National Institute of Standards & Technology

Certificate

Standard Reference Material® 2460

Standard Bullet

Serial No.: SAMPLE

Standard Reference Material (SRM) 2460 is a bullet signature standard comprising bullet profile signatures of six land engraved areas (LEAs) from fired bullets. This SRM is intended primarily for use as a check standard for crime laboratories to help verify that the computerized optical equipment for bullet imaging and profiling is operating properly. A unit of SRM 2460 consists of an SRM standard bullet that is mounted on a blue stub (see Figure 1).

A Virtual/Physical Bullet Signature Standard: The SRM 2460 physical bullet signature standard is derived from a virtual standard. The virtual standard, as shown in Figure 2, is a set of six digitized bullet profile signatures that provided the information for machining the bullet signatures on the physical standards, the SRM 2460 standard bullets [1,2]. The virtual standard also provides the reference profiles for comparison measurements of these bullet signatures [3].

Certified Cross Correlation Function Maximum CCF_{max} and Signature Difference D_s: The certified values for cross correlation function maximum CCF_{max} and signature difference D_s are based on results obtained from profile comparisons between the six profile signatures on the SRM 2460 standard bullets and those of the virtual bullet signature standard. For an ideal match between the bullet signature and the virtual standard, CCF_{max} is equal to 1 and D_s is equal to 0. Forty SRM 2460 standard bullets, with serial numbers S/N 001 to S/N 040, were measured and compared with the virtual standard. The measurement results were statistically analyzed. The values of six cross correlation function maxima CCF_{max} and signature differences D_s for the six bullet signatures were averaged for each SRM 2460 bullet. These averages were designated $\overline{CCF}_{max}$ and $\overline{D}_s$. For the 40 SRM standard bullets, the collective lower limit for $\overline{CCF}_{max}$ and upper limit for $\overline{D}_s$ with a 95 % confidence level (α = 95 %) [4] are reported in Table 1. A NIST certified value is a value for which NIST has the highest confidence in its accuracy in that all known or suspected sources of bias have been investigated or accounted for by NIST [5]. The current distribution of SRM 2460 consists of 35 bullets. These bullets were etched and corrosion protected. Five of the 35 bullets were measured again to show that the etching process produced no detectable change in the surface topography measured by the stylus instrument.

Expiration of Certification: The certification of SRM 2460 is expected to be valid, within the measurement uncertainties specified, until **30 June 2016**, provided the SRM is handled, stored, and used in accordance with the instructions given in this certificate (see "Notice and Warning to Users"). However, the certification is nullified for an inspected area that is damaged, contaminated, or modified. NIST reserves the right to withdraw, amend, or extend this certification at anytime.

Maintenance of SRM Certification: NIST will monitor this SRM over the period of its certification. If substantive surface changes occur that affect the certification before the expiration of this certificate, NIST will notify the purchaser. Registration (see attached sheet) will facilitate notification.

The coordination of SRM 2460 production and the technical measurements leading to the certification of this SRM were performed by J. Song and T. Vorburger of the NIST Precision Engineering Division, and S. Ballou of the NIST Office of Law Enforcement Standards (OLES).

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Certificate Issue Date: 30 October 2006

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Consultation on the statistical design of the experimental work and evaluation of the data were provided by J. Yen of the NIST Statistical Engineering Division.

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The SRM 2460 standard bullets were manufactured by R. Clary and B. Dutterer of the NIST Manufacturing Engineering Laboratory, and D. Kelley and C. Johnson of the NIST Materials Science and Engineering Laboratory. Preparation of and analytical measurements on the SRM were performed by E. Whitenton, B. Renegar and A. Zheng of the NIST Manufacturing Engineering Laboratory, L. Ma of the Kent State University (Kent, OH), and M. Ols of the Bureau of Alcohol Tobacco, Firearms and Explosives (ATF) (Ammendale, MD).

The support aspects involved in the issuance of this SRM were coordinated through the NIST Measurement Services Division.

NOTICE AND WARNING TO USERS

Storage and Handling: The SRM 2460 must be used and kept in a dry and clean environment at temperatures between 10 °C and 30 °C. Touching the surface of the SRM 2460 standard bullet with bare hands may cause corrosion on the SRM 2460 surface and damage the bullet signatures and, therefore, should be avoided. See Appendix for "Handling and Cleaning Procedure".

