PAPILLON SYSTEMS

ARSENAL

Automated Ballistics Identification System

The latest generation of ARSENAL ABIS (Automated Ballistics Identification System) offers a highly automated and comprehensive way to examine ballistic evidence when investigating firearm-related crimes. Unlimited in size, ARSENAL databases of fired bullets and cartridge cases raise the trace evidence analysis to a new level, responding to the needs of law enforcers worldwide.

State-of-the-art communication networks open up the possibilities to get a remote access to ABIS databases for sharing and comparison of ballistic information and images anytime, as well as for creating geographically distributed systems, and thereby substantially boost ARSENAL's crime-solving power.

ARSENAL

Automated Ballistics Identification System

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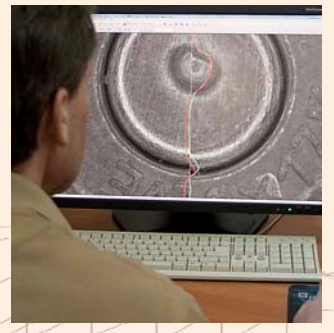
ARSENAL ABIS technology provides scalable storage and backup services for the following ballistic collections:

- ***Testfire objects***: bullets, cartridge cases and pellets (shots), i.e. representative specimens of known origin obtained while test firing firearms in a laboratory or other controlled environment to be used for comparison or analysis.
- ***Evidence objects:*** bullets and cartridge cases, including fragments, and pellets (shots) collected at scenes of firearms incidents.

ARSENAL is powered by its non-contact, non-invasive imaging technology that provides superior and unparalleled image quality of the full range of ballistic specimens encountered by forensic laboratories today. Using proprietary algorithms, ARSENAL processes the unique digital signatures extracted from the ballistic images, performs relevant comparisons and produces ranked lists of possible matches.

Digital images of bullets, cartridge casings and other projectiles (individually and collectively called 'object(s)') as well as selective images of specific regions are submitted to ABIS where they are compared to those stored in ARSENAL databases and ranked according to similarity in order of the highest probability of a match.

With diverse tools and controls available to assist in making conclusions, comparative analysis of the prospective match results returned by ARSENAL empowers the firearm examiner to:



- connect a specific gun and its owner to a firearm-related crime if its test-fired samples match with any piece of recovered ballistic evidence stored in ARSENAL database
- solve gun-related crimes if the fired specimens found at crime scenes match with test-fired counterparts available in ARSENAL collection of registered firearms and owners
- combine different shooting crimes that involve the same gun if ARSENAL makes ballistic matches across crime scenes.

Furthermore, the ample capabilities for visualization and image analysis that are available in ARSENAL ABIS allow ballistic examiners to:

- estimate the wear and tear caused by regular use, and determine the individual characteristics of the barrel by examining striations on the bullet face
- determine the shape, size, relative position of the parts and mechanisms of a firearm that produce marks on a cartridge case
- prepare examination worksheets and reports of any type

FUNCTIONAL CAPABILITIES

- Capacity to operate with bullets and cartridge cases fired from rifled and smoothbore weapons
- High-quality data collections of fired bullets, cartridge cases, fragmented specimens, shotgun ammunition components
- Separate data storage based on firearm registration types (for example, military weapons, police guns, etc.)
- Comprehensive information on every object stored in ARSENAL database: characteristics, case history and other administrative and forensic data
- Non-contact, non-invasive way of doing ballistic imaging of the full range of ammunition and fragments thereof
- Automatic mapping of driven and driving edges on a bullet's circumference image
- Interactive outlining on the bullet of:
  - Skid (primary) marks
  - Land impressions
  - Groove impressions
- Automatic extraction on a cartridge case's head of:
  - Firing pin impression
  - Breech face mark
- Interactive outlining on a cartridge case's head of:
  - Ejector mark
  - Feed mark
- Interactive labeling of toolmarks produced on a cartridge case's side from contact with:
  - Extractor
  - Slide hole
  - Magazine edge at loading and ejecting
  - Chamber wall
  - Breech edge
  - Cartridge inlet
  - Breech-block bottom
- WSQ compression of images before storage
- Profile view capability and 3D imaging
- Automatic database searches
- Automatic origination of candidate lists
- Powerful analysis and visualization tools
- Retrieving and printing any information from database files
- Import and export of database files over an IP connection
- Database security based on the authorization policy and secured data transmission
- Statistics gathering and reporting.

1 *Alphanumeric data entry*

2 *Image acquisition*

3 *Automatic processing of images*

4 *Coding of surface images*

5 *Automatic processing of images*

6 *Database search*

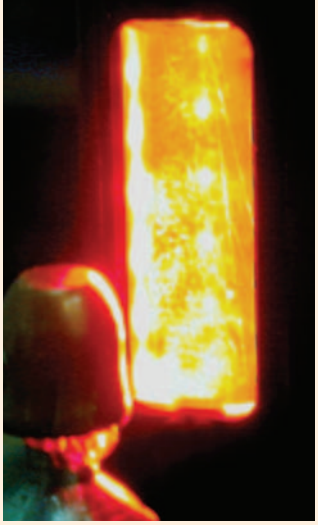
7 *Generation of candidate lists*

8 *Comparative examination of images*

9 *Verification of candidate lists*

10 *Generation of Hit Lists*

ARSENAL ABIS OPERATION LOGIC



The first ARSENAL installations date back to 1995.

Today, ARSENAL ABIS in various networked and stand-alone configurations are in operation in over 25 regional centers in the Russian Federation and at forensic laboratories in 17 other countries: Azerbaijan, Albania, Bangladesh, Bosnia and Herzegovina, Zambia, Iran, Kazakhstan, Lebanon, Mongolia, Nigeria, Poland, Transnistria, Serbia, Sudan, Thailand, Turkmenistan and Uzbekistan.

PAPILLON is striving to improve its ARSENAL technology by combining the leading edge research findings in the field of automated ballistic identification with the latest technological advances, and thereby constantly enhances the robustness of its correlation algorithms, providing more powerful analysis tools and ample capabilities for ballistic examinations.

Every new release of ARSENAL embodies the totality of innovations and engineering solutions pioneered by PAPILLON, which makes it considerably different from its earlier versions as well as from other ballistic identification systems in the market.

At the same time, PAPILLON's philosophy of retaining the highest possible quality-to-cost ratio in the business makes ARSENAL both affordable and valuable in terms of its qualitative and operational characteristics.

IMAGE ACQUISITION TECHNOLOGY

The most important element of any ABIS exerting decisive influence on its efficiency is a device and related software that provide electronic imaging of ballistic objects under examination.

Universal PAPILLON BS Surface Scanner is an indisputable success attained by the system developers who managed to create an extremely easy-to-operate and easy-to-service device having superb functional characteristics that fully comply with the highest requirements to contemporary ABISs.

The scanner provides high-resolution imaging of surfaces of all specimens submitted to ARSENAL – bullets and cartridge case fired from rifled and smoothbore weapons, shots and pellets, deformed bullets and fragmented shells with relief deformation of up to 7 mm.

Moreover, the capability to capture images of non-ballistic objects that may also have unique surface markings left, for example, by a burglar's tool or fingers, is an added bonus available for forensic examiners now. The diameter of cylindrical objects to be scanned may range from 1 mm to 22 mm.

Owing to the versatility of PAPILLON's scanner, data acquisition stations in ARSENAL ABIS are not divided to those used for collecting only bullet data and those for cartridge cases. One ARSENAL station equipped with PAPILLON BS allows experts to submit to ABIS all types of objects – bullets, cartridge cases, shells and fragments – in any sequence.

The other side of the scanner's versatility is its capacity to operate not only under laboratory conditions but in the field as well. Its compactness and transportability has made it possible to create a mobile ARSENAL that is a full-featured ABIS with an internal database.

Compact and ruggedized, the scanner housing protects the high-class optics and original design of the device making the object holder the only place for direct communication between the user and the device.

PAPILLON BS Versatile Surface Scanner

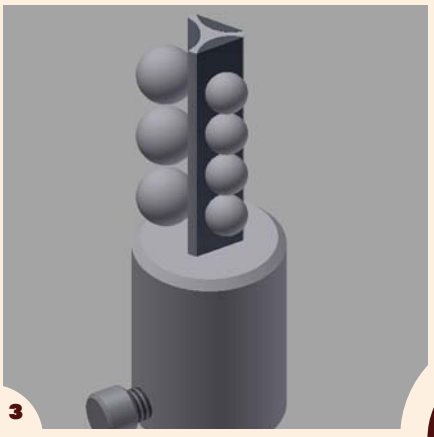
The process of setting up and centering a specimen takes only a few seconds, facilitated by simple and robust labor-saving attachments:

- magnetic, plasticine- and adhesive-coated stands for bullets/cases and deformed specimens of any length and material
- centering collets
- cartridge case holder for scanning an object's base
- holder for projectiles (shots/pellets) fired from smoothbore guns
- semiautomatic dial-type holder for continuous scanning of headstamps of ten cartridge cases.

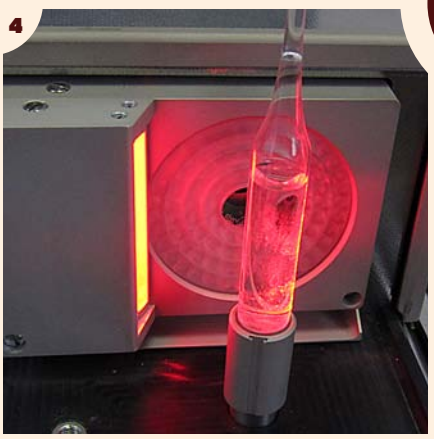
ARSENAL provides 360-degree circumference imaging of bullets and cartridge cases and imaging of cartridge cases' full headstamps as well as selective imaging of specific regions on deformed and fragmented specimens, on shotgun projectiles that bear unique ballistic signatures.

1 *Centering a bullet with the collet to prepare for scanning its side surface*

2 *Positioning a cartridge case to scan its headstamp*



3 *Shotgun projectiles prepared for scanning*



4 *An ampoule scanned for further examination*

The open stage on which objects are placed allows the firearm examiner to scan any exhibits, even severely deformed as well as those of a great length (e.g. shotgun cases), and to control visually the scanning process.

