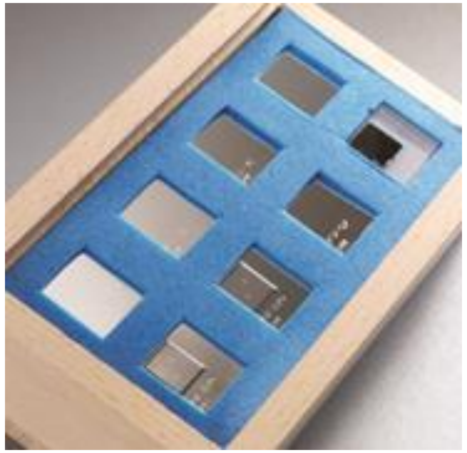
Roughness Standard

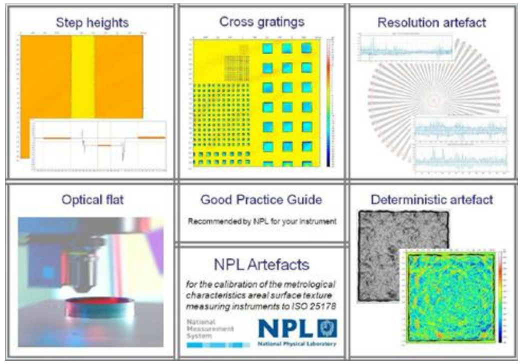
Thorlabs

2D chrome-on-glass scale and resolution combination targets

NPL Areal Bento Box

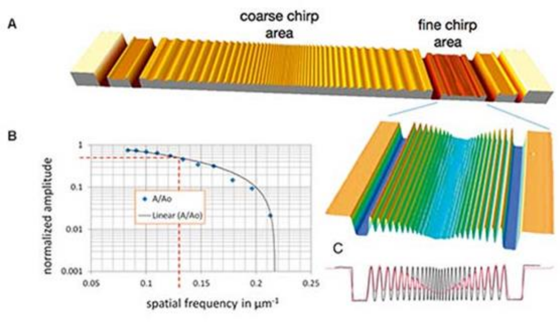
(sold through Rubert and Co. Ltd.)

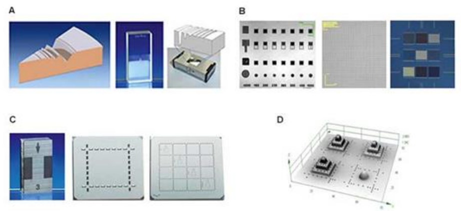


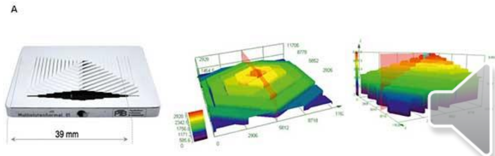


PTB research

Chirped lateral resolution target and various areal artifacts



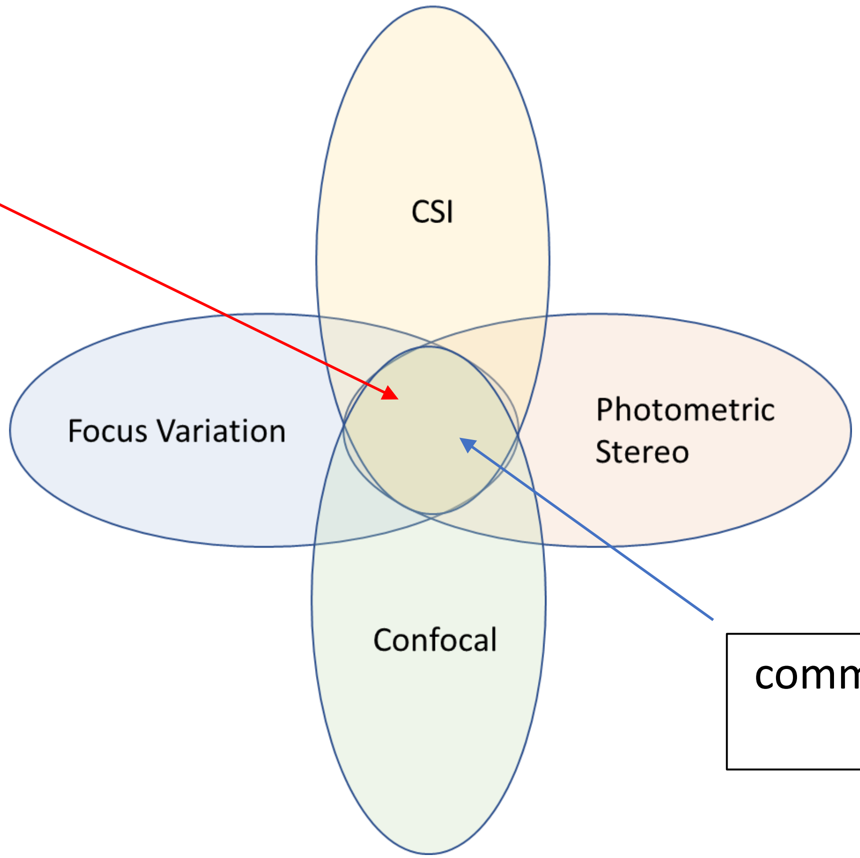




Measurability

<u>Design Challenges for ***Measurability***:</u>

1. Form factor for certain instruments
2. Relevant dimensional scales
3. Surface contains nominal roughness (or contrast mechanism)
4. Surface normals close to numerical aperture (NA) of optical system
5. Need to avoid surface discontinuities (vertical transitions)



common denominator of methods

Other Challenges:

- The determination of minimum instrument requirements for forensic applications is an active topic of research, both for VCM and automated comparisons.
- The definition of areal instrument performance parameters, test procedures, and artifacts is still being standardized within ISO.

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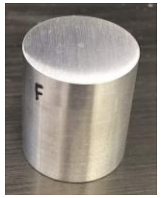
Performance Specifications

Performance Specification	Physical Artifact
1. XY Scale	X
2. XY Linearity	X
3. Z Scale	X
4. Z Linearity	X
5. Lateral Resolution	X
6. Maximum Measurable Slope (convex)	X
7. Maximum Measurable Slope (concave)	X
8. Aberration Correction (field curvature)	X
9. Measurement Stitching	SRM 2461
10. Instrument Noise	SRM 2461

Prototype Summary

XY Array



micro-indentation

micro-endmill

micro-laser ablation

Z Step Height

EDM

endmilling

gage blocks

MMS

convex hemisphere

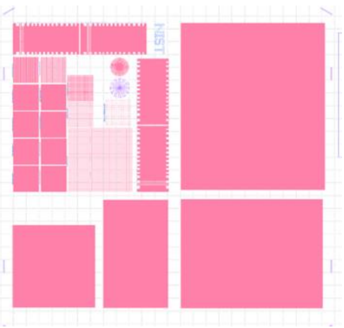
discrete angled planes

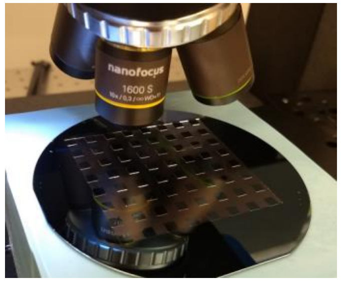
convex hemisphere

Aberration Correction

commercial mirror

Si Development





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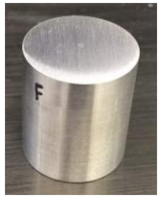
Prototype Summary

XY Array



micro-indentation

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Z Step Height

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commercial mirror

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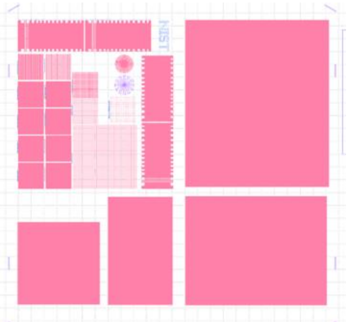
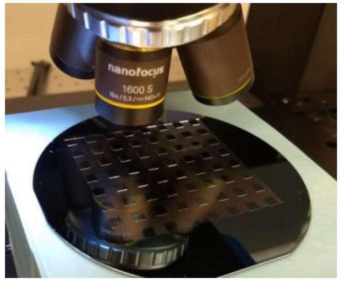


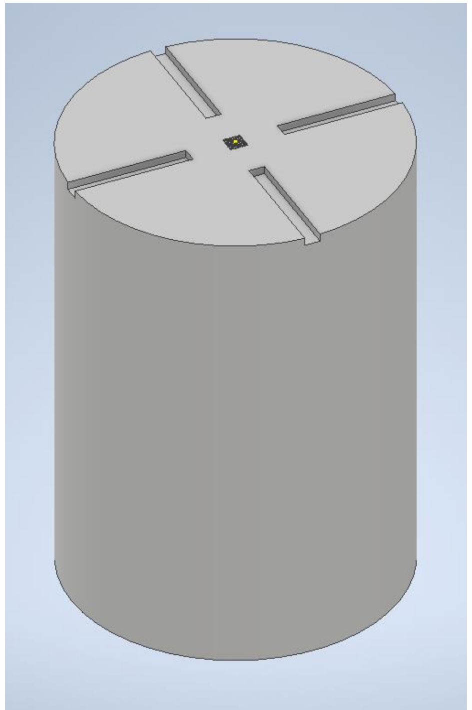


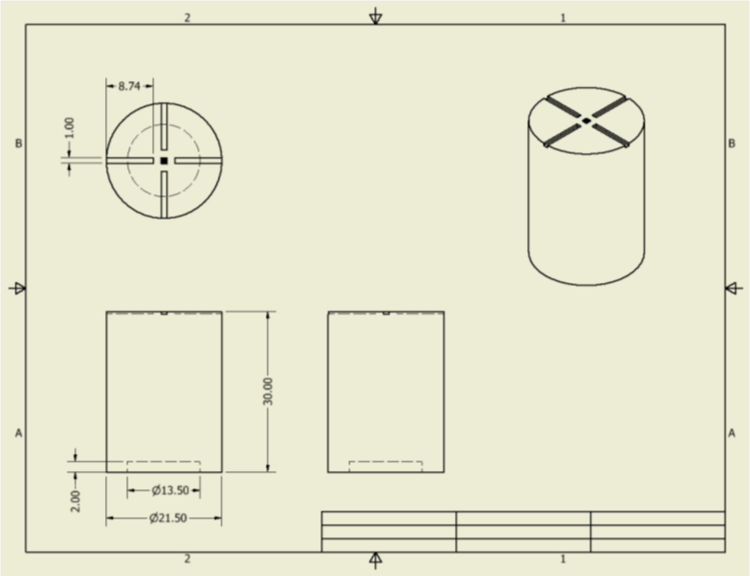
Prototype Design – XY Array

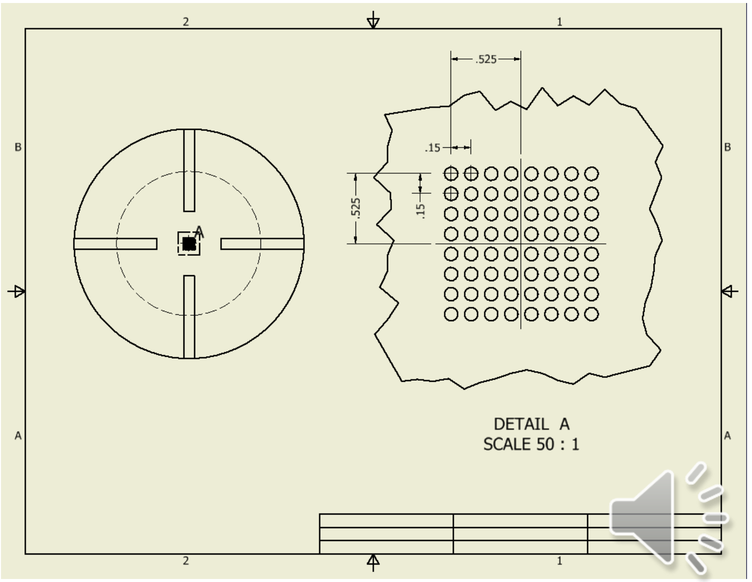
Addresses XY Scale and Linearity

Design Features

- Current design based on array of small hemi-spherical features
- Will allow for measurement of scale and linearity
- Array dimensions: nominally 100 µm diameter at 150 µm pitch.
- Hemi-spherical features have maximum surface normal of 22° to facilitate measurability
- Fiducial lines pointing to array in center to help locate in microscope.
- Machined on a cylindrical blank that is the size of a 12 gauge shot shell
- Also allows for evaluating distortion







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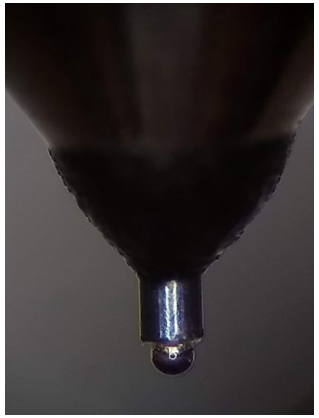
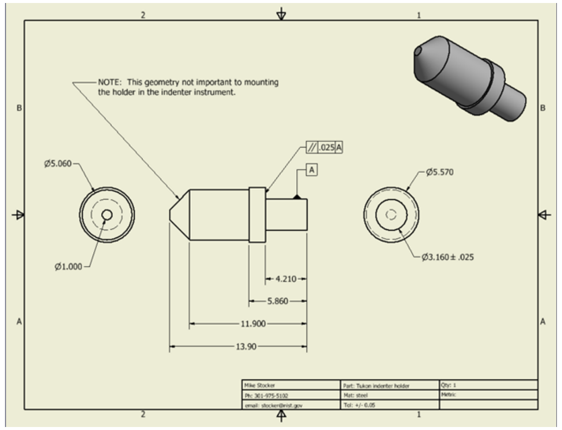
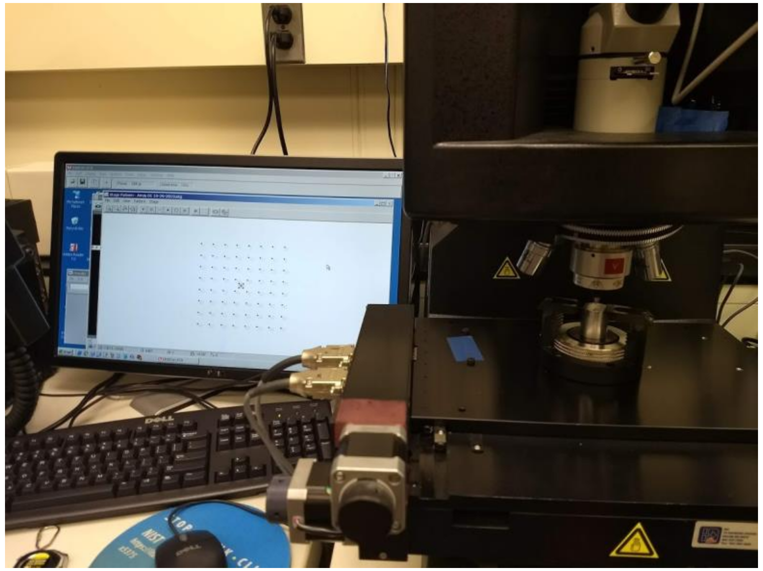
Prototype Fabrication – XY Array

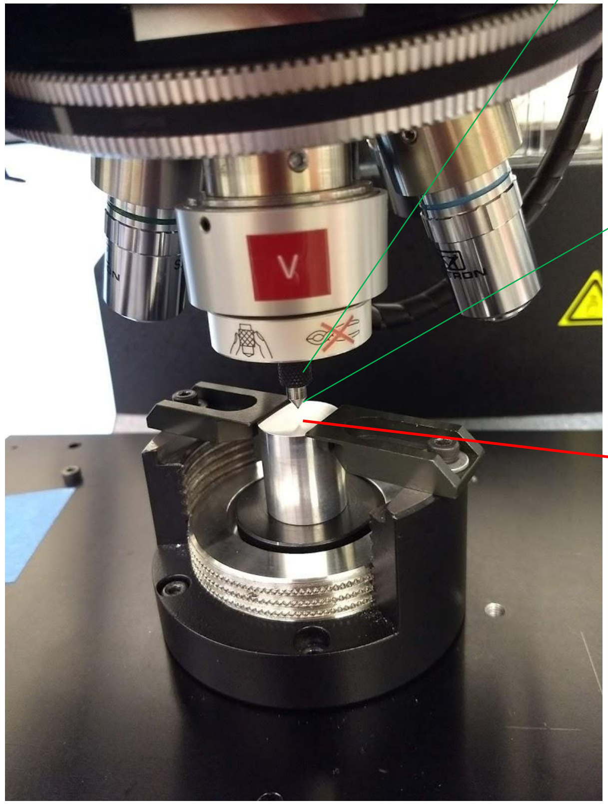
160 µm diameter micro-indenter

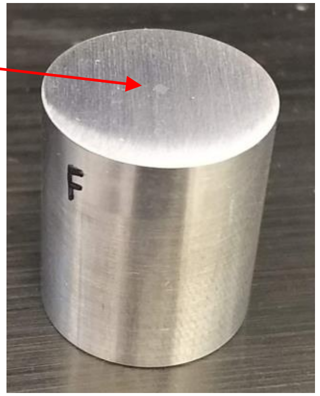




Automated Hardness Indenter Instrument

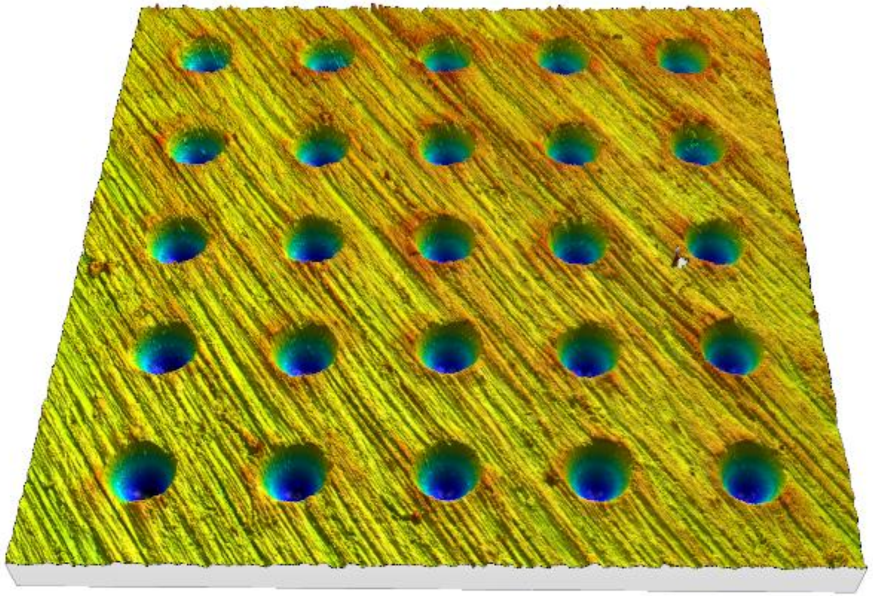


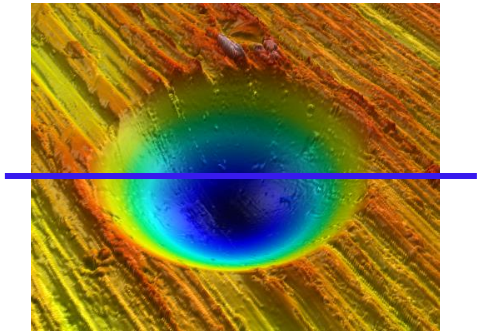




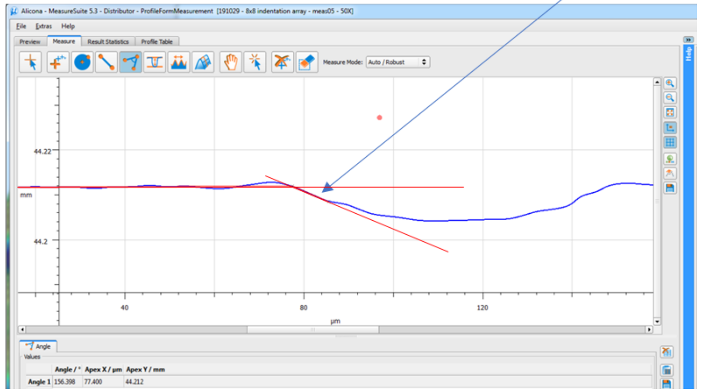
Prototype Fabrication – XY Array

Able to achieve excellent geometry with micro-indentation

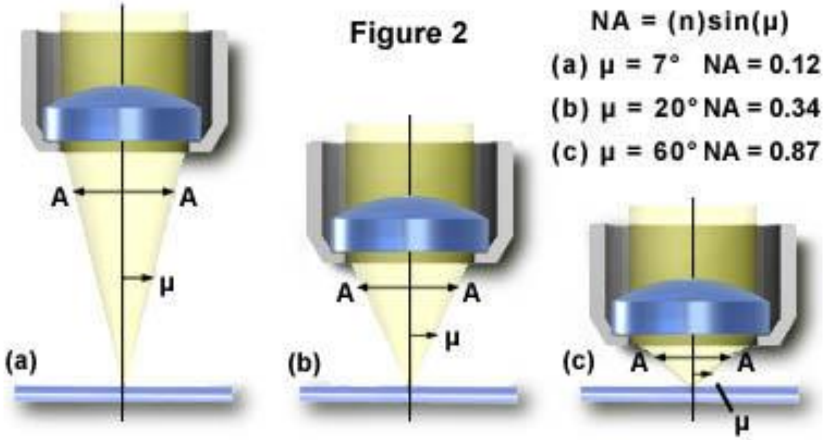




~22 degrees



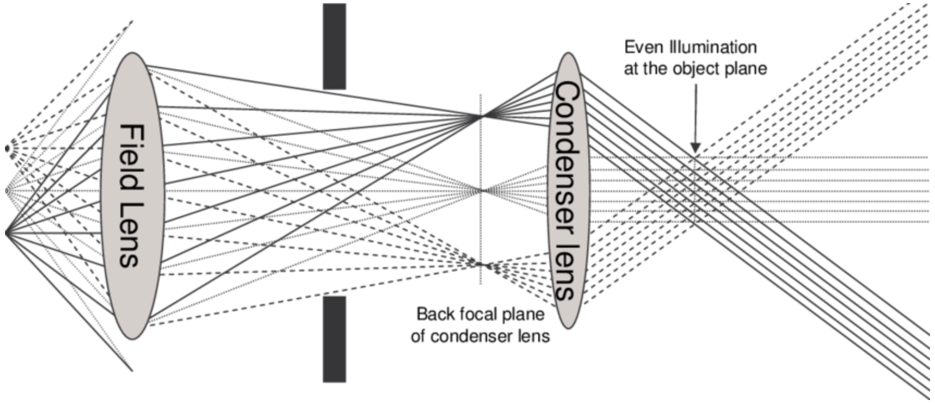
Microscope numerical aperture (NA)



https://www.olympus-lifescience.com/en/microscope-resource/primer/anatomy/numaperture/

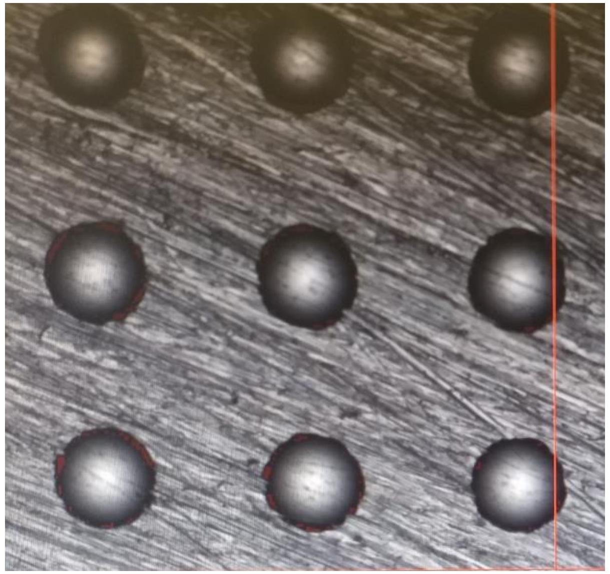
Prototype Fabrication – XY Array

Koehler Illuminated Microscope

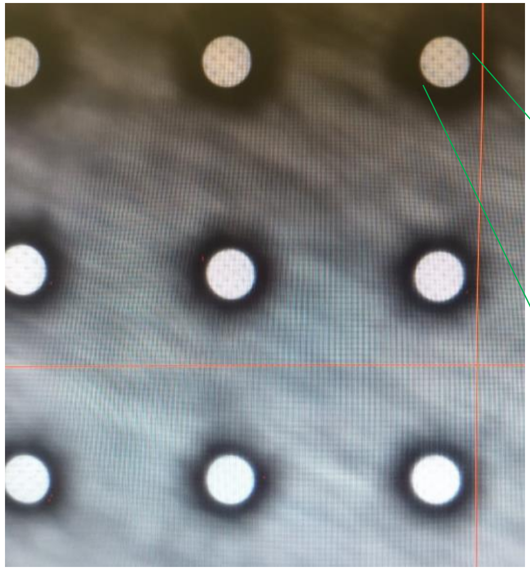


Fabrication Challenges

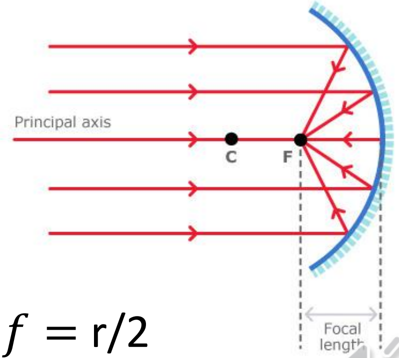
Focused approx. at bottom of indentation



Focused approx. 40 µm above bottom of hemispherical indent



Spherical Reflector

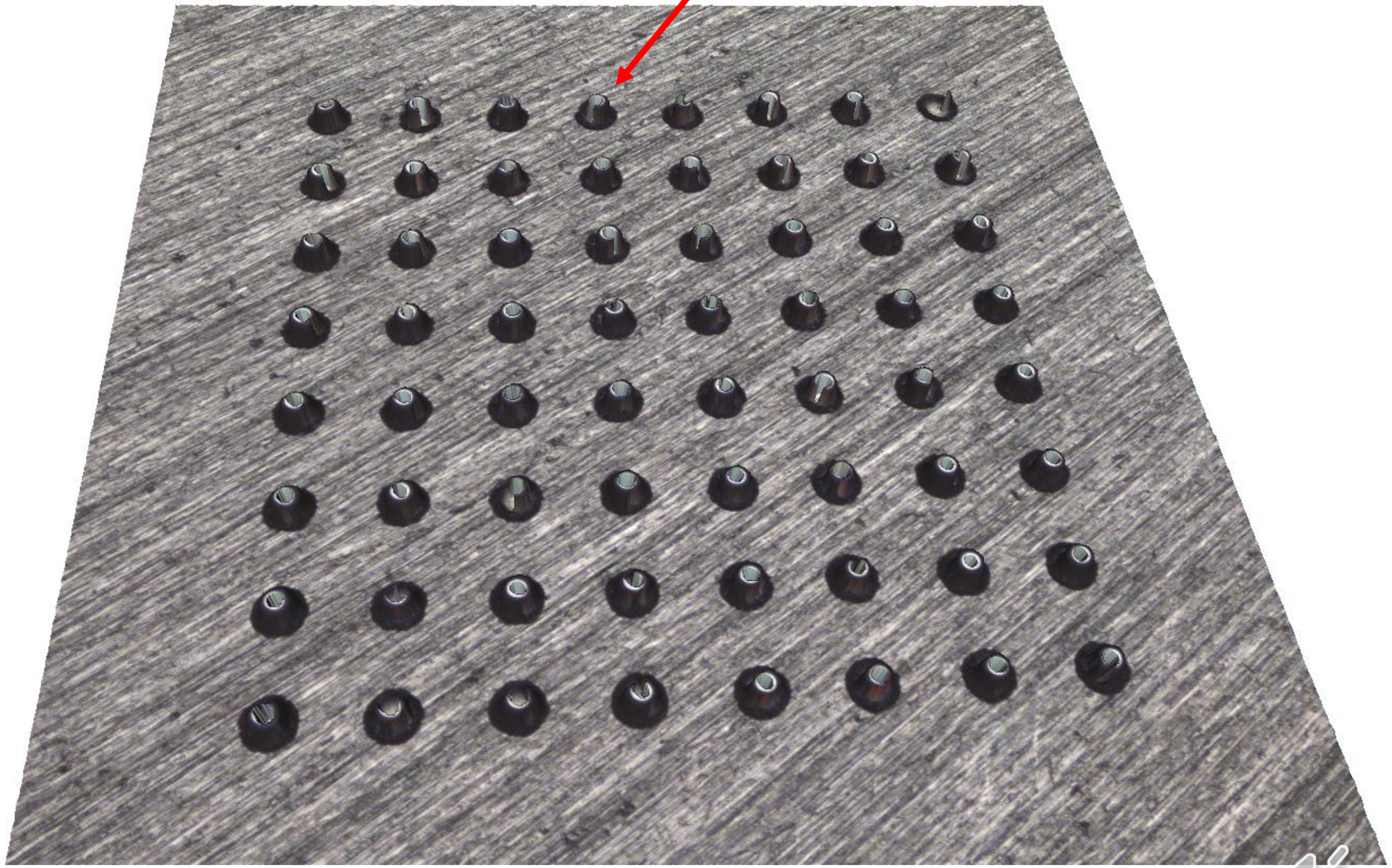


$f = r/2$

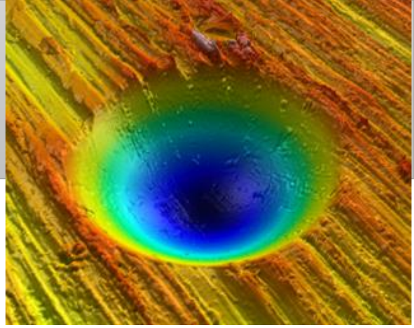
Prototype Fabrication – XY Array

- Some instruments can't correctly determine the actual surface topography with the image of the source coming into focus, usually at low magnification, high depth of field
- 1) Microscope objective magnification/depth of field and 2) focal length of indentation are factors in presence of this error
- Solutions:
    1. Preliminary etching (NaOH) on our aluminum sample significantly reduces the optical power of the indentation.
    2. Larger diameter impressions for lower magnification (larger FOV) measurements