INSTRUCTIONS FOR USE

These SRM 2460 standard bullets (example shown in Figure 1) are made of oxygen-free, high conductivity (OFHC) copper rod with about a 1 mm thick bright-copper coating. Six LEAs are machined on the bullet surface by a numerically controlled (NC) diamond turning machine. Each LEA has a unique bullet signature in accordance with the virtual bullet signature standard (see Figure 2), but the SRM bullets are intended to be essentially identical to one another. The bullet LEAs are produced with a 5° right hand twist (see Figure 1), which makes the SRM 2460 resemble a real 9 mm Luger type bullet. There is a dot (see Figure 1, A, not visible) located close to the nose of each bullet that shows the No. 1 LEA for each bullet. The No. 1 LEA is also not visible in Figure 1; the No. 3 LEA is facing the reader. The SRM 2460 standard bullet is mounted on a blue stub. A notch on the blue stub (see Figure 1, B) is oriented at approximately 90° with respect to the dot (A). For initial setup on a microscope, the notch is aligned to face the user so that the No. 1 LEA is facing up into the objective of the microscope. The NIST measurements, using a stylus instrument, were performed near the top sections of each bullet LEA (see Figure 1, C). In order to avoid possible scratches caused by the diamond stylus, it is suggested to avoid the use of the top section (C) for optical measurements.

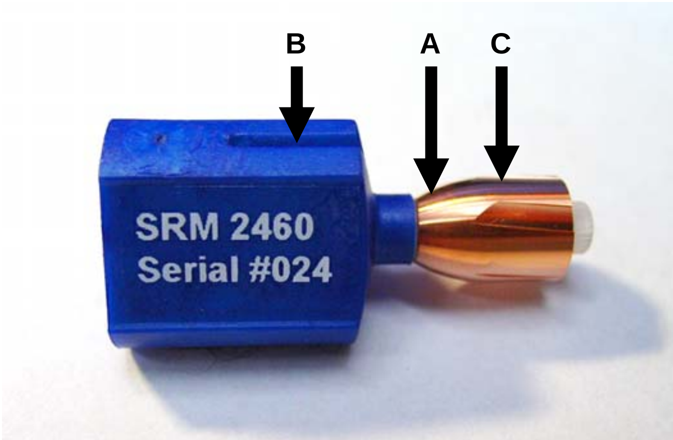


Figure 1. A NIST SRM 2460 standard bullet mounted on a blue stub. A dot (A, not visible) indicates the No. 1 land engraved area (LEA) of the bullet. The No. 3 LEA is facing the reader here in the Figure. A notch (B) on the bullet stub is approximately aligned at 90° with respect to the dot (A). The NIST stylus measurements are traced at the top sections (C) of each LEA. In order to avoid possible scratches caused by the diamond stylus, it is suggested to avoid the use of the top section (C) for optical measurements.

