

NIJ Standard 0101.07, Ballistic Resistance of Body Armor: Changes and Challenges

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Abstract. The National Institute of Justice (NIJ) has completed development of its seventh revision to NIJ's standard for ballistic resistance of body armor, NIJ Standard 0101.07. This revision takes into consideration the changing landscape of policing in the U.S. and implements lessons learned over the past decade of testing using NIJ 0101.06. The improvements include more widespread stakeholder engagement, improved test methods and procedures, and updated test threats and protection levels, all of which result in better protection for officers wearing body armor. This standard was developed with the guidance and input of a large group of end users and technical experts, and it incorporates by reference ten ASTM standards that were developed by an expanded group of stakeholders, including manufacturers. The test threats have been updated to reflect the evolving threats faced by U.S. law enforcement end users, including a wider range and more severe ballistics threats. The protection levels have been modified accordingly, with the protection level nomenclature also changed for better clarity and to reduce officer and end user confusion. Several new rifle test threats were added, and one of those is a 7.62 x 39 mm mild steel core round, which is commonly seen by officers but is known to have huge variability in performance. That variability has driven the development of a surrogate test round to ensure consistency in testing. Additionally, the laboratory accreditation process has been addressed in order to inform technical assessors of potential issues to be aware of and specific processes to observe during laboratory assessments. This paper will describe the improvements and changes to the NIJ standard and related conformity assessment activities and how those changes ultimately lead to enhanced officer safety and protection.

1. U.S. LAW ENFORCEMENT: A DANGEROUS PROFESSION

Law enforcement is a dangerous profession. The United States (U.S.) Bureau of Labor Statistics reports that in 2018 police and sheriffs' patrol officers in the U.S. experienced a fatality rate on the job of 13.7 in 100,000 officers—four times higher than the overall fatality rate on the job of 3.5 in 100,000 workers across all industries in the U.S. that year [1]. A majority of the accidental fatalities each year are traffic-related, while a majority of the felonious fatalities are due to assaults with firearms. The Federal Bureau of Investigation's (FBI) Law Enforcement Officers Killed and Assaulted (LEOKA) statistics show that from 1987 through 2018, over 78,000 officers were assaulted with firearms. Furthermore, of the 1,874 officers feloniously killed in the line of duty by all means over that time span, 1,728 were feloniously killed by firearms. That equates to *over 92% of all felonious deaths* in the line of duty being due to firearms. Handguns alone accounted for at least 1,284 of those firearms fatalities [2].

Research funded by the National Institute of Justice (NIJ) examined detailed information on 1,789 officers who were killed or severely injured between 2002 and 2011 due to assaults with firearms, knives, or other cutting instruments. This information, taken from the FBI's LEOKA dataset, was analyzed for cases where officers were shot in the torso. Analysis revealed that among the 637 officers who were shot by a firearm in the torso, those who wore body armor were 76% less likely to be killed than those who did not wear armor, controlling for an array of individual and incident characteristics [3]. This research is consistent with previous reporting on the benefits of wearing body armor to save lives [4].

2. NIJ STANDARD 0101.07: BALLISTIC RESISTANCE OF BODY ARMOR

NIJ published its first performance standard for ballistic-resistant police body armor in 1972 [5]. The current revision is the seventh, NIJ Standard 0101.07, *Ballistic Resistance of Body Armor*, which includes improved test methods for female body armor and updated body armor protection levels that incorporate additional rifle threats faced by U.S. law enforcement, as discussed previously [6]. This revision takes into consideration the changing landscape of policing in the U.S. and implements lessons learned over the past decade of testing using NIJ Standard 0101.06, published in 2008 [7]. The

improvements include more widespread stakeholder engagement, improved test methods and procedures, and updated test threats and protection levels, all of which result in better protection for officers wearing body armor.