Orientation-independent positioning of a cartridge case makes the image acquisition process easier. Besides, it is not imperative to set up the cartridge case its base to be strictly parallel to the lens plane – the setting error is compensated by the software algorithm and has no impact on the image quality.

PAPILLON BS Surface Scanner Features

CCD-sensor	7500 elements
Resolving capacity	2D: 3 microns ◗ 3D: 10 microns
Maximum scanning depth	7 mm
Field of vision	20 x 20 mm
Diameter of objects	1 to 22 mm
Bullet scanning time	1.5 minutes
Cartridge case head scanning time	1 minute (1 annular lighter) 10 minutes (1 annular lighter & 8 sectors)
Measurement accuracy	Land width: ±0.015 mm ◗ Rifling pitch: ±0.15°
Power supply	15V DC
Power consumption	70 watts
Dimensions	400 x 228 x 217 mm
Weight	10.3 kg
Interface	PCIe

Images are captured with a linear CCD sensor over the entire scanning window (20 mm x 20 mm) in much the same way as flatbed scanners do this.

The seamless image of the entire surface is generated in the process of scanning, which makes a valuable advantage this method provides versus fragmentary techniques where the final image is a result of "pasting together" separate fragments with elimination of inevitable borderline defects and compensation for light differences on neighboring areas with significant differentials in relief altitudes.

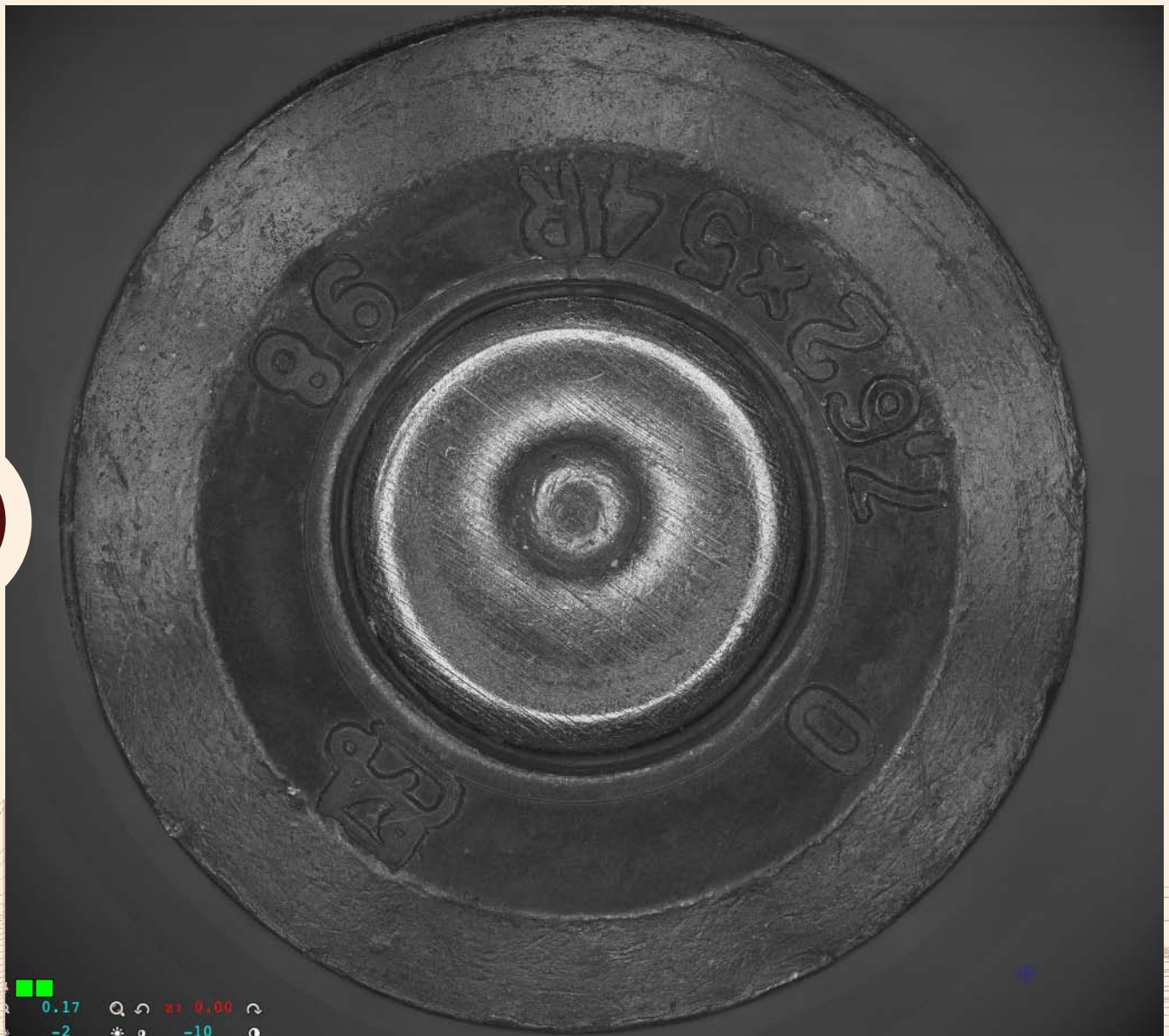
The outcome of each scanning session presents exact digital copies of an object's surface:

- 2D grayscale image (65,536 gray shades) of optimal for ballistic examination resolution of 3 μm/pixel, reproducing all informative and identifiable features of the microrelief without any blur through fine noise ("nanonoise") coming from the structure of metal and other random factors relating to properties which are not essential to the target of investigation
- 3D image of the surface, with the resolution of 10 μm/pixel on all axes.

The declared resolution in any place of any surface, including distorted and those with salient relief, is ensured by the "layer-by-layer" scanning technology applied with the small depth of focus along the entire profile of an object's deformation. Every next layer is scanned with the optical system automatically shifted.

After all layers are captured, the best fragments from all layers are automatically selected and assembled into a high-quality, evenly crisp image accurately reproducing every portion of the surface, whatever the deformation.

2D image of a cartridge case's headstamp available for examination right after it's scanned



2D image of a bullet's side available for examination right after it's scanned

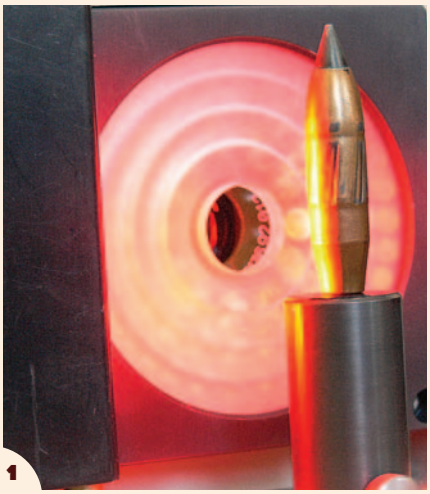
High-quality digitization of surfaces along with 2D and 3D imaging is performed at a high speed:

- scanning fully the side surface of a 9.0 bullet (d=10mm, 0.2-0.3 mm relief height) takes 1.5 minute
- scanning a cartridge case's full headstamp (cartridges 9x18 or 9x19, d=10mm, 0.4-0.5 mm relief height) under one type of lighting takes 1 minute.

The scanner allows diverse modes of lighting in which objects can be scanned:

- bullets' and cartridge cases' sides, shell fragments and deformed bullets are scanned in oblique lighting that produces a natural view of surface markings
- cartridge cases' full headstamps are scanned in:
  - direct annular lighting
  - 45°-sectored lighting at various angles.

Thus, 9 images of a cartridge case's head can be captured per session – 1 annular and 8 sector-lighted.



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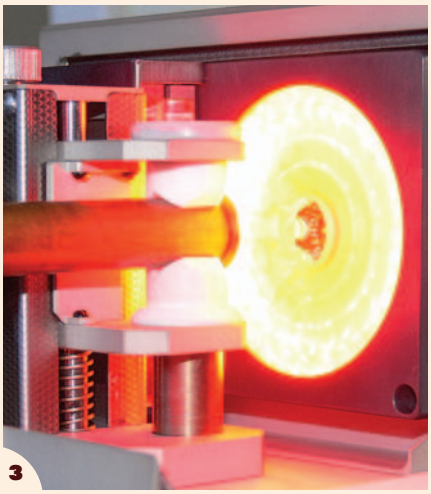

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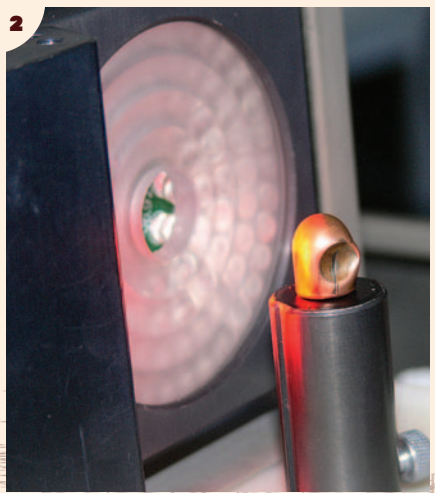

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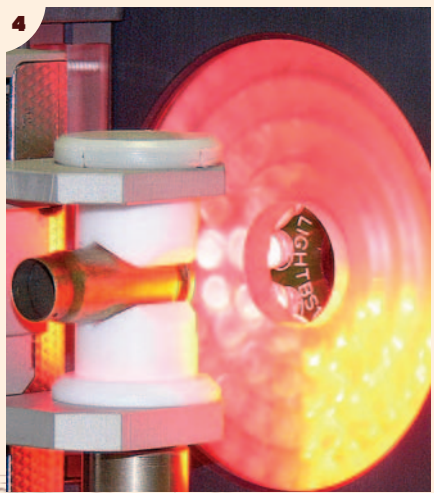

