NIJ Forensic Laboratory Needs Technology Working Group (FLN-TWG)

IMPLEMENTATION STRATEGIES:

3D Imaging for Firearms and Toolmark

OCTOBER 2021

The Forensic Laboratory Needs Technology Working Group (FLN-TWG) developed this Implementation Strategy. The FLN-TWG is an activity administered under the National Institute of Justice (NIJ) Forensic Technology Center of Excellence (FTCoE) program. RTI International leads the FTCoE, which is supported through an NIJ Cooperative Agreement (2016-MU-BX-K110), Office of Justice Programs, U.S. Department of Justice (DOJ). Any opinions or points of view expressed in this white paper are those of the FLN-TWG and do not necessarily reflect the official position or policies of NIJ or the DOJ.

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Introduction

Forensic laboratories have relied on light microscopy for a multitude of disciplines since the inception of forensic science, including questioned documents, trace evidence, and firearm and toolmark examination. Within the discipline of firearm and toolmark examination, light microscopy has been the traditional means for conducting physical comparisons of microscopic marks on ammunition components and toolmarked surfaces. In the past decade, the application of three-dimensional (3D) imaging methods capable of measuring the x, y, and z coordinates of microscopic features within a toolmark has allowed the development of high-resolution digital images and measurement of the surface topographies of those microscopic features. The advancement in instrumentation used for virtual comparison microscopy allows examiners to view accurate representations of toolmarked surfaces and to collect and measure topographic data from the evidence, facilitating comparisons that are more objective compared with conventional light microscopy comparison methods. This technology enables virtual technical reviews without the physical transfer of evidence. These tools show promise to revolutionize the field of forensic firearms examination and to address the need for more automated, quantitative methods for pattern evidence comparison, as expressed by the National Academies of Science (NAS) and President's Council of Advisors on Science Technology (PCAST) reports. This paper summarizes the current state of 3D imaging technology used in firearm and toolmark forensic analysis and offers guidance to laboratory managers considering adopting this technology. The appendix includes a vendor table listing available instrumentation at the time this document was published.

Personnel Considerations

Examinations using virtual comparison microscopy will be similar to light microscope examinations for fully trained firearms examiners, although transitioning to performing on-screen examinations of digital images will require an adjustment period. This transition will include learning the mechanics of the instrument and software and viewing the images of firearms components in a slightly different way; however, the principles of the examination will not change. Consequently, the adjustment period should not generally be expected to take more than a few months. Staff will be required to acquire a skill set for understanding instrument maintenance; conducting performance checks, validation requirements, monthly quality assurance, and quality control documentation; and maintaining equipment records. Depending on the specific instrument(s) and software packages a laboratory selects, some level of training for sample acquisition and analysis will be necessary. The current instruments available for use in laboratories have different types of software and hardware, and those differences may make one piece of equipment for a laboratory more suitable over another, simply because of laboratory staff preferences or aptitudes. The general aptitude needed by examiners using the systems is similar to that of a firearms examiner using a comparison microscope for the examination of microscopic features and making conclusions regarding source attribution.

Laboratories should assess needs based on staffing, types of evidence examined, and required processing needs. For example, a non-examiner position could perform the scanning duties for the examiner to then review and render opinions. Laboratory management can find a reference for personnel requirements within the Organization of Scientific Area Committees (OSAC) upon publication, entitled "Minimum Education Requirements for Firearm and Toolmark Examiner Trainees."

Some considerations additional considerations include the following:

- The physical interaction of laboratory personnel with the instrument will be different than with comparison microscopes.
- Attention to detail will be important if a laboratory selects an automated instrument capable of processing multiple samples.
- A laboratory that routinely receives a large number of cartridge cases may want to consider a system with multi-sample capability. As the technology evolves, more options may become available.
- Personnel can be applied strategically to complete the work. Depending on the technology selected, technicians could prepare and scan the evidence for examiner review. Examiners could conduct the interpretation, verification, and technical review.