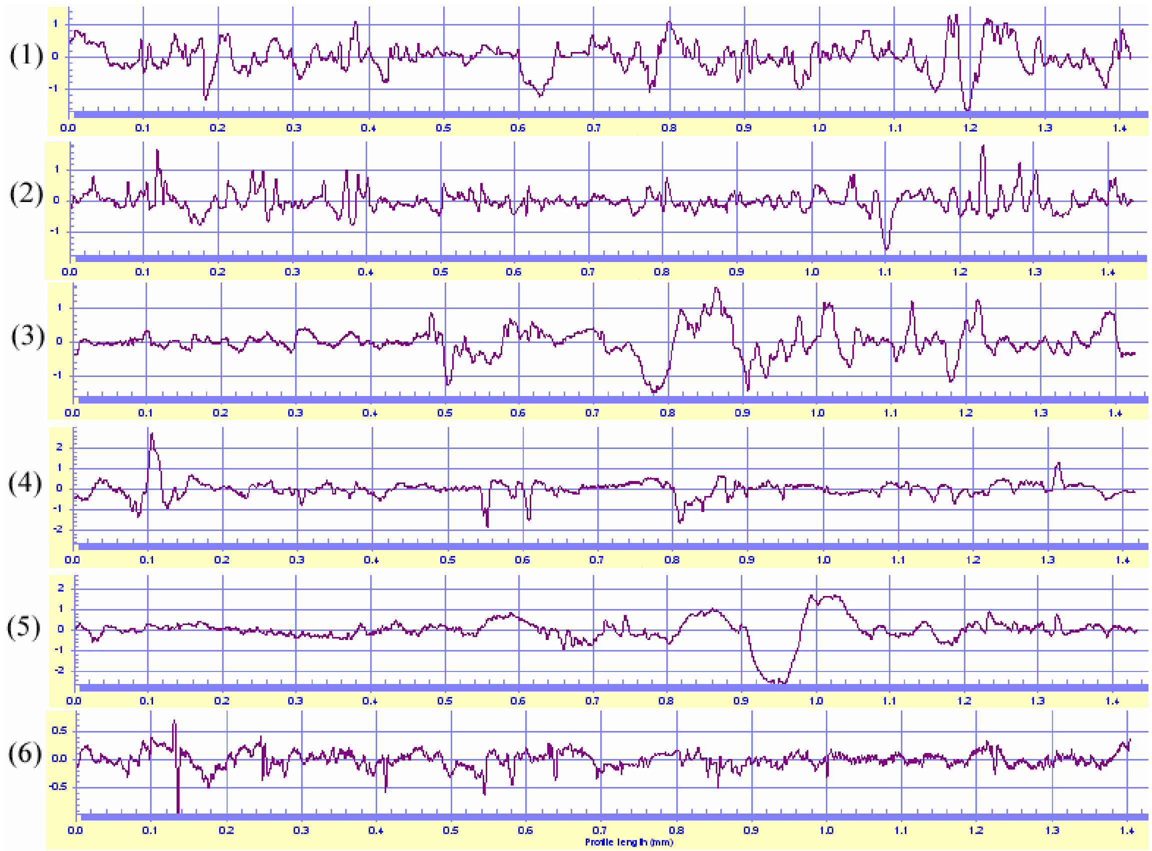


Figure 2. The virtual bullet signature standard consists of six digitized bullet profile signatures measured by a stylus instrument on six master bullets fired at the ATF and FBI. The virtual standard profiles shown above are modified profiles after curvature removal and Gaussian filtering with a short-wavelength cutoff of 0.0025 mm and a long-wavelength cutoff of 0.25 mm [6]. The vertical scale is in µm; the horizontal scale is in mm.

PREPARATION AND ANALYSIS

The virtual bullet signature standard was obtained from topographic profiles traced on six master bullets fired at the Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) and the Federal Bureau of Investigation (FBI) under standardized shooting procedures [1]. The virtual bullet signature standard was stored in a computer and used for control of the tool path of a NC diamond turning machine at the NIST Instrument Shop to machine the six bullet signatures on the SRM 2460 standard bullets [2]. After machining, a specially designed chemical etching process was used for slightly roughening the surface of the bullet to improve its diffuse reflection and make the SRM bullet appear like a real bullet when observed under an optical microscope. Then, a commercial corrosion protection was applied to the surface of the SRM bullets.

In order to evaluate the uniformity and reproducibility of the bullet signatures between the SRM 2460 standard bullets and the virtual bullet signature standard, the NIST bullet signature measurement system was developed [2,3]. This system includes a stylus instrument to measure the profile signature following procedures in ASME B46.1 [6]. The nominal stylus radius is 2 µm. The nominal contact force is 0.001 N. The vertical digital resolution is 0.01 µm. The sampling interval is 0.25 µm over an evaluation length of about 1.4 mm. Before the measurement of the bullet signatures, a Gaussian filter [6] with a short-wavelength cutoff of 0.0025 mm is used for removing the high frequency noise. Then the curvature on the traced signature profile is removed, and a Gaussian filter with a long-wavelength cutoff of 0.25 mm is used to attenuate long surface spatial wavelengths. The Gaussian filter truncates the measured profile across the LEA from its measuring length of about 1.9 mm to an evaluation length of about 1.4 mm. Detailed information for the NIST measurement system can be found in reference 3.