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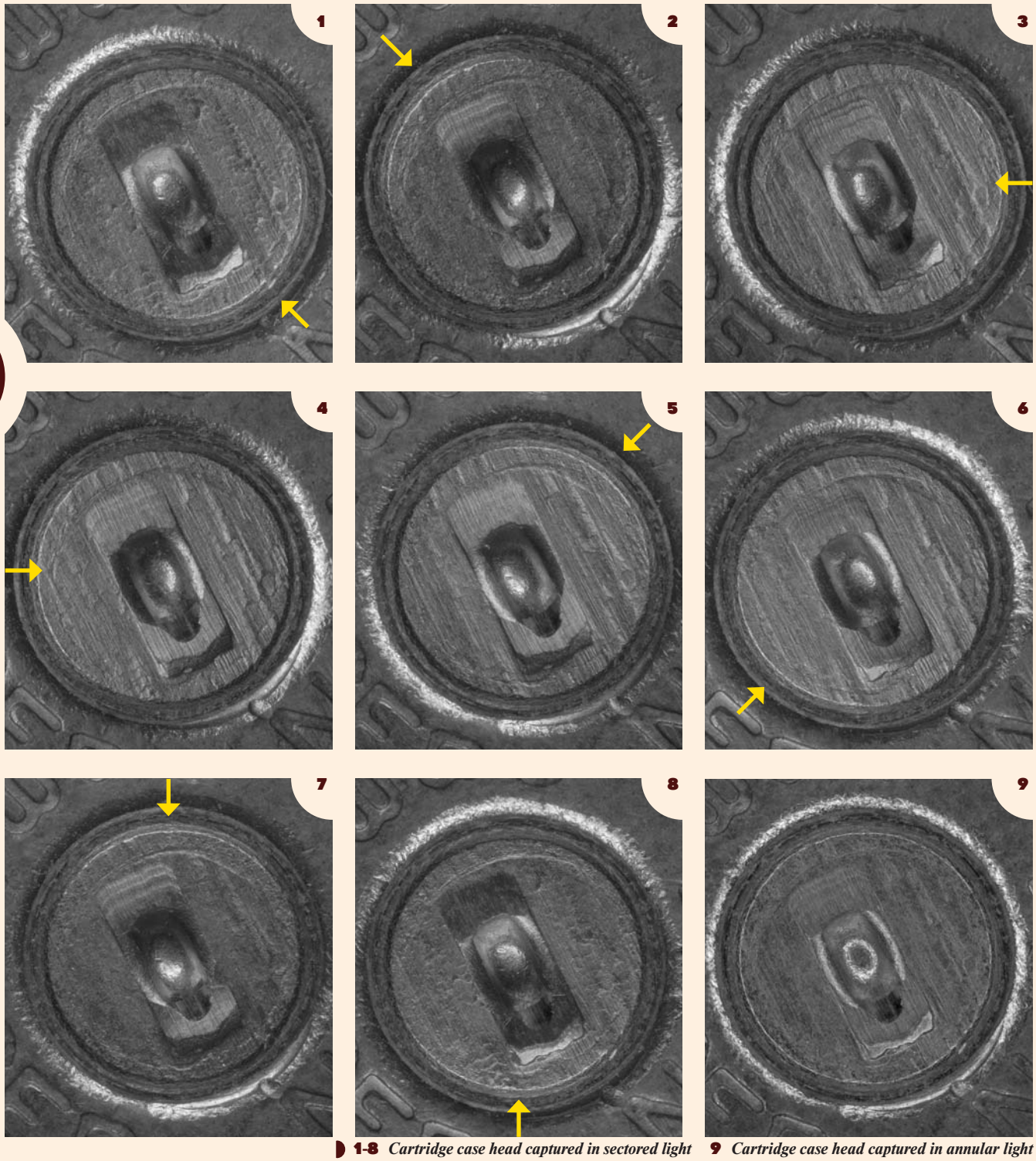
- *1 Bullet side scanning in oblique light*
- *2 Deformed bullet scanning in oblique light*
- *3 Cartridge case head scanning in annular light*
- *4 Cartridge case head scanning in sectored light*



1-8 *Cartridge case head captured in sectored light* **9** *Cartridge case head captured in annular light*

ARSENAL's innovative sectored lighting used for scanning cartridge cases' heads offers a variety of indisputable advantages:

- Sectored lighting produces a more complete shadow picture which is particularly valuable both for visual examination of images and for more precise outlining of regions of interest when coded. Besides it increases the selectivity of automatic searches.
- Orientation-independent sectored lighting, like annular one, allows uniformity of image acquisition, thus reducing operator variability.
- Images of firing-pin impressions and breechface and ejector marks captured in sectored lighting are more legible and informative.
- Sectored lighting makes technological marks less pronounced.

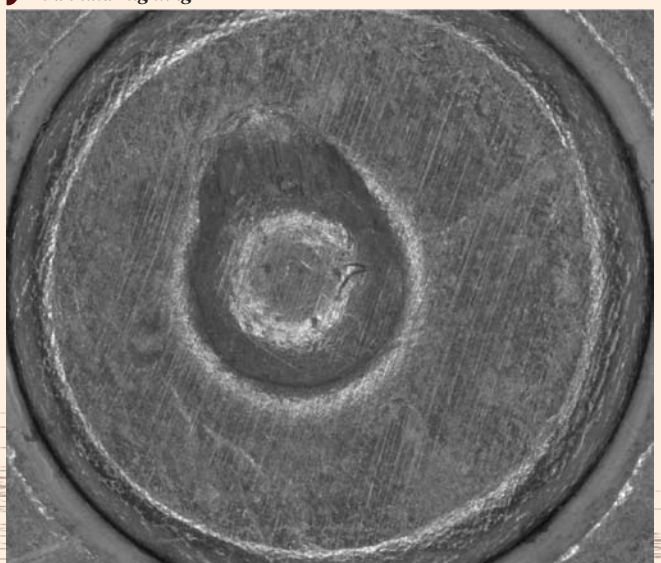
IMPORTANT! ***Sectored lighting is giving significantly improved results in automatic comparisons for breechface and ejector marks on cartridge cases fired from weapons that normally use high-powered cartridges (e.g. TT) and those imparting some specific toolmarks to a cartridge case (e.g. Glock's firearms).***

Number of case sets: 30 Number of cartridge cases: 90	*Increased correlation accuracy for breechface marks captured under sectored lighting vs. annular lighting (cartridge cases of 7.62x25mm TT)*	
Lighting conditions	**Annular**	**Sectored**
True candidate is first on the list	27,5%	68,89%
True candidate is in the top 10 on the list	57,5%	90,56%
True candidate is in the top 20 on the list	68,61%	95,00%
True candidate is in the top 50 on the list	91,39%	99,44%

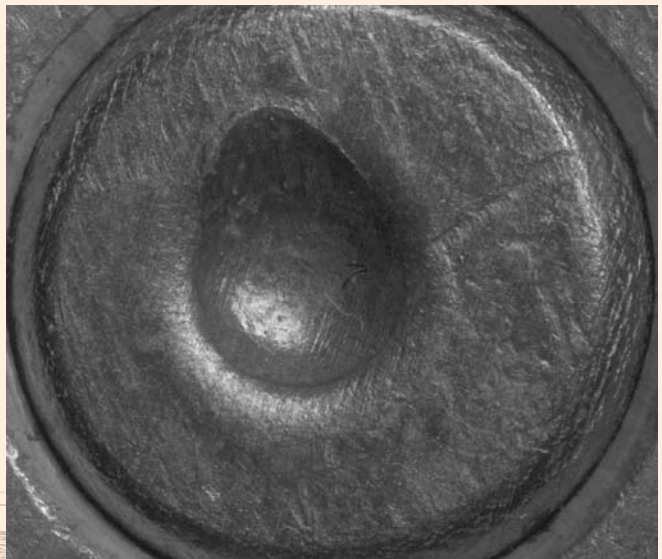
Cartridge case markings in annular light

Same cartridge case markings in sectored light

In annular lighting



In sectored lighting. Mechanism marks are more visible, while accidental marks are less pronounced.

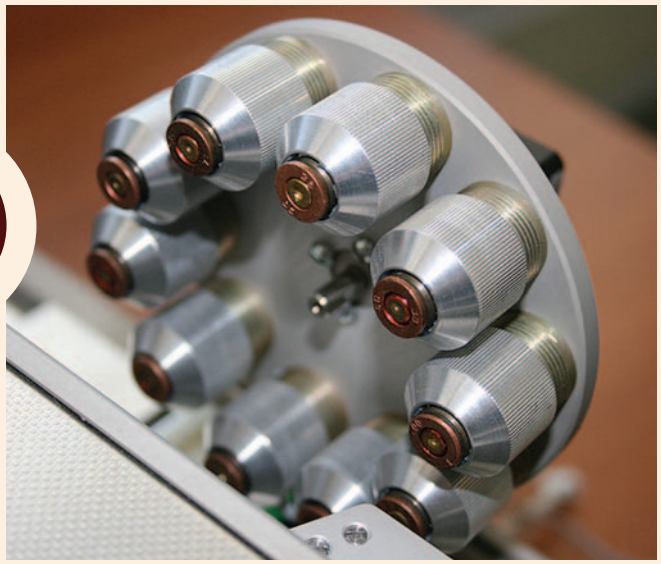


Scanning cartridge cases under sectored lighting takes unavoidably more time, but this drawback is compensated with an ability to use a semi-automatic dial-type holder that is specially designed for continuous scanning of 10 cartridge cases, reducing time and effort for setting up cartridge cases and freeing up the operator for other tasks.

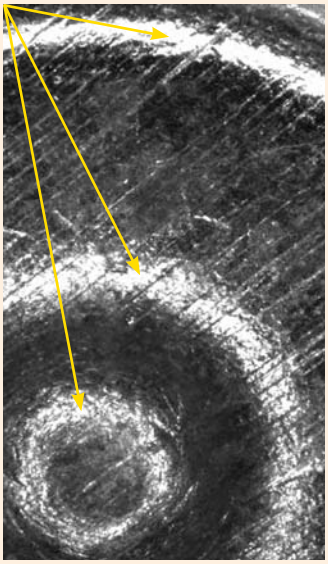
Both automatic focusing and calculation of requisite light intensity exclude the overexposure when capturing images, thereby avoiding loss of information.