Potential Funding Sources

When evaluating current processing and staffing needs, laboratories should consider the long-term benefits these systems will bring, like batch processing, remote viewing, digital image retention, databasing, and future algorithm capability for statistical applications. The initial investment for 3D forensic firearms imaging instruments is almost double the cost of a traditional comparison microscope, and historically, forensic firearms units have been allocated small operating budgets. Although a larger initial investment is typically necessary, multi-user capability can be achieved on one purchased unit—depending on the technology a laboratory selects. Purchasing considerations include the following:

- The availability of grant funding,
- Leasing versus purchasing options, and
- Pooling resources across agencies to fund, implement, and use a shared system.

Pros and Cons of Investing in 3D Imaging Technology

Advantages of the implementation of 3D technologies are as follows:

- Greater level of detail in the scanned images than on a comparison microscope and a 360-degree view;
- 3D sample manipulation using various levels of lighting and shading to enhance areas of interest;
- ability to group sample sets after scanning (i.e., grouping scanned samples by class characteristics);

- Reduced evidence analysis time;
- Option to integrate non-examiner personnel for image acquisition of evidence, allowing examiners to focus on comparisons;
- Previously issued inconclusive results could be imaged and re-examined with these instruments;
- Some instruments allow for batch scanning;
- Reduced physical strain on staff;
- Data can be backed up to server/network for later analysis;
- Images can be printed or integrated into casework documentation;
- Customizable options for Laboratory Information Management Systems;
- Ability to highlight areas on images for documentation of examination;
- Desktop footprints of 3D instruments are comparable to comparison microscopes and may obviate the need for 2D examinations;
- One 3D instrument can scan and upload images to a network, alleviating the need for multiple instruments;
- Potential for a national training set design;
- Interoperability: a laboratory can scan evidence and acquire the images and other sites can review the data without being present at the parent site and without physically possessing the original evidence;
- Universal format allows agencies to share scanned data for quality review or re-examination;
- Scanned images can be shared electronically for off-site examinations and verifications
- Electronic internal/external proficiency test distribution;
- Access to data for assessing performance during training; and
- Some instruments have software with built-in algorithms for score-based matching, and there is future potential for quantifying the statistical basis of conclusions.

Some of the disadvantages of integrating 3D technology include the following:

- Initial cost and on-going support for maintenance and software,
- Integration of new technology to an established discipline may meet initial resistance and may require a culture shift;
- Investment of time to validate the instrument and train staff will take time and resources from casework;
- Additional daily and monthly performance checks on instruments;
- Non–Integrated Ballistics Identification System images currently cannot be incorporated into National Integrated Ballistic Information Network; and
- Court challenges to the early implementation of this technology may arise.

Considerations for Implementation

Procurement

- Laboratories should evaluate their workflow and decide which systems may provide the most benefit. Conduct on-site visits of other laboratories already using these systems or request vendor visits to determine the best fit for the laboratory.
- Justification should include expectations of initial equipment costs, extended warranty (if applicable), consumables associated with using the instrument, and maintenance costs.
- Funding should be solicited from departmental or grant sources.

Purchase

Delivery and setup will depend on the vendor and equipment specifications. Acquisition can take weeks to months depending on availability. Purchasers should specify delivery expectations, setup, and acceptance testing before payment execution, if allowed by their department. They should also assess maintenance and service options from the vendor, and if permitted, incorporate these into the initial contract.

Training

- Communicate with the vendor when discussing instrument acquisition about what training (e.g., virtual, at the laboratory location, or at the vendor's location) will be included for laboratory staff during setup and for continued support.
- Ensure that training parameters are acceptable to the laboratory's quality system.
- Inquire about classroom-based courses with established minimum requirements.