The profile signature of the virtual bullet signature standard (see Figure 2) is used as a reference standard against which the corresponding profile signature on each SRM bullet is compared. Two parameters are used for the comparison of bullet signatures to determine the similarity of two profile signatures [2,3]. One of these is called CCF_{max}. This is the maximum value of the cross correlation function CCF [6], which occurs when the two correlated profile signatures, the compared bullet signature $Z_{(B)}$ of the SRM bullet and the virtual signature standard $Z_{(A)}$, are in phase. At this position, a signature difference profile $Z_{(B-A)}$ is calculated, which equals the difference between signature $Z_{(B)}$ and $Z_{(A)}$.

$$Z_{(B-A)} = Z_{(B)} - Z_{(A)} \tag{1}$$

The second parameter, the signature difference, D_s, is defined as a ratio of the mean-square roughness Rq^2 [6] of the signature difference profile $Z_{(B-A)}$ and the mean-square roughness of the virtual standard signature $Z_{(A)}$:

$$D_s = Rq^2_{(B-A)} / Rq^2_{(A)} \tag{2}$$

When the measured signature $Z_{(B)}$ is exactly the same as the virtual signature standard $Z_{(A)}$ (point by point), CCF_{max} is equal to 100 %, and D_s is equal to 0.

The six bullet signatures of each SRM bullet were measured by the signature measurement system and correlated with the virtual bullet signature standard. The measurements were performed before the surface etching process and statistically verified after the etching and corrosion protection process for the SRM 2460 standard bullets. Statistical analyses show that there is no significant change for the bullet signatures before and after the etching and protection process.

The CCF_{max} and D_s values from the measurements of the six LEAs of each SRM bullet were averaged as $\overline{CCF}_{max}$ and $\overline{D}_s$. The $\overline{CCF}_{max}$ and $\overline{D}_s$ values for the 40 SRM bullets were statistically analyzed and collectively reported with a confidence level of α = 95 % [4]. That means 95 % of the measured SRM standard bullet signatures have $\overline{CCF}_{max}$ values higher and $\overline{D}_s$ values lower than the values shown below in Table 1:

Table 1. The Average Cross Correlation Maximum $\overline{CCF}_{max}$ and the Average Signature Difference $\overline{D}_s$ for the SRM 2460 Bullets (Serial Numbers: S/N 001 to S/N 040)

Average Cross Correlation Maximum	Average Signature Difference
$\overline{CCF}_{max} > 98.67\ \%\ (\alpha = 95\ \%)$	$\overline{D}_s < 2.64\ \%\ (\alpha = 95\ \%)$

The virtual bullet signature standard, including six digitized bullet profile signatures, is illustrated in Figure 2. They may be obtained from the NIST website for the Surface Metrology Algorithm Testing Service (SMATS) at http://ats.nist.gov/VSC/jsp/. The files may be downloaded in the sdf, smd, and XML formats for testing and comparison with profiles of the LEAs measured by the user on the SRM 2460 standard bullet and modified by a Gaussian filter [6] with a short-wavelength cutoff of 0.0025 mm, a curvature removal program, and a Gaussian filter with a long-wavelength cutoff of 0.25 mm.

A "User Guide for NIST SRM 2460 Standard Bullets" is appended here for customers using the SRM bullet to check instrument calibration and measurement quality control of an optical instrument, such as the Integrated Ballistics Identification System (IBIS™)[1], for bullet signature acquisitions and correlations.

[1] Certain commercial equipment, instruments, or materials are identified in this certificate to specify adequately the experimental procedure. Such identification does not imply recommendation or endorsement by the National Institute of Standards and Technology, nor does it imply that the materials or equipment identified are necessarily the best available for the purpose.

REFERENCES

[1] Song, J.; Vorburger, T.; Ols, M.; *Establishment of a Virtual/Physical Standard for Bullet Signature Measurements*; NCSL Conference Proceedings, Washington, D.C. (August 2001).

[2] Song, J.; Whitenton, E.; Kelley, D.; Clary, R.; Ma, L.; Ballou, S.; Ols, M.; *SRM 2460/2461 Standard Bullets and Casings Project*; J. Res. Natl. Inst. Stand. Technol. Vol. 109**,** pp. 533–542 (2004).

[3] Ma, L.; Song, J.; Whitenton, E.; Zheng, A.; Vorburger, T.; Zhou, J.; *NIST Bullet Signature Measurement System for RM (Reference Material) 8240 Standard Bullets*; J. Forensic Sci., Vol. 49, No. 4, pp. 649–659 (2004).

[4] ISO; *Guide to the Expression of Uncertainty in Measurement*; ISBN 92-67-10188-9; 1st ed.; International Organization for Standardization: Geneva, Switzerland (1993); see also Taylor, B.N.; Kuyatt, C.E.; *Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results*; NIST Technical Note 1297; U.S. Government Printing Office: Washington, DC (1994); available at http://physics.nist.gov/pubs/.