The scanner works equally fine with all specimens though made of different material compositions – the reflecting and diffusing properties of material are considered when calculating the light intensity.

The color of surfaces being scanned has also no impact on the quality of imaging.



Semi-automatic dial-type holder for continuous scanning



Loss of information caused by overexposure

Image without loss of information captured with PAPILLON's mechanism of lighting

Resultant image of a criminal object acquired with PAPILLON BS

Digital copies of surfaces are ready for visual analysis as soon as the scanning is completed, before submission to the ABIS database. To this end, the scanning operator's software module provides all necessary tools, including zooming and panning, instruments for the precise measurement of angles and distances, automatic and manual brightness/contrast controls that work very fast thanks to performance capabilities provided by the PC's graphical subsystem.

The view of a 3D topographic model reveals useful spatial information about the exhibit's surface, at once providing the ability to rotate and resize the model. This 3D information measured with precision to the nanometer level allows the examiner to use such advanced visualization tools as the pseudocolor and the profile for 2D images, and to quantify the depth of any indentation on the exhibit's surface.

High-quality, easy and time-saving digitization of surfaces is the pride of the ARSENAL developers. The PAPILLON ballistic scanner is utterly user-friendly and fail-safe and it does not require any regular adjustments and calibrations. The application interface of the module that handles the automatic scanning process is intuitively comprehensible and it requires just the simplest computer skills from the operator.

All these factors, coupled with the absence of necessity in detailed analysis and classification of surface markings at the step of image acquisition, let the data collection be entrusted to employees who have no high qualification freeing up ballistic experts from this routine task, thereby considerably increasing cost-effectiveness of the system. It is especially important for the initial stage of the ABIS operation – when using the 'bulk'-entry technology to create electronic collections of bullets and cartridge cases, which often demands additional labour power to convert thousands and tens of thousands of objects to electronic images and in the shortest possible time.

3D IMAGING OF OBJECT SURFACES

In the early stages of the developing ABIS market, all systems offered then to consumers were operating exclusively with two-dimensional (2D) methods of acquisition, comparison and examination of digital images.

Later on, some of the systems, ARSENAL being among them, provided the ability to acquire three-dimensional (3D) information about the topography of markings on a specimen's surface.

ARSENAL acquires accurate 3D information about the surface relief of an exhibit in the process of layer-by-layer scanning, mapping details to the full depth of deformation. This technology PAPILLON's researchers developed for enhancing the image quality of heavily deformed surfaces got further improvements and in the course of time was transformed to an effective and powerful tool for measuring the topographical differences caused by the markings on ballistic specimens. This technology makes possible the three-dimensional imaging, the in-depth analysis and comparative examination of 3D models, the imaging and comparison of surface cross-sections, and precise measurements at any point across the surface. The use of 3D information also helps increase correlation accuracy. ***What makes up an exceptional value to this method is that the migration to using the three-dimensional measurements in ARSENAL ABIS has been accomplished without any substantial rise of its cost for end users.***

3D imaging of cartridge case head in ARSENAL ABIS

The method of topographical measurements using confocal sensors, like that used in Forensic Technology's IBIS, is considered the most precise one for obtaining 3D information about bullets' and cartridge cases' surfaces in ballistic systems. As of today, this method delivers the most realistic three-dimensional models of surfaces and markings. According to official statistics, there's observed some improvement in the results of automatic comparisons concerning particular types of surface markings caused by some specific types of firearms. Despite this proven appeal, an essential disadvantage of this method is its expensiveness – the high cost of equipment in addition to high operating costs caused by the extremely low speed of confocal scanning.

PAPILLON's team of researchers explores the possibility of improving the selectivity of automatic comparisons by further increasing the precision of topographical measurements, including those done with confocal sensors. But the question of embedding such equipment into ARSENAL ABIS is not on the agenda now, and it won't, at least until it can be confidently said that the use of this highly expensive technology is reasonable and does provide a qualitative leap forward in automatic correlation performance.

We believe that as of today the universal PAPILLON BS surface scanner and traditional 2D-imaging technology, creatively recast in the ARSENAL ABIS, are showing results that are not inferior to the confocal scanning, besides being incomparably cheaper and much easier to operate. The capabilities of this technology is far from exhausted. Great and achievable potential for improving the accuracy of automatic comparisons include:

- *further refinement of the optical circuit used in the ballistic scanner for more precise measurements of the surface topography*
- *use of new types of lighting at various angles when scanning bullets*
- *development and implementation of new methods for automatic image comparisons*

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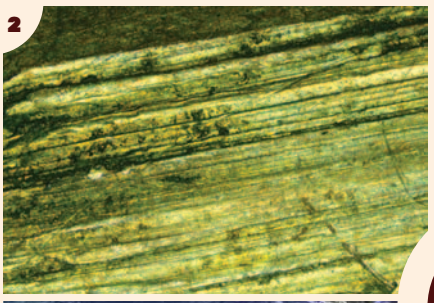

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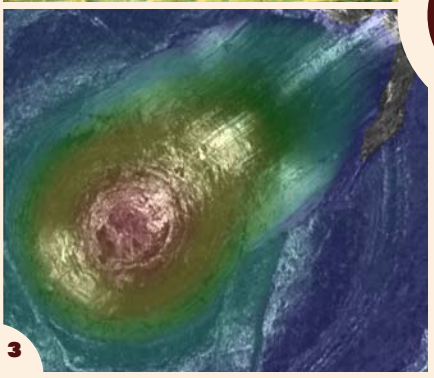

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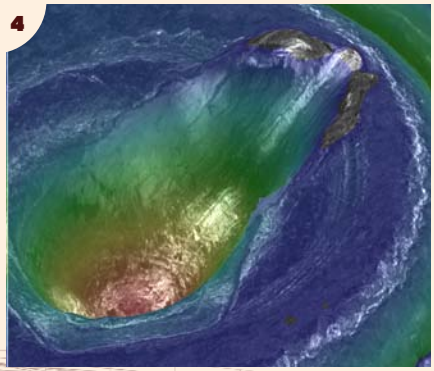

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1 AND 2 *are images acquired with a confocal sensor*
3 AND 4 *are 2D and 3D respectively represented in pseudo color in ARSENAL ABIS*

CODING IMAGES FOR AUTOMATIC COMPARISONS

Using specialized algorithms, ARSENAL processes the unique digital signatures automatically extracted from the ballistic images.

For bullets, ARSENAL automatically evaluates the rifling angle and the land width, the location of leading and trailing edges.

For cartridge cases, ARSENAL automatically locates the firing pin and the breechface impressions, and outlines the outer boundary of the headstamp and the primer area.

Other areas of significance, markings and striations visible on the images, are outlined or labeled by the expert. This process is called 'interactive image coding'.

ARSENAL allows for the interactive coding of the following surface markings:

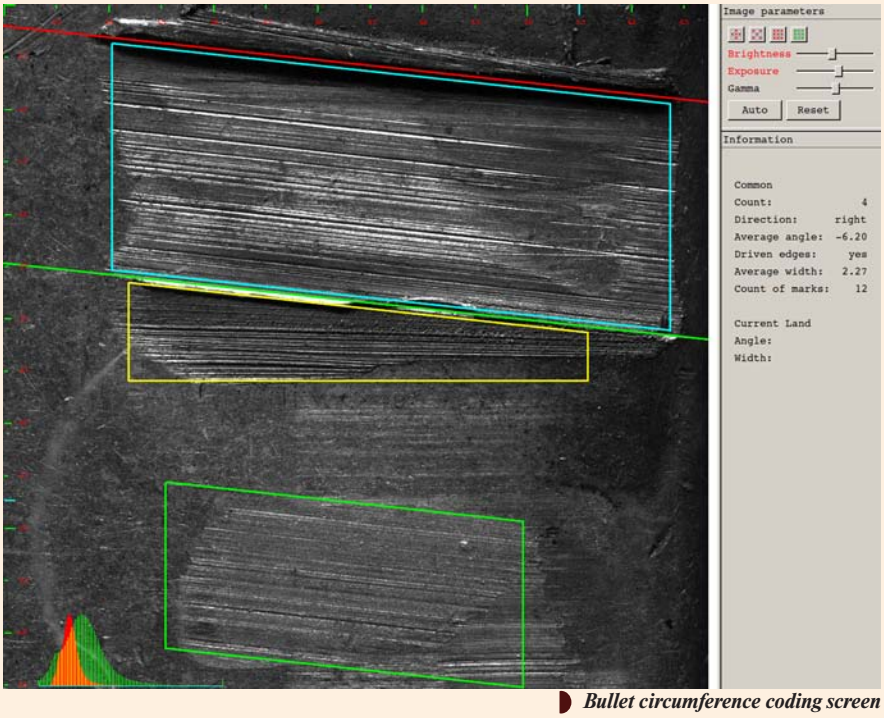
On bullets, the expert can code primary (skid) marks, and land and groove impressions.

On cartridge cases, the expert can mark 12 various types of toolmarks imparted to cartridge cases from having been loaded in, fired and extracted from firearms.