Resources needed for implementation

- Adequate physical space for the instrument
- Coordination with the laboratory's IT network and IT services ecosystem (including adequate local network or cloud storage for images, increased speeds, databases)
- Other vendor-specific facility requirements (e.g., electrical, data storage; see table).
- Training
- Personnel dedicated to implementation
- Sample sets for assessment and competency training
- Development of standard operating procedures
- Firearms Process Map
- Ongoing maintenance and support costs
- Conformance with accreditation requirements

Challenges

Bringing a new or innovative technology to an established discipline can be a significant disruption for many personnel and a definite culture shift. Starting the discussion by laying the foundation regarding the benefits to casework and the enhancement of examination capabilities can begin the transition. Implementors should address 3D technology's implications on current casework and communicate the return on investment to laboratory staff. Agencies should also communicate these changes and advantages with their stakeholders (e.g., investigators, prosecutors), so that they are prepared for new types of reporting and application to their cases. Although adoption of this technology can initially be expensive, the long-term returns may prove beneficial. Laboratory hurdles will be the initial funding, staff resistance to change, training and personnel demands, and ongoing maintenance and support costs. Space and workflow considerations must also be established. Laboratories must determine the role that this new technology will play in complementing the conventional technology and consider the potential court challenges they may encounter. It is not anticipated that 3D technology will supplant light microscopy in the near future. Larger laboratories may be in a better position to implement this new technology, whereas smaller laboratories with limited examiners may not be able to implement this new technology in a complementary manner because of the impact validation can have on casework output.

Solution

For laboratories exploring the use of 3D technology, considerations should be given to conducting site visits of laboratories who have implemented the new technology to assess the pros and cons of the process. In addition, laboratories could invite vendors to demonstrate their instrumentation capabilities. Laboratories should assess workflow and consider the impact on their casework processes.

Validation Considerations

Validation parameters based on scope of the method

Because this technology is so new to the field, few validation studies are readily available. When considering a validation plan, laboratories should focus on the types of ammunition and toolmark components that they already routinely analyze and for which they plan to apply this new instrumentation. They should also consider seminal challenging scenarios for the discipline like best-known non-matches and consecutively manufactured samples.

The FBI Laboratory posted a validation summary that can serve as a resource for laboratories and provide direction for manufacturers. Another future resource for validation plans will be the 3D Toolmark Technologies Technology Working Group (3D2TWG) and the validation subgroup; however, the 3D2TWG does not have resources available at the time of this report's development. The 3D2TWG website can be checked periodically for updates. The OSAC Firearms & Toolmarks Subcommittee will also have broad guidance for the discipline.

Considerations when conducting method validation

Because only a few forensic laboratories have installed these instruments and completed validation as of the writing of this report, information on validations is limited. Laboratories should have a documented validation plan that outlines how the instrument will be used and the types of evidence that will be analyzed. It should include an outline of the qualification of technicians and examiners qualified to operate the instrument. Some considerations when validating new technologies include the following:

- Preparing a validation plan;
- Ensuring the plan is developed to assess accuracy, precision, sensitivity, and specificity (this will vary with the different vendors because they each have software that does different things);
- Including a description of the samples to be used during the study that represent the type of evidence regularly encountered (reference standards may be a part of the instrument purchase, but it should be noted that the National Institute of Standards and Technology (NIST) is developing a calibration suite for performing quality assurance/quality control of 3D forensic firearms imaging instruments, check the NIST website for updates);
- Maintaining the analytical data supporting the validation;
- Updating the procedure manual upon approval of the plan; and
- Training and testing staff to ensure competency.

Other factors that must be considered include the following:

- Inquiring about on-site validation from the vendor or other sources;
- Ensuring the availability of materials to conduct validation;
- Communicating to management and customers about new technology and staff requirements needed for completing validation assessment; and
- Making sure performance parameters are identified and implemented (laboratories should consider performance parameters and ensure that performance checks are in place as part of validation).