NIJ Standard 0101.07 was developed with the guidance and input of a large group of end users and technical experts, and it incorporates by reference ten ASTM standards that were developed by an expanded group of stakeholders, including manufacturers. NIJ established a Special Technical Committee to aid the development of NIJ Standard 0101.06 in the 2004-2008 timeframe and has continued this approach for developing NIJ Standard 0101.07. NIJ also hosted a workshop in 2018 for manufacturers of body armor and protective materials to provide an update on the progress of the standard's development and field questions from the manufacturing community [8]. Furthermore, ASTM provides a forum and infrastructure that enables all interested stakeholders to collaborate, discuss differences and commonalities, and come to consensus on standards, test methods, and practices [9].

NIJ published a draft of the new standard as well as the new threat specification in 2018 through the *Federal Register* to request comments and input from the public, a practice commonly used by U.S. Government agencies to seek input on important guidance, policy, or regulations they plan to publish [10,11]. The threat specification document is published as a companion to NIJ Standard 0101.07 and, as a standalone specification, may also enable testing of a variety of ballistic-resistant equipment, not just ballistic-resistant body armor, against contemporary U.S. law enforcement threats. However, the threat specification itself does not define any test methods like the body armor standard does.

The test threats have been updated to reflect the evolving threats faced by U.S. law enforcement end users, including a wider range and more severe ballistics threats. Several new rifle test threats were added, and one of those is a 7.62 x 39 mm mild steel core (MSC) round, which is commonly seen by officers but is known to have huge variability in performance. That variability has driven the development of a surrogate test round to ensure consistency in testing, however NIJ Standard 0101.07 makes use of a factory round until the surrogate test round development activities are completed. The protection levels have been modified accordingly, with the protection level nomenclature also changed for better clarity and to reduce officer and end user confusion.

3. ASTM TEST METHODS: THE NEW BUILDING BLOCKS OF BODY ARMOR STANDARDS

Unlike previous revisions of the NIJ body armor standard which have been comprehensive, standalone documents, NIJ Standard 0101.07 incorporates ten standard test methods and practices published by ASTM. In 2013, the U.S. Army, NIJ, and the National Institute of Standards and Technology (NIST) began a partnership to harmonize the standards and their implementation for ballistic-resistant vests. The federal agencies chose to work through ASTM's E54 Committee on Homeland Security Applications to develop standard test methods and practices for the purpose of improving and validating methods, increasing consistency between test laboratories, and ultimately increasing confidence in ballistic-resistant equipment.

Incorporation of relevant ASTM standards into NIJ standards and U.S. Army requirements and testing documents affords the opportunity to harmonize laboratory test procedures and practices for both law enforcement and military ballistic-resistant armor and other ballistic-resistant equipment while allowing those end user communities ultimate control over product specifications, such as the specific threats against which their equipment must protect. Table 1 below lists the standardized test methods, practices, and specifications published by ASTM that are incorporated into NIJ Standard 0101.07. These include standardized methods for laboratory measurements, female armor testing, and data collection, among others.

Table 1. ASTM standards that are incorporated into NIJ Standard 0101.07.