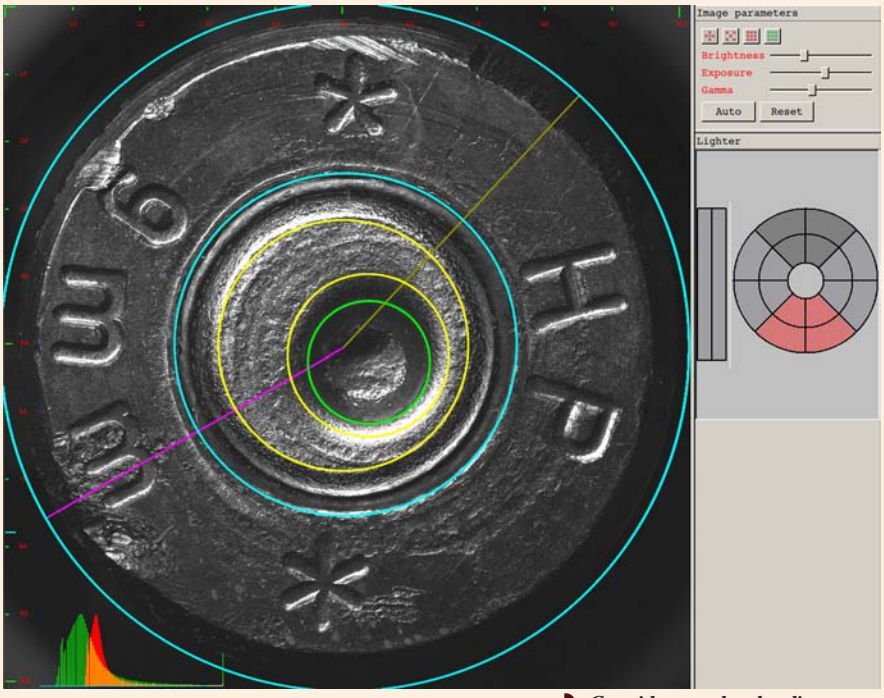
When coding the images of shots fired from shotguns, the expert can extract and save any number of fragments that contain characteristic striations.

Each significant surface marking is framed or outlined with a circle of a predefined color (a marquee box), depending on its type. If necessary, the size, shape and position of automatically set marquee boxes can be changed. The correctness of what is coded on the bullet image is automatically checked by the system.

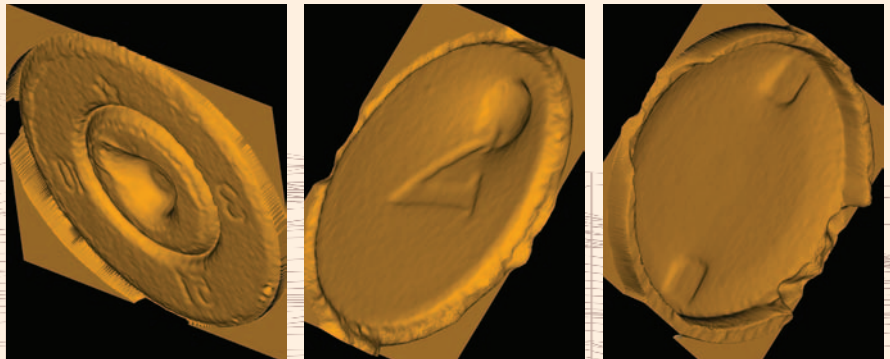
ARSENAL provides the firearm examiner with diverse tools that help him accurately locate and classify any surface marking, such as the 3D view, the pseudo color the tone of which informs about any depth variation of the microrelief, the profile view and depth measurement at any point on the exhibit's surface, the tools for measuring angles and distances.



Bullet circumference coding screen



Cartridge case head coding screen



3D reverse visualization of the cartridge case head reveals the design peculiarities of the firing pin

When coding surface markings on the cartridge case head, the examiner can switch to any of the nine images available, on which the area of significance is more clearly seen. The marquee boxes that are set or adjusted on one image are automatically updated on all the other images associated with the specimen.

A special tool has been developed and can be applied to extract and code the images of surface markings on specimens fired from smooth-bore weapons.

Coding is the last interactive operation in submitting objects to the ABIS database.

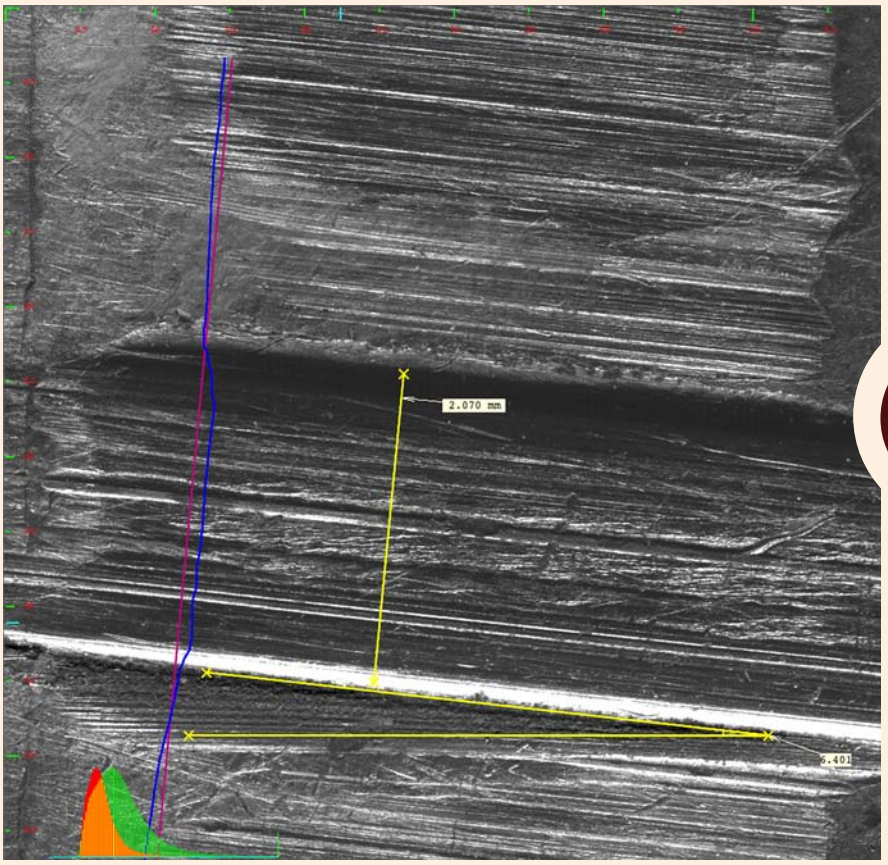
The coded exhibits are then processed with high-precision recognition algorithms, which have an excellent track record proven by many years of irreproachable operation of PAPILLON's identification products.

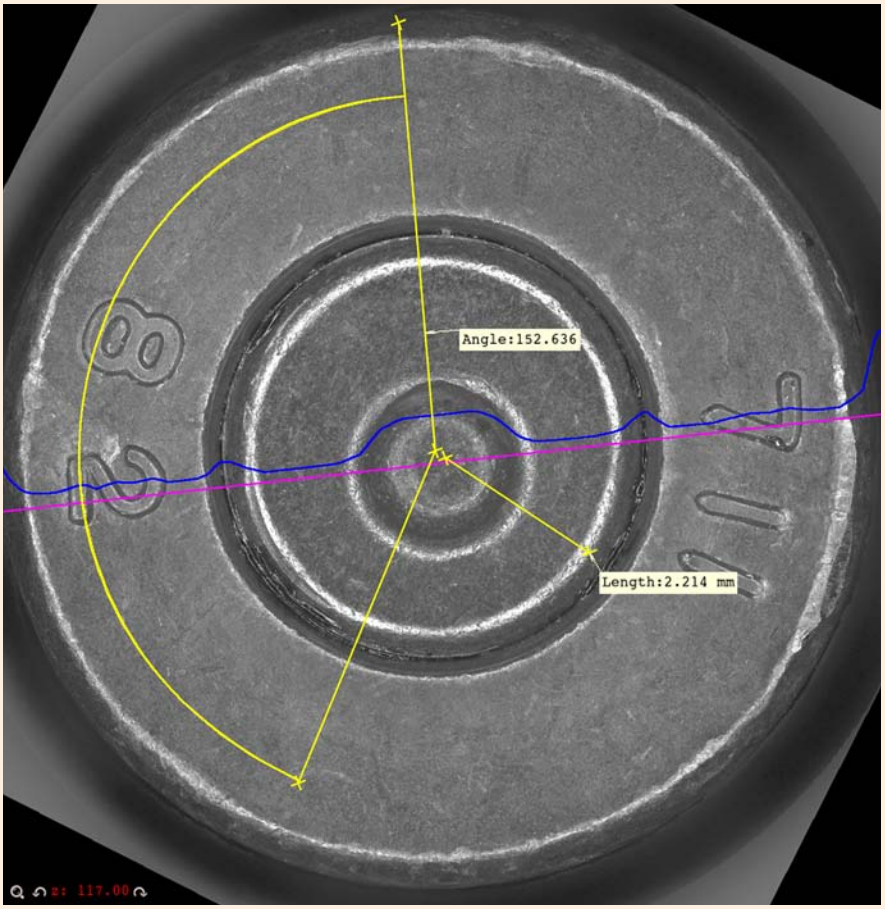
Each exhibit that is sent to the database is compared to those of the same class stored therein.

The probabilistic comparison algorithms compensate for arbitrary distortions of significant surface markings, caused by object deformations.

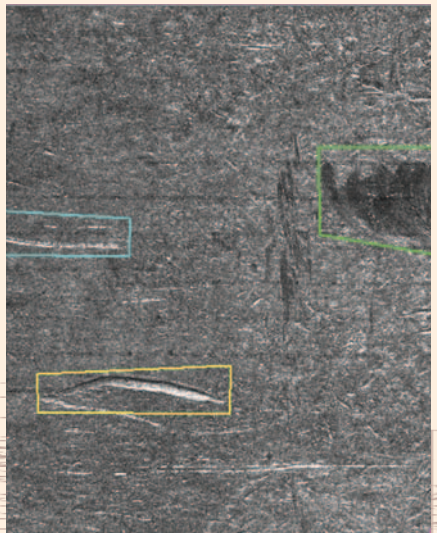
ARSENAL ABIS uses different methods for automatic comparison of ballistic fingerprints referring to different types.

The new approach combining 2D and 3D information provides a greater hit rate and considerably reduces the number of potentially matching candidates to be reviewed by an expert.





The view of the bullet's circumference and the cartridge case headstamp with the profile and measurement tools applied



Areas of significance coded on the cartridge case's circumference

DATABASE OPERATIONS AND COMPARATIVE ANALYSIS

In response to the user's command, ARSENAL ABIS immediately updates any list of objects, candidates, or identifications (hits), providing at any time the latest information on the database and the results of searches.

ARSENAL Database Viewer is an application that allows experts to retrieve and visualize administrative, technical and forensic information as well as images of all types of cartridge cases and bullets in both 2D and 3D representation and with areas of significance coded.