Resources

List of Laboratories that have Implemented the Technology:

- FBI Laboratory in Quantico, VA
- Kern County Crime Lab in CA
- Orange County Crime Lab in CA
- Virginia Department of Forensic Sciences

List of Laboratories in the Process of Implementation as of the Publication Date of This Document:

- Arizona Department of Forensic Science
- Armed Forces Crime Laboratory (USACIL)
- DC Department of Forensic Sciences
- Phoenix Police Department
- Royal Canadian Mounted Police Forensic Science Services
- Center of Forensic Sciences, Toronto, Canada

- Wyoming State Crime Lab
- New York State Police
- Los Angeles County Sheriff's Office

FBI Resources

FBI Quality Systems Documents: https://fbilabqsd.fbi.gov/

FTCoE Resources

1. FTCoE 2015 working group meeting and final report: https://forensiccoe.org/workshop/forensic-optical-topography-working-group/
2. 2016 Landscape study of forensic optical topography: https://forensiccoe.org/a-landscape-study-of-forensic-optical-topography/
3. Success Story: Advancing 3D Virtual Microscopy for Firearm Forensics: https://forensiccoe.org/success-story-advancing-3d-virtual-microscopy-for-firearm-forensics/
4. 2017 Podcast interview with Ryan Lilien & Todd Weller: https://forensiccoe.org/episode-three-3d-optical-topography/

Suggested Citation

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Appendix A: Overview of Currently Available Instruments

	Alicona	Cadre Research Labs	Leica Microsystems	Laboratory Imaging s.r.o.	Leeds	Sensofar	Ultra Electronics Forensic Technology	
Model	InfiniteFocus InfiniteFocus SL (SL)	TopMatch-GS 3D	Leica DCM8	Balscan	Evofinder 4x4	S Neox	IBIS BULLETTRAX	IBIS BRASSTRAX
Instrument type	Focus variation	Photometric stereo	Confocal, interferometry, and focus variation in one system	Combined focus variation and photometric stereo	Combined focus variation and photometric stereo	Confocal, interferometry, and focus variation in one system	Nonlinear photometric stereo sensor	Nonlinear photometric stereo sensor
Availability	Commercial, research	Commercial, research	Commercial, research	Commercial	Commercial	Commercial	Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF), commercial	
Mounting	Air/None	Custom mount holds case against custom gel pad; 15 cartridge case holder tray allows batch scanning	Air/Dry	Bullet holders and universal cartridge case holder	Detachable universal cassette for bullets and cartridge cases.	Universal bullet or cartridge case holder	Specialized universal bullet or cartridge case holder	
Type of light source	LED, coaxial and ring light (SL LED, ring light)	LED	Quad LEDs (red, green, blue, and white)	LED	LED	Quad LEDs (red, green, blue, and white)	LED	LED
Software for display and analysis	Alicona software can export to the following: STL, AL3D, G3D, Open GPS, CVS, QDAS, SUR, and X3P	TopMatch (includes remote viewer software allowing examiners to view scans from their desktop windows computer)	Leica Map (Mountain Maps) and Leica Scan	LUCIA BalScan	EVidence FINDER	SensoVIEW, SensoCOMP, SensoMatch, and SensoMap (version of Mountain Maps)	IBIS MATCHPOINT	

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	Alicona	Cadre Research Labs	Leica Microsystems	Laboratory Imaging s.r.o.	Leeds	Sensofar	Ultra Electronics Forensic Technology
Facility requirements	100–240 VAC, 1,000 W, 50–60 Hz, 18–28 C, 1 C/hour 45% ± 5	No special requirements; scanner requires standard 120 V power outlet	115 V power, 10 A, active or passive vibration suppression	No special requirements, standard 100–240 VAC power outlet	Standard laboratory requirements	Power; vibration isolation typically included	Office environment
Data Management							
Database search	Can search within a local database	Yes, the TopMatch software does implement a database that can be searched; Remote database (with search) via Cadre Nexus	Windows File Explorer	Yes, correlation search based on marks (firing pin, breech face, ejector marks, land and groove impressions)	Yes, bullets can be searched by primary (slippage), land, and groove traces. Cartridge cases can be searched by, firing pin, breech face, and ejector marks.	Windows File Explorer	Yes, historical crime-related exhibits and test fires
Data storage capacity	Current control servers have 2 TB storage	6,000 GB; 50,000 scans (base), unlimited with expansion	Depends on local hard drive and server availability	1 TB (20,000 images), expandable	Unlimited storage requires approx. 1 TB per 40,000 objects	Depends on local hard drive and server availability	Scalable, unlimited; JPEG2000 lossless compression
Statistics available for data dropouts	Yes	No dropouts with photometric stereo	Leica MAP		Yes	Yes	No dropouts with photometric stereo