ASTM Standard	Description
ASTM E3004, <i>Standard Specification for Preparation and Verification of Clay Blocks Used in Ballistic-resistance Testing of Torso Body Armor</i>	This standardizes a method for preparation and verification of backing assemblies used in ballistic-resistant torso body armor testing and is intended to reduce variability within and between laboratories. The backing assembly is a clay block that contains ROMA Plastilina No. 1® clay as the backing material, which serves as a witness material and provides a measurable indication of test item performance.
ASTM E3005, <i>Standard Terminology for Body Armor and Related Items</i>	This standardizes terminology for body armor providing protection against ballistic threats, stabbing, fragmentation, blunt impact, or a combination of threats. The intent of this terminology is to have terms and definitions that are applicable across federal agencies, law enforcement and corrections agencies, testing and certification bodies, and manufacturers.
ASTM E3062/E3062M, <i>Standard Specification for Ballistic Test Range Configuration for Small Arms and Fragmentation Testing of Ballistic-resistant Items</i>	This specifies indoor ballistic test range requirements for small arms and fragmentation testing of the following ballistic-resistant items: soft body armor, hard armor plates, body armor accessories, shields, and helmets. The specification includes requirements for range geometry, range conditions, test equipment, instrumentation, and measurement procedures. The purpose is to specify critical test range parameters in order to achieve consistency and repeatability among test ranges.
ASTM E3068, <i>Standard Test Method for Contact Measurement of Backface Deformation in Clay Backing During Body Armor Testing</i>	This describes test methods for the contact measurement of backface deformation (BFD) in clay backing caused by a test threat that produces a partial penetration in a body armor test item. The purpose is to achieve consistent measurements between laboratories and reduce differences that could result from using different measurement techniques. This test method is applicable to testing of planar and nonplanar soft armor and hard armor.
ASTM E3078/E3078M, <i>Standard Practice for Conditioning of Hard Armor Test Items</i>	This applies to the conditioning of hard armor test items prior to ballistic resistance testing. This practice describes requirements for subjecting test items to conditions intended to assess the capability of the test item to withstand environmental conditions that induce responses similar to those that might result from conditions encountered during use.
ASTM E3086, <i>Standard Practice for Creating Appliques for Use in Testing of Nonplanar Soft Body Armor Designed for Females</i>	This specifies a procedure for creating appliques (e.g., build-up of clay) for use behind nonplanar, soft body armor test items and affixing the appliques to the clay block. The purpose is to specify critical parameters for creating appliques in order to improve consistency of the test setup between laboratories. This practice describes a single applique shape applicable only to nonplanar, soft body armor designed for females.
ASTM E3107/E3107M, <i>Standard Test Method for Resistance to Penetration and Backface Deformation for Ballistic-resistant Torso Body Armor and Shoot Packs</i>	This standardizes testing the resistance to ballistic penetration and to BFD for ballistic-resistant torso body armor and shoot packs. This test method is intended for testing of soft body armor, hard armor plates, in conjunction with armor, and shoot packs mounted on a clay block as the backing assembly.
ASTM E3110/E3110M, <i>Standard Test Method for Collection of V_x Ballistic Limit Data for Ballistic-resistant Torso Body Armor and Shoot Packs</i>	This describes procedures for collecting ballistic limit data for ballistic-resistant torso body armor and shoot packs. Several commonly used test item mounting procedures and ballistic limit procedures are included in this test method; however, this test method does not specify computation or performance criteria for the ballistic limit.
ASTM E3112/E3112M, <i>Standard Test Method for Ballistic-resistant Products and Shoot Packs</i>	This standardizes assessing the resistance to complete penetration by projectiles and applies to ballistic-resistant products or shoot packs, either flexible or rigid, that are intended

	to provide protection against projectiles from small arms. This test method is applicable to products or shoot packs that are constructed with identical layups of ballistic materials over the entire product or shoot pack. This test method does not assess blunt impact resistance.
ASTM E3192/E3192M, <i>Standard Practice for Soft Body Armor Conditioning By Tumbling</i>	This describes subjecting test items to conditions intended to provide some indication of the test item ability to withstand conditions of heat, moisture, and mechanical wear (folding and abrasion) that might be encountered during wear. This practice is intended for soft armor for law enforcement applications and applies only to the conditioning of soft body armor via temperature, humidity, and tumbling exposure prior to ballistic resistance testing.

4. NEW NIJ THREAT SPECIFICATION DEFINES BALLISTIC THREATS TO U.S. LAW ENFORCEMENT

NIJ opted to develop a standalone specification of ballistic threat levels and associated test ammunition rather than specify the information directly in NIJ Standard 0101.07, as had been done in NIJ 0101.06 and prior revisions. Its primary purpose will be to specify the test threats—including projectiles and reference velocities—identified by U.S. law enforcement as representative of prevalent threats in the United States which will be used to test ballistic-resistant equipment for U.S. law enforcement applications. It is incorporated into NIJ Standard 0101.07 for body armor and may be incorporated into future NIJ standards for ballistic-resistant helmets and ballistic-resistant shields.