Many controls and tools are available to assist in conducting examination and making conclusions such as quick change from one image to another, tools for zooming, scrolling, rotating, moving to the next/previous surface marking coded on the exhibit's image, for displaying or hiding surface profiles, marquee boxes and other encoding labels, controls for automatic or manual adjustment of brightness and contrast and much more.

The examiner is provided with a comprehensive set of tools allowing him to sort and make selections of any kind, to search for specific information in the database, to edit the object's demographic data, keeping at that the history of such editing, to send exhibits for re-coding and to initiate new searches against either the entire database or only objects that match the specified search criteria.

Any deletion from the database is carried out together with the recording of the date, time, reasons for deletion and the name of an operator who deleted the object. To recover mistakenly deleted objects, there is a 'recycle bin' capability but available only to the system administrator.

The user can print out any text or graphical information associated with database objects as well as lists of any or all ballistic collections, candidate lists, to obtain statistical data on the quantitative and qualitative composition of the database.

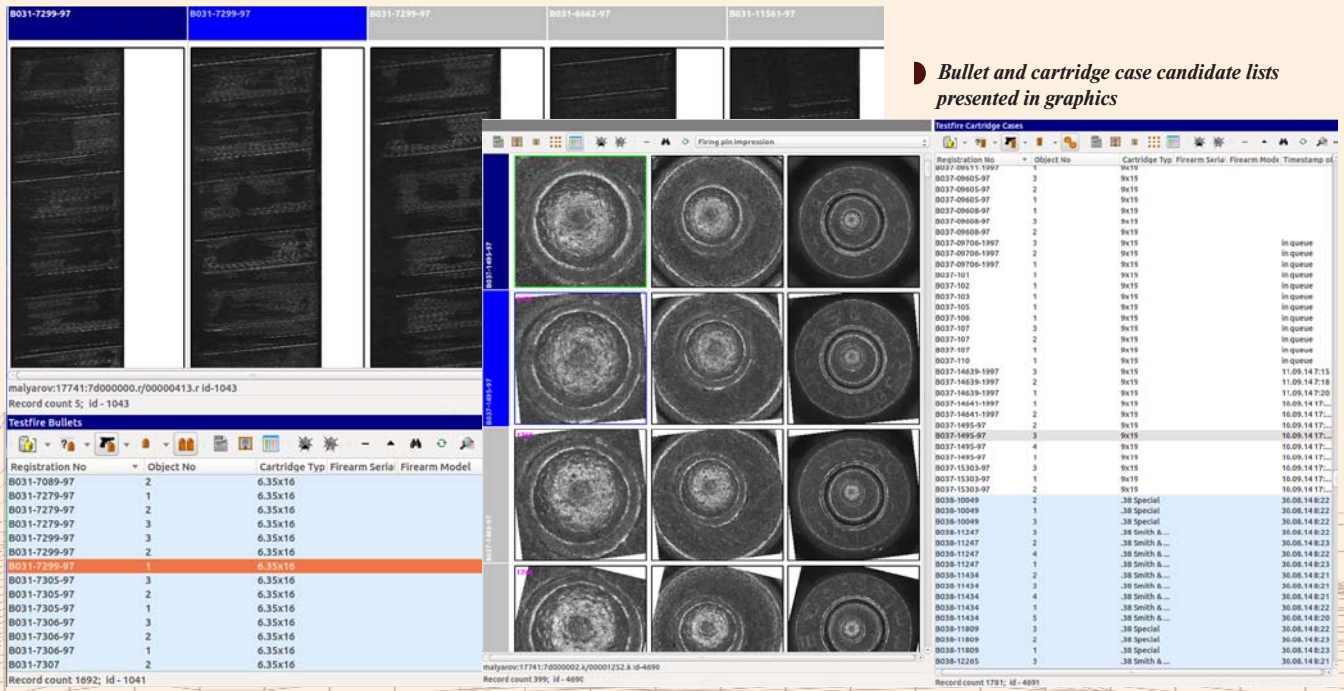
Import/export of objects via communication channels that support IP connectivity enables remote transfer of data to other ARSENAL systems quickly across jurisdictions and makes it easier and faster to feed and share data and to perform ballistic comparisons across crime scenes and data collections. ARSENAL supports also the exchange of information recorded on removable media.

ARSENAL ABIS uses Firebird, an open source SQL relational database management system that allows reliable and efficient operation with database objects.

Lists of objects, candidates, hits and other information stored in the ARSENAL database can be presented on the screens of operators' workstations, including those at remote sites, according to permissions assigned to ARSENAL users by the system administrator.

ARSENAL provides scalable storage for thousands of exhibits divided within the database in the following collections: testfire and evidence bullets, testfire and evidence cartridge cases, fragments and shots fired from smooth-bore guns.

Once the user finishes his session with the database and exits, the last screen is saved and will be restored next time the user opens a new session.



Bullet and cartridge case candidate lists presented in graphics

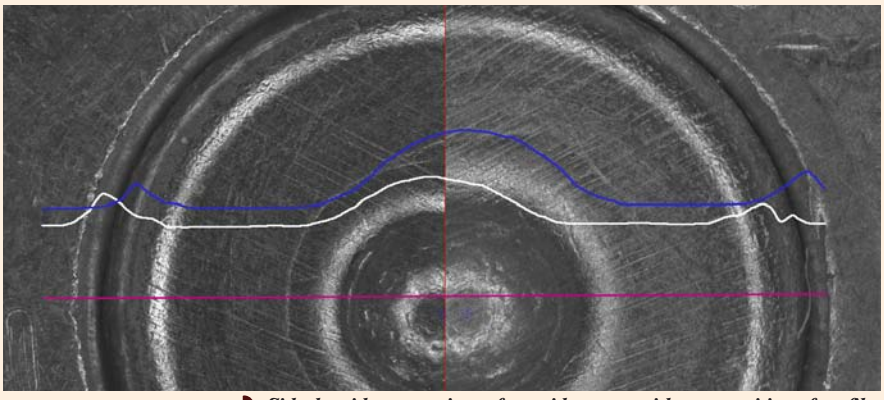
The match results returned by the system are arranged in the form of candidate lists – for a bullet, a single candidate list will be generated, while several can be produced for a cartridge case depending upon the number of unique markings coded on its image.

Moreover, ARSENAL ABIS creates special candidate lists for markings found on the cartridge case head, which take into account the results of comparisons produced for the same marking but scanned in different light modes – so-called 'synthesized' lists that allow firearm examiners to make comparative conclusions faster and with less effort.

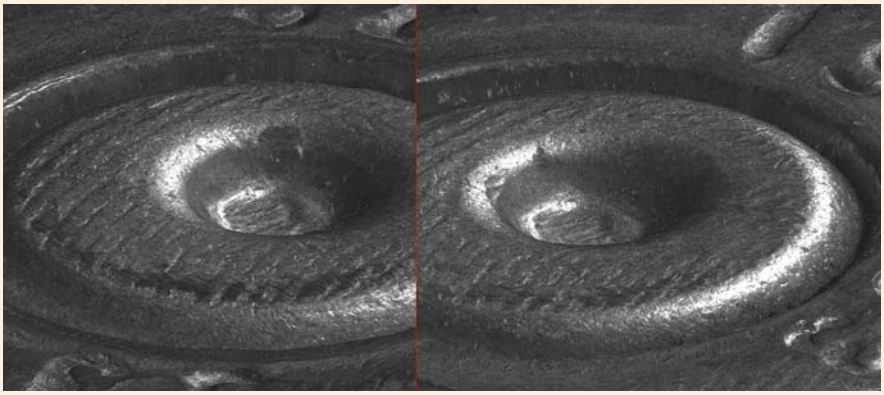
Visual comparison of images when analyzing candidates, as well as simultaneous view/comparison of multiple exhibits/markings, is available in a side-by-side or multiview screen (up to six windows) mode that virtually emulates the functions of a comparison microscope, and also allows the image superposition.

Superposition (or overlay) of images with the ability to adjust the transparency of layers ('onion skin' mode) is carried out within a variable-sized "floating" window.

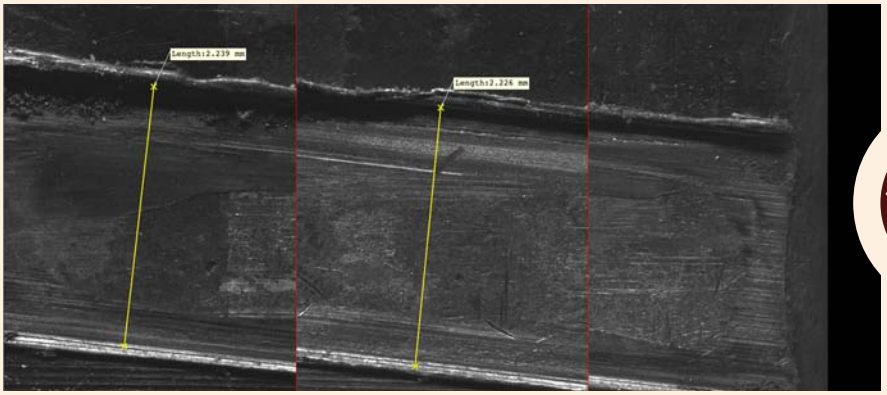
The system is capable to superpose both two-dimensional and three-dimensional images.