[5] May, W.; Parris, R.; Beck, C.; Fassett, J.; Greenberg, R.; Guenther, F.; Kramer, G.; Wise, S.; Gills, T.; Colbert, J.; Gettings, R.; MacDonald, B.; *Definitions of Terms and Modes Used at NIST for Value-Assignment of Reference Materials for Chemical Measurements*; NIST Special Publication 260-136, U.S. Government Printing Office: Gaithersburg, MD (2000).

[6] ASME B46.1-2002; *Surface Texture (Surface Roughness, Waviness, and Lay)*; American Society of Mechanical Engineers, NY (2003).

Users of this SRM should ensure that the certificate in their possession is current. This can be accomplished by contacting the SRM Program at: telephone (301) 975-6776; fax (301) 926-4751; e-mail srminfo@nist.gov; or via the Internet at http://www.nist.gov/srm.

APPENDIX

USER GUIDE FOR NIST SRM 2460 STANDARD BULLETS

A Draft Data Acquisition Procedure for the Integrated Ballistics Identification System (IBIS)

1. The NIST SRM standard bullet is intended for quality testing of automated ballistics signature acquisitions. It is recommended that an acquisition of the standard bullet be entered into IBIS once a month to verify the integrity of the system. However, you should refer to your laboratory's policy and procedure guidelines (PPGs) for the frequency of acquisition. The bullet should also be entered into the system during each software and hardware upgrade as well as after any scheduled or unscheduled maintenance. All entries and results should be documented.

2. Follow standard procedures from the manufacturer for maintenance and setup of the system and for calibration check at turn-on.

3. Procedure for creating a Case Maintenance (Filling Critical Fields in the Case Maintenance Box):

   (EXAMPLE)
   Case ID: Smith/QA/2006-08
   Event Type: TF
   Law Agency: Unknown
   Date of Occurrence: Date entered into system
   (All other categories can be left blank.)

   Note: Under "Case ID", the "Smith" represents the last name of the IBIS user, the "QA" indicates that it is a Quality Assurance test, and the "2006-08" represents the year and month it was entered into the system. Under "Event Type", the "TF" indicates that it is a test fire. The remaining case information should be self-explanatory.

   Procedure for creating an Exhibit:

   (EXAMPLE)
   Exhibit ID: BP-037/TF
   Caliber: 9 mm Luger
   Twist: R
   LEA's: 6
   Composition: Copper cased metal
   Event Type: TF
   (All other categories can be left blank.)

   Note: Under "Exhibit ID" the "BP" indicates a bullet, the "037" represents the three digit serial number associated with the SRM 2460 bullet and the "TF" indicates that it is a test fire. Under "Twist", the "R" indicates a right hand twist. The remaining exhibit information should be self-explanatory.

4. Follow the manufacturer's procedure for acquiring a bullet. For most conditions, use the same procedure as that for automated imaging of ordinary bullets. However, the following actions are recommended:

   - Normally use the area near the base of each bullet land engraved area (LEA). However, if a large blemish is in the field of view, feel free to move the field of view away from the base to a clean area on the LEA.

   - Check the *y*-variation graph after acquisition. This graph would indicate any difficulties in stitching the sub-images into one image. The graph should show a fairly constant point series with no large excursions. Large excursions would indicate that the stitching was not accurate, likely due to poor contrast, image saturation, or insufficient brightness.