Threat level nomenclature has been revised from previous NIJ standards to be more descriptive of threats and to reduce possible confusion among law enforcement end users of body armor. Level II and Level IIIA have been replaced with “NIJ HG1” and “NIJ HG2,” respectively, to represent handgun (HG) threats, as listed in Table 2 below. The lowest threat Level IIA that appears in NIJ Standard 0101.06 has been dropped with no equivalent threat level in the new NIJ specification.

Table 2. Proposed NIJ handgun (HG) threat levels and associated test ammunition.

NIJ HG Threat Level	Test Threat Ammunition	Manufacturer & Model ID	Reference Velocity
NIJ HG1	9mm Luger full metal jacketed (FMJ) round nose (RN) 124 grain	Remington #23558	1305 ft/s (398 m/s)
	.357 Mag jacketed soft point (JSP) 158 grain	Remington #22847	1430 ft/s (436 m/s)
NIJ HG2	9mm Luger FMJ RN 124 grain	Remington #23558	1470 ft/s (448 m/s)
	.44 MAG jacketed hollow point (JHP) 240 grain	Speer #4453 or #4736	1430 ft/s (436 m/s)

Level III and Level IV have been revised to three levels representing rifle (RF) threats as “NIJ RF1,” “NIJ RF2,” and “NIJ RF3.” These rifle threats are listed in Table 3 below. Noteworthy about the specification is that several new rifle test threats were added to the ones specified in NIJ Standard 0101.06. One of those threats is a 7.62 x 39 mm mild steel core (MSC) round, which is commonly seen by law enforcement officers but is known to have huge variability in performance. That variability has driven the development of a surrogate test round to ensure consistency in testing; however, NIJ Standard 0101.07 makes use of sealed lots of Type 56 factory rounds of Chinese origin until the surrogate test round development activities are completed.

NIJ engaged ammunition experts to investigate the possible solutions to define a 7.62x39mm MSC test round for the purposes of NIJ certification testing and Follow-up Inspection Testing (FIT) testing. Physical characteristics of the ammunition as well as factors such as availability of supply were factored into the assessment of the various factory rounds available. An audit procedure, included as an appendix

to the NIJ threat specification document, was used for a multi-laboratory evaluation of the candidate ammunition, which performed consistently across the NIJ-approved laboratories.

Use of a purpose-built surrogate round for testing to 7.62x39mm MSC has many advantages and should prove to be the most sustainable solution in the long run, rather than relying on the finite supply of a factory round. NIJ had previously proposed use of a surrogate under development by the U.K. Government and has also coordinated with the U.S. Department of Defense's Combatting Terrorism Technical Support Office on the development of a U.S.-based surrogate [12]. Given the status of the surrogate round development, NIJ determined that the best solution at the time of publication is to specify a factory round for certification testing.

Table 3. Proposed NIJ rifle (RF) threat levels and associated test ammunition.