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	Alicona	**Cadre Research Labs**	**Leica Microsystems**	**Laboratory Imaging s.r.o.**	**Leeds**	**Sensofar**	**Ultra Electronics Forensic Technology**	
Data collection time	1.7 million points/ second	Less than 1 minute per primer at 1.8 µm/px sampling	1 minute	Bullets ~3–8 minutes CC bottom ~1 minute CC surface ~9 minutes	Less than 2 minutes for both object types (bullet and cartridge)	Approximately 6–16 minutes per bullet for a bullet with 6 lands	10 minutes for a pristine 9 mm bullet (land and groove areas)	5 minutes for breech face and firing pin on a center fire cartridge case
Network compatible	Yes	Yes	Yes	Yes	Yes	Yes	Yes, automated search across regional and international networks of instruments	
Data exchange standards	Now standard; have added .x3p since 2016	Yes, founding member of OpenFMC; fully supports .x3p now	.dat, .csv	.x3p	.x3p and proprietary format	.x3p supported	.x3p, .jpg, .png	
Background correction	Yes, optionally to the user but not as a default	Automatic baseline correction can be applied	Yes, vignetting and objective aberrations calibrations	Automatic corrections during scanning, corrections for correlation	Yes	Yes, proprietary objective calibrations	Yes, shape, waviness, and texture are acquired; shape and waviness are removed for correlation	No

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	Alicona	**Cadre Research Labs**	**Leica Microsystems**	**Laboratory Imaging s.r.o.**	**Leeds**	**Sensofar**	**Ultra Electronics Forensic Technology**	
Measurements and Standards								
Calibration	Traceable to PTB by using an Alicona calibration tool	Calibration uses a known ball grid array (calibration takes just a few minutes); sinusoidal reference standards are used for determining lateral and depth resolution; yes, system can scan the NIST standard casing	Field flatness is corrected for all available objectives as well as objectives aberration within field of view (FOV); Systems are always verified for z accuracy and repeatability with NIST-traceable step height standards	Automatic calibration	Factory calibration only; Can be checked periodically with reference standard	Objectives are calibrated for field flatness and aberration using optical flat; systems are typically verified for z accuracy with NIST-traceable step height standards	Self-calibration every 50 acquisitions (configurable) with the use of a special target inside the acquisition unit	Self-calibration every 50 acquisitions (configurable) with the use of a special target inside the acquisition unit
Spatial resolution	Limited by illumination type ~400 nm (SL 640 nm)	Typical lateral resolution: 1.8 µm/px (system can scan up to 0.9 µm/px)	Best spatial resolution is 150 µm (half pitch criteria)	3.08 µm/px	3.5 µm	Dependent on technology and objective; highest resolution is 0.15 µm lateral (half pitch); typical resolutions are 0.7 µm for bullets and 1.44 µm for cartridge cases	2.975 µm/px	Primer (breech face): 4.84 µm/px firing pin and ejector: 3.25 µm/px
Best vertical resolution	10 nm (SL 20 nm)	Typical depth resolution of 1 µm (assessed using reference standard)	Best vertical resolution 0.1 µm	µm (result of photometric stereo interpolation)	Theoretically ~1 µm	Dependent on technology and objective; interferometry resolution is better than 1 µm	0.2 µm	Approx. 1 µm