Side-by-side comparison of cartridge cases with superposition of profiles

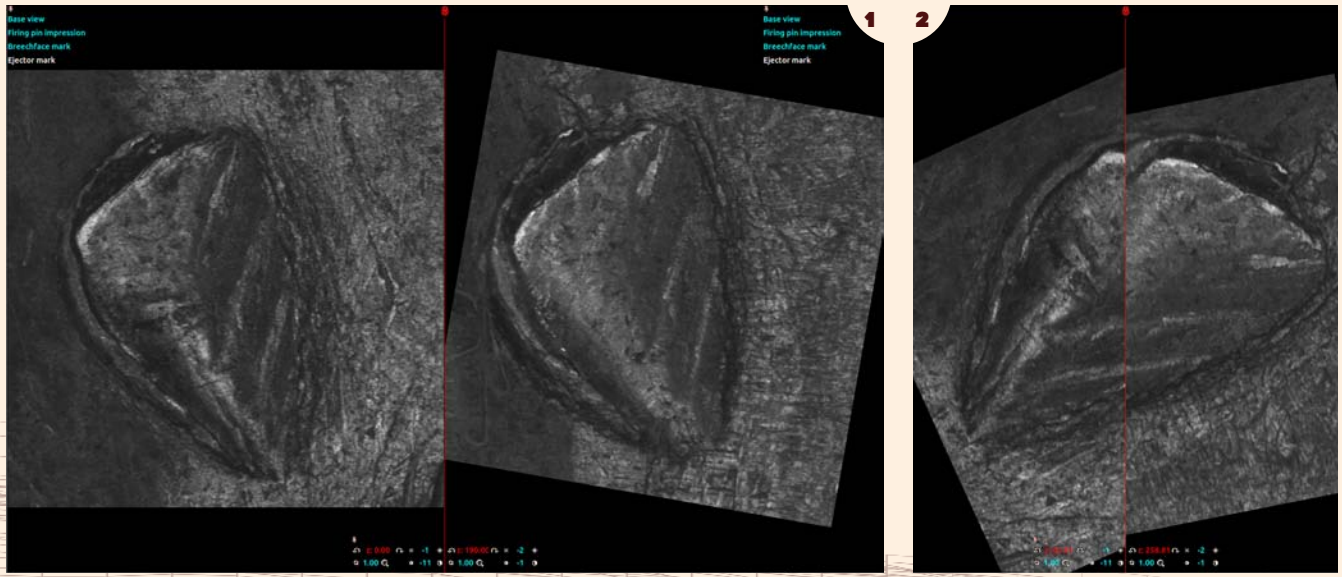


Side-by-side comparison of 3D images of cartridge cases

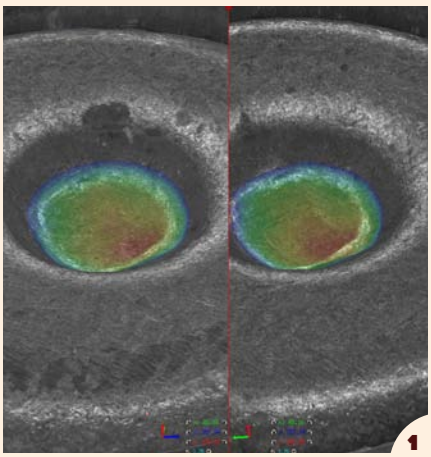


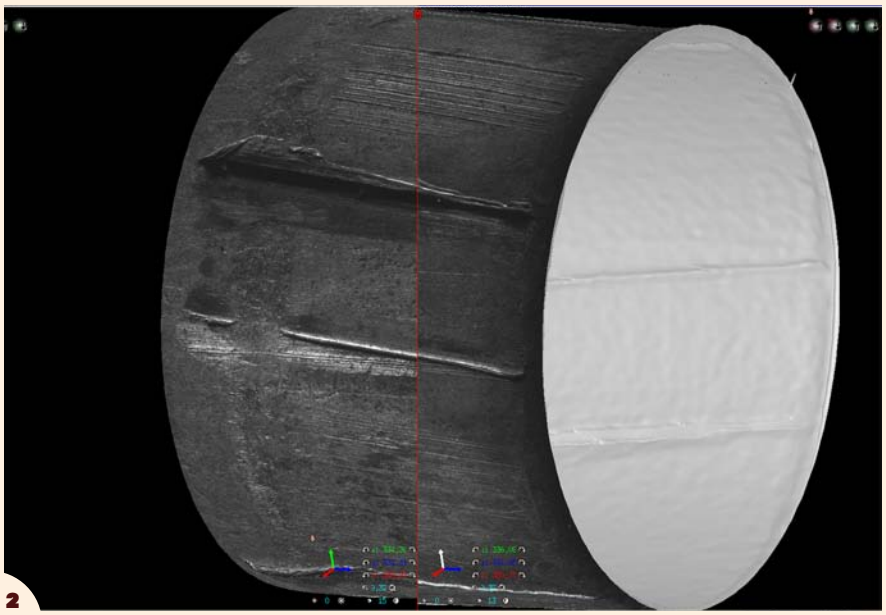
Multiview mode for comparative examination of bullets' circumferences

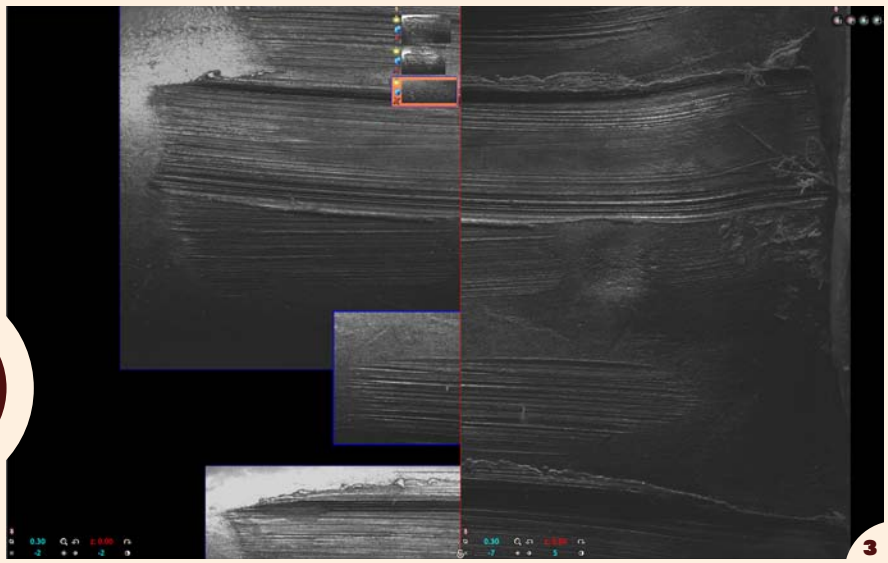
1, 2 *Comparative analysis of ejector marks*

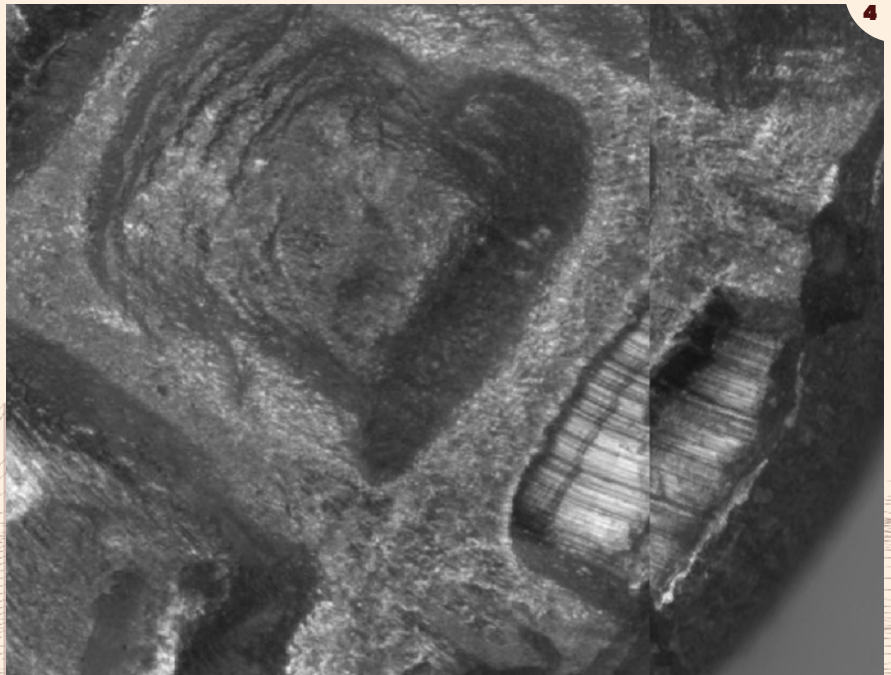


The surface profile, pseudocolor and depth map visualization tools can be applied to 2D images. The pseudocolor function is available for 3D images as well.









The dividing line creating a split field on the screen is movable. The images can be rotated, moved, scaled separately, each in its window, or together in a 'splice' mode.

ARSENAL ABIS allows the firearm examiner to virtually reconstruct a bullet just by using the images of its fragments available and comparing them with the circumference or set of fragments referring to some other bullet. The position and mutual orientation of the fragments the examiner finds are recorded, and this resulting combination can be treated as a single object usable for comparative studies.

The program interface of the comparative analysis module replicates the methods of working with and the functions of a comparison microscope and therefore it is familiar and intuitive to every expert.

ARSENAL provides a lot of flexible settings and options for the expert to individually organize the process of reviewing match results and working with the database, reducing the wait time between the submission of an exhibit and the delivery of a conclusion.