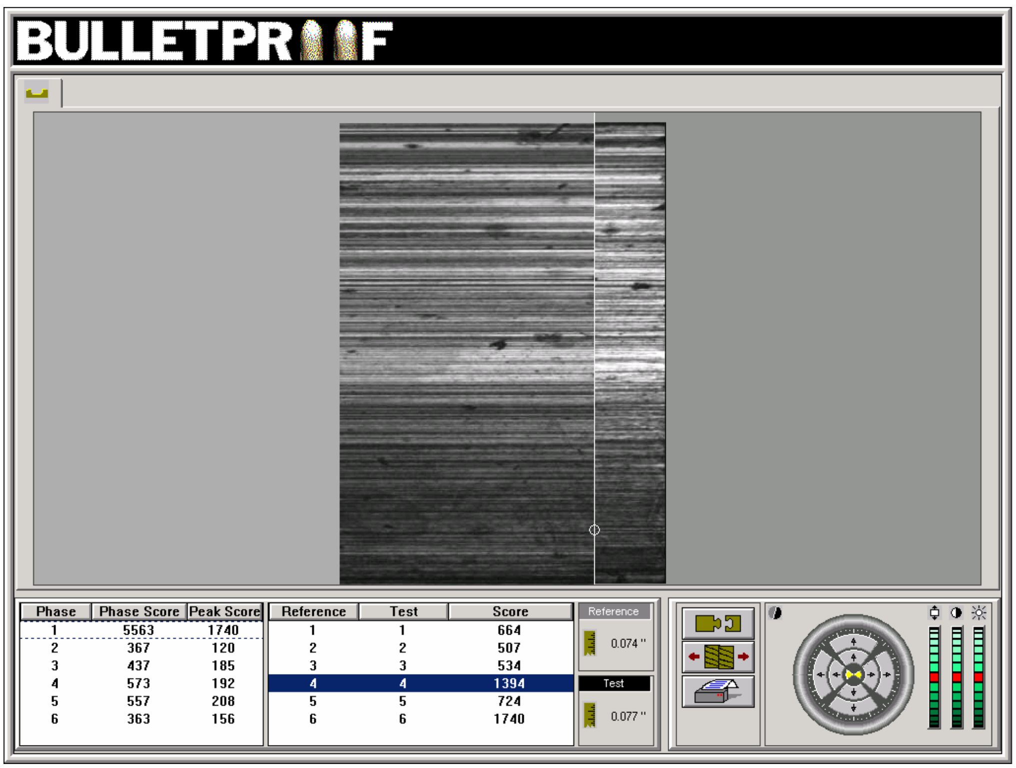
5. Record the width of the measured LEA. The widths of LEAS 1, 2, 3, 4, and 6 should be approximately 1.93 mm ± 0.08 mm (0.076 inch ± 0.003 inch), and the width of LEA #5 should be approximately 2.18 mm ± 0.08 mm (0.086 inch ± 0.003 inch).

6. If the LEA acquisition seems incorrect, either because the *y*-variation graph shows large excursions or the measured LEA width seems incorrect, then reacquire the LEA image. Change the measurement conditions slightly, either by moving the position of the leading and trailing shoulders in the acquisition box on the monitor screen or by switching from “laser focus” to “pixel focus” for this LEA or by doing both.

7. Once the acquisition is complete, conduct a manual correlation of that exhibit with the Region 6 server, where the "Golden Image" resides. Once the correlation has been completed, print out two copies of the scores and rank: (1) for your supervisor and (2) for your records. Then, delete the Case ID from the system, this will ensure that your case does not get correlated against any future evidence-type cases entered into the system.

8. The total score for the six-land correlation (Max Phase parameter) must be higher than a minimum control value, *C* (SRM 2460), when compared with the master entry, as calculated with IBIS Software Rev. 3.4.5 The control value may change in the future as the IBIS software or hardware changes. Start with a trial common control value of 4000 for the *C* (SRM 2460) Max Phase score. Once the local laboratory has established a history of control values, the user may wish to set a control value that is higher than 4000, consistent with, for example, a 95 % confidence level of achieving the control value.

9. A typical result might look like the following:



10. Plot the correlation score on a control chart along with previous scores to indicate the uniformity of the high correlation. If the correlation score drops below *C* (SRM 2460), flag the results and the date, then double check the alignment and reacquire the bullet images.

11. If the correlation score still remains below *C* (SRM 2460), have another trained IBIS operator enter the bullet into the system. If the bullet scores at or above the *C* (SRM2460), the user’s technique may be the issue. If the bullet score is still low, what is being observed may be a change in the system’s performance that needs to be diagnosed. Check the image acquisition procedure. This may include checking the calibration of the IBIS system, as well as the alignment, anchor points, and lighting conditions for the bullet.

Handling and Cleaning Procedure

The standard bullets are expected to be robust and maintain their quality over many years. However, it is good procedure to avoid handling the bullet surface in order to avoid unnecessary scratches and finger contamination from marring their surfaces. Likewise, cleaning should also be avoided as much as possible because the cleaning process itself can introduce irreversible changes in the surface topography of the bullet. If it is clear that contamination has been unavoidably introduced on the surface to the extent that it has been visibly changed, then a mild cleaning procedure may be used. The suggested procedure is to clean only the contaminated LEAs with a lab swab/cotton tip applicator moistened with ethyl alcohol.