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	Alicona	Cadre Research Labs	Leica Microsystems	Laboratory Imaging s.r.o.	Leeds	Sensofar	Ultra Electronics Forensic Technology	
Smallest vertical slice interval	Same as vertical resolution		Best achieved with PSI interferometry technology and Heidenhain sensor (close to 1 µm)			Dependent on technology and objective; PSI vertical slice with optional Piezo stage is about 1 nm	N/A	N/A
Lateral range	50 × 50 mm for SL, 100 × 100 mm or 200 ×200 mm for G5	N/A	2D and 3D stitching available up to big dimensions (biggest XY stage is H112 with 300 × 300 mm range)	50 × 50 mm	25 × 25 mm	Images can be stitched to cover large areas; depending on stage size, up to 300 × 300 mm	2.86 mm width, unlimited height	4.65 mm × 4.65 mm
Measurements and standards								
Vertical measurement range for a single image	Objective dependent; max Z-axis range for G5 is 100 mm, SL is 25 mm	N/A	Depends on tech used and obj. From 10 µm to few mm<40 when using low numerical aperture (NA)	Theoretical maximum 50 mm; typically <10 mm	Subject to be clarified in detail	Dependent on technology and objective; ranges from 150 µm for high NA objectives to 37 mm for low NA objectives	Undefined	Undefined
In-process surface follower technology	Yes	N/A	Yes	Yes	Yes	Yes	Yes, automatic surface following for pristine and deformed bullets as well as fragments (including "V" shaped)	N/A

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	Alicona	Cadre Research Labs	Leica Microsystems	Laboratory Imaging s.r.o.	Leeds	Sensofar	Ultra Electronics Forensic Technology	
Varied surfaces	Yes	Works with any surface, including glass or mirror; it is also possible to scan live tissue (e.g., fingerprints)	From very smooth/ polished to very rough surfaces; Thick/Thin film measurement	Yes, optimal for non-translucent surfaces (metal, castings)	Metal surfaces of bullets and cartridges, and plastic surfaces (castings)	Yes, from mirror surface to very rough	Yes	
Dynamic range of camera	N/A	N/A	N/A	12 b	>48 dB		57 dB	57 dB
Working distance	Objective lens–dependent Max of 37.5 mm with 10× HX and min of 4.5 for 100×	N/A	13 (5×)–0.2 mm (150×)	88 mm	41 mm	Dependent on technology and objective; ranges from 300 microns for high NA objectives to 17 mm for low NA objectives; super long working distance objectives are available with working distance up to 37 mm	9 cm	9 cm

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	Alicona	Cadre Research Labs	Leica Microsystems	Laboratory Imaging s.r.o.	Leeds	Sensofar	Ultra Electronics Forensic Technology	
Measurements and Standards								
Measurable range of caliber	All	22 short to 7.62 ×39 mm (additional calibers can be accommodated with adapters)	40 mm	All (up to 50 × 50 mm)	Up to 20 mm	Virtually unlimited	Calibers from 0.17–0.700, and an effective diameter from 4–20 mm	Calibers from 0.17–0.50 and from .410 bore to 8-gauge for shot shells, and an effective diameter from 2–27 mm
Motorized scanning (x,y,z)	Yes, motorized rotation and tilt optional (SL Yes, motorized rotation optional)	N/A	Yes (x,y,z)	Yes	Yes	Yes (x,y,z)	Yes, automated acquisition: x, y, z (focus), tilt, rotation, lighting	Yes, automated acquisition, y, z (focus), zoom, rotation, lighting
Reliability of measure-ments (based on mechanical stage movement)	N/A	Reproducibility, repeatability, precision assessed by recently completed study; publication to be submitted in 2016	X-Y scanning reproducibility is in the range of (x,y) scanning	XYZ stages repeatability 0.1 µm	High reliability is defined by self-designed optics and mechanical platform	X-Y scanning reproducibility is in the range of (x,y) scanning	Measurements are not dependent on the mechanical stages reproducibility	N/A, all returns on investment are captured on a single camera's FOV