Error creates a positive **protruding shape,** instead of the actual spherical impression

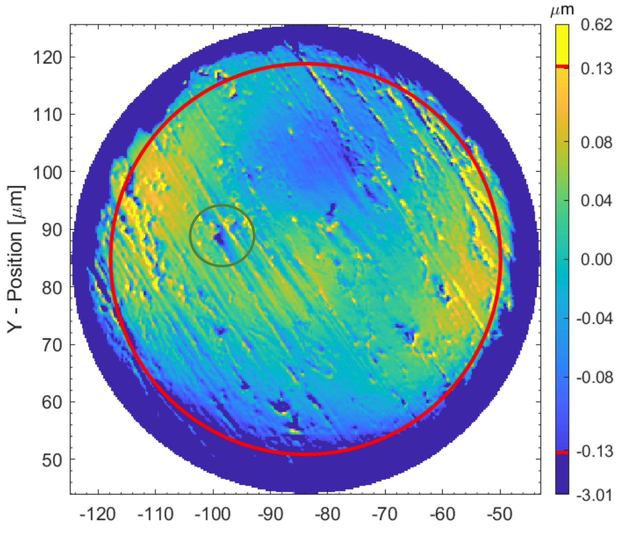


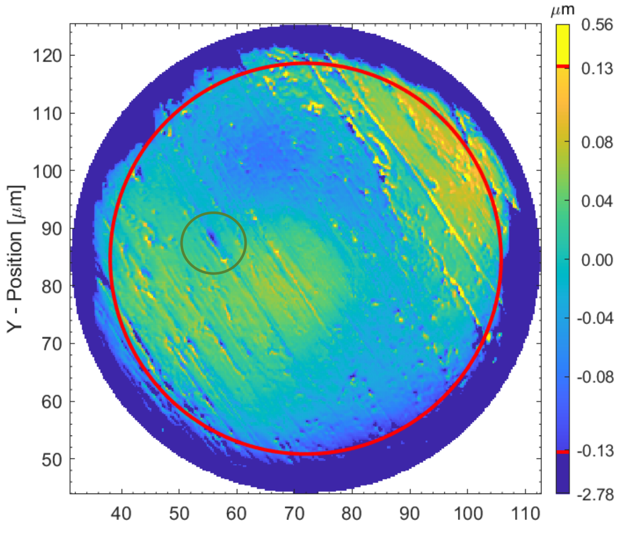
XY Array Sphericity



50X (Top Left Corner, NanoFocus)

S90 = 57 nm
R90 = 84.29 µm

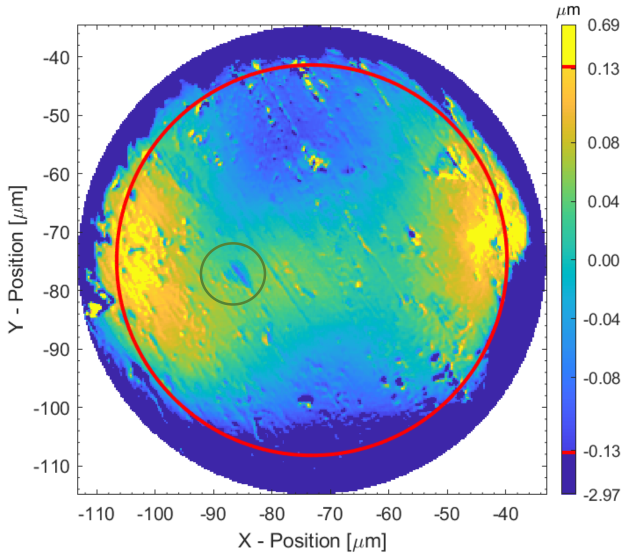


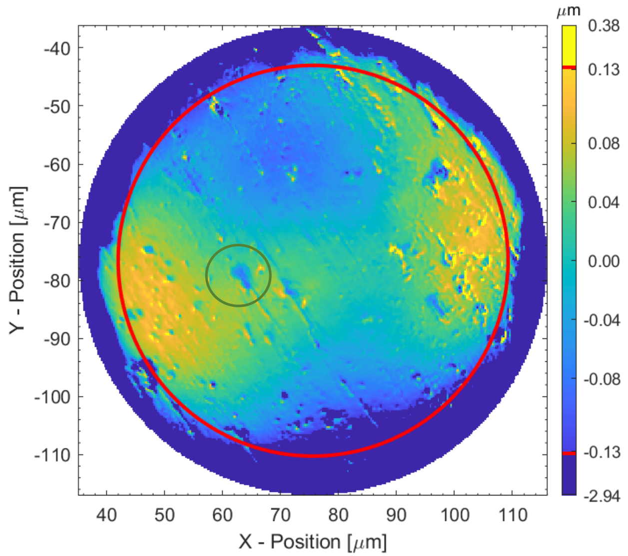


S90 = 44 nm
R90 = 84.14 µm

<u>Sphericity deviation</u>
indentation topography
(estimated for data within
90 % of intersection radius)

S90 = 65 nm
R90 = 84.85 µm





S90 = 58 nm
R90 = 84.37 µm

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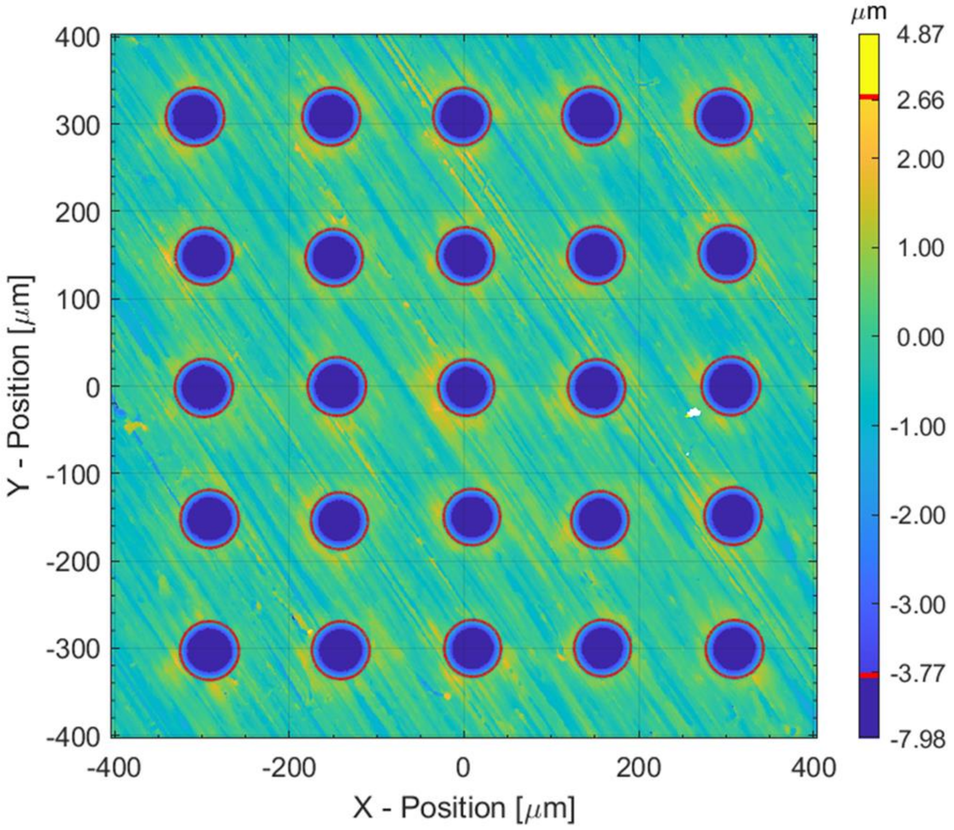
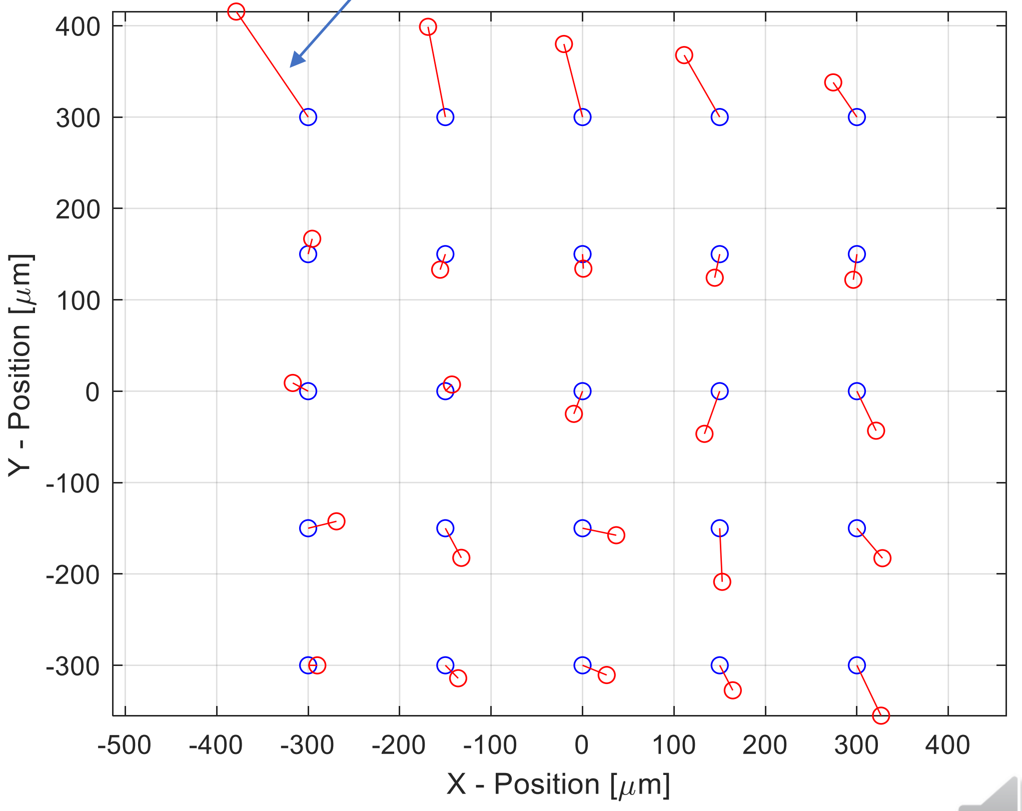
XY Array Positional Analysis

Position errors relative to best fit nominal grid (10X magnified)

20X (Top Left Corner, Nanofocus)

Maximum error: 14 µm



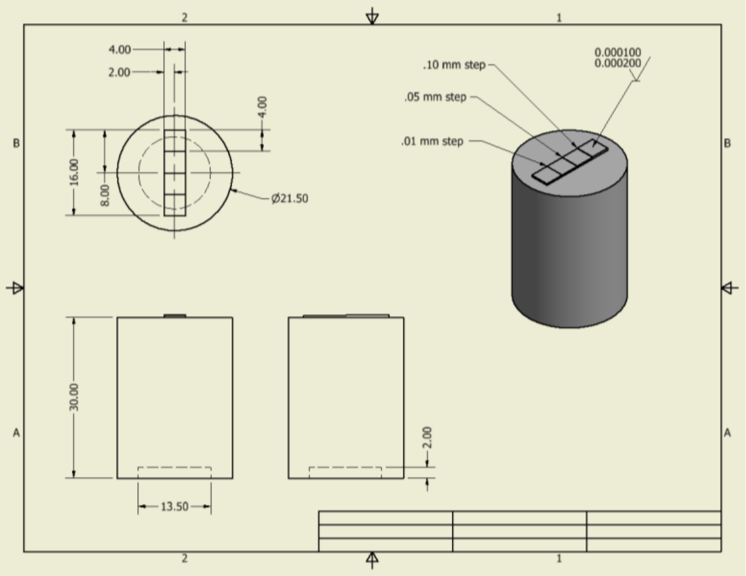


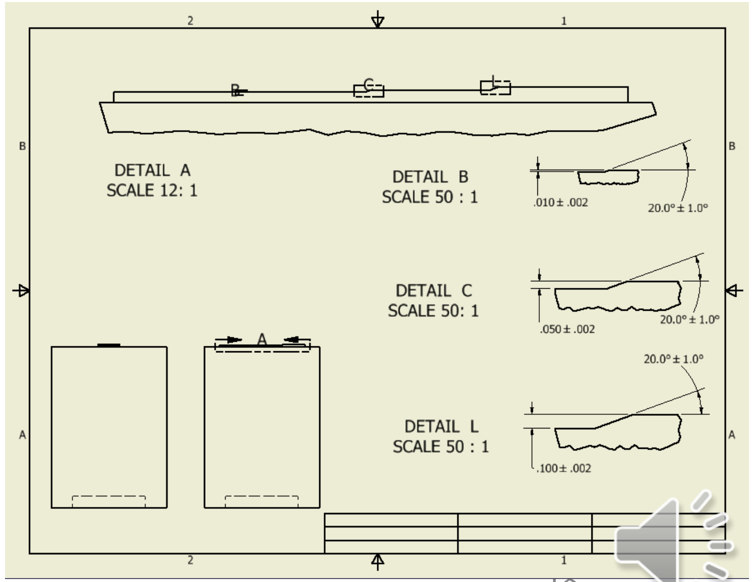
Prototype Design – Z Step

Addresses Z Scale and Linearity

Design Features

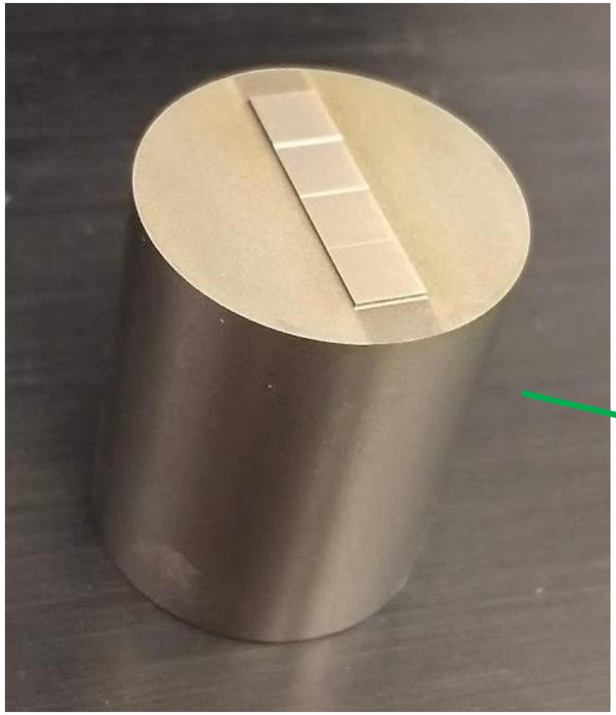
- Current design based on array of Qty=4 2mm x 2mm parallel pads.
- Pads at defined vertical spacings, providing 3 nominal steps of 100 µm, 50 µm, and 10 µm.
- No surface discontinuities. 20° transition region between pads for measurability
- Nominal surface roughness to be achieved through:
    1. Native machined marks
    2. Etching
    3. Media Blasting
- Machined on a cylindrical blank that is the size of a 12 gauge shot shell

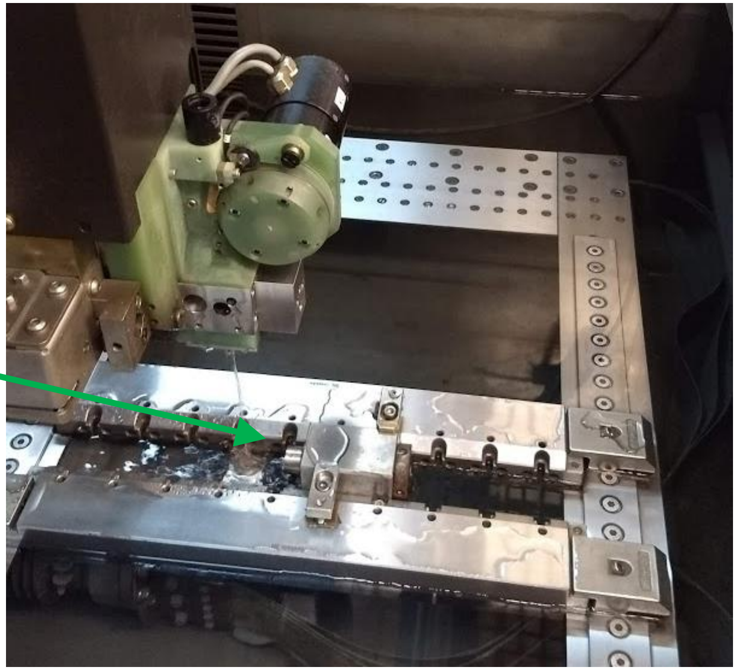




Prototype Fabrication – Z Step

Fabrication technique is wire Electrical Discharge Machining (EDM)





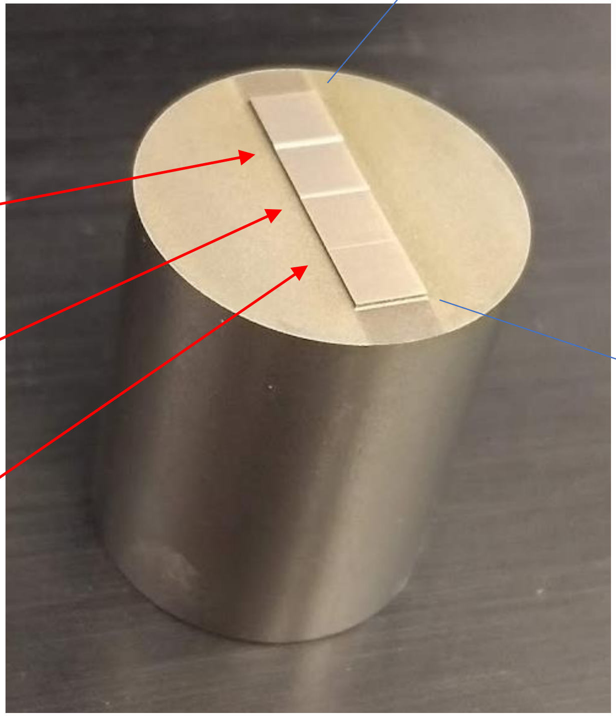
Prototype Fabrication – Z Step

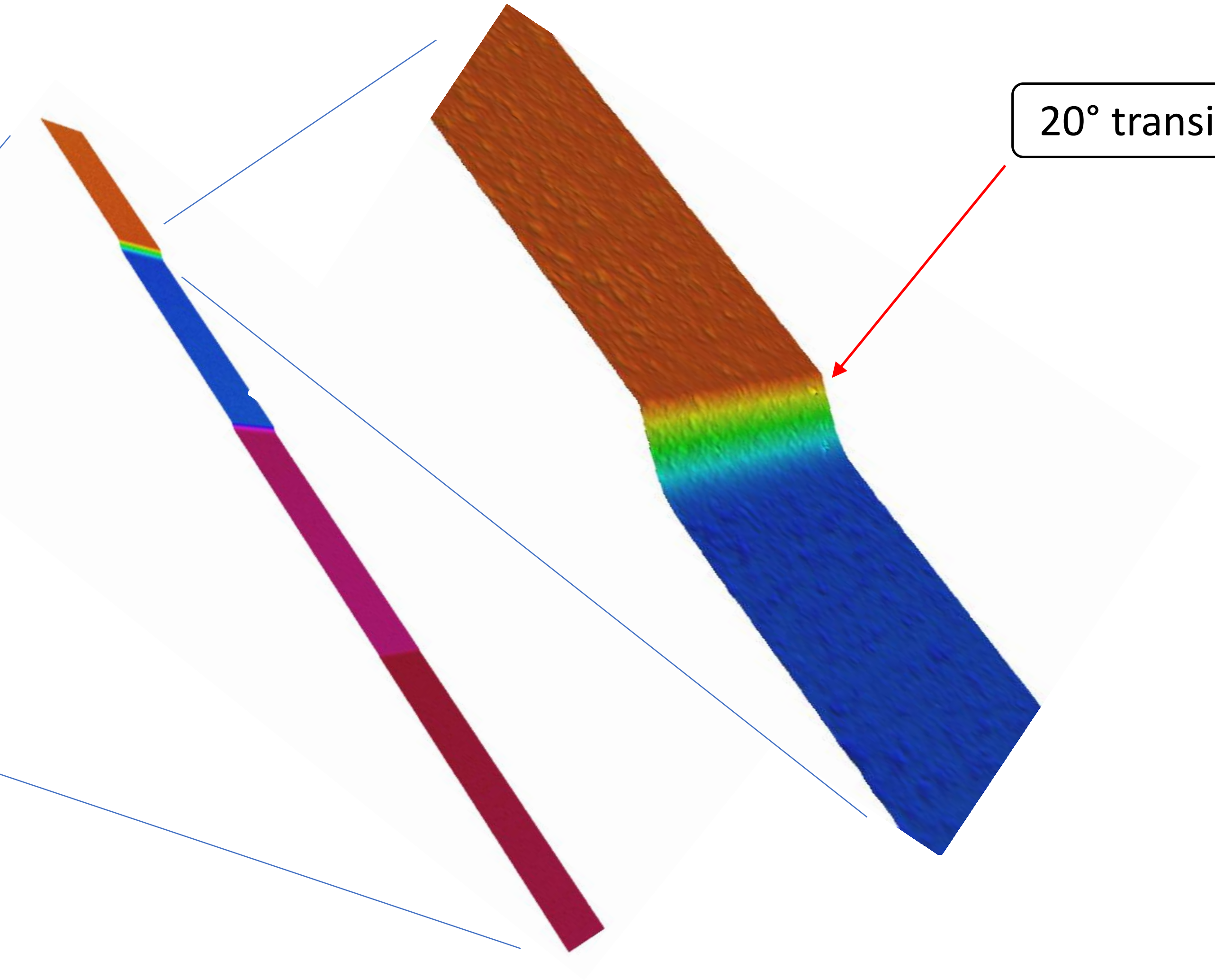
- Planar surfaces cut with NIST wire-EDM
- We're able to hit the target surface roughness of 100 nm to 150 nm

100 µm Step

50 µm Step

10 µm Step





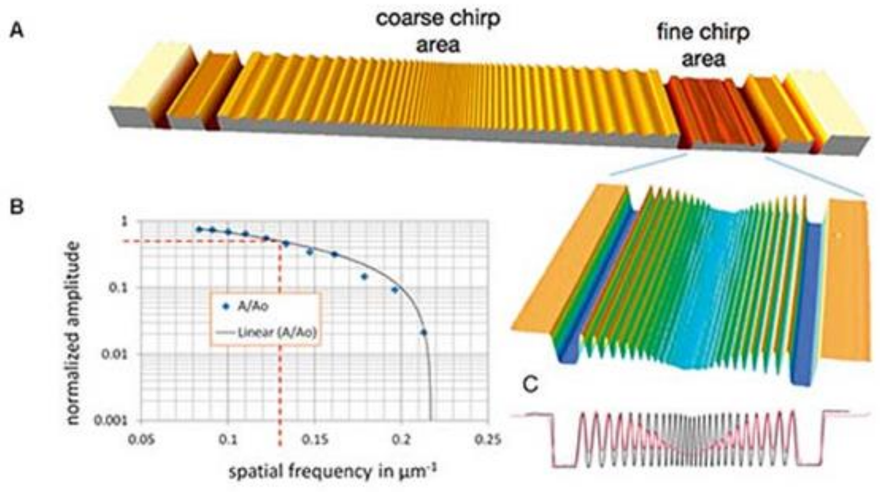
Performance Specifications

Performance Specification	Physical Artifact
1. XY Scale	✓
2. XY Linearity	✓
3. Z Scale	✓
4. Z Linearity	✓
5. Lateral Resolution	X
6. Maximum Measurable Slope (convex)	✓
7. Maximum Measurable Slope (concave)	✓
8. Aberration Correction (field curvature)	✓
9. Measurement Stitching	SRM 2461
10. Instrument Noise	SRM 2461

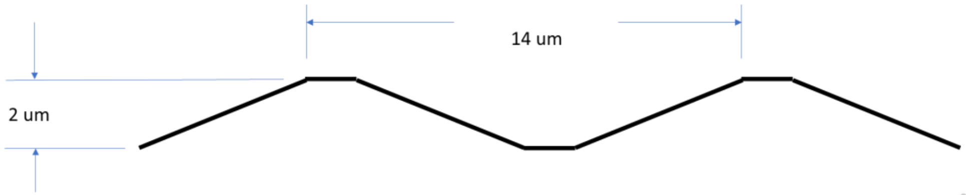
Lateral Resolution

- We recognize the importance of this specification
- We don't have a solid solution for evaluating this across the spectrum of instruments that will be used in the forensic laboratories
- <u>We are currently considering three options:</u>
  1. 2D optical resolution using a siemens star (not preferred)
  2. Diamond turning a non-sinusoidal "chirped-style" profile that could be used to provide a *Go-No Go* for lateral resolution, but not necessarily an actual measurement of the instrument's resolution limit
  3. Evaluating the difference in spatial frequency content between a known surface and a measurement of that surface from an instrument being tested

