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DHS Standardization

RFID Devices in Homeland Security Applications

Reducing the Radiological and Nuclear Threat

Performance Standards for Urban Search and Rescue Robots

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