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	Alicona	Cadre Research Labs	Leica Microsystems	Laboratory Imaging s.r.o.	Leeds	Sensofar	Ultra Electronics Forensic Technology	
Number of camera pixels	1,840 × 1,840 (SL 2,000 × 2,000) for a single measurement, up to 500 million for a stitched dataset	Current: 12 million;	1,360 × 1,024	1,920 × 1,440	510 × 492; 2,048 × 1,536 (under development)	2,442 × 2,048	1,920 × 1,200	1,920 × 1,200
Maximum slope	87°	Theoretical: Up to 90°	85° (with 0.95 NA objective)	Theoretical <90°	Up to ~90º (reported theoretical)	71° for confocal with 0.95 NA objective, slopes up to 86° can be measured with focus variation and with rough surfaces	20°–25° on rough surfaces with nominal FOV size	25°–35° on rough surfaces with nominal FOV size
Measurements and standards								
Field of view with 20x objective	0.81 × 0.81 mm (SL 1 × 1 mm)	N/A, using our 3× objective single image field of view is ~35 mm^2	877 × 660 µm	N/A, objective is 1.48×, FOV 5.7 × 4.3 mm	2.1 × 1.7 mm for objective 2×	877 × 660 µm	2.9 mm × limited by stitching (10× objective); a full circumference of the bullet can be done	3.1 × 3.1 mm (firing pin, ejector, and rim fire) with 1.5× zoom objective and 4.8 × 4.8 mm for breech face with 1.0× zoom objective

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	Alicona	Cadre Research Labs	Leica Microsystems	Laboratory Imaging s.r.o.	Leeds	Sensofar	Ultra Electronics Forensic Technology	
Measurement point density	Depending on objective, best: 0.09 µm (SL Depending on objective, best: 0.2 µm)	Typical: 1.8 µm/px; maximum 0.9 µm/px	Depends on technology and objective	8,400 PPI	280 points/mm	Depends on technology and objective	2.975 µm/px	Primer (breech face): 4.84 µm/px firing pin and ejector: 3.25 µm/px
Conformance with standards for roughness measurement	Yes, ISO and ASME	System will comply with NIST OSAC standards once published; these standards are still being created and will build from the cited ISO and ASME documents	ISO 4287, ISO 13565, ISO 12085, ISO 12780, ISO 12181, ASME B46.1, MBN 31 007-12, VDA 2007	Not tested	N/A	Yes	N/A	
Conformance with standards for surface measurement	Yes, ISO and ASME	System will comply with NIST OSAC standards once published; these standards are still being created and will build from the cited ISO and ASME documents	ISO 4287, ISO 13565, ISO 12085, ISO 12780, ISO 12181, ASME B46.1, MBN 31 007-12, VDA 2007	Not tested	N/A	Yes	System will comply with NIST OSAC standards once published	

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	Alicona	Cadre Research Labs	Leica Microsystems	Laboratory Imaging s.r.o.	Leeds	Sensofar	Ultra Electronics Forensic Technology
Measurements and standards							
Form measurement	Yes, 2D and 3D profiles and contour; surface processing, including filtering and form removal are also provided	3D surface height map	Can filter between roughness and form on both 2D and 3D profiles according to ISO standards	3D surface profile overlaid with texture; 3D profile measurements available	2D, 2D+D, 3D, profile, and color hear map	2D, 3D, and profile; software provides a wide variety of methods to process surfaces, including form removal, and ISO filters	Shape and waviness are distinguished using a spatial frequency cutoff maximizing correlation performances
Conformance with ISO 17025	No	System will comply with NIST OSAC standards once published; these standards are still being created and will build from the cited ISO and ASME documents	No	No	N/A	Yes	Yes
Color imaging	Yes	N/A	Yes	No (alternative color camera available upon request)	No	Yes	No
Illumination	Coaxial and ring light (24 segments) (SL Ring light [24 segments])	Photometric stereo ring light configuration	Four LED light sources (red, green, blue, and white)	8 segment LED ring light, 2 segment LED side light	Diffusive LED light, four ring segments	Four LED light sources (red, green, blue, and white)	LEDs for 3D Annular light, side lights for 2D; LEDs for 3D