<u>PTB Chirped Array</u>



<u>Possible Diamond-turned profile</u>



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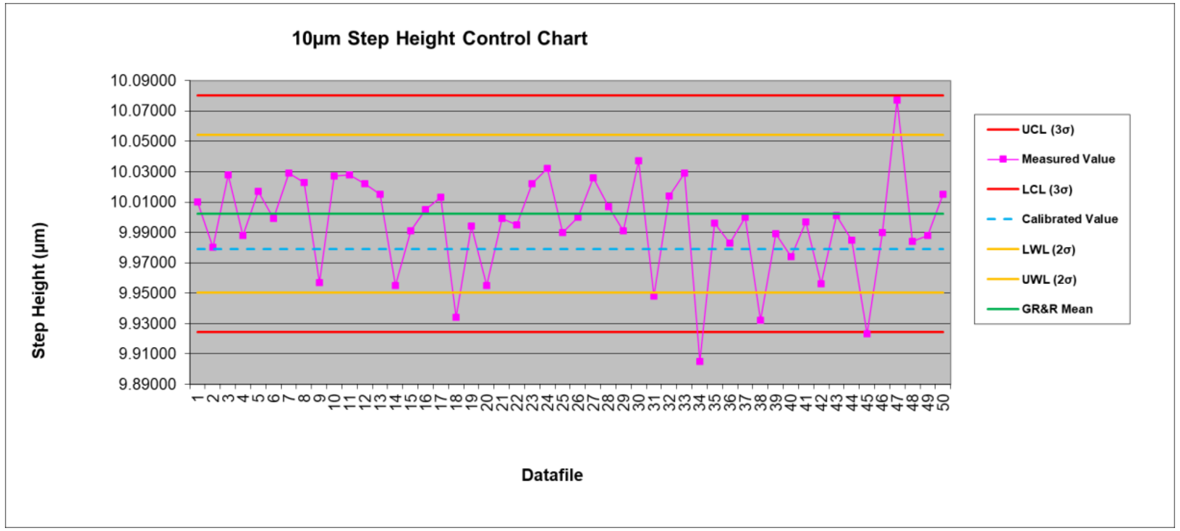
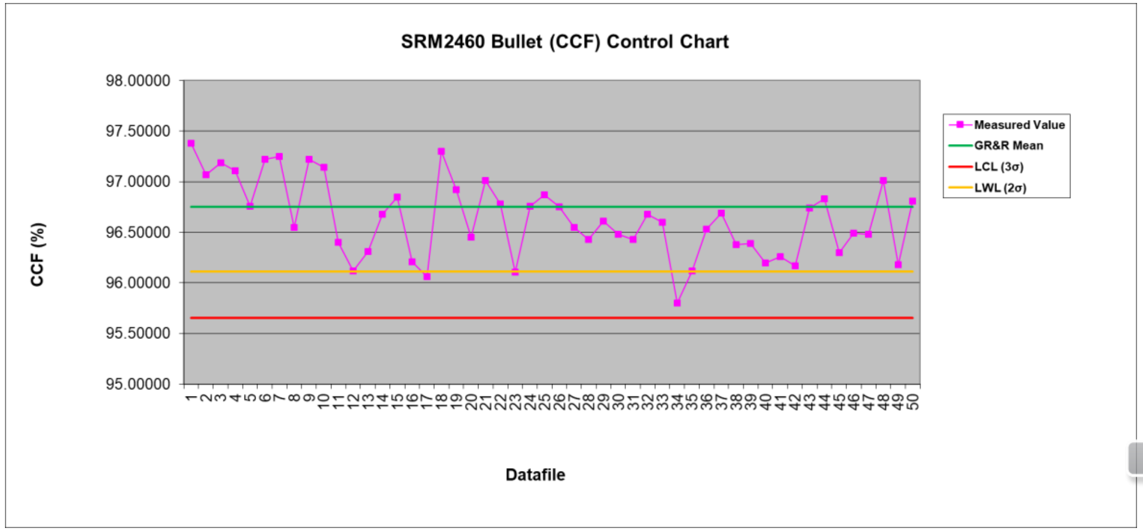
Quality Assurance

NIST and FBI FTU Memorandum of Understanding (MOU):

- QA implementation on their 3D Surface Topography Instruments
    - Detailed QA protocols
    - Detailed measurement protocols
    - Uncertainty budget development
    - Measurement consultation and troubleshooting
    - Results will be used in TWG documents





SUPPLEMENTAL SLIDES

Reference Population Database of Firearm Toolmarks (RPDFT)

Xiaoyu Alan Zheng[1], Johannes Soons[1], Erich Smith[2], Martin Baiker[3]

1. National Institute of Standards and Technology
2. Federal Bureau of Investigation
3. Netherlands Forensic Institute

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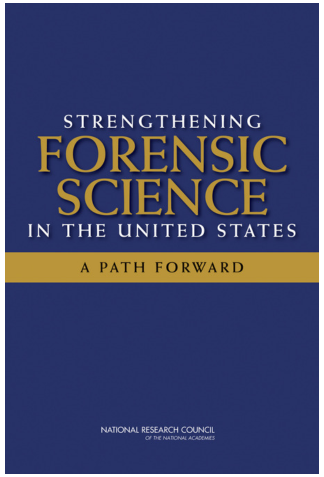
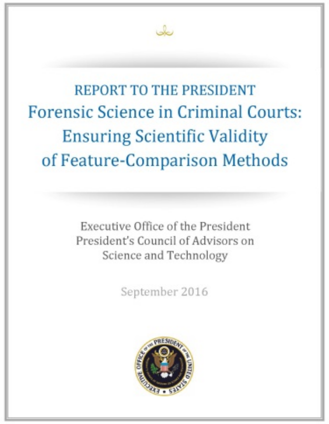
Netherlands Forensic Institute
Ministry of Justice and Security

Motivation

RPDFT



- NAS 2009 “..the decision of the toolmark examiner remains a **subjective decision** based on unarticulated standards and no statistical foundation for **estimation of error rates**.”



- PCAST 2016: “PCAST finds that firearms analysis currently falls short of the criteria for foundational validity, because there is only a single appropriately designed study to **measure validity and estimate reliability**.”

  “If firearms analysis is allowed in court, the scientific criteria for validity as applied should be understood to require **clearly reporting the error rates seen in appropriately designed black-box studies.**”

  “A second – and more important – direction is … to convert firearms analysis **from a subjective method to an objective method**…”

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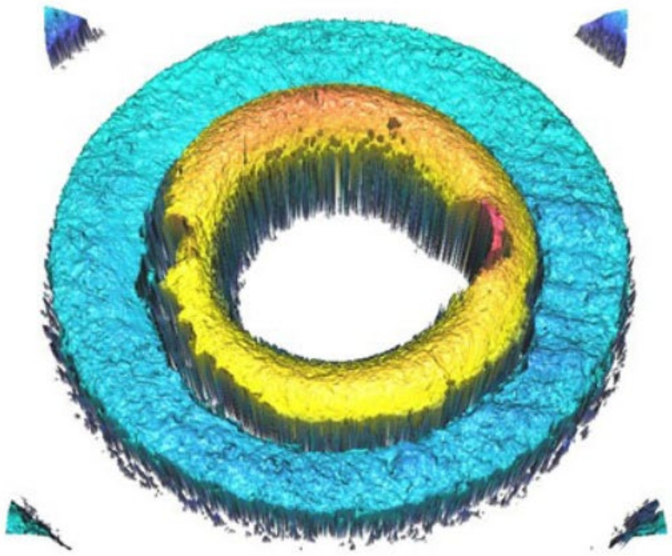
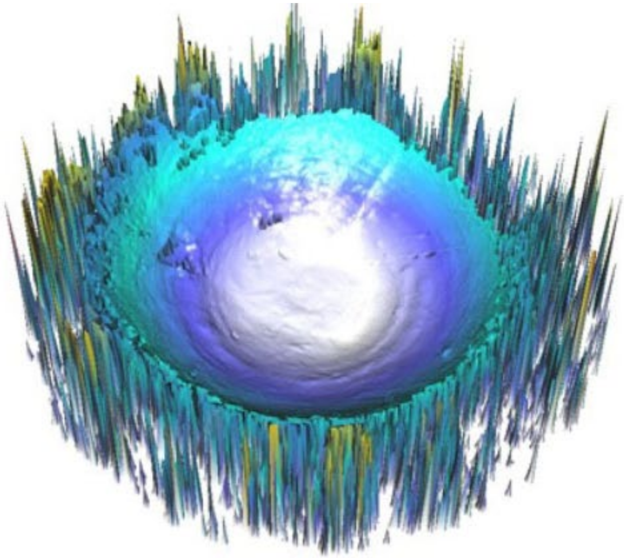
Goals

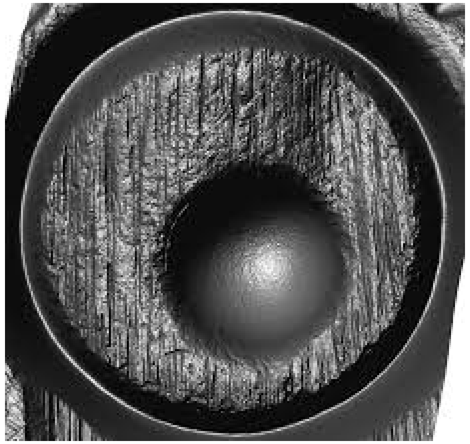
- Establish a national database of ground truth firearm and toolmark comparison scores
- Build a database of statistical distributions using the relevant population on the fly
- Provide an objective measure of similarity
- Provide a statistical statement of uncertainty
- Provide reference data for continued innovation of correlation algorithms

3D Measurements

RPDFT





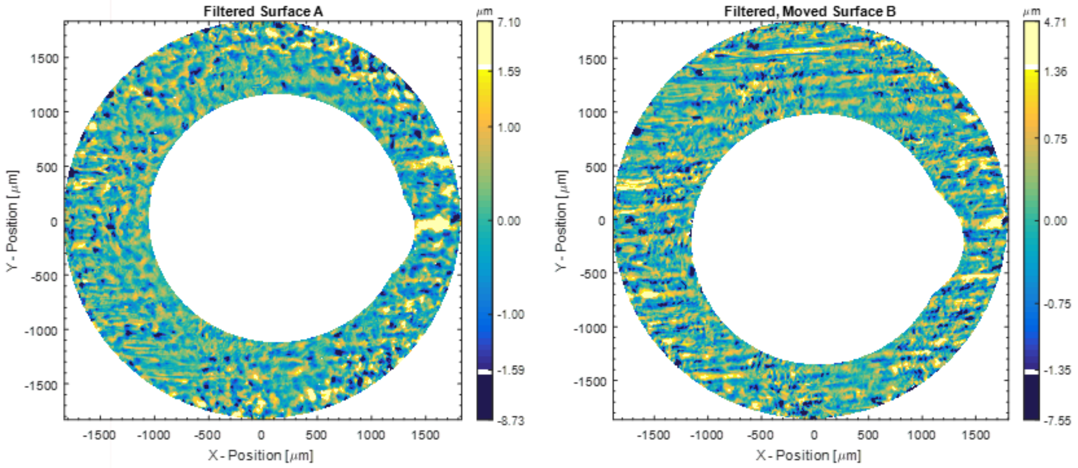


Bullet Land Engraved Area

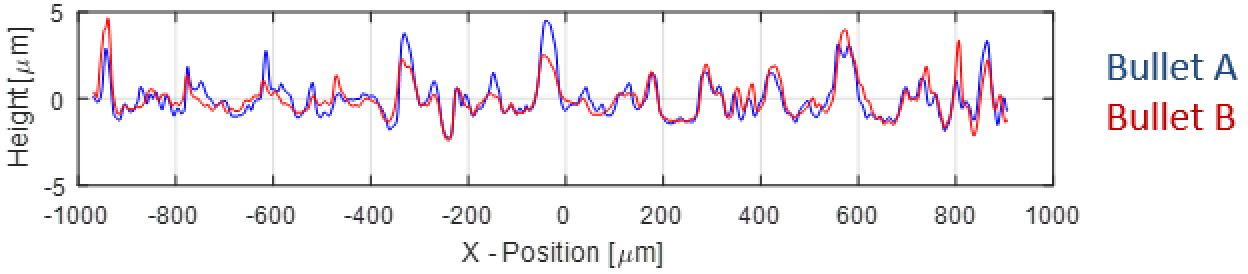
Algorithms

RPDFT

Area Based Correlation

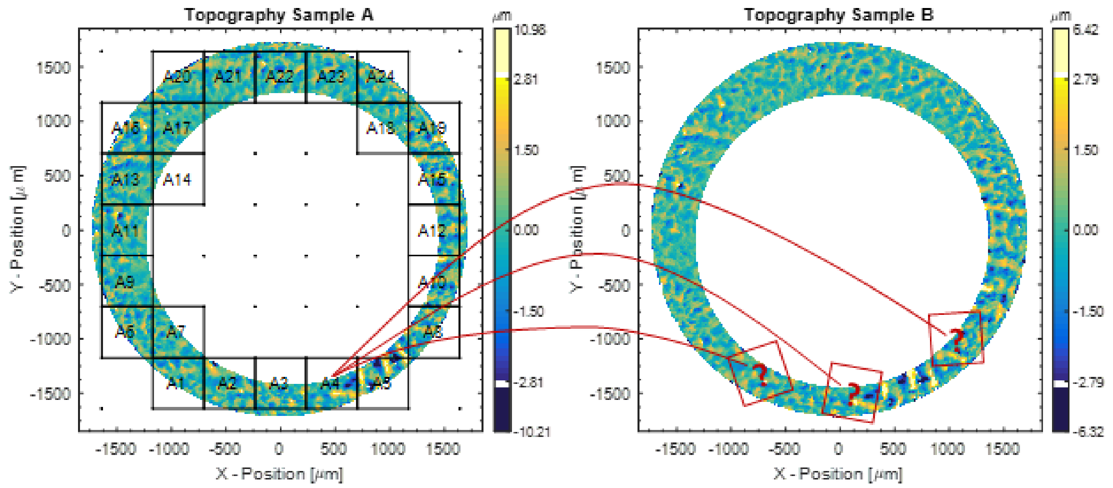


Areal Cross Correlation Function ($ACCF_{MAX}$)

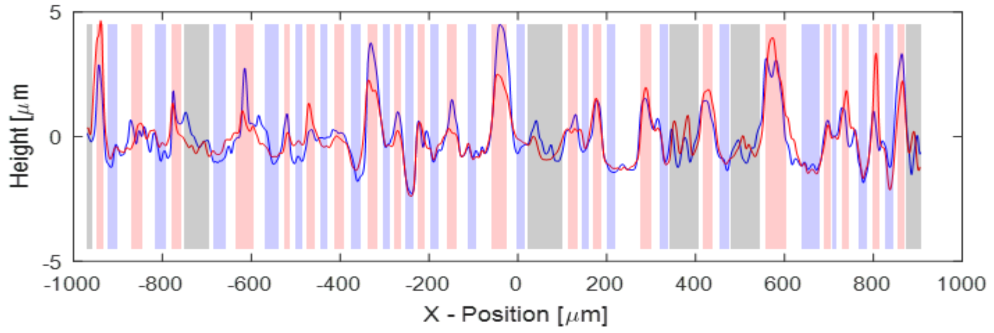


Cross Correlation Function (CCF_{MAX})

Feature Based Correlation



Congruent Matching Cells (CMC)



Consecutive Matching Striae (CMS)

NIST FORENSIC SCIENCES

Standardization

- Standard for Toolmark Topography Comparison Software
- Standard for Implementation of 3D Technologies in Forensic Laboratories
- Standard for 3D Measurement Systems and Measurement Quality Control

- Unambiguous file exchange standard
- OpenFMC.org
- ISO25178-72 XML 3D Profile

Collaboration

RPDFT

- Firearms expertise
- Consecutively manufactured reference collection
- Multi-instrument capabilities
- Communication Access to database for laboratories

NIST

- Algorithm Suite
- Metrology Expertise
- Standardization
- Statistics

Netherlands Forensic Institute
Ministry of Justice and Security

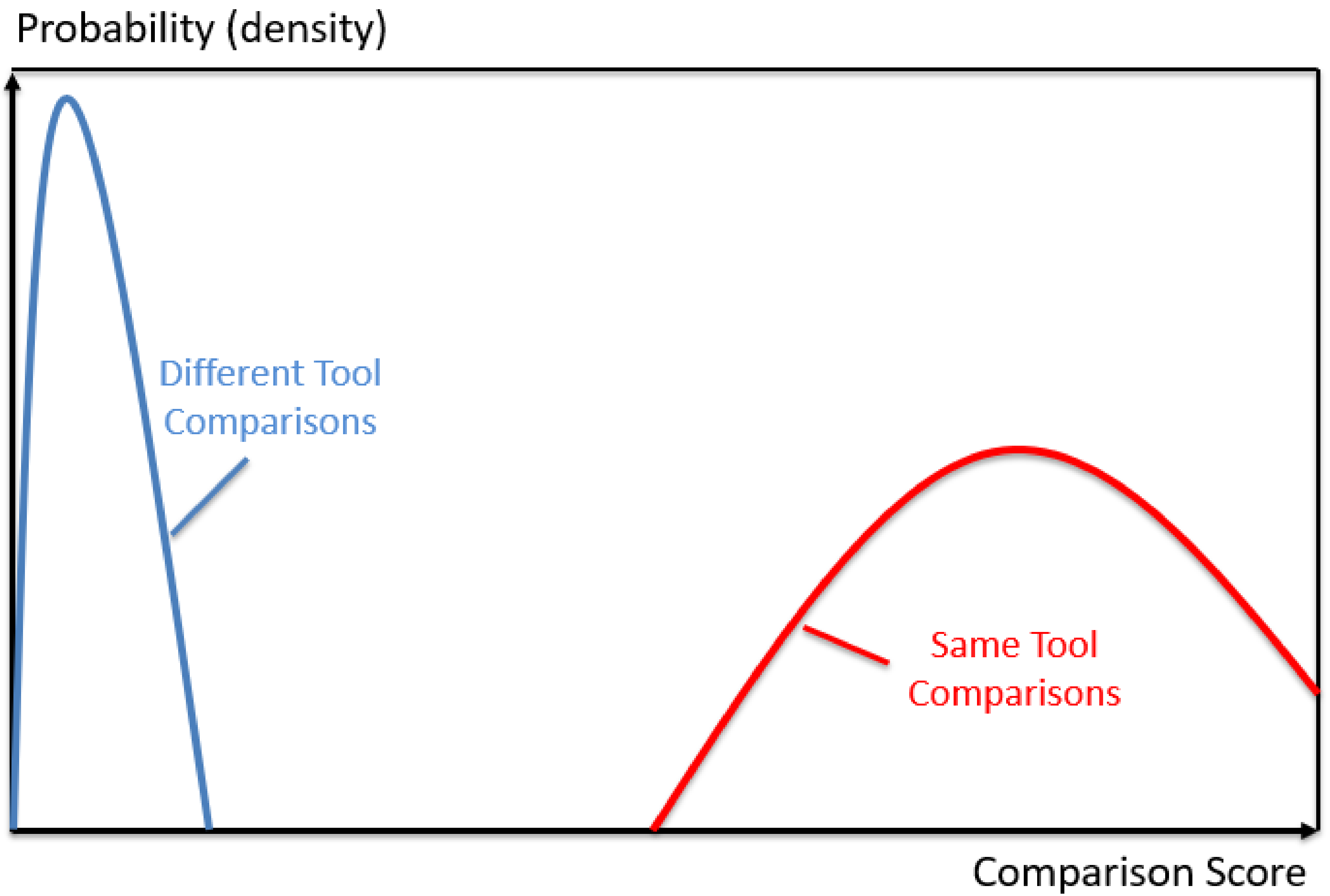
- Firearm and Toolmark expertise
- Software platform for distribution database
- Software development
- Scratch 2.0

What is RPDFT ?

Firearm 1	Firearm 2	FA1 Metadata	FA2 Metadata	Comparison Score
FA-1 Firearm Meta Data	FA-1 Firearm Meta Data	FA-1, Cartridge Case Meta Data, Measurement Meta Data	FA-1, Cartridge Case Meta Data, Measurement Meta Data	78
FA-1 Firearm Meta Data	FA-2 Firearm Meta Data	FA-1, Bullet, Measurement Meta data	FA-2, Bullet, Measurement Meta data	4
…	…	…	…	…
FA-N Firearm Meta Data	FA-N Firearm Meta Data	FA-N, Cartridge Case/Bullet, Measurement Meta data	FA-N, Cartridge Case /Bullet, Measurement Meta data	N

Perfect World

RPDFT



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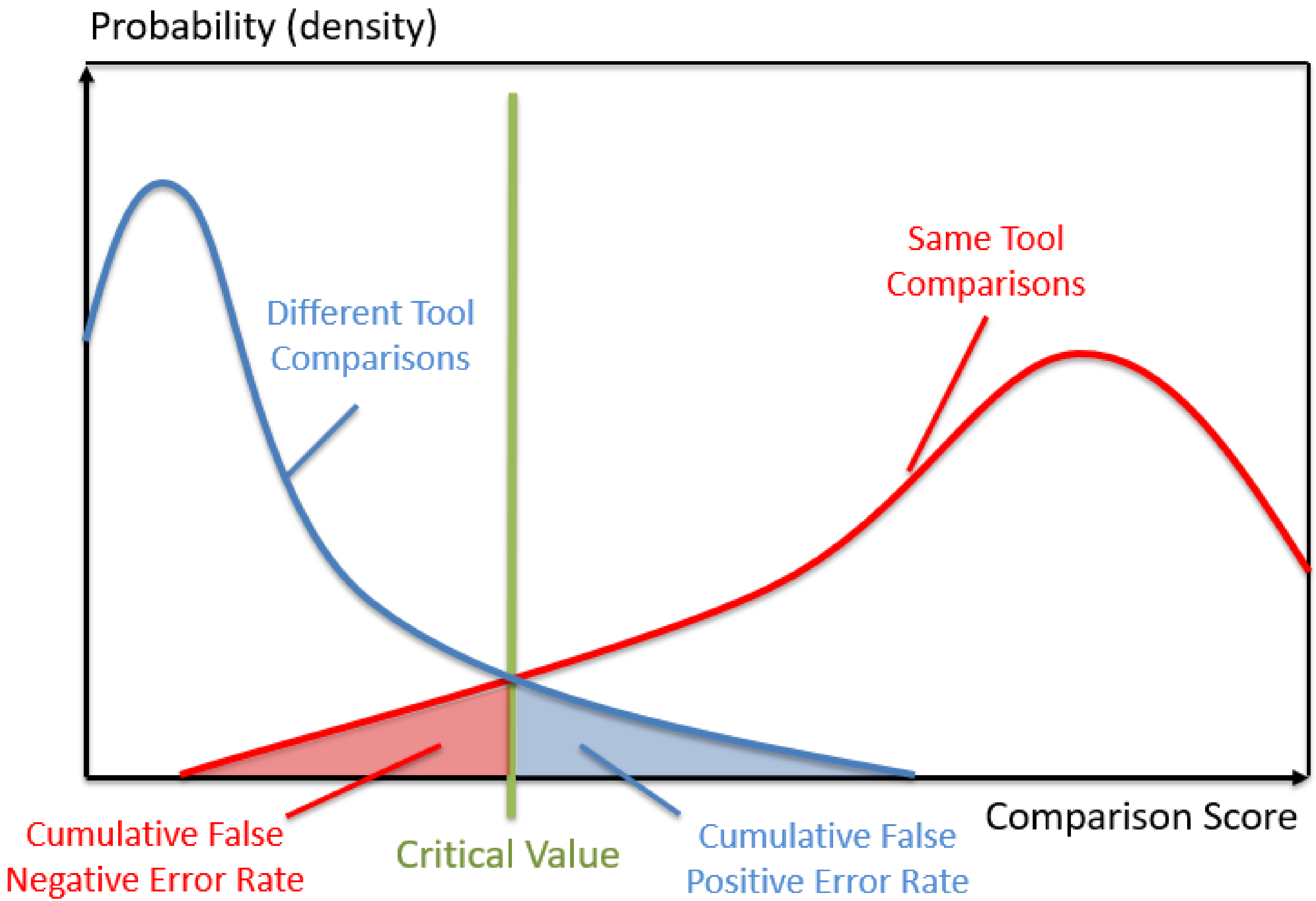
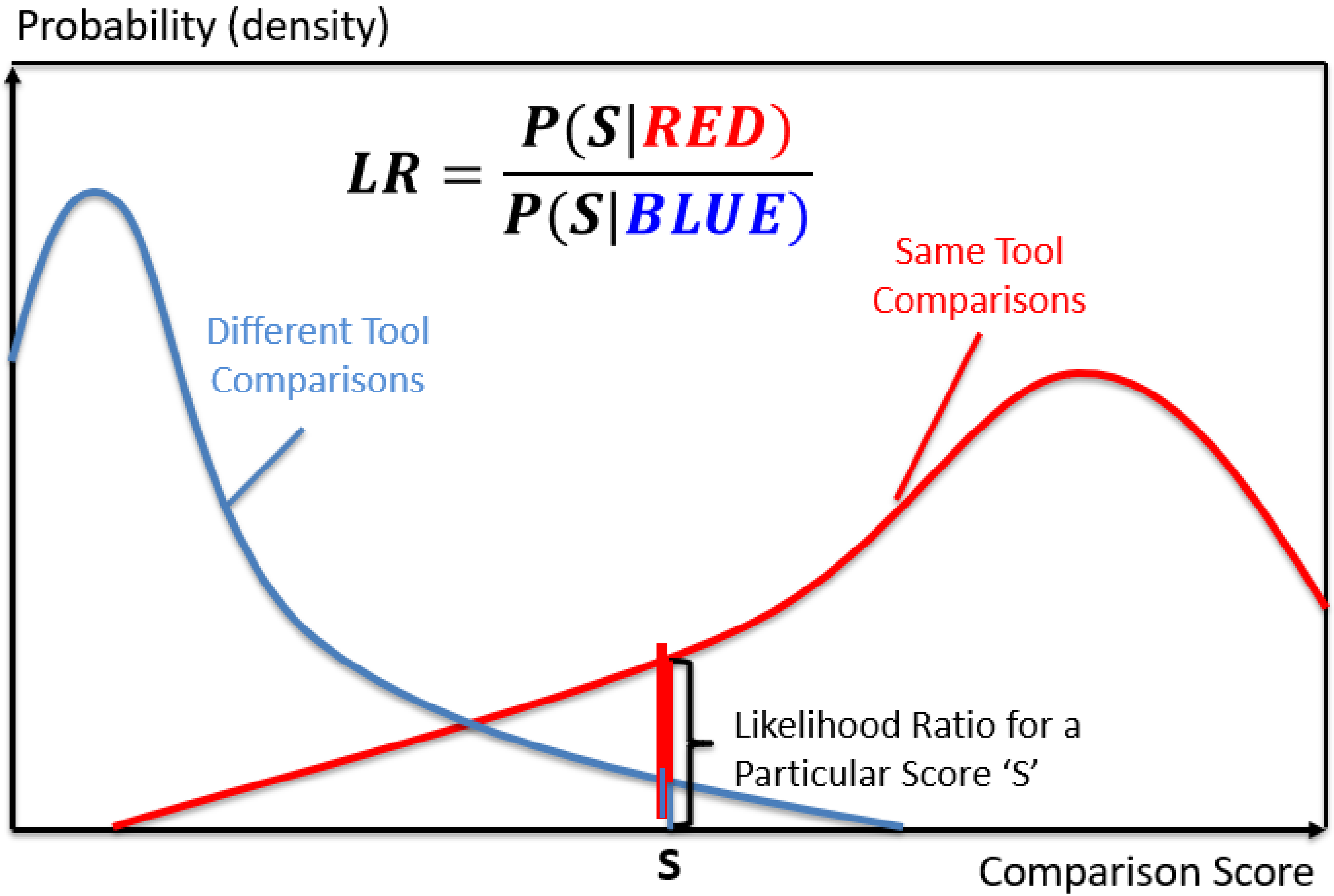
Error Rates


Probability (density)
Different Tool Comparisons
Same Tool Comparisons
Cumulative False Negative Error Rate
Critical Value
Cumulative False Positive Error Rate
Comparison Score

Likelihood Ratios

RPDFT



Relevant Populations

Relevant Populations

RPDFT

- An important assumption in the statistical models we use is that the background population is representative of the relevant population.
  - Similar to why you would never visually compare a Glock to a Hi-Point.
  - In our framework, putting a Glock correlation score in a Hi-Point background population is erroneous.

- The **RPDFT** is a database filled with pairwise correlations of ground truth results.
  - Each correlation result has its relevant meta data stored with it.
  - These meta data indexed results are pulled on demand to build the relevant population.

Hierarchical Meta Data

RPDFT

- The system tries to build relevant populations using class characteristics as specific as possible.
  - A minimum number (TBD) of data points are required before the distribution can be created.
  - If that minimum number can't be met, the system moves up a level in the hierarchy to satisfy the minimum data requirement.
  - Moving up the hierarchy could negatively affect your statistics due the loss of specificity.