1 *Comparative analysis of 3D images of cartridge cases in pseudocolor*

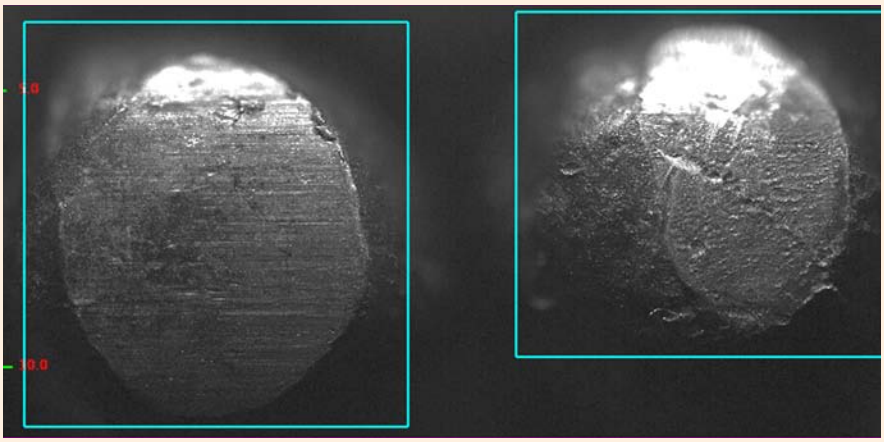
2 *Comparison of 3D bullets' closed circumferences*

3 *Bullet image reconstructed from fragments and matched the solid image of another bullet*

4 *Comparison of toolmarks*

OBJECTS FIRED FROM SMOOTHBORE AND TRAUMATIC WEAPONS

Areas of significance coded on projectiles fired from a shotgun



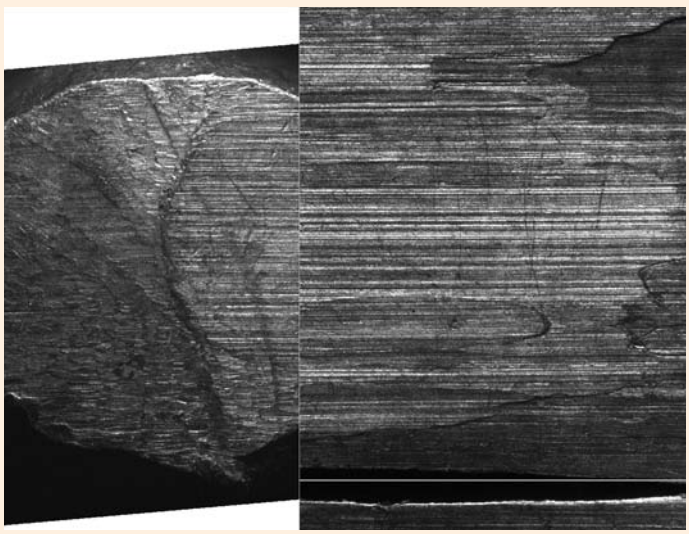
ARSENAL ABIS provides law enforcement agencies with a valuable service to organize automated collections of specimens fired from smoothbore and traumatic weapons, which increasingly appear on police reports today.

The procedure for working with cartridge cases referring to traumatic weapons is similar to that followed when working with rifled firearms.

The system provides ad hoc capabilities for examining shotgun cases (bullets, pellets, grape-shots).

It is to this end that PAPILLON engineers have designed a special holder for easy positioning and simultaneous scanning of multiple projectiles. The encoding procedure is simple and consists in partitioning the acquired image of simultaneously scanned objects into pieces, and then turning them to make the striae be oriented horizontally. The exhibits are then compared using a specifically designed algorithms. This type of objects can be stored in a separate section within the database.

PAPILLON engineers have also solved the problem of obtaining representative samples fired from shotguns. For this purpose, they developed a special mechanism that simulates a shot by pulling a projectile through the weapon's barrel, thereby ensuring the safety of the projectile and superior imaging of the markings left by the barrel.



Matching striae on smoothbore fired exhibits

PICKLISTS AND DICTIONARIES

Data input in ARSENAL allows for the entry of comprehensive administrative, technical and forensic information related to the case. This does not mean that the official submitting an exhibit must possess encyclopedic knowledge of brands and models of weapons, or keep handy a library of technical literature on ballistics.

The task to unify the descriptions of objects and to exclude mistakes at typing is successfully solved through the specially developed system of picklists and dictionaries. 30 dictionaries provided in ARSENAL have been made up on the basis of authoritative specialized sources and provide a comprehensive description of design features and components for more than 1,000 models of firearms, ammunition and their modifications produced by various manufacturers.

The dictionaries ensure the uniformity of submitted data, high speed and maximum automation for creating technical descriptions of specimens. For example, as soon as the operator specifies the caliber and type of a cartridge associated with the bullet/cartridge case, all other fields (such as *Length*, *Diameter*, *Shape*, *Design*, etc.) get automatically completed.

The picklists help the operator to save time when entering any administrative information such as, for instance, the name of *Initiator* or *Agency* submitting the inquiry.

Only the system administrator is authorized to compose picklists that can be used by all users at the ARSENAL ABIS site, to update and edit the ballistic dictionaries.

But the user can customize the view of picklists and dictionaries to suit his tasks and preferences – thus, he can edit, delete unnecessary or add new values such as, for example, his last name to quickly complete the *Operator's Name* field.

A single-computer ARSENAL is able to support a database of up to 10,000 objects and to operate as a full-featured ABIS enabling the input of text information and images, coding operations, automatic comparisons, verification of candidate lists, database archiving.

The workstation can operate either a standalone ABIS or it can be networked for file sharing and searching all or some of the databases within a network, including remote ones.

- *Configuration of an ARSENAL workstation*
  - *Universal PAPILLON BS surface scanner*
  - *PC*
  - *Laser printer*
  - *Modem (in case of remote use)*
  - *Uninterruptible power supply*
  - *PAPILLON ARSENAL software*

SYSTEM ARCHITECTURE

The architecture of ARSENAL is based on the client-server model that allows ARSENAL workstations to independently request the server's functions and services. The matching process is organized on the principles of distributed computing technology.

In larger ARSENAL systems, the server's functions, such as data input and storage, searches, connections and communications, are distributed among several subsystems. In complexes with small databases, the server's functions are provided by the resources of a single server unit or distributed among workstations.

The text part of any ARSENAL database is saved in a separate database, which is open for interaction with external SQL systems.

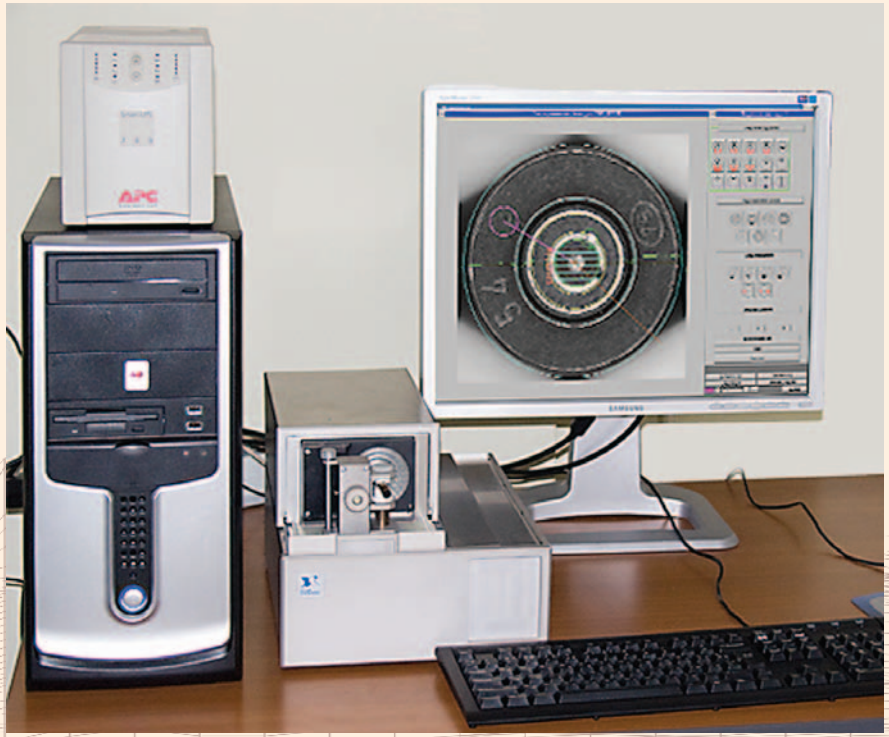
The server software runs under the Linux operating system. The client software is developed with the use of the QT technology as a cross-platform application for Linux and Windows. Both server and client software is a set of modules that provides a flexible system customization to meet an individual customer's requirements as well as freedom for their further development and scaling.

The configuration of any ARSENAL system is determined by database capacity, estimated throughput requirements and density of inquiries submitted from workstations, including those located at remote sites.

To create ARSENAL complexes, we use only commercially available equipment, the latest developments in the field of servers, storage systems and data protection, programmable control of computational processes. Our great design expertise allows us to offer such software and hardware solutions that are optimal in terms of price and performance, that ensure the most effective use of all computing facilities involved, and that are easily scalable at a minimal cost.

ARSENAL systems are working around the clock without constant supervision by the staff, which is achieved though the use of fault-tolerant technologies providing, inter alia, complete redundancy of critical components and automatic data backup.

ARSENAL provides automatic recovery of its databases and the state of matching processes after force majeure and emergency power outages.



ARSENAL is designed to be part of a LAN or any other form of networks that support IP connectivity.

The ARSENAL administrator's functions include:

- Users and user rights management (including the remote access mode), operators' performance monitoring
- Search processes monitoring
- Database status monitoring and database segment management
- Control of data security facilities
- Monitoring of automatic import/export of data and database remote calls
- Statistics gathering and reporting
- Compilation and editing of picklists and dictionaries for the input modules of administrative and forensic information.

Peripheral components connected to the ARSENAL ABIS via secure communication channels supporting TCP/IP to transfer data and to work with databases include:

- Data collection stations without local databases
- Remote workstations / networked systems with own databases
- Mobile workstations with local databases.

Mobile ARSENAL ABIS in a shockproof case. Fully adapted for efficient operation in any vehicle (powered by a car's on-board accumulators)

ARSENAL ABIS WORLDWIDE

Examples of the most massive supplies and installations of ARSENAL ABIS abroad:

- *Republic of Mongolia, National Forensic Center of the Ministry of Interior (rated database capacity – 100,000 objects):*
  - Central server
  - Matcher
  - 3 operator's workstations, each fitted with PAPILLON surface scanner

- *People's Republic of Bangladesh, Forensic Laboratory of the Criminal Investigation Department, Bangladesh Police (rated database capacity – 100,000 objects):*
  - Central server
  - Communication server
  - 3 matchers
  - 4 operator's workstations, each fitted with PAPILLON surface scanner

- *Republic of Serbia, Criminal Police (rated database capacity – 50,000 objects):*
  - Central server
  - Matcher
  - 2 operator's workstations, each fitted with PAPILLON surface scanner
  - 2 remote workstations with PAPILLON surface scanners and internal databases

PAPILLON
SYSTEMS

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