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	Alicona	Cadre Research Labs	Leica Microsystems	Laboratory Imaging s.r.o.	Leeds	Sensofar	Ultra Electronics Forensic Technology	
Measurement time for a 9 mm cartridge case primer area	Resolution-dependent	Less than 1 minute (using 15 cartridge case holder tray)	TBD	50 seconds for complete 9 mm cartridge case bottom	~0.5 minute	2 minutes	N/A	4 minutes for a breech face and firing pin on a center fire cartridge case
Measurement time for a 9 mm bullet	Resolution-dependent	N/A	TBD	3D surface profile overlaid with texture; 3D profile measurements available 3.5 minutes for 5.8 mm wide 360° stripe of whole bullet	~1.5 mins	6 minutes for a pristine 9 mm bullet (land areas)	10 minutes for a pristine 9 mm bullet (land and groove areas)	N/A
Measurements and Standards								
Security	No	System will comply with NIST OSAC standards once published; these standards are still being created and will build from the cited ISO and ASME documents	No	No	N/A	Not at present	Yes, ISO 27001 and NIST SP 800-53	
Training, Costs, and Current Users								
Is training offered?	Yes	Yes, firearms examiners and technicians have been successfully trained	Yes, Leica-certified trainer	Yes	Yes, computer experience and ballistics grounds	Yes, minimal background required	Yes, wide selection of training courses, on site and via eLearning; No specific background required	

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	Alicona	Cadre Research Labs	Leica Microsystems	Laboratory Imaging s.r.o.	Leeds	Sensofar	Ultra Electronics Forensic Technology	
Technical support provided?	Yes, all methods and different service contracts available	Yes, phone, email, and web	Installation and training provided with purchase; online, telephone, and Internet training and support available per request	Yes, 2 years warranty, 3 years of software updates and support included	Yes, full range support	Yes, typical installation includes two days on site, with follow-on training available	1-year warranty included and extended SafeGuard warranty coverage; Customized support packages available for national programs; 24/7 worldwide remote and on-site support.	
Estimated cost <$100,000		×		×				
$100,000–$500,000	× (Both SL and G5)	× (2020 pricing: System 118k; Delivery, Setup, First Year Support: 11k)	×		×	×	×	
>$500,000					×			
Other		$129k all in price; Peer-reviewed validated VCM tools; batch scanning tray; remote viewer			Depends on configuration			
Training, Costs, and Current Users								
Confirmed use: State and local crime laboratories	Yes, local laboratories	Yes, state and local laboratories	N/A		United States, Germany, Brazil, Greece, and France	Yes (United States, Czech Republic, and China)	2 units deployed in state and local laboratories	Approx. 220 units deployed in state and local laboratories

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	Alicona	Cadre Research Labs	Leica Microsystems	Laboratory Imaging s.r.o.	Leeds	Sensofar	Ultra Electronics Forensic Technology	
Federal crime laboratories	Yes, several laboratories worldwide	Yes, federal laboratories	N/A	Yes	Germany, France, Switzerland, Belgium, Finland, Brazil, Uruguay, United States, and Morocco	FBI laboratories	3 units deployed in ATF laboratories	Approx. 45 units deployed in ATF labs, U.S. Customs and Border Protection, and FBI laboratories
Other	Research laboratories worldwide	Yes, research laboratories	N/A		More than 60 laboratories in more than 22 countries	Over 800 systems installed around the world for a variety of applications, from anthropology to micro-electronics, including 5 units at universities doing research of 3D technologies for firearms identification	Approx. 200 units deployed worldwide	Approx. 550 units deployed worldwide
For further information	www.alicona.com	www.cadreforensics.com/	www.leica-microsystems.com/home/	www.forensic.cz/	www.leedsforensics.com/	www.sensofar.com/	www.ultra-forensictechnology.com/	

All data are based on vendor input that is subject to interpretation and verification.

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