Mfg: Glock
Model: G19
BF Mfg: Broach
FP Mfg: Turning
Barrel Mfg: Hammer Forge
# of LEA: 6

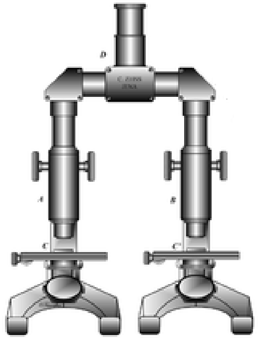
Mfg: Remington
Model: UMC
Caliber: 9 mm Luger
Primer Mat.: Nickel
Case Mat.: Brass

Bullet Weight: 115 Grain
Twist: Right
Surface Mat.: Copper

Workflow Example

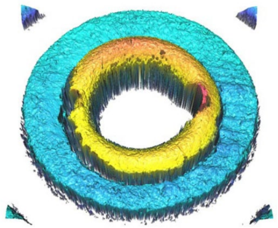
RPDFT

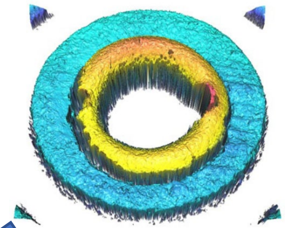
Questioned Item



FA Examiner

Suspect Firearm

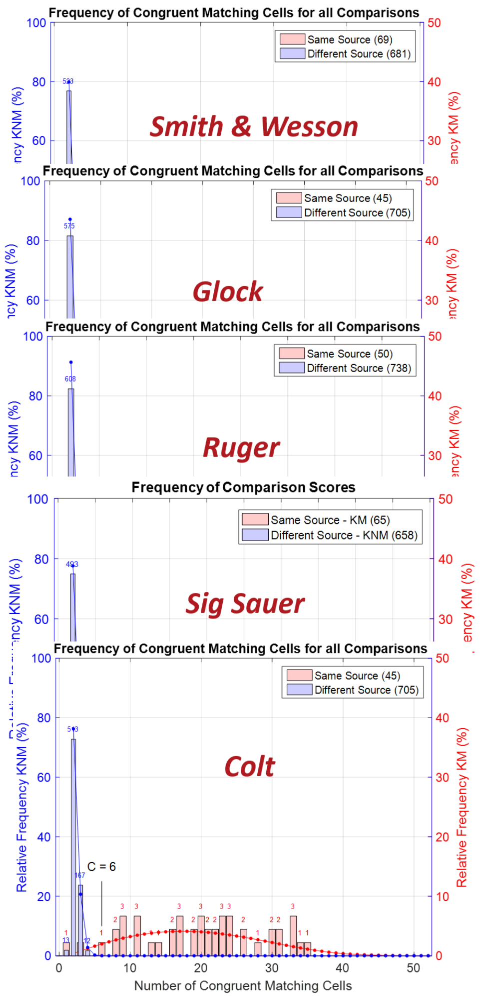




Correlation Algorithm

CMC Correlation Score: 24 Cells

RPDFT Distributions Organized by Brand



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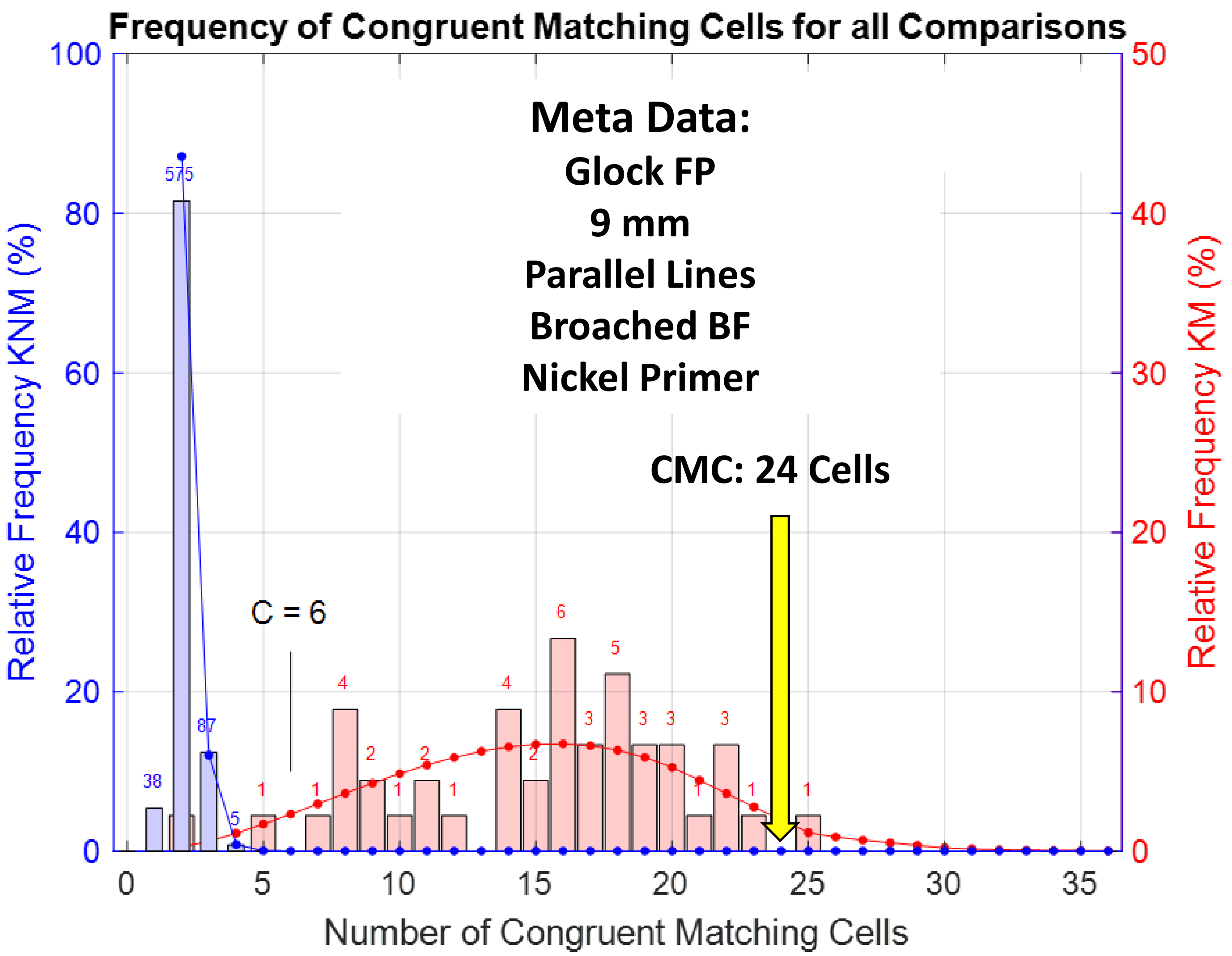
Workflow Example

RPDFT



Statistics are then calculated based on the relevant population distributions

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National Framework

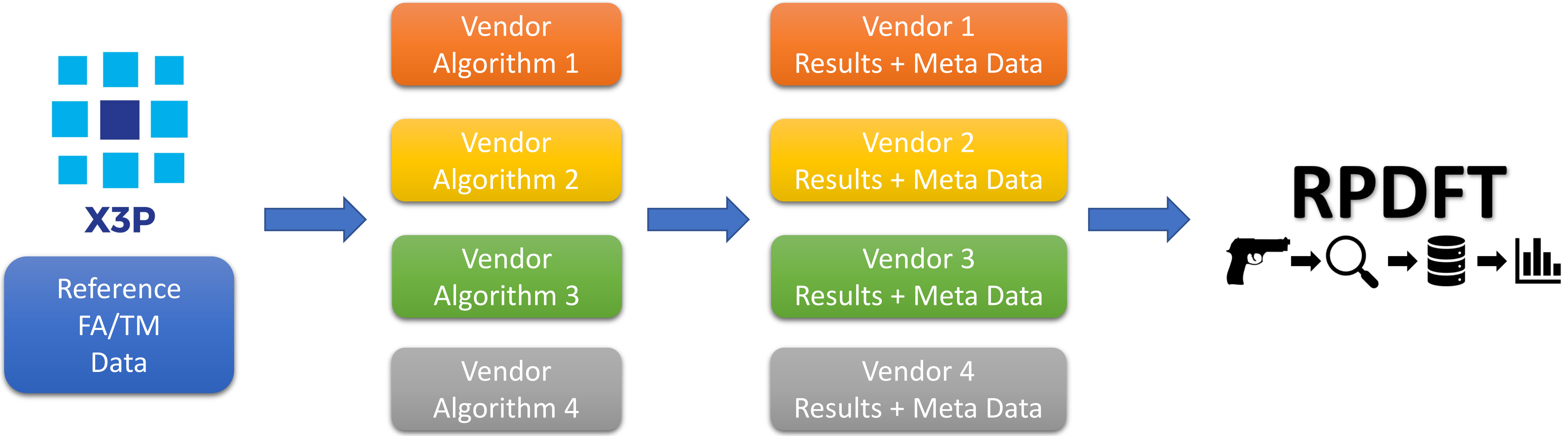
- FBI with the aid of NIST and the TWG3D2T will maintain the reference data and distributions. Updates to the **RPDFT** will occur periodically based on need.
- Laboratories will submit their correlation result along with meta data to **RPDFT** and request the weight of evidence (WOE).
- **RPDFT** will pull the relevant population to build the background distribution and report WOE back to the requesting laboratory.

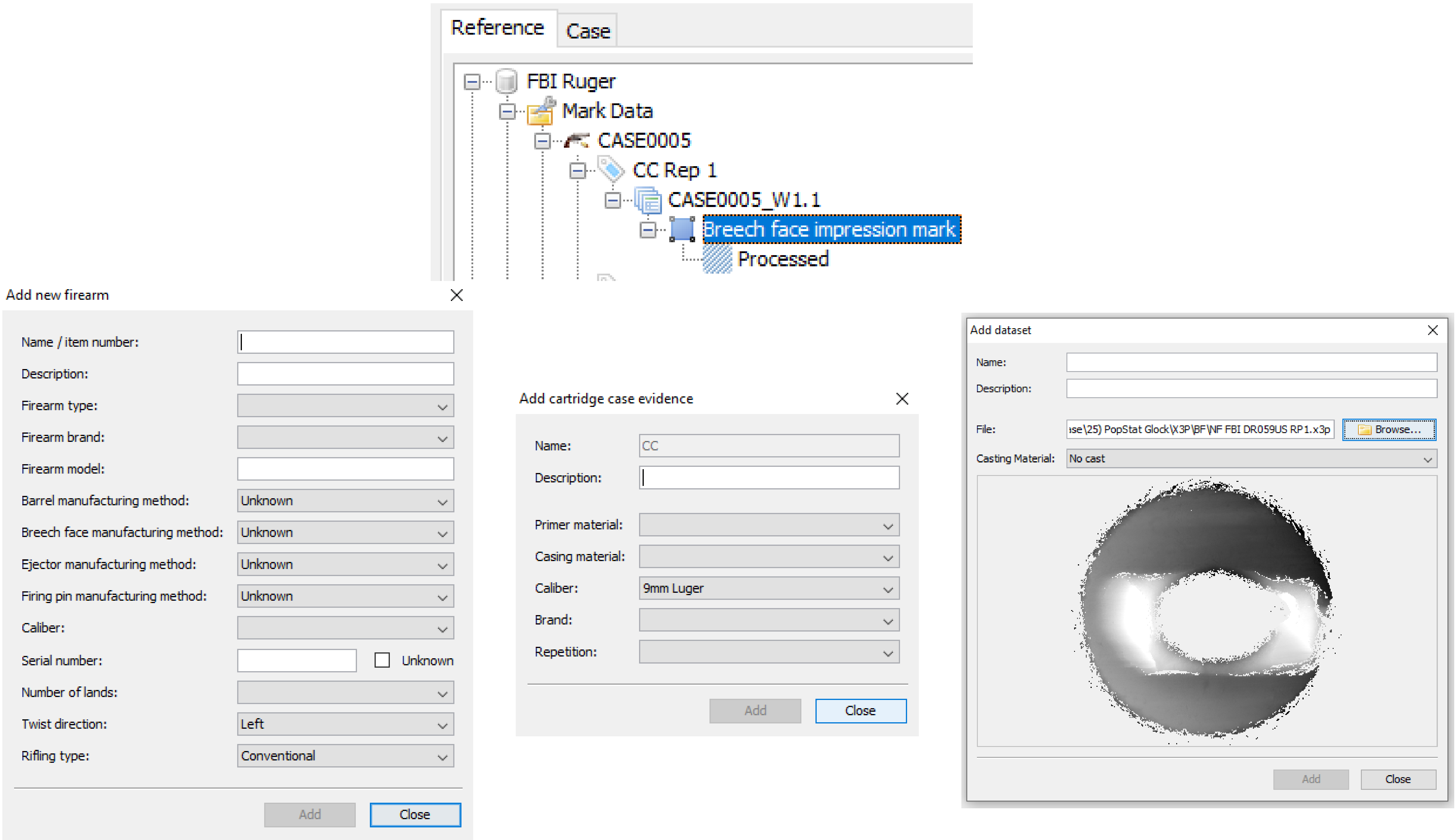
Commercial Vendor

RPDFT

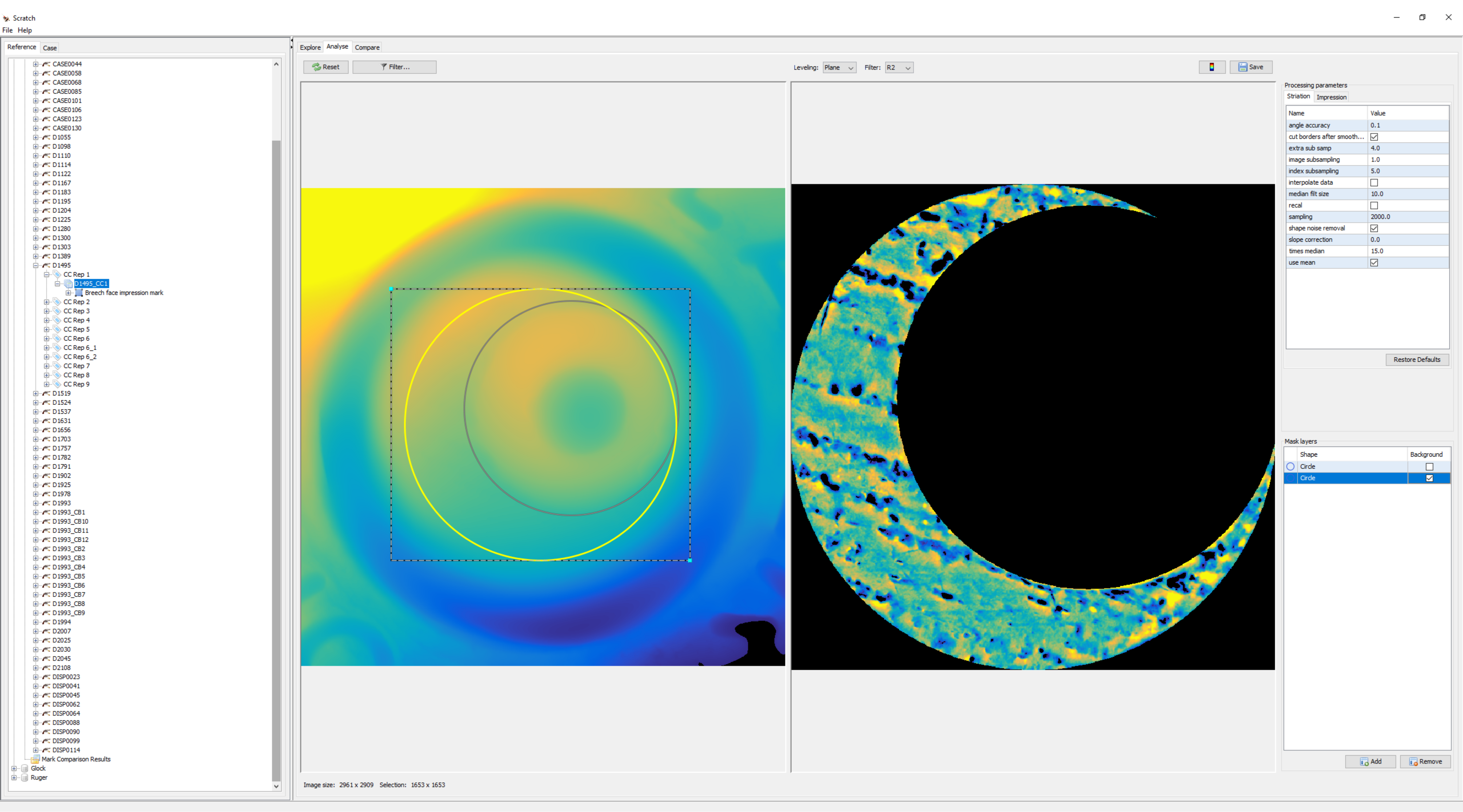
- Commercial vendors will need to conform to the OSAC standards with respect to Hardware and Software.
- Reference geometric standards and bullets/cartridge case replicas will be used to confirm minimum specifications.
- Vendor's correlation algorithm will be used on the **RPDFT** reference dataset to build vendor specific statistical distributions.
- This keeps the market open to drive innovation and allow for competition.

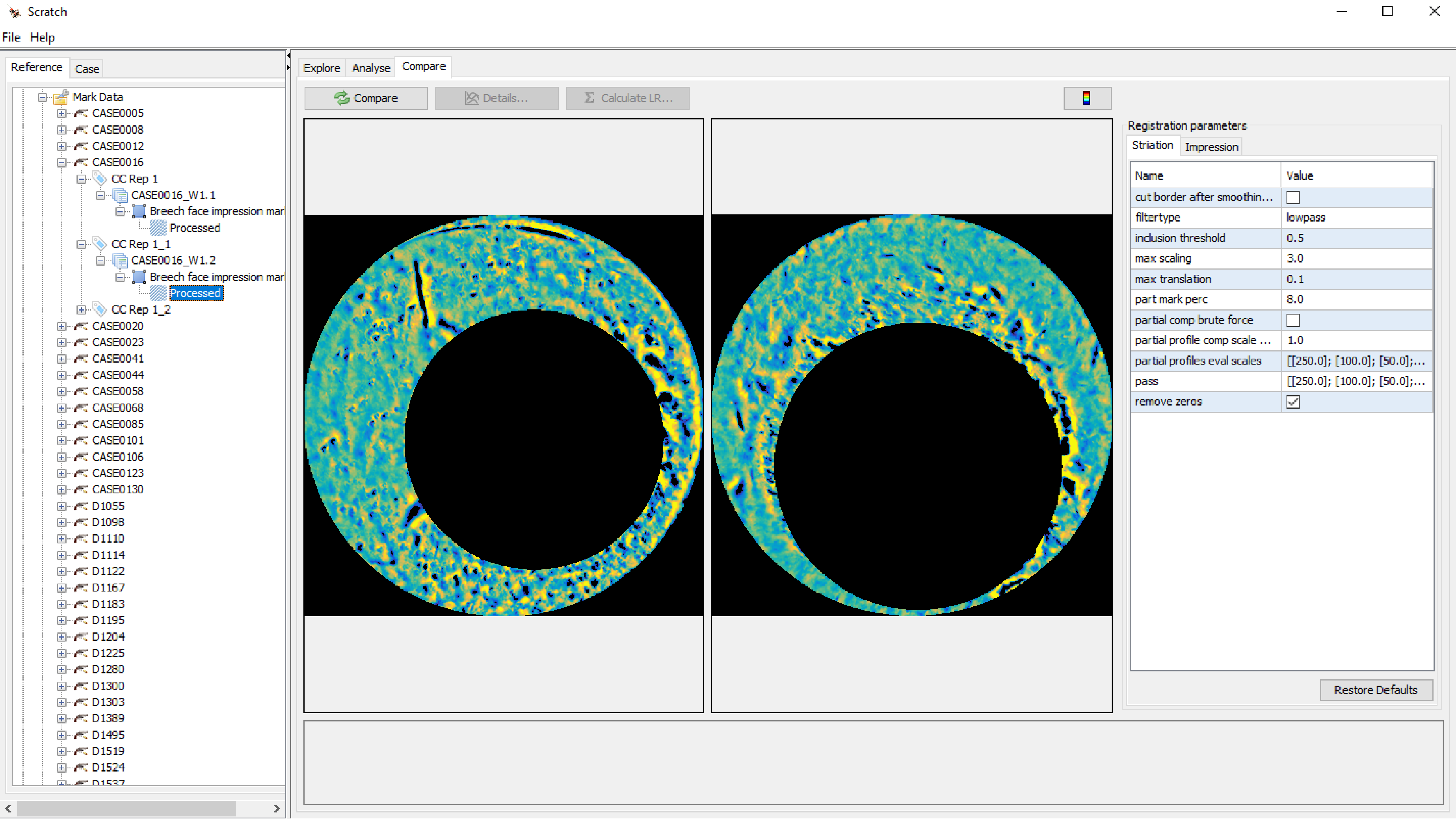
Commercial Vendor





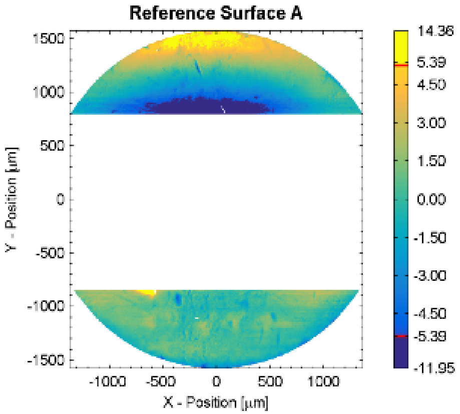
Reference
Case
FBI Ruger
Mark Data
CASE0005
CC Rep 1
CASE0005_W1.1
Breech face impression mark
Processed
Add new firearm
Name / item number:
Description:
Firearm type:
Firearm brand:
Firearm model:
Barrel manufacturing method:
Unknown
Breech face manufacturing method:
Unknown
Ejector manufacturing method:
Unknown
Firing pin manufacturing method:
Unknown
Caliber:
Serial number:
Unknown
Number of lands:
Twist direction:
Left
Rifling type:
Conventional
Add
Close
Add cartridge case evidence
Name:
CC
Description:
Primer material:
Casing material:
Caliber:
9mm Luger
Brand:
Repetition:
Add
Close
Add dataset
Name:
Description:
File:
se\25) PopStat Glock\X3P\BF\NF FBI DR059US RP1.x3p
Browse...
Casting Material:
No cast
Add
Close

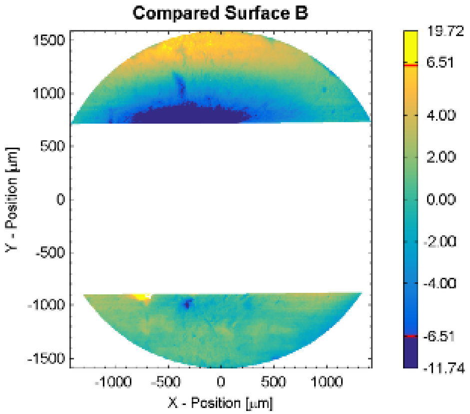

Scratch
File Help
Reference
Case
CASE0044
CASE0058
CASE0068
CASE0085
CASE0101
CASE0106
CASE0123
CASE0130
D1055
D1098
D1110
D1114
D1122
D1167
D1183
D1195
D1204
D1225
D1280
D1300
D1303
D1389
D1495
CC Rep 1
D1495_CC1
Breech face impression mark
CC Rep 2
CC Rep 3
CC Rep 4
CC Rep 5
CC Rep 6
CC Rep 6_1
CC Rep 6_2
CC Rep 7
CC Rep 8
CC Rep 9
D1519
D1524
D1537
D1631
D1656
D1703
D1757
D1782
D1791
D1902
D1925
D1978
D1993
D1993_CB1
D1993_CB10
D1993_CB11
D1993_CB12
D1993_CB2
D1993_CB3
D1993_CB4
D1993_CB5
D1993_CB6
D1993_CB7
D1993_CB8
D1993_CB9
D1994
D2007
D2025
D2030
D2045
D2108
DISP0023
DISP0041
DISP0045
DISP0062
DISP0064
DISP0088
DISP0090
DISP0099
DISP0114
Mark Comparison Results
Glock
Ruger
Explore
Analyse
Compare
Reset
Filter...
Leveling:
Plane
Filter:
R2
Save
Processing parameters
Striation
Impression
Name
Value
angle accuracy
0.1
cut borders after smooth...
extra sub samp
4.0
image subsampling
1.0
index subsampling
5.0
interpolate data
median filt size
10.0
recal
sampling
2000.0
shape noise removal
slope correction
0.0
times median
15.0
use mean
Restore Defaults
Mask layers
Shape
Background
Circle
Circle
Add
Remove
Image size: 2961 x 2909
Selection: 1653 x 1653


Scratch
File Help
Reference
Case
Mark Data
CASE0005
CASE0008
CASE0012
CASE0016
CC Rep 1
CASE0016_W1.1
Breech face impression mar
Processed
CC Rep 1_1
CASE0016_W1.2
Breech face impression mar
Processed
CC Rep 1_2
CASE0020
CASE0023
CASE0041
CASE0044
CASE0058
CASE0068
CASE0085
CASE0101
CASE0106
CASE0123
CASE0130
D1055
D1098
D1110
D1114
D1122
D1167
D1183
D1195
D1204
D1225
D1280
D1300
D1303
D1389
D1495
D1519
D1524
Explore
Analyse
Compare
Compare
Details...
Calculate LR...
Registration parameters
Striation
Impression
Name
Value
cut border after smoothin...
filtertype
lowpass
inclusion threshold
0.5
max scaling
3.0
max translation
0.1
part mark perc
8.0
partial comp brute force
partial profile comp scale ...
1.0
partial profiles eval scales
[[250.0]; [100.0]; [50.0];...
pass
[[250.0]; [100.0]; [50.0];...
remove zeros
Restore Defaults

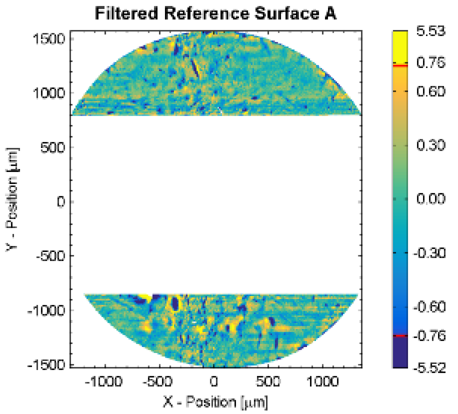
RPDFT

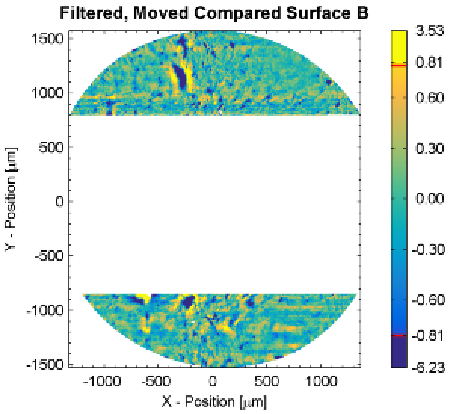
Reference Surface (A)		Compared Surface (B)	
Collection:	**Firearm ID:**	**Collection:**	**Firearm ID:**
Firearm Brand:	**Specimen ID:**	**Firearm Brand:**	**Specimen ID:**

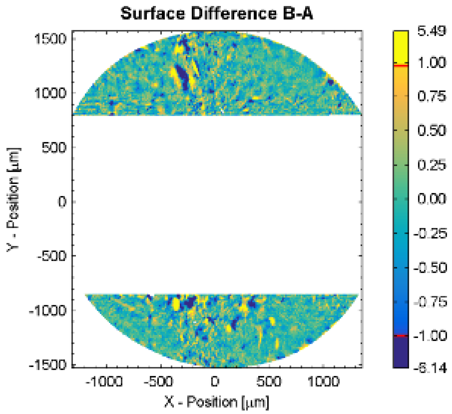




Date comparison:	**2020-10-05**
ROI:	
Correlation Coefficient:	**20.08 %**
Sq(A):	**0.3811 µm**
Sq(B):	**0.4056 µm**
Sq(B-A):	**0.4976 µm**
Sq(B) / Sq(A):	**106.4358 %**
Sign. Diff. DsAB:	**160.23 %**
Overlap:	**94.19 %**
Data spacing (X):	3.5003 µm
Data spacing (Y):	3.5002 µm
Cutoff length low-pass filter:	15 µm
Cutoff length high-pass filter:	250 µm