NIJ RF Threat Level	Test Threat Ammunition	Manufacturer & Model ID	Reference Velocity
NIJ RF1	7.62x51mm M80 ball NATO FMJ steel jacketed spire point boat tail (BT) 147 +0/-3 grain	U.S. military supply or rounds meeting NATO specifications	2780 ft/s (847 m/s)
	7.62x39mm mild steel core (MSC) ball ammunition Type 56 from Factory 31 123 grain	Factory 31 Ammunition conforming to specifications in sealed lots only.	2400 ft/s (732 m/s)
	5.56mm M193 BT 56 +0/-2 grain	U.S. military supply or rounds meeting NATO specifications	3250 ft/s (990 m/s)
NIJ RF2	7.62x51mm M80 ball NATO FMJ steel jacketed spire point BT 147 +0/-3 grain	US military supply or rounds meeting NATO specifications	2780 ft/s (847 m/s)
	7.62x39mm mild steel core (MSC) ball ammunition Type 56 from Factory 31 123 grain	Factory 31 Ammunition conforming to specifications in sealed lots only.	2400 ft/s (732 m/s)
	5.56mm M193 BT 56 +0/-2 grain	U.S. military supply or rounds meeting NATO specifications	3250 ft/s (990 m/s)
	5.56mm M855 BT 61.8 ± 1.5 grain	U.S. military supply or rounds meeting NATO specifications	3115 ft/s (950 m/s)
NIJ RF3	30.06 M2 Armor Piercing (AP) FMJ spire point AP 165.7 +0/-7 grain	U.S. military supply or rounds meeting NATO specifications	2880 ft/s (878 m/s)

5. BODY ARMOR COMPLIANCE TESTING

NIJ operates a body armor certification program called the NIJ Compliance Testing Program (CTP) to provide U.S. law enforcement confidence that the body armor they purchase and use performs according to minimum performance requirements to protect against common handgun and rifle threats. NIJ established body armor compliance testing in the late 1970s after publishing the first 0101.00 standard, and the NIJ CTP has evolved along with the standard through the decades.

Today, the NIJ CTP is the recognized authority on body armor for law enforcement use—not only in the United States, but across the world. Use of NIJ-certified body armor is ubiquitous among U.S. law enforcement agencies, and many law enforcement agencies outside the U.S. make use of NIJ standards and NIJ-certified armor as well. While participation in the program by manufacturers is voluntary, it is recognized by industry as the standard in body armor quality assurance, with manufacturers representing approximately 100 manufacturing locations and 19 countries participating. Since the CTP began accepting armor submissions to meet the requirements of NIJ Standard 0101.06 in 2009, over 1,400

unique models of ballistic-resistant body armor have been submitted to the CTP for compliance testing through the end of 2019.

With the publication of NIJ Standard 0101.07, the NIJ CTP anticipates accepting armor for certification to the new standard sometime in 2021. The primary purpose of NIJ Standard 0101.07 is for use by the NIJ CTP for testing, evaluation, and certification of ballistic-resistant body armor. The standard will be used by both ballistics laboratories that test body armor and body armor manufacturers participating in the NIJ CTP. The standard will be added by the National Voluntary Laboratory Accreditation Program (NVLAP) to the Personal Body Armor scope of accreditation used to accredit ballistics laboratories that participate in the NIJ CTP.

While NIJ will begin to certify body armor to the new NIJ Standard 0101.07 and will publish a new Compliant Products List (CPL) for those armor models, it will also continue to accept armor for certification to NIJ Standard 0101.06 during a transitional period. NIJ will also continue to maintain its CPL for armor models compliant with NIJ Standard 0101.06 for a period of time and will continue to require FIT on these models. This will allow law enforcement agencies the time needed to transition their equipment as smoothly as possible over a reasonable amount of time.

6. CONCLUSION

NIJ develops body armor performance standards, and the seventh revision, NIJ Standard 0101.07, *Ballistic Resistance of Body Armor*, includes improved test methods for female body armor and updated body armor protection levels that incorporate additional rifle threats faced by U.S. law enforcement as well as more widespread stakeholder engagement, all of which result in better protection for officers wearing body armor. Unlike previous revisions of the NIJ body armor standard which have been comprehensive, standalone documents, NIJ Standard 0101.07 incorporates ten standard test methods and practices published by ASTM. NIJ has also developed a standalone specification of ballistic threat levels and associated test ammunition rather than specify the information directly in NIJ Standard 0101.07, which may also enable more consistent testing of a variety of ballistic-resistant equipment, not just ballistic-resistant body armor, against contemporary U.S. law enforcement threats. Several new rifle test threats were added, including a 7.62 x 39 mm mild steel core (MSC) round, which is commonly seen by law enforcement officers but is known to have huge variability in performance. NIJ has specified a factory round for certification testing but is also pursuing the use of a surrogate round as a long-term solution. With the publication of NIJ Standard 0101.07, the NIJ CTP anticipates accepting armor for certification to the new standard sometime in 2021. However, NIJ will also continue to maintain its list for NIJ Standard 0101.06-compliant armor for a period of time to allow law enforcement agencies the time needed to transition their equipment as smoothly as possible over a reasonable amount of time.