Scratch, Research only, 2020-04-26

|< << >> >|

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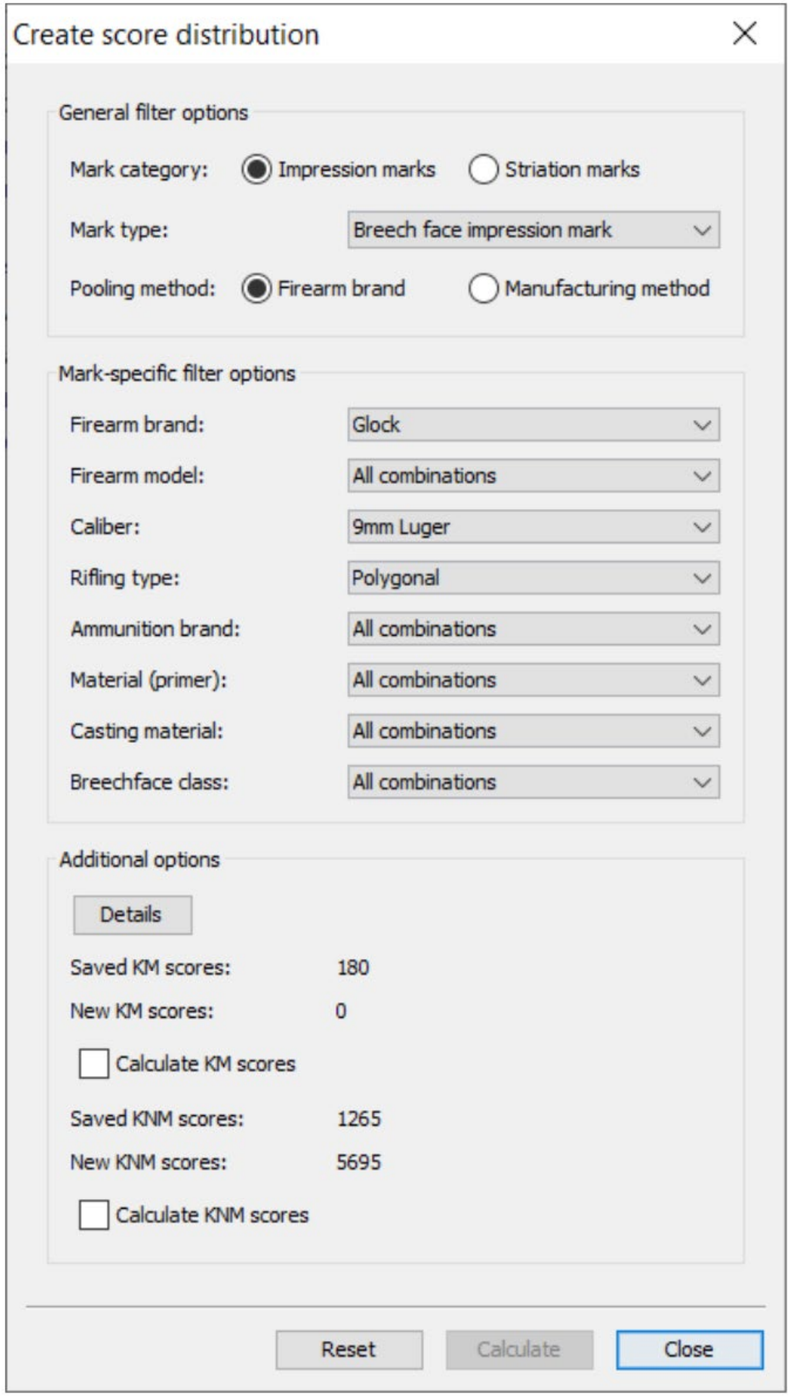
RPDFT



Toolmark Type Selection

Mark Specific Class Characteristics
Firearm and Ammunition

Database statistics for # of KM and KNM based on filter set above

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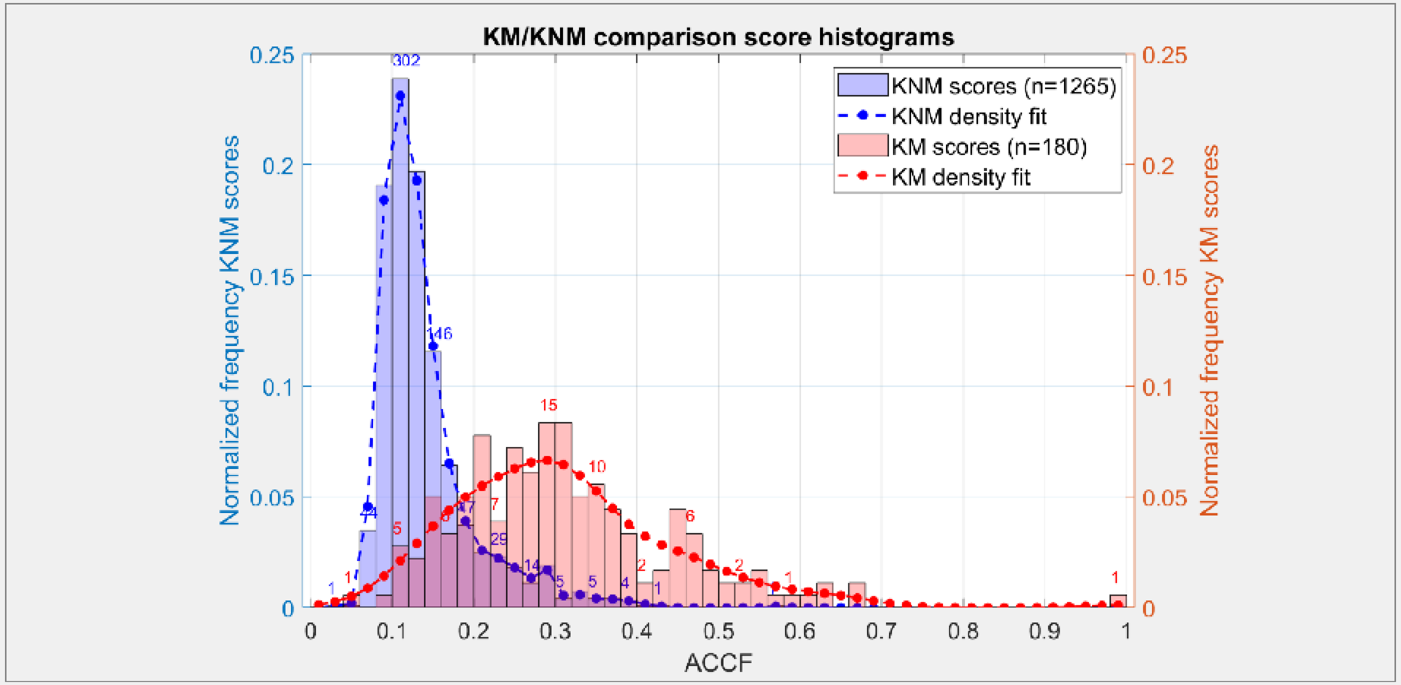
RPDFT

Distribution details



KM Scores
- Histogram
- Bin Counts
- KDE

KNM Scores
- Histogram
- Bin Counts
- KDE

Update

<< >>

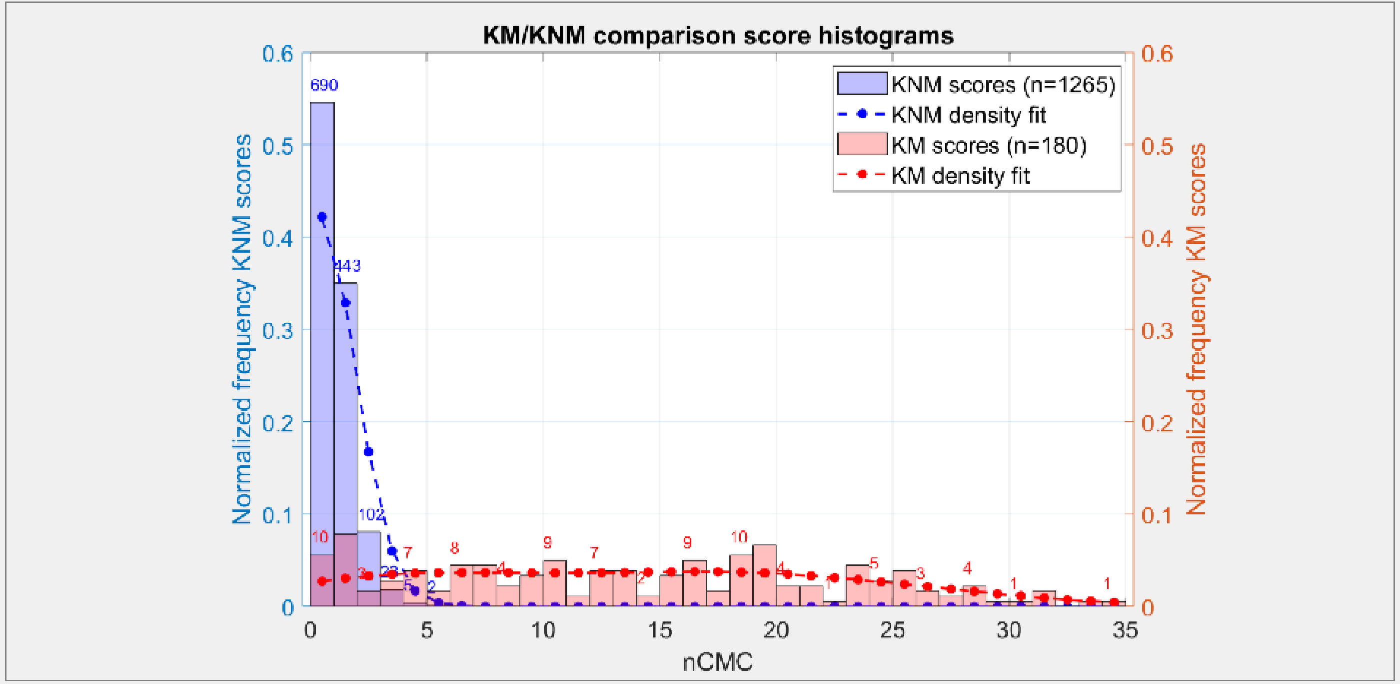
Known Matches | Known Non-Matches

	Reference	Compare	ACCF	nCMC	nCells	Additional values
	0023_amsterdam	0023_amsterdam	66.207	16	31	DsA %: 67.1638, Center Y: 0, Center X: 0, Sku(A): 4.2884, DsAB %: 67.5902, Sku(B): 10.1246, Scale: 1, Overlap...
	0023_amsterdam	0023_amsterdam	27.954	4	31	DsA %: 95.2681, Center Y: 0, Center X: 0, Sku(A): 4.547, DsAB %: 209.3314, Sku(B): 9.3657, Scale: 1, Overlap ...
	0023_amsterdam	0023_amsterdam	31.8	6	31	DsA %: 94.7455, Center Y: 0, Center X: 0, Sku(A): 4.8469, DsAB %: 175.9736, Sku(B): 13.616, Scale: 1, Overlap...
	0023_amsterdam	0023_amsterdam	17.397	0	29	DsA %: 104.9926, Center Y: 0, Center X: 0, Sku(A): 9.1416, DsAB %: 229.6683, Sku(B): 4.5828, Scale: 1, Overla...
	0023_amsterdam	0023_amsterdam	17.838	0	29	DsA %: 107.1557, Center Y: 0, Center X: 0, Sku(A): 9.1629, DsAB %: 214.3541, Sku(B): 14.4177, Scale: 1, Overl...
	0023_amsterdam	0023_amsterdam	27.453	5	32	DsA %: 158.1801, Center Y: 0, Center X: 0, Sku(A): 8.1389, DsAB %: 145.7635, Sku(B): 17.3654, Scale: 1, Overl...
	0066_tilburg	0066_tilburg	37.256	23	28	DsA %: 130.5975, Center Y: 0, Center X: 0, Sku(A): 3.6337, DsAB %: 125.6376, Sku(B): 3.9772, Scale: 1, Overla...
	0066_tilburg	0066_tilburg	28.259	6	28	DsA %: 106.0064, Center Y: 0, Center X: 0, Sku(A): 3.6337, DsAB %: 161.4333, Sku(B): 8.1961, Scale: 1, Overla...
	0066_tilburg	0066_tilburg	29.508	10	28	DsA %: 118.9236, Center Y: 0, Center X: 0, Sku(A): 3.6337, DsAB %: 144.8997, Sku(B): 4.5754, Scale: 1, Overla...
	0066_tilburg	0066_tilburg	33.462	23	40	DsA %: 98.7706, Center Y: 0, Center X: 0, Sku(A): 3.7821, DsAB %: 151.8775, Sku(B): 30.8278, Scale: 1, Overla...

Export Results | Close

RPDFT

Distribution details



KM Scores
- Histogram
- Bin Counts
- KDE

KNM Scores
- Histogram
- Bin Counts
- KDE

Update

<< >>

Known Matches | Known Non-Matches

Reference	Compare	ACCF	nCMC	nCells	Additional values
0023_amsterdam	0023_amsterdam	66.207	16	31	DsA %: 67.1638, Center Y: 0, Center X: 0, Sku(A): 4.2884, DsAB %: 67.5902, Sku(B): 10.1246, Scale: 1, Overlap...
0023_amsterdam	0023_amsterdam	27.954	4	31	DsA %: 95.2681, Center Y: 0, Center X: 0, Sku(A): 4.547, DsAB %: 209.3314, Sku(B): 9.3657, Scale: 1, Overlap ...
0023_amsterdam	0023_amsterdam	31.8	6	31	DsA %: 94.7455, Center Y: 0, Center X: 0, Sku(A): 4.8469, DsAB %: 175.9736, Sku(B): 13.616, Scale: 1, Overlap...
0023_amsterdam	0023_amsterdam	17.397	0	29	DsA %: 104.9926, Center Y: 0, Center X: 0, Sku(A): 9.1416, DsAB %: 229.6683, Sku(B): 4.5828, Scale: 1, Overla...
0023_amsterdam	0023_amsterdam	17.838	0	29	DsA %: 107.1557, Center Y: 0, Center X: 0, Sku(A): 9.1629, DsAB %: 214.3541, Sku(B): 14.4177, Scale: 1, Overl...
0023_amsterdam	0023_amsterdam	27.453	5	32	DsA %: 158.1801, Center Y: 0, Center X: 0, Sku(A): 8.1389, DsAB %: 145.7635, Sku(B): 17.3654, Scale: 1, Overl...
0066_tilburg	0066_tilburg	37.256	23	28	DsA %: 130.5975, Center Y: 0, Center X: 0, Sku(A): 3.6337, DsAB %: 125.6376, Sku(B): 3.9772, Scale: 1, Overla...
0066_tilburg	0066_tilburg	28.259	6	28	DsA %: 106.0064, Center Y: 0, Center X: 0, Sku(A): 3.6337, DsAB %: 161.4333, Sku(B): 8.1961, Scale: 1, Overla...
0066_tilburg	0066_tilburg	29.508	10	28	DsA %: 118.9236, Center Y: 0, Center X: 0, Sku(A): 3.6337, DsAB %: 144.8997, Sku(B): 4.5754, Scale: 1, Overla...
0066_tilburg	0066_tilburg	33.462	23	40	DsA %: 98.7706, Center Y: 0, Center X: 0, Sku(A): 3.7821, DsAB %: 151.8775, Sku(B): 30.8278, Scale: 1, Overla...

Export Results | Close

NIST FORENSIC SCIENCES

Milestones

RPDFT

- **Test Database Population**
  - Initial target populations will only include Glock and Ruger firearms.
  - Currently there are 393 Glock, 314 Ruger Firearms entered into the database.
- **Data Pre-Processing and Ground Truth Correlations**
  - Approximately 80% of the data has been trimmed and filtered, ready for correlations.
  - Over 3000 KM scores can be generated. A subset of the total # of KNM scores will be used.
- **Statistics**
  - NIST, FBI, and NFI statisticians have had an initial meeting to discuss strategies for statistical model fits, LR calculations, and given sample data.
  - Nien-fan Zhang and James Yen at NIST are currently conducting tests on the sample data.

Future Milestones

RPDFT

- **Complete software development**
  - Complete implementation of requirements in the software development process.
  - Testing and validation of routines and results.
  - Implement full statistical reporting package.

- **Reference Database population**
  - Conduct reference population measurements at the FBI.
  - Implement a full QA protocol for their 3D instrument.

- **Parameter Optimization**
  - Optimize correlation and analysis parameters to suit sub-populations.

- **Pilot test at FBI**
  - The completed RPDFT system will be pilot tested at the FBI using old case work and proficiency test sets.
  - Pilot RPDFT with FBI web portal for external laboratories to gain access.

Questions?

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Johannes Soons (NIST) johannes.soons@nist.gov

Erich Smith (FBI) edsmith2@fbi.gov

Martin Baiker (NFI) m.baiker@nfi.nl

Digital Preservation of the President John F. Kennedy Assassination Bullet Artifacts

Project Team: Robert M. Thompson, T. Brian Renegar, Michael Stocker, Alan Zheng, Johannes Soons

**Certain commercial equipment, instruments, or materials are identified in this presentation in order to specify the experimental procedures adequately.
Such identification is not intended to imply recommendation or endorsement by the National Institute of Standards and Technology, nor is it intended to imply that the materials or equipment identified are necessarily the best available for the purpose.**

Overview

- Project background (What was needed? Why NIST?)
- Phase 1
  - Photography
  - 3D LEA/GEA Scans (Confocal)
- Phase 2
  - 3D surface scans (Focus Variation)
  - Complete 3D Surface Models including surface color
- Phase 3
  - Data Processing and Merging
  - Transfer to NARA
- Preview of 3D Surface Models

Project Motivation

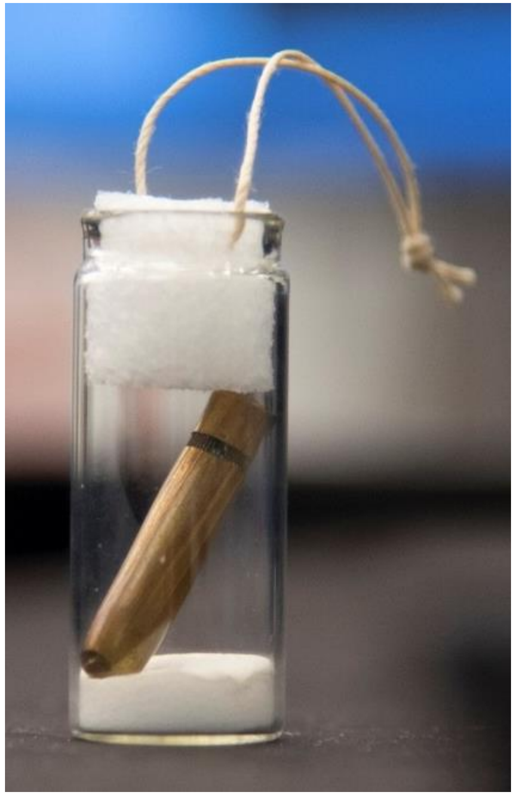
National Archives and Records Administration (NARA) receives numerous requests for access to the physical JFK assassination artifacts

1. **Digitally preserve the artifacts (56 years old!)**
2. **Facilitate access to the general public**

NARA, College Park, MD

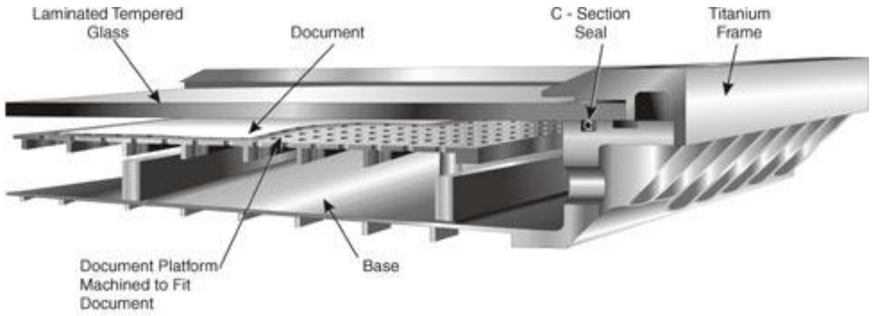
NATIONAL ARCHIVES

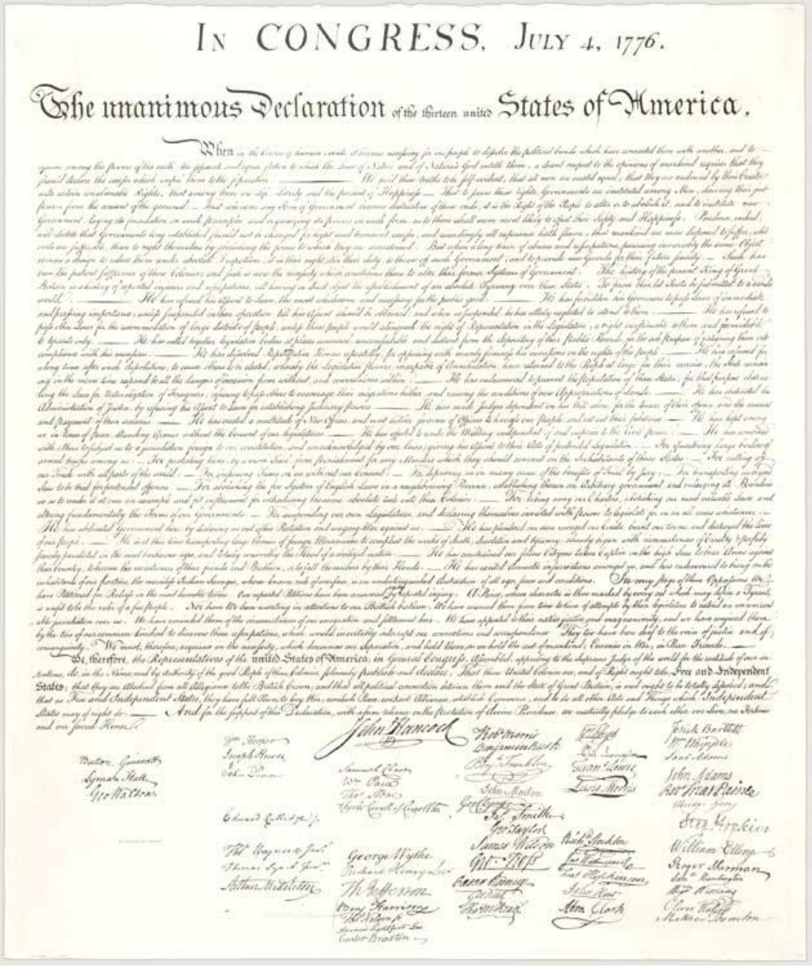
Several JFK artifacts in their protective case



CE399 (Stretcher Bullet)

NIST Technology in Artifact Preservation



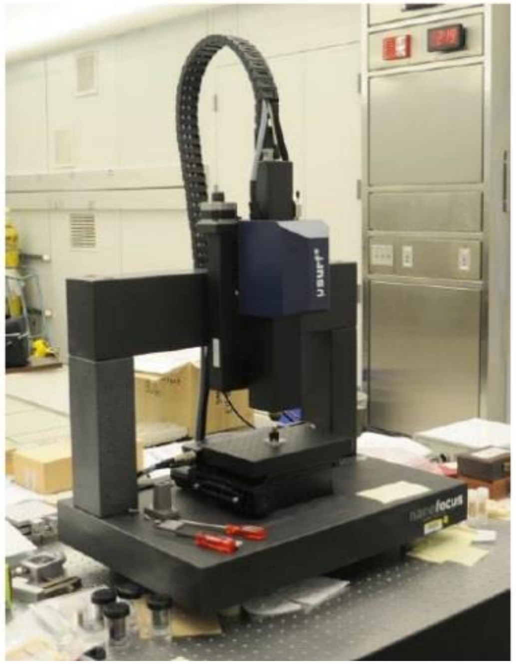

IN CONGRESS, JULY 4, 1776.

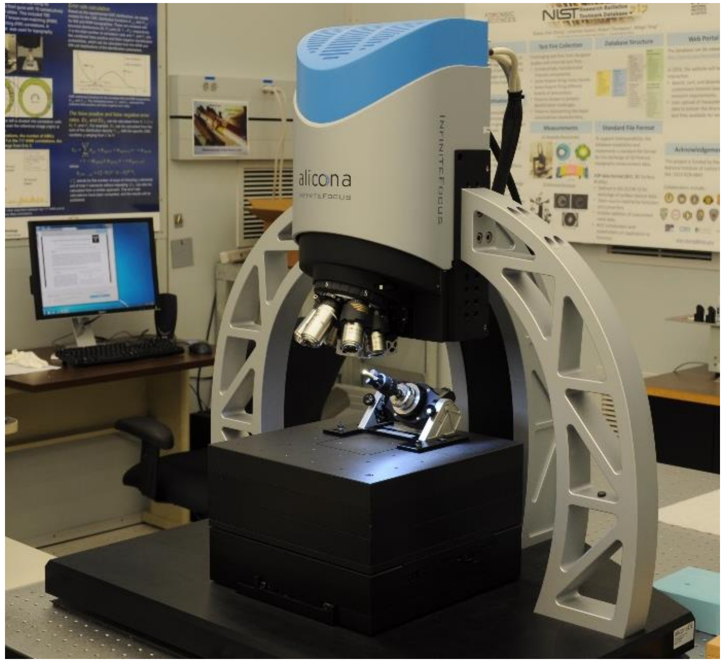
The unanimous Declaration of the thirteen united States of America,

NIST FORENSIC SCIENCES

NIST Technology in Artifact Preservation

- State of the art 3D surface imaging microscopes
  - Confocal
  - Focus Variation
- Expertise in surface topography measurements
- Expertise in Forensic Science


NanoFocus µsurf - Confocal

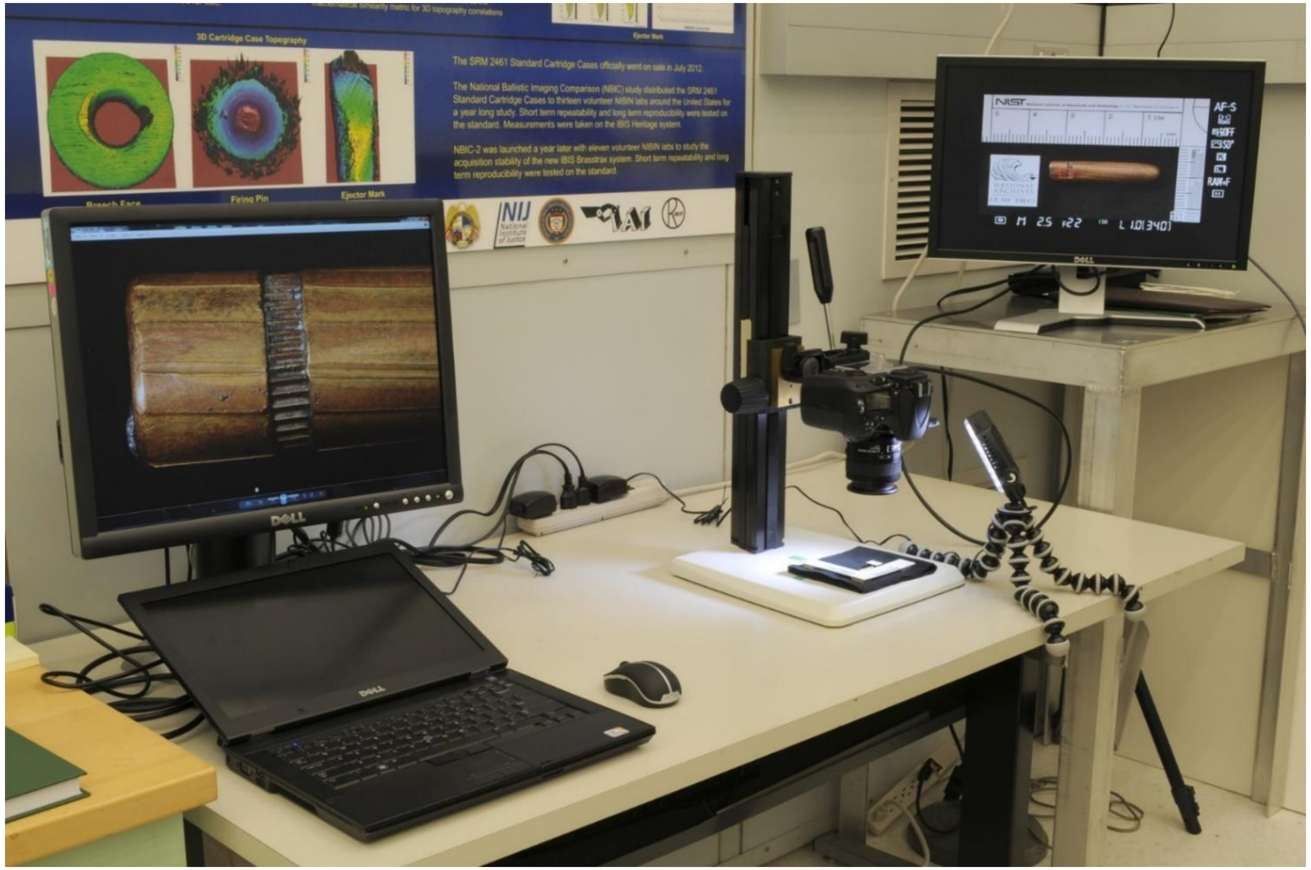


Alicona Infinite Focus G5 – Focus Variation

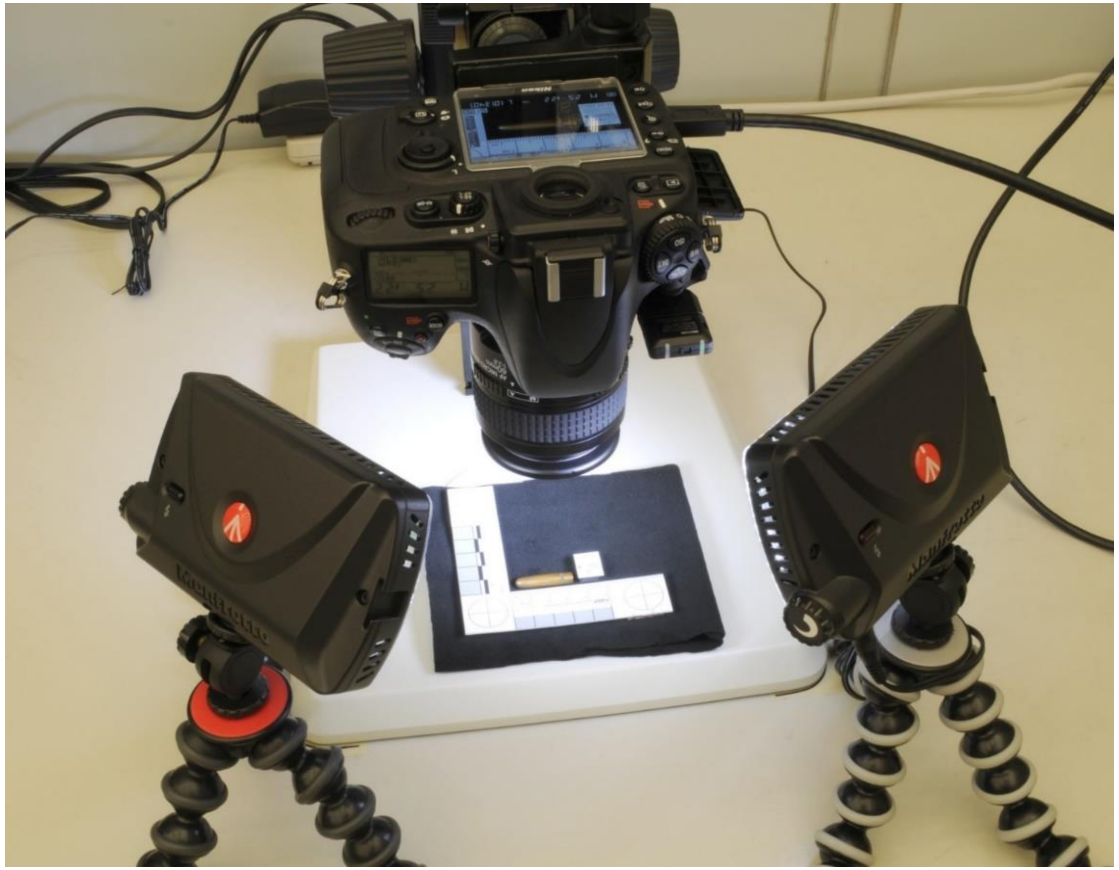
Phase 1 (2013 - 2014)

- **Scans of 6 bullet/fragment artifacts**
- **Digital Photography**
- **Film “analog” Photography**
- **Confocal Microscopy**
  - **3D Scans of forensically relevant areas - Land Engraved Areas/Groove Engraved Areas (LEA/GEA)**

Digital Camera Setup



- Captured image review station (left)
- Camera setup on microscope stand (center)
- Live video feed from camera (right)



Overhead view of camera station

Camera Setup

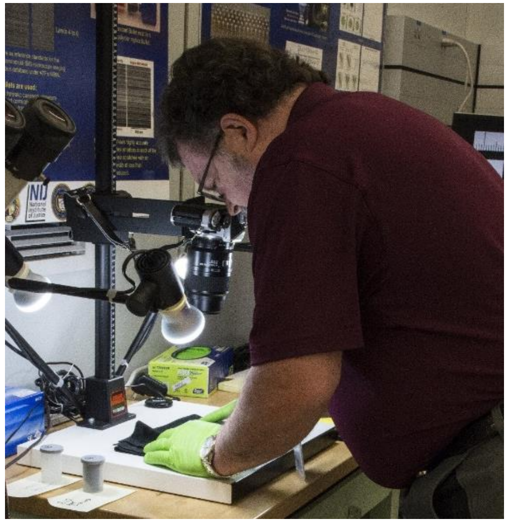
Digital Photography (Renegar)

Camera	Nikon D800 (36 Megapixel) – FX Full Frame mode
White Balance	Manual - 5560K
ISO	100
Lens	Nikon AF Micro-Nikkor 60 mm, f/2.8
Exposure Mode	Manual
Release	Electronic Remote Trigger
Mount	Copy stand (microscope mount)
Lighting	LED arrays
Image format	High res JPG & Raw (.NEF)

Renegar w/ digital setup

Film Photography (Thompson)

Camera	Nikon FE
Film	Kodak Ektar 100
ISO	100
Lens	Nikon AF Micro-Nikkor 105 mm, f/2.8
Exposure	f/11 at 1/4 sec - 1/8 sec
Lighting	(4) Flood; Daylight Spectrum



Thompson w/ film setup

Procedure for Digital Photography

- Each day Color & Grayscale Calibration

- Calibrated X-Y scale bars in all shots, NIST & NARA logos

- Photograph each artifact from each position/orientation
  - Pristine bullets
    - All 4 LEAs and 4 GEAs photographed
      (Scribe marks from previous forensic examiners are visible!)
    - Nose & Base
  - Fragments
    - Top and bottom photographed
    - Different focal planes taken to capture all features

Over 375 images captured

- Exposure bracketing (EV)
  - up to 5 shots each pose (-0.7, -0.3, 0, +0.3, +0.7)

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Assassination Ballistic Artifacts

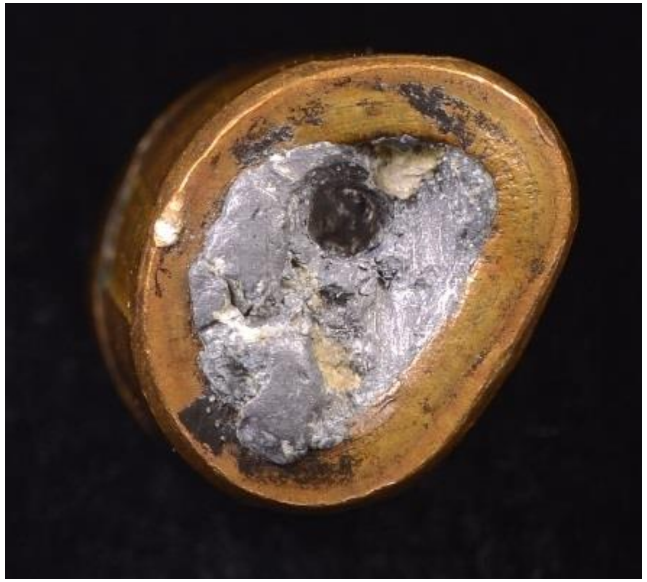


Exhibit #	Description
CE399	**"Stretcher Bullet"**
CE567	Nose fragment recovered from Presidential vehicle
CE569	Base fragment recovered from Presidential vehicle
CE572-A	Test Fire from recovered Carcano 6.5mm rifle
CE572-B	Test Fire from recovered Carcano 6.5mm rifle
CE573	"Walker Bullet" recovered from General Walker's house

Assassination Ballistic Artifacts

Exhibit #	Description
CE399	"Stretcher Bullet"
CE567	**Nose fragment recovered from Presidential vehicle**
CE569	Base fragment recovered from Presidential vehicle
CE572-A	Test Fire from recovered Carcano 6.5mm rifle
CE572-B	Test Fire from recovered Carcano 6.5mm rifle
CE573	"Walker Bullet" recovered from General Walker's house

Assassination Ballistic Artifacts

<u>Exhibit #</u>	<u>Description</u>
CE399	“Stretcher Bullet”
CE567	Nose fragment recovered from Presidential vehicle
CE569	**Base fragment recovered from Presidential vehicle**
CE572-A	Test Fire from recovered Carcano 6.5mm rifle
CE572-B	Test Fire from recovered Carcano 6.5mm rifle
CE573	“Walker Bullet” recovered from General Walker’s house

Assassination Ballistic Artifacts

Exhibit #	Description
CE399	"Stretcher Bullet"
CE567	Nose fragment recovered from Presidential vehicle
CE569	Base fragment recovered from Presidential vehicle
CE572-A	**Test Fire from recovered Carcano 6.5mm rifle**
CE572-B	**Test Fire from recovered Carcano 6.5mm rifle**
CE573	"Walker Bullet" recovered from General Walker's house

Assassination Ballistic Artifacts

Exhibit #	Description
CE399	"Stretcher Bullet"
CE567	Nose fragment recovered from Presidential vehicle
CE569	Base fragment recovered from Presidential vehicle
CE572-A	Test Fire from recovered Carcano 6.5mm rifle
CE572-B	Test Fire from recovered Carcano 6.5mm rifle
CE573	**"Walker Bullet" recovered from General Walker's house** (7 months prior to JFK assassination)

CE399 “Stretcher Bullet”

NIST image 2013

Current image of CE399 available to public on several internet sites (NARA image, circa 1985)

CE399 “Stretcher Bullet”

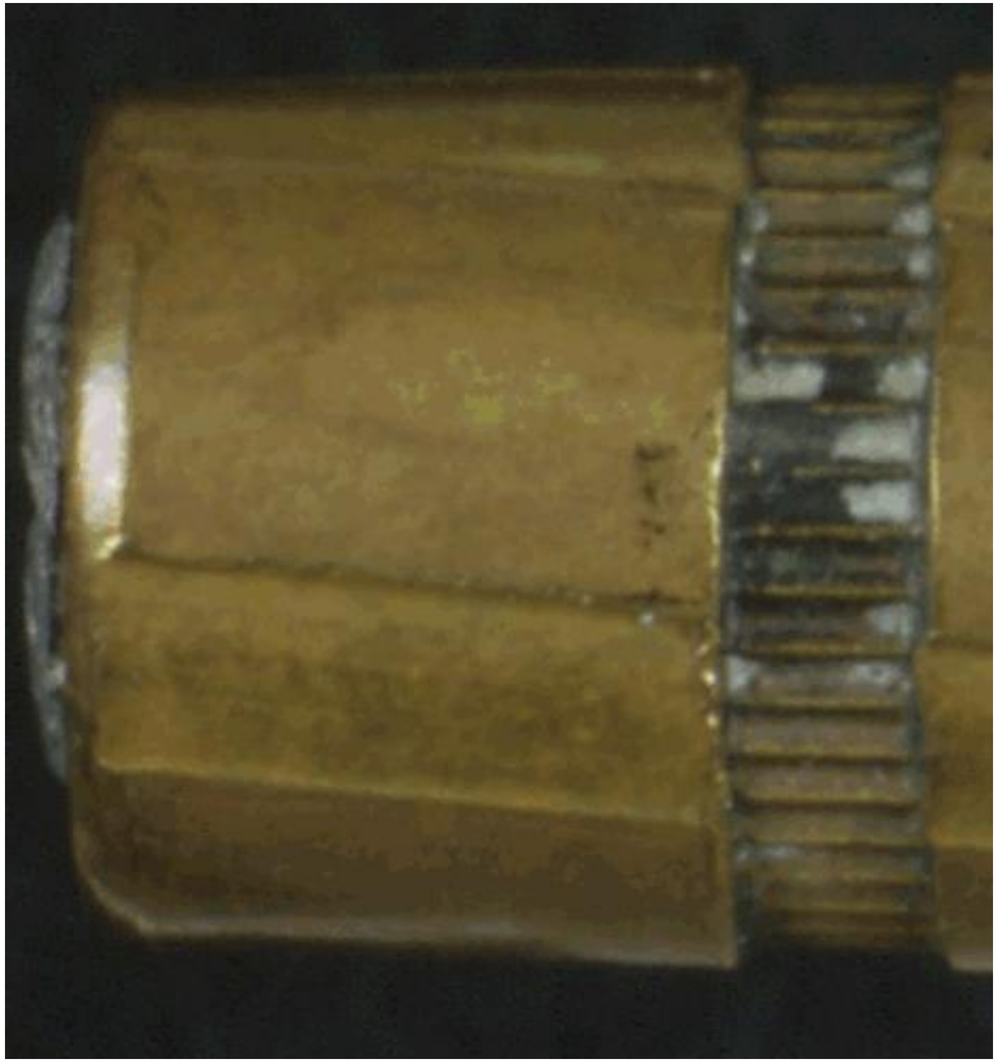
NIST image (Digital capture, 2013)

Existing NARA image (Film/scanned, 1985)

CE399 “Stretcher Bullet”

Close-up showing level of detail

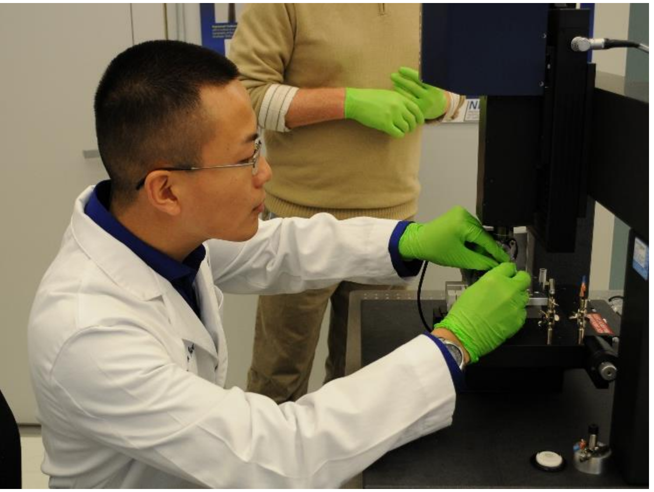
NIST (2013)



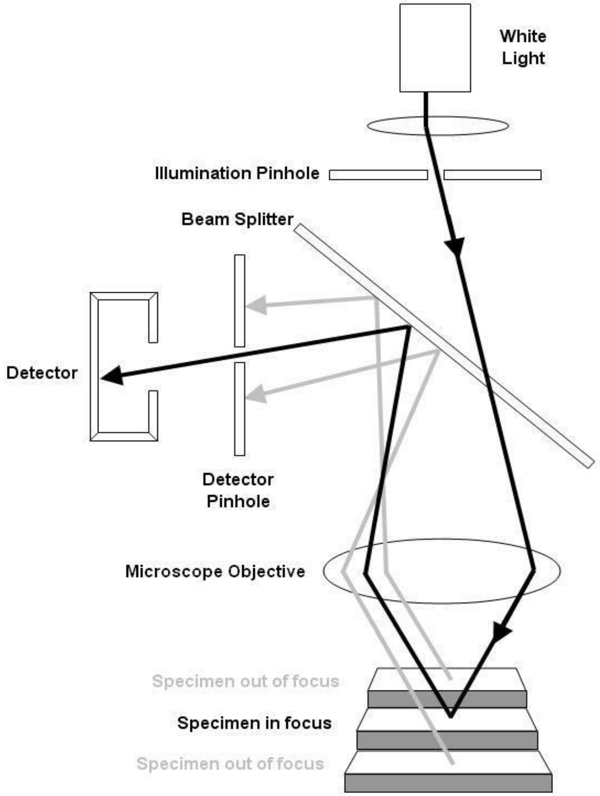
NARA (1985)

3D Scans of Forensically Relevant Areas – Confocal Microscopy

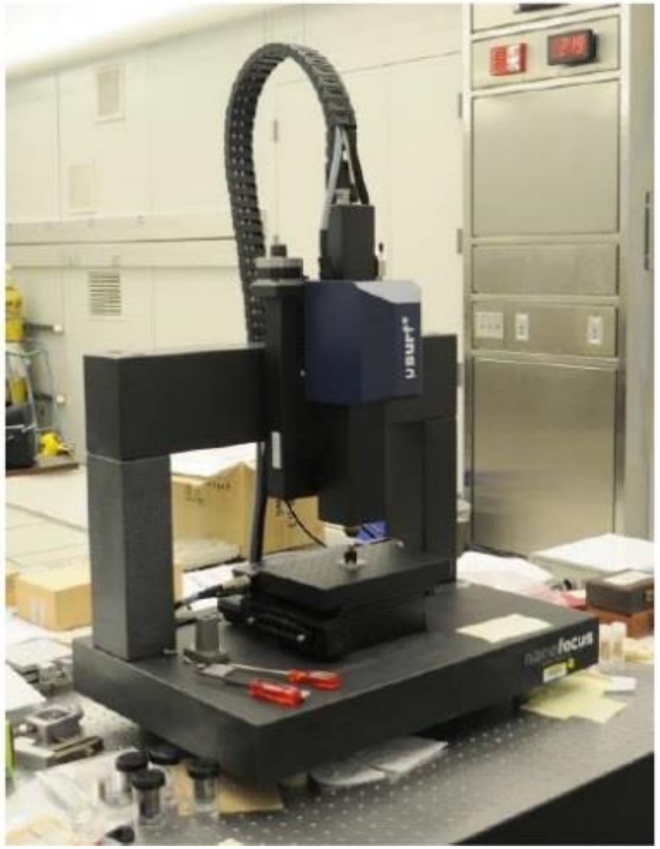
- Objective is scanned vertically through focus. Image "Slices" are captured at specific intervals.
- Pinhole apertures are used to reject out of focus light
- Computer calculates Z height of each pixel based on intensity distribution through slices.



Zheng mounting CE572-A for measurement on confocal microscope



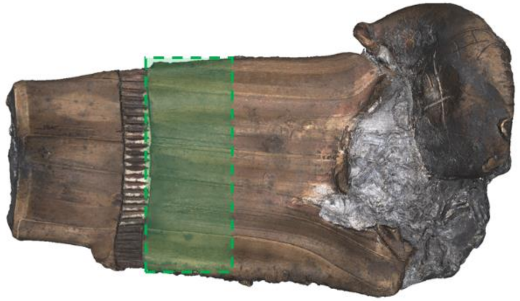
ASME B46.1-2019



NanoFocus µsurf Disc-scanning confocal

3D Scans of Forensically Relevant Areas – Confocal Microscopy

Shaded areas indicate regions that were scanned



CE399 (stretcher)
CE572-A (test fire)
CE572-B (test fire)

CE567 (nose frag)

CE569 (base frag)

CE573 (walker)

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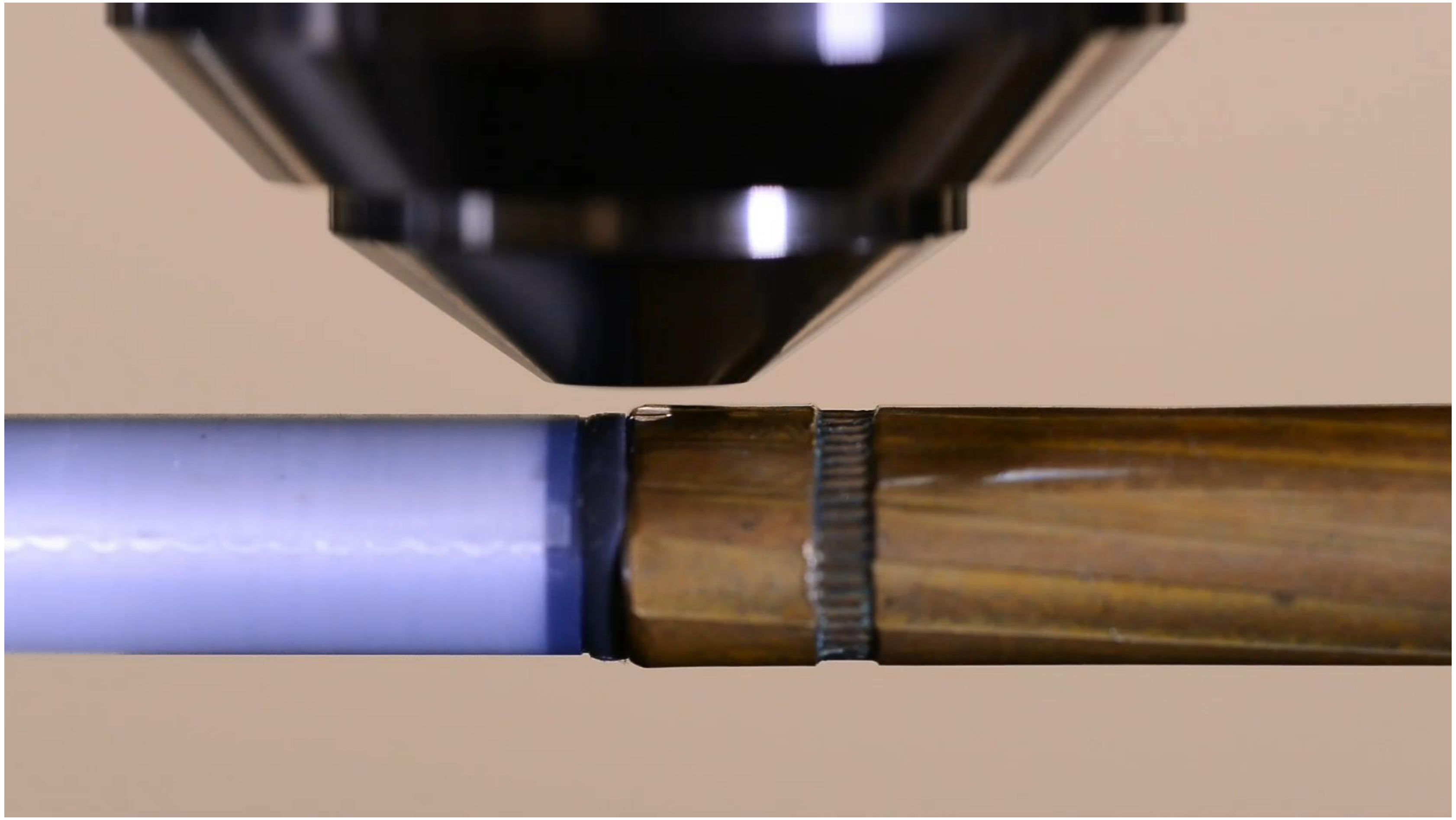
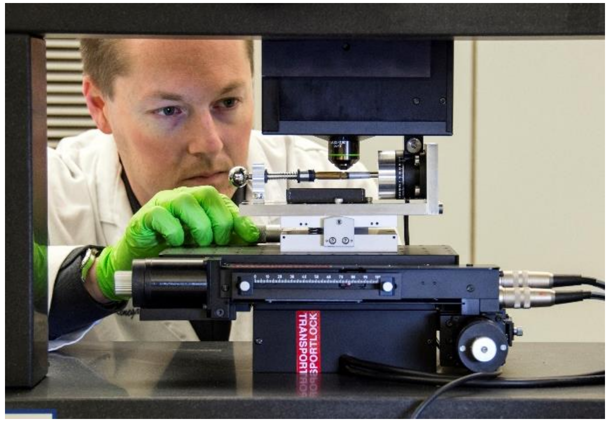
3D Scans of Forensically Relevant Areas – Confocal Microscopy

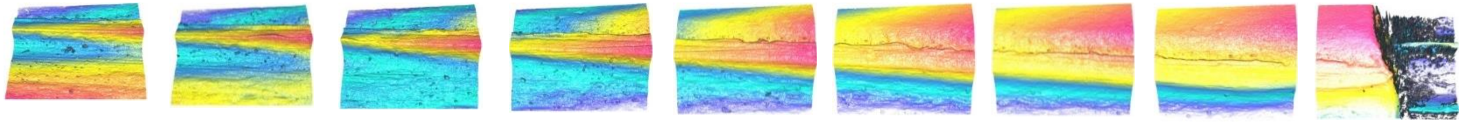
Time-lapse of CE399 Measurement Strip: 9 images stitched together – 32X Speed



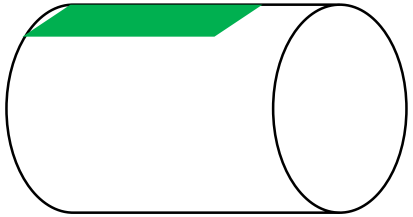
Rotary Stage Animation

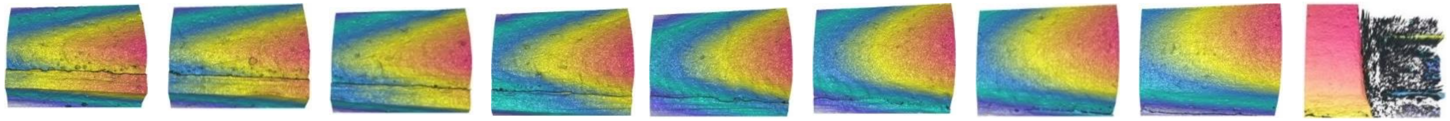


Renegar aligning CE399 for measurement

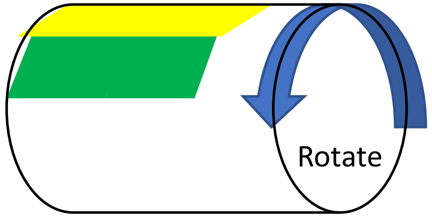


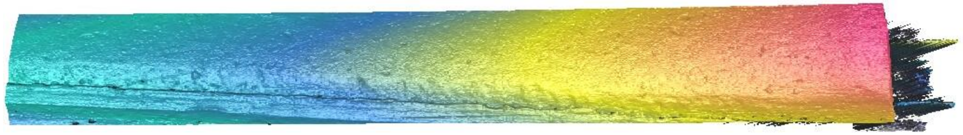
Position 1 Complete



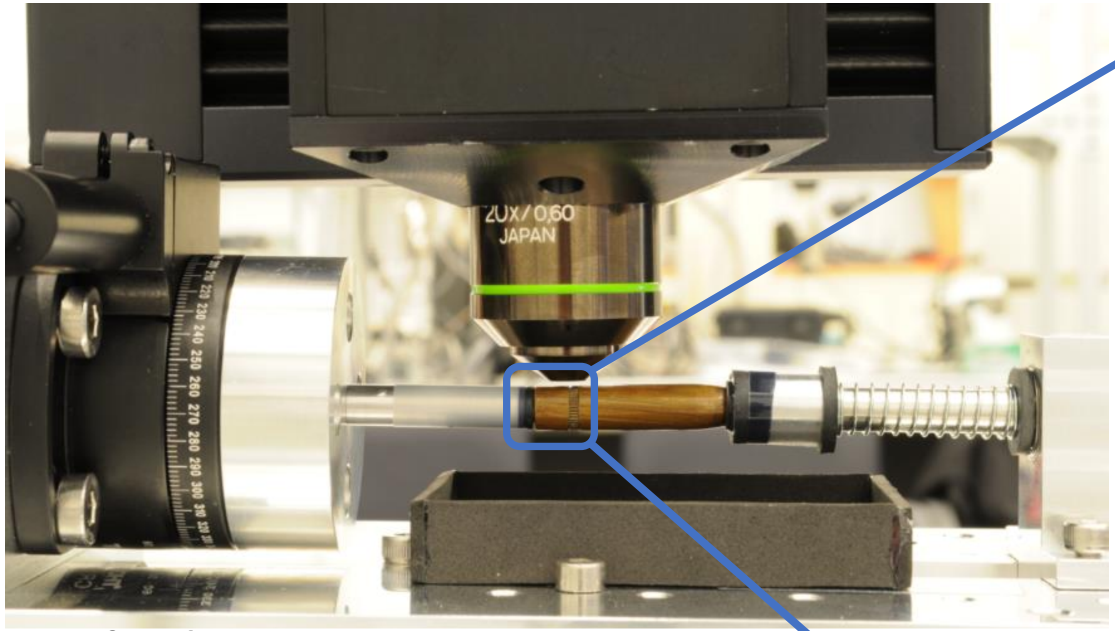


Position 2 Complete

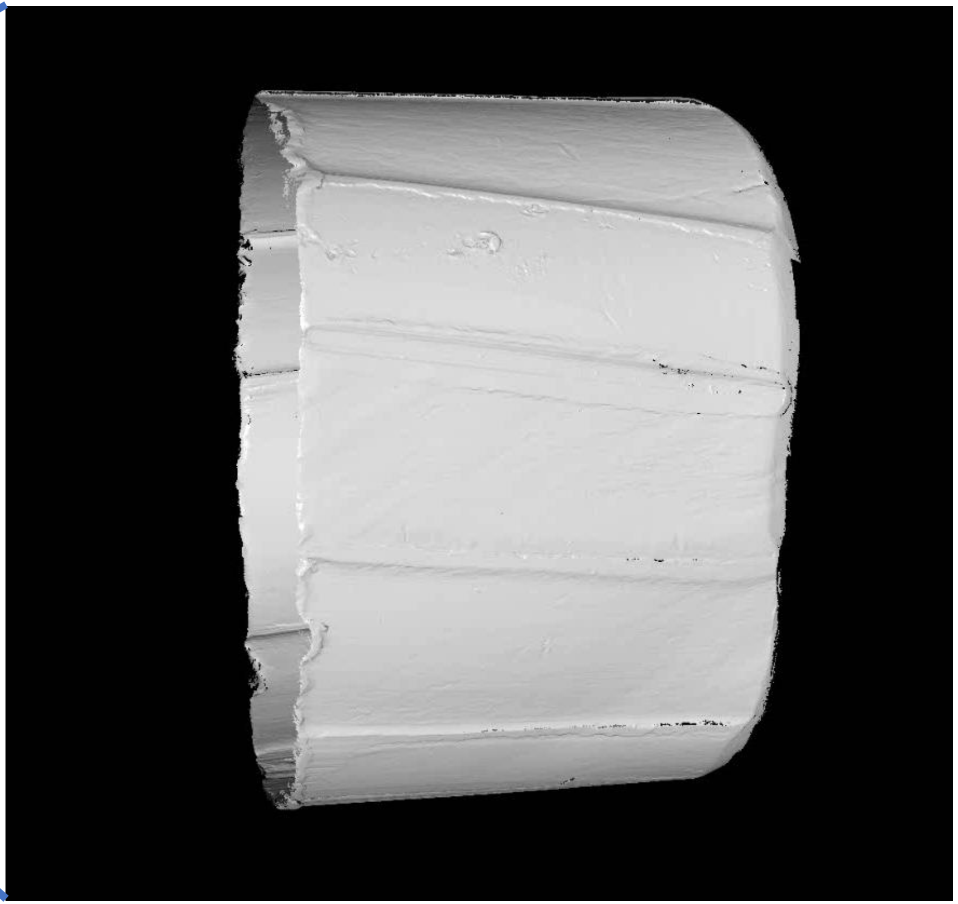




3D Scans of Forensically Relevant Areas – Confocal Microscopy



Confocal microscope scanning CE399



3D Render of CE399 after merge

20X Objective	
CE399	(stretcher)
CE572-A	(test fire)
CE572-B	(test fire)
CE573	(walker)