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References

- [1] “Injuries, Illnesses, and Fatalities: Fact Sheet – Police Officers 2018,” U.S. Department of Labor, Bureau of Labor Statistics, July 2020, <https://www.bls.gov/iif/oshwc/foi/police-2018.htm>.
- [2] U.S. Department of Justice, Federal Bureau of Investigation, Law Enforcement Officers Killed and Assaulted, <https://ucr.fbi.gov/leoka>.
- [3] Weiwei Liu and Bruce Taylor, “The effect of body armor on saving officers’ lives: An analysis using LEOKA data,” *Journal of Occupational and Environmental Hygiene*, Vol. 14, No. 2, 73-80, 2017, <https://doi.org/10.1080/15459624.2016.1214272>.

- [4] Tom LaTourrette, “The Life-Saving Effectiveness of Body Armor for Police Officers,” *Journal of Occupational and Environmental Hygiene* 7, no. 10, (2010): 557-562. doi:10.1080/15459624.2010.489798.
- [5] *NILECJ Standard on the Ballistic Resistance of Police Body Armor*, NILECJ Standard 0101.00, March 1972, <https://www.ncjrs.gov/pdffiles1/Digitization/7037NCJRS.pdf>.
- [6] M. E. Greene, J. Horlick, D. A. Longhurst, L. L. Miller, M. O’Shea, D. Otterson, C. Robinson, D. A. Stoe, and R. A. Sundstrom, “The Next Revision of the NIJ Performance Standard for Ballistic Resistance of Body Armor, NIJ Standard 0101.07: Changes to Test Methods and Test Threats,” *15th Personal Armour Systems Symposium*, Washington, DC, October 1-5, 2018.
- [7] *Ballistic Resistance of Body Armor*, NIJ Standard-0101.06, July 2008, <https://www.ncjrs.gov/pdffiles1/nij/223054.pdf>.
- [8] “Body Armor Manufacturer Workshop,” *Federal Register*, 83 FR 40568, August 15, 2018, <https://www.federalregister.gov/d/2018-17466>.
- [9] C. Robinson, D. Stoe, and J. Zheng, Improving the Testing of Ballistic-Resistant Body Armour through Harmonization of Standards,” *14th Personal Armour Systems Symposium*, Amsterdam, Netherlands, September 19-23, 2016.
- [10] “Request for Public Comment on Proposed Revision of NIJ Standard 0101.06, Ballistic Resistance of Body Armor,” *Federal Register*, 83 FR 7776, February 22, 2018, <https://www.federalregister.gov/d/2018-03674>.
- [11] “Request for Public Comment on Proposed Specification Threat Levels and Associated Ammunition To Test Equipment Intended To Protect U.S. Law Enforcement Against Handguns and Rifles,” *Federal Register*, 83 FR 7776, February 22, 2018, <https://www.federalregister.gov/d/2018-03672>.
- [12] Combatting Terrorism Technical Support Office/ Technical Support Working Group (CTTSO/TSWG), Broad Agency Announcement 19S3011, January 7, 2019, [https://legacy-bids.cttso.gov/TSWG/bids.nsf/0/35F93ED00B35E3F885258313004F54C9/\\$FILE/19S3011+2019-01-07.pdf](https://legacy-bids.cttso.gov/TSWG/bids.nsf/0/35F93ED00B35E3F885258313004F54C9/$FILE/19S3011+2019-01-07.pdf).