10X Objective	
CE567	(nose frag)
CE569	(base frag)

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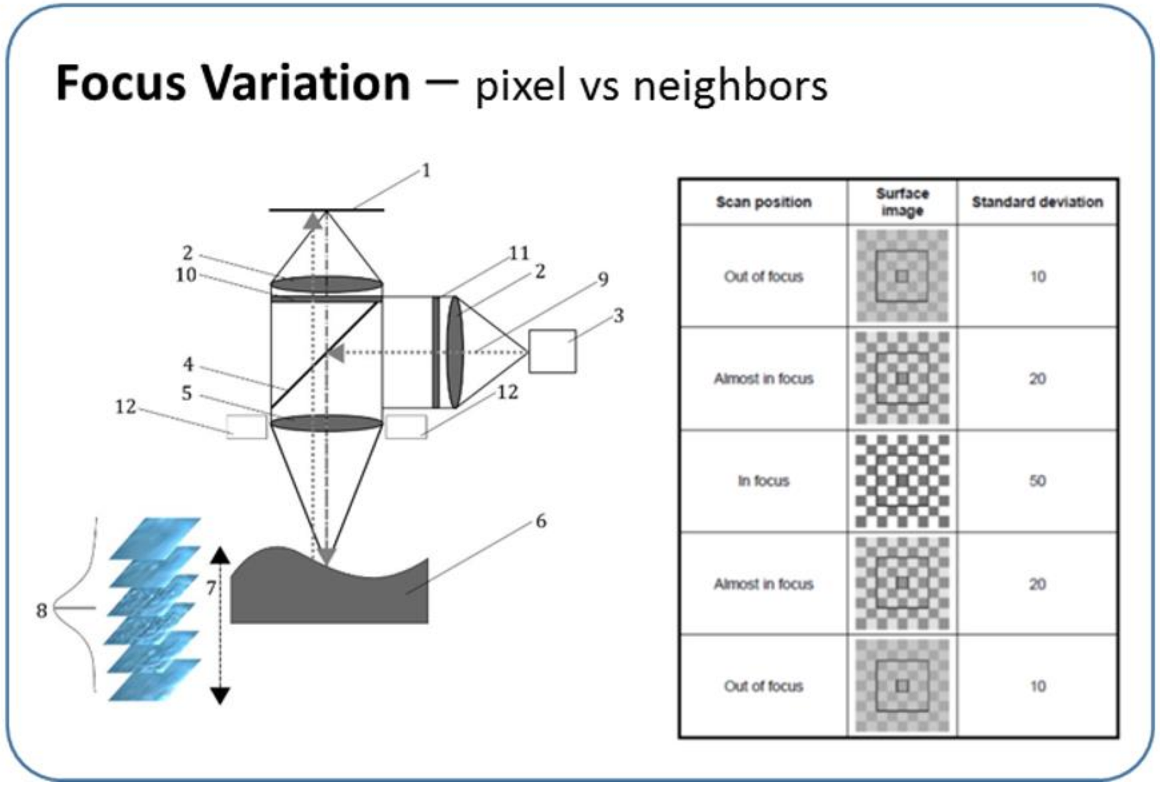
Phase 2 (2015 – 2016)

- **Worked with CE399, CE567, CE569, and CE573**
- **Focus Variation Microscopy**
  - **Complete 3D Surface Models**
  - **Surface color information**

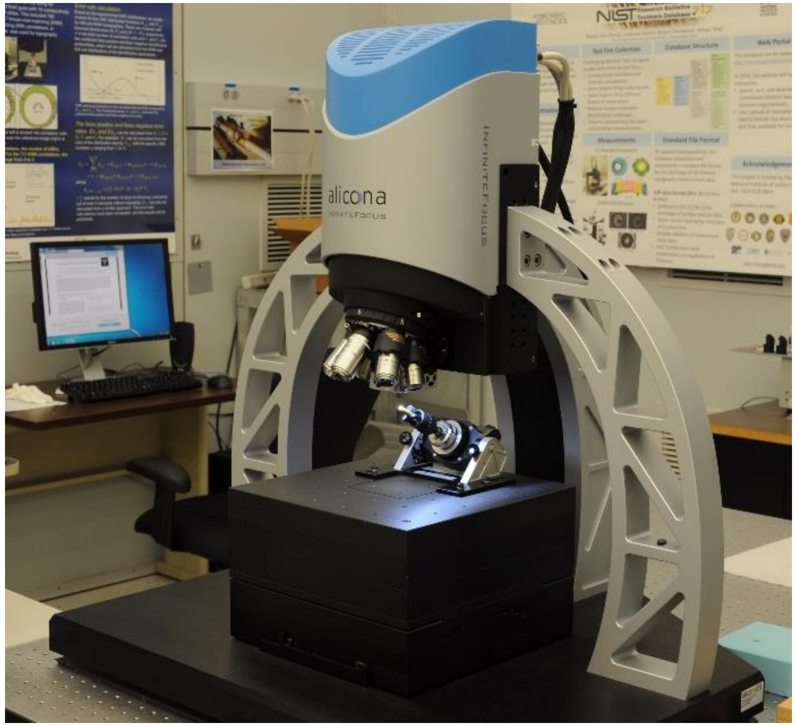
Instrumentation

Focus variation topography microscopes collect through-focus data and analyze pixel positions to determine where they were in best focus, enabling a 3D surface to be generated.



Schematic diagram of a measurement device based on focus variation: (1) CCD sensor, (2) lenses, (3) white light source, (4) semi-transparent mirror, (5) objective lens with limited depth of field, (6) sample, (7) vertical movement with driving unit, (8) contrast curve calculated from the local window, (9) light rays from the white light source, (10) optional analyser, (11) optional polarizer and (12) optional ring light

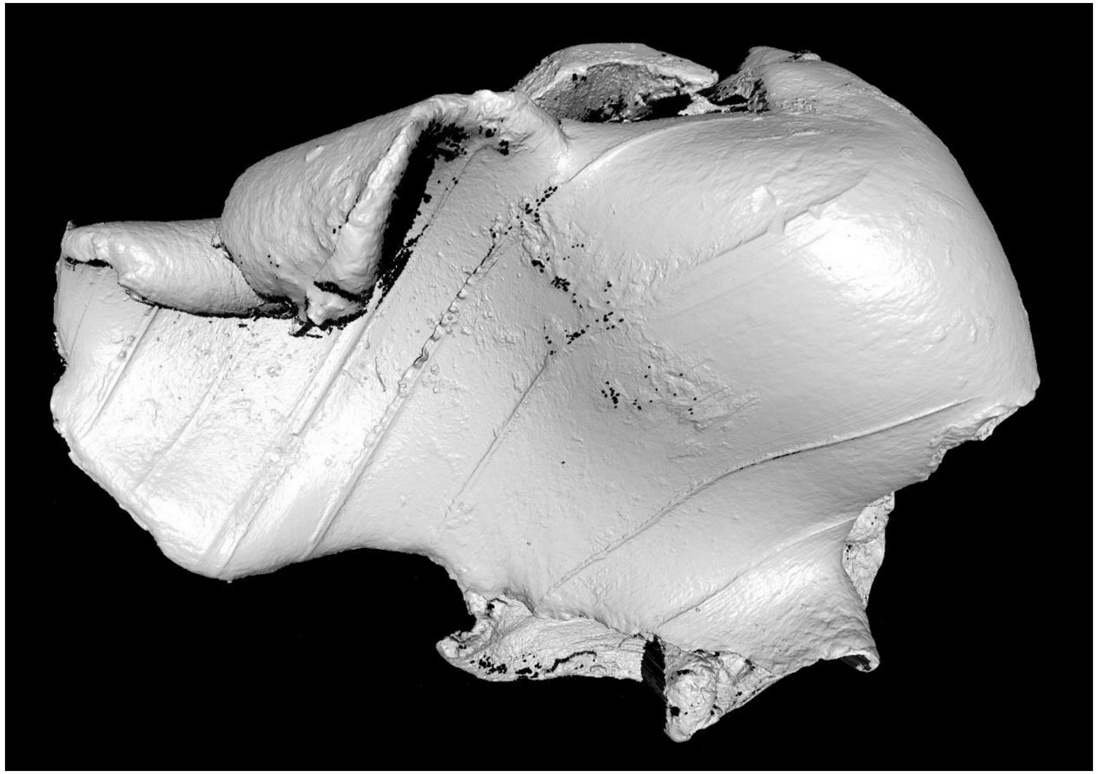
Alicona InfiniteFocus G5



Topography vs Color Information

The focus variation method gave us the ability to acquire accurate topography in addition to capturing color information from the surface

CE567 - 3D Topography Data



CE567 - Surface Color Information

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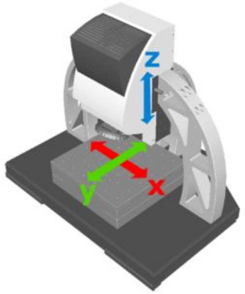
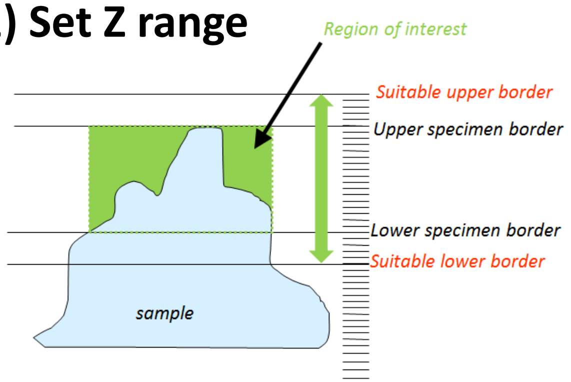
Image Field Measurements – Focus Variation

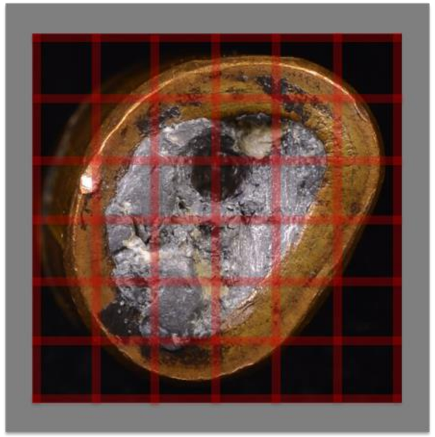


Measurements performed in the XY plane

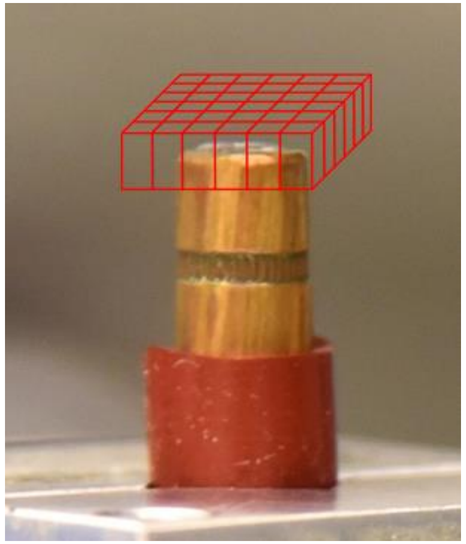
1) Set Z range



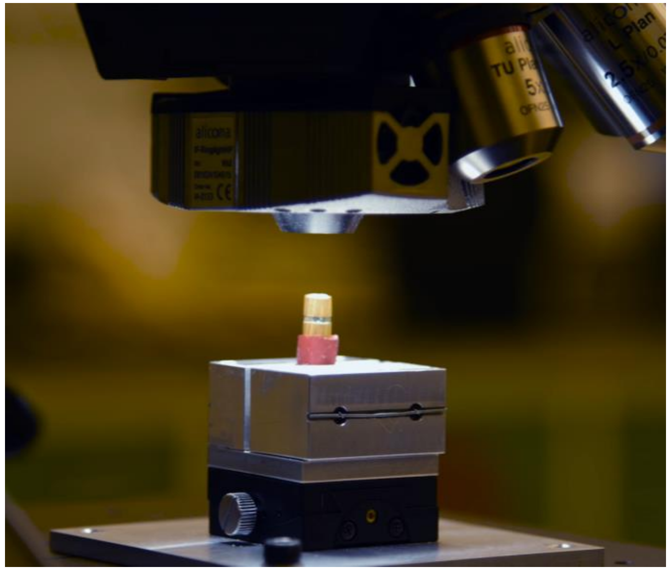
2) Set XY range



Results in an array of through focus data acquisitions



Time-lapse of an image field acquisition



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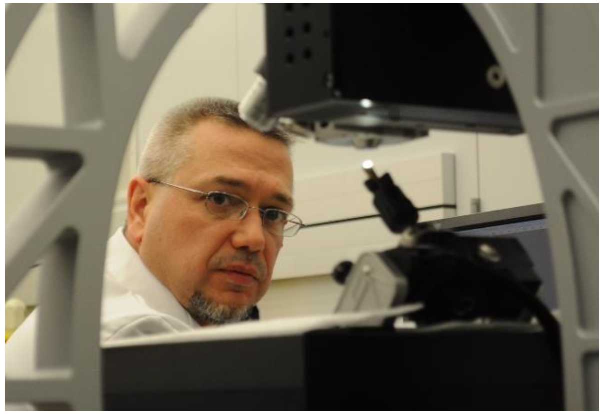
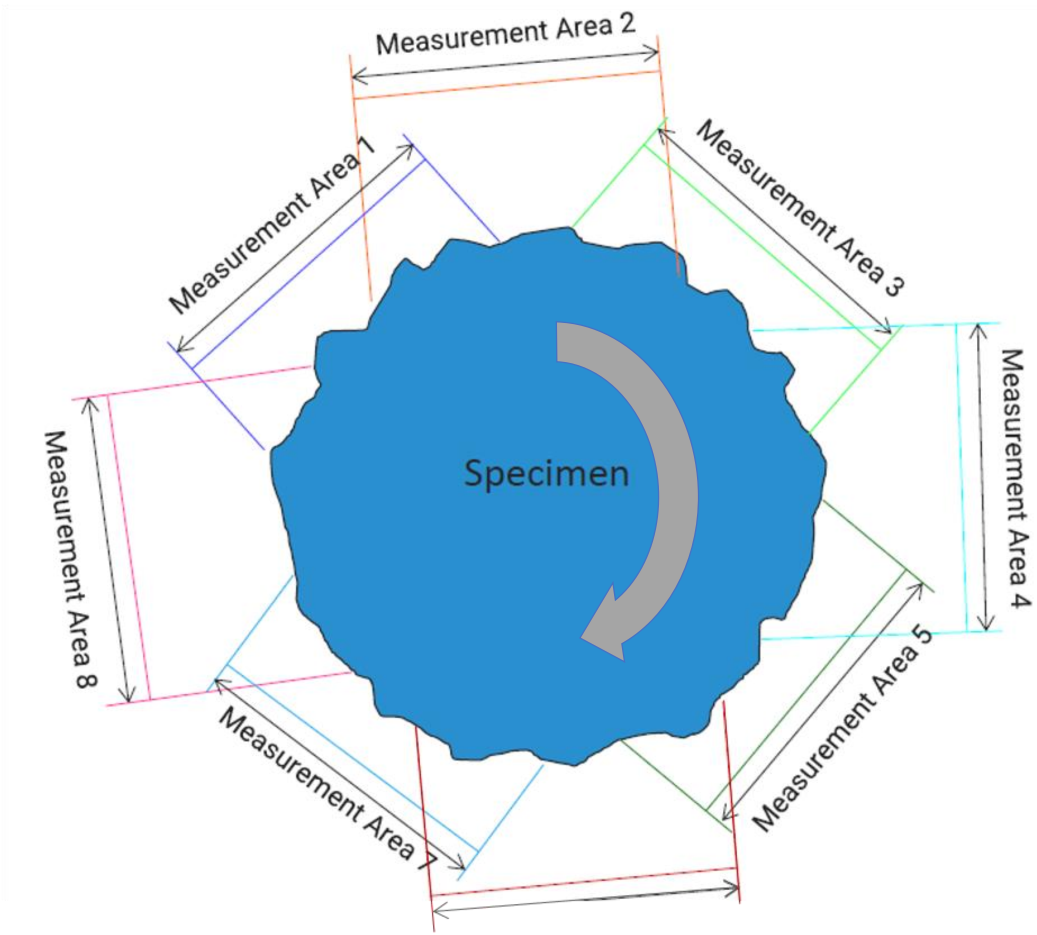
Real3D Rotation Measurements – Focus Variation

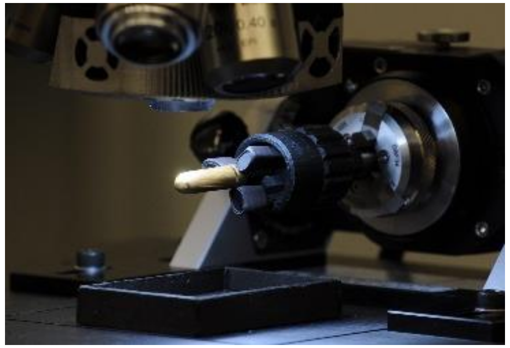


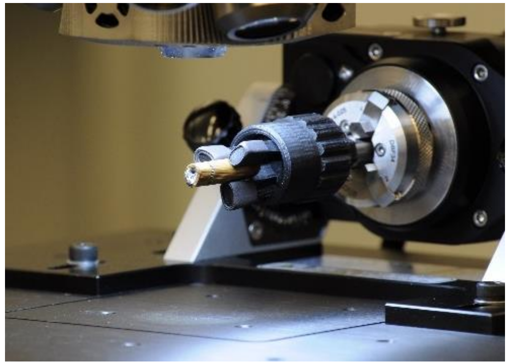
Stocker measuring CE399 on focus variation microscope

Measurements performed utilizing rotary axis



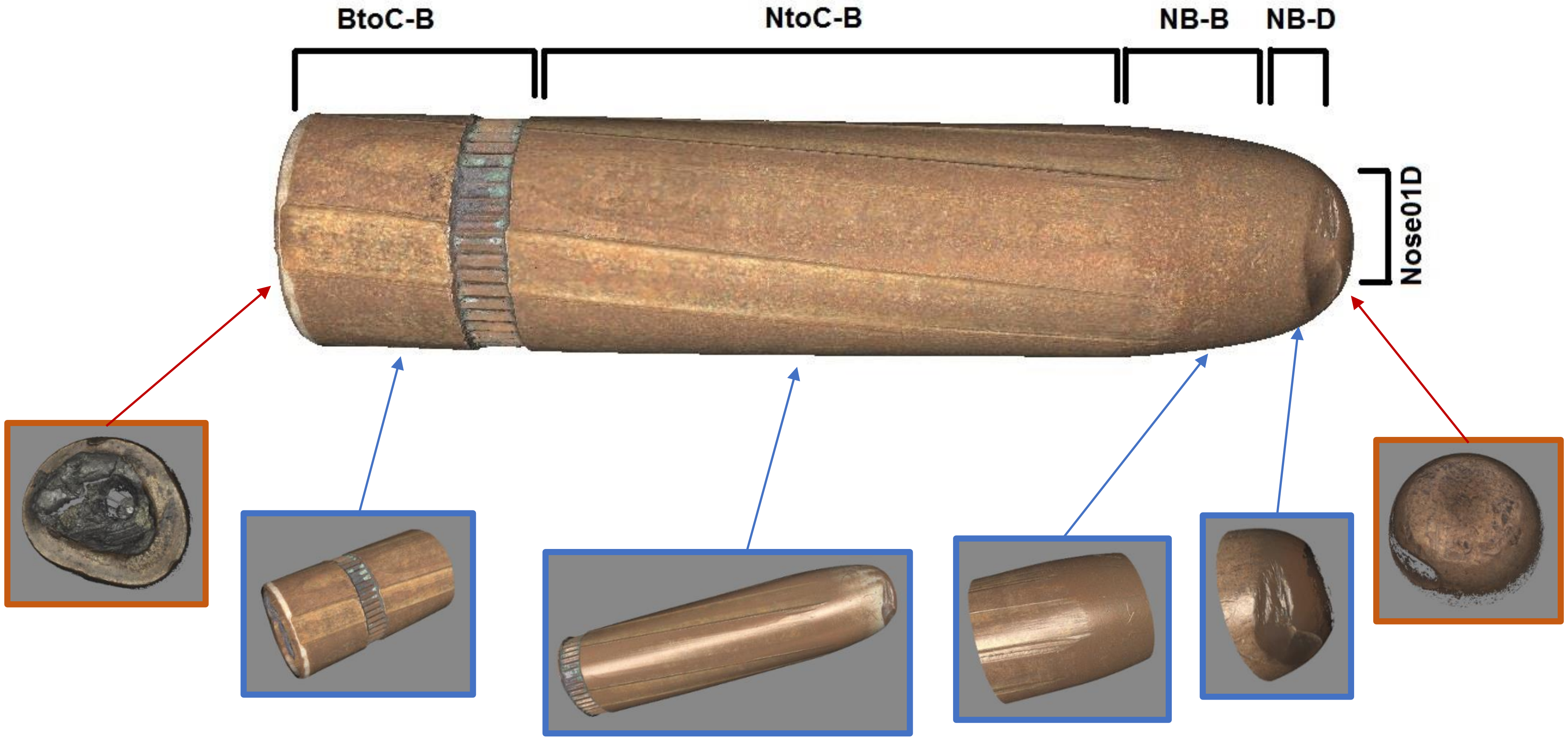
CE399 in different orientations





CE399 Measurement Plan

Building CE399 model with image field and rotary stage measurements

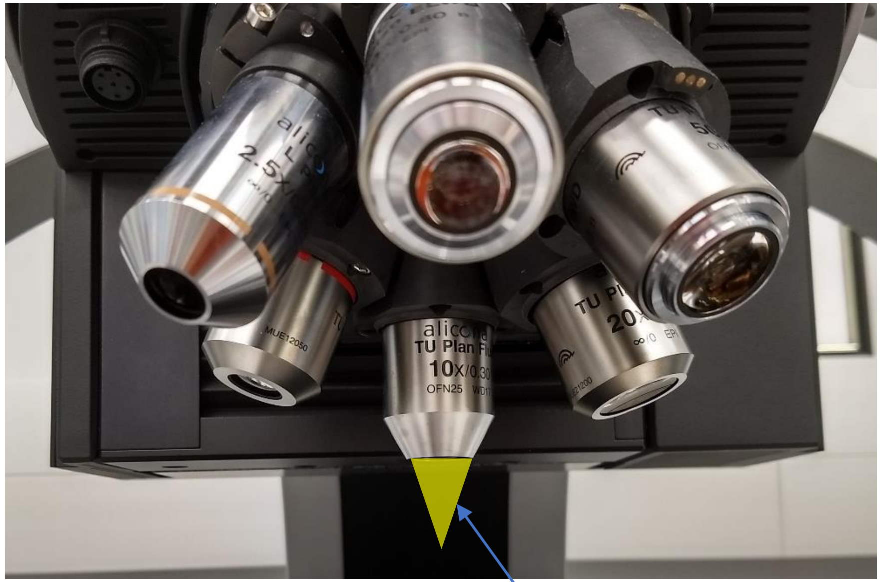


- Image Field Measurements

- Real3D Rotary Stage Measurements

Illumination modes

Coaxial Illumination



Coaxial produces a cone of illumination that comes through the microscope objective

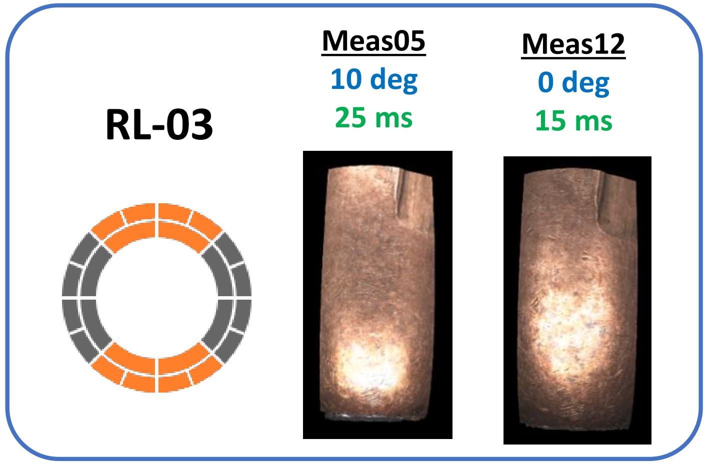
Ring Light Illumination

Ring light produces an annular ring of illumination that comes in at a shallower angle. (Also segmentable)

Illumination modes

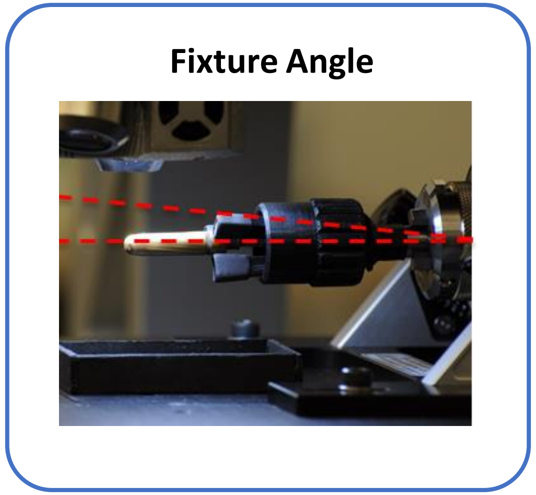
Geometry related intensity hot spots

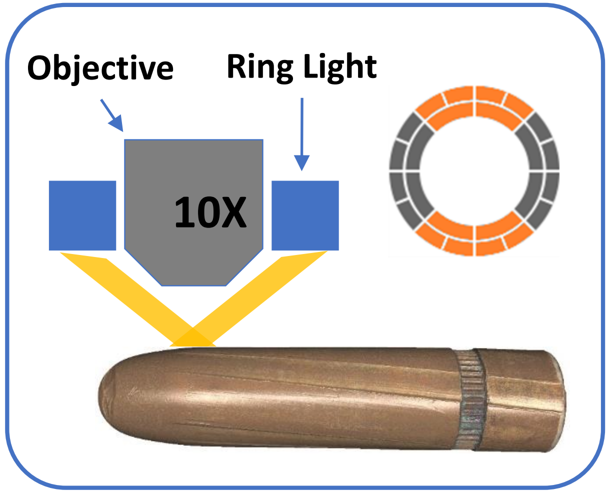
<u>Hot spots </u>(banding) due to illumination angle matching surface normal that reflects light straight back into objective



<u>Experimented with a few different variables:</u>

1. Exposure time
2. Fixture angles
3. Ring light segmentation





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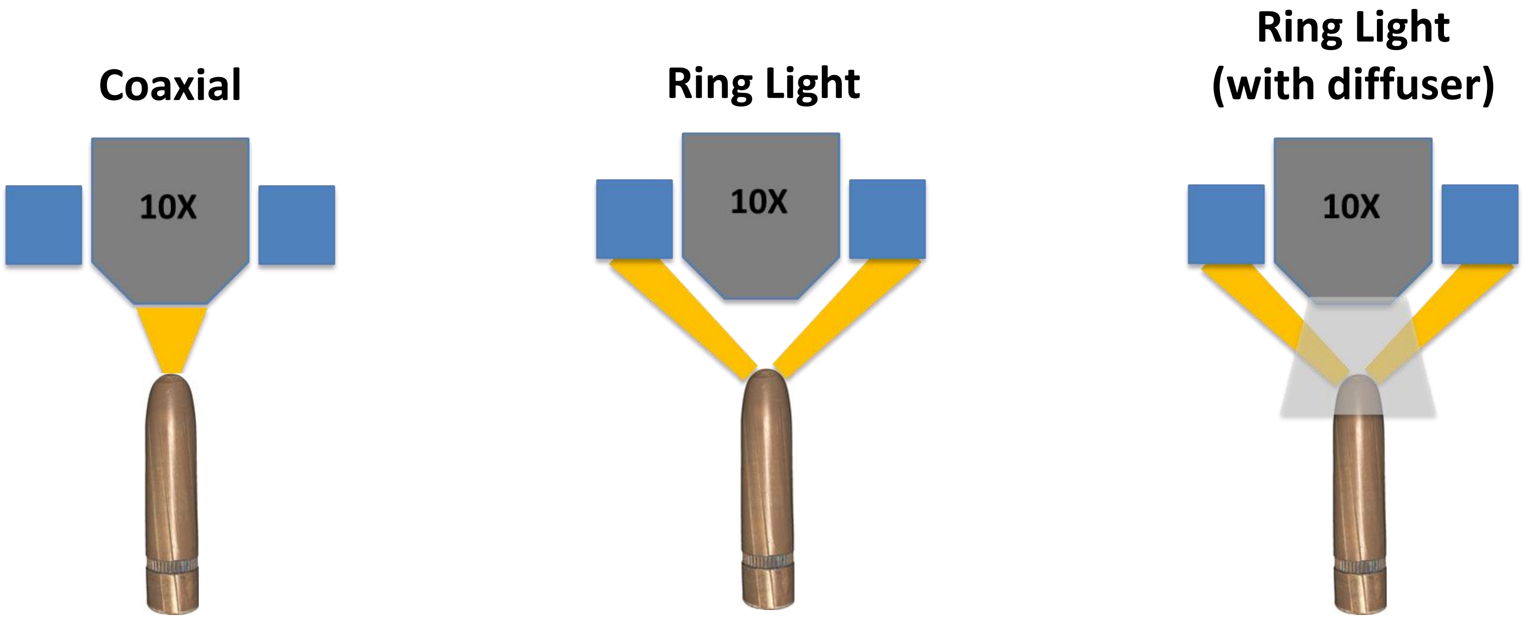
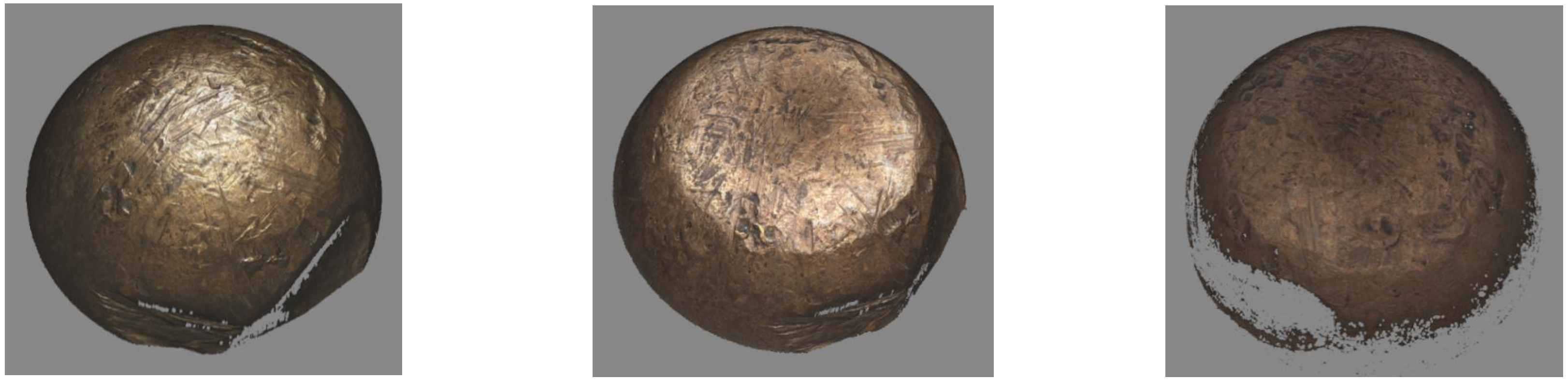
Illumination modes

Experimenting with different configurations on nose measurements



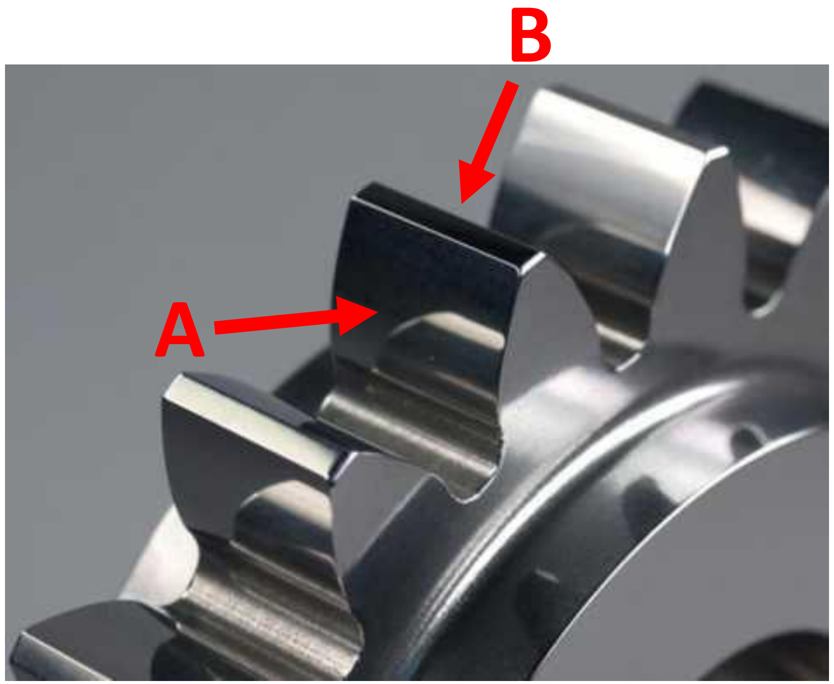
Diffuser cone



Phase 3 (2016 – 2019)

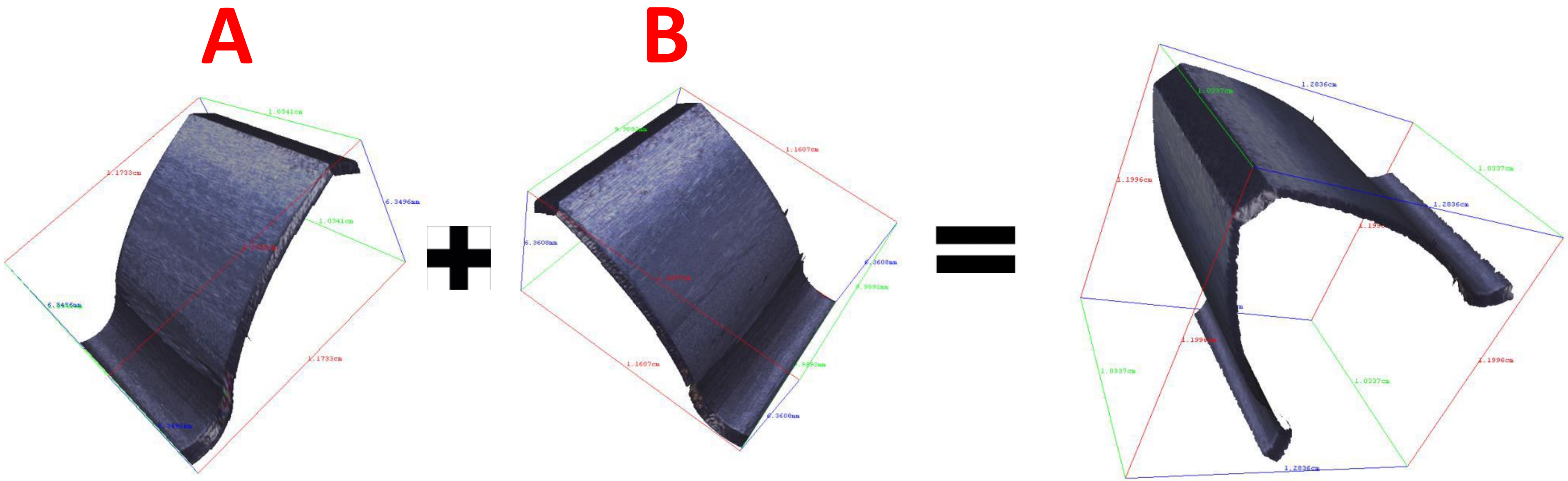
- **Data Processing**
  - **Merging**
  - **Data format**
- **Transfer to NARA / Public Release**

3D Data Fusion



Taking independently measured 3D datasets, aligning and fusing together to form a single 3D dataset

Necessary when multiple sides or surfaces of an object are measured and to be combined



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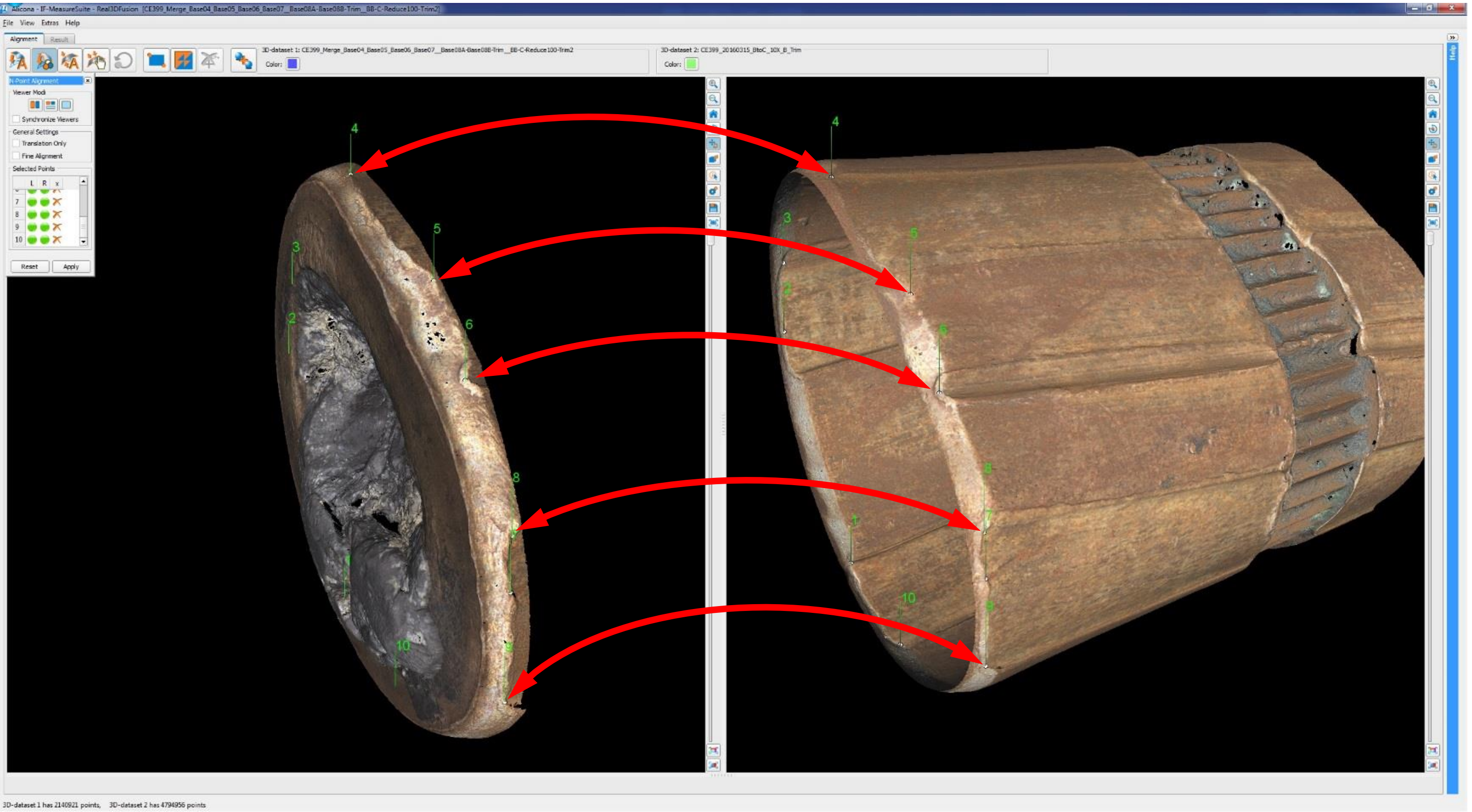
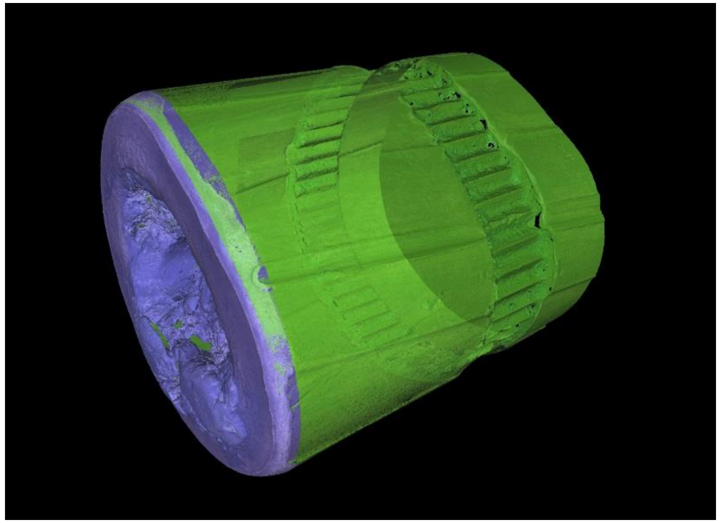
Data Fusion Process

<u>**3 step process:**</u>

1. **Manual alignment**
2. **Automatic alignment (fine adjust)**
3. **Merging (Fusing)**



CE399 - Base **CE399 - Base to Cannelure**



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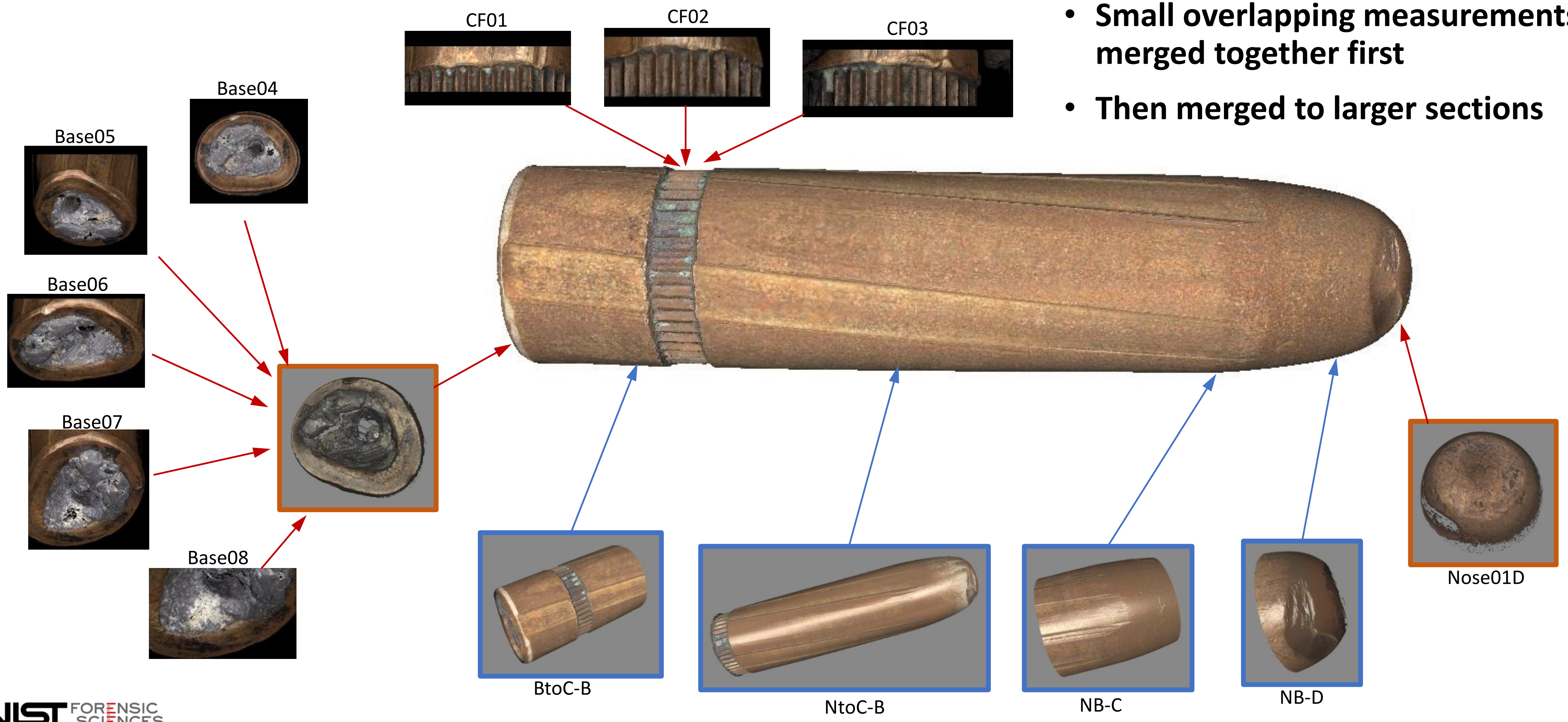
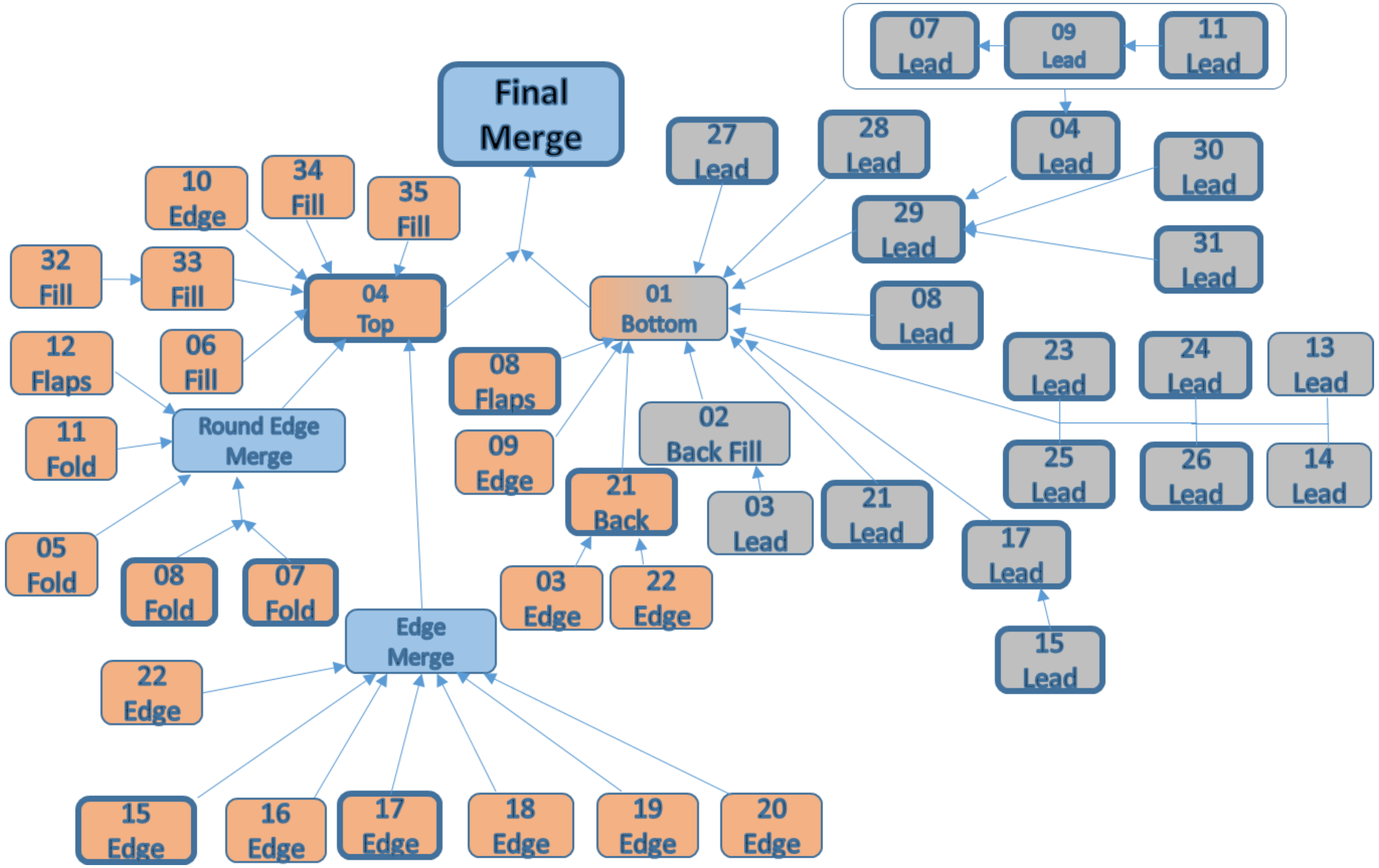
CE399 Merge Diagram (Roadmap)

- **Small overlapping measurements merged together first**
- **Then merged to larger sections**



CE567 Merge Diagram (Roadmap)

Copper side



Soons explaining dataset alignment

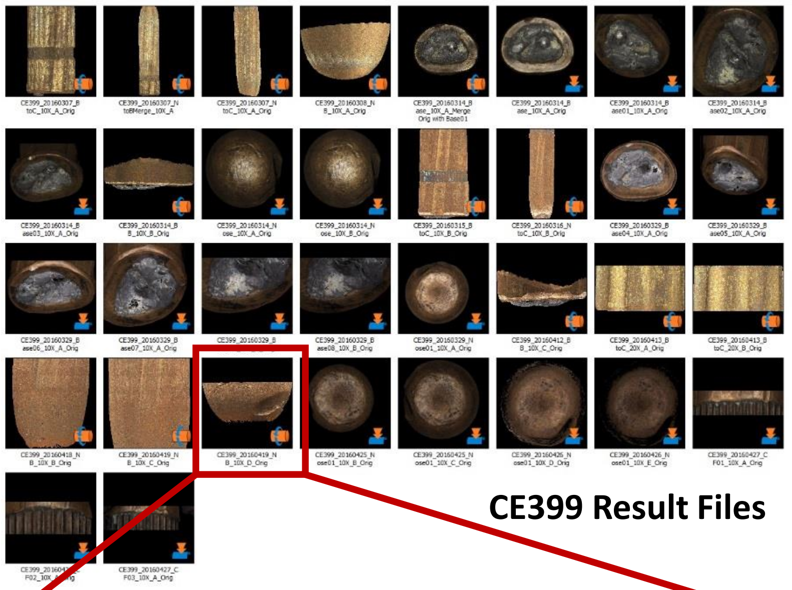
Lead side

Data Storage

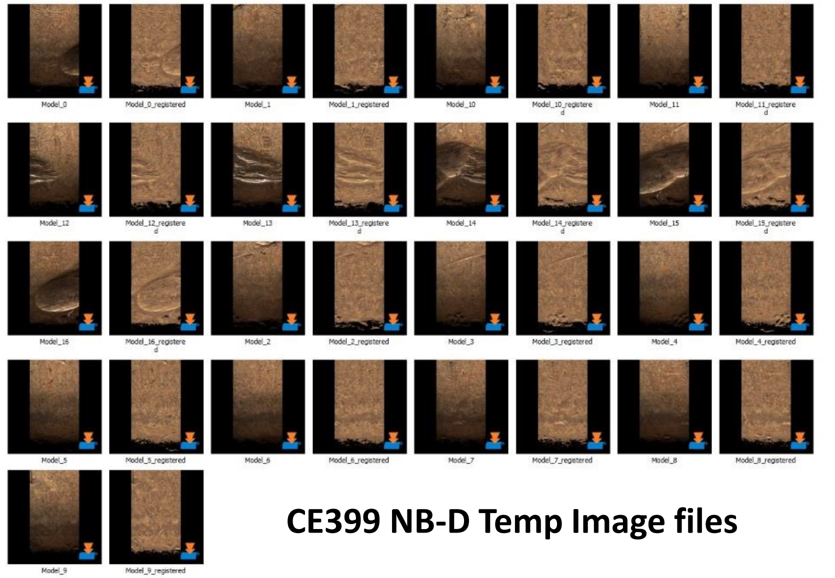
- Measurement results stored
  - 3D Result Files
  - Saved Temp Files (for offline assembly as necessary)
  - Merged files (trimmed, decimated, etc.)

>13 Billion Measured Points
1+ Terabyte of 3D Data

Artifact	Measurement Runs used	Total # 3D Images
CE399 (stretcher)	22	1699
CE567 (nose frag)	35	1636
CE569 (base frag)	37	935
CE573 (walker)	32	1559
Total	126	5829



CE399 Result Files



CE399 NB-D Temp Image files

Data Decimation

Detail/resolution versus Area

- Necessary to decimate data while merging, and for visualization requirements by users

Individual images

Measurement strips

Assembled measurements

Fully merged 3D model

~ 18 million points (triangles)

Assembly of CE399 measurements

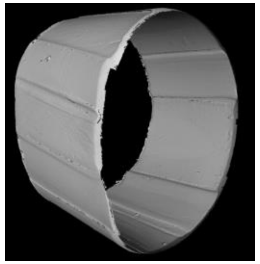
High detail, Small areas → Lower res., Large area

ALL DATA IS AVAILABLE (eg. Final Merge files to Individual Images)

Public Release

- **3D Data & Images on NARA site**
  - **https://catalog.archives.gov/id/149274356 (direct link to files: https://catalog.archives.gov/id/149279166)**
  - **25 files in a ZIP'ed array. 10 GB each file. 250 GB download size! (446 GB uncompressed)**
  - **"Readme" file includes instructions on how to view 3D data files using publicly available software**

- **NIST Article & video**
  - **Article: https://www.nist.gov/news-events/news/2019/12/kennedy-assassination-bullets-preserved-digital-form**
  - **Photo essay: https://www.nist.gov/featured-stories/preserving-kennedy-assassination-bullets-digital-form**
  - **Blog article: https://www.nist.gov/blogs/taking-measure/how-jfk-assassination-bullets-were-digitally-preserved-nist**
  - **Video: https://youtu.be/JdBp3TU8r34**





CE399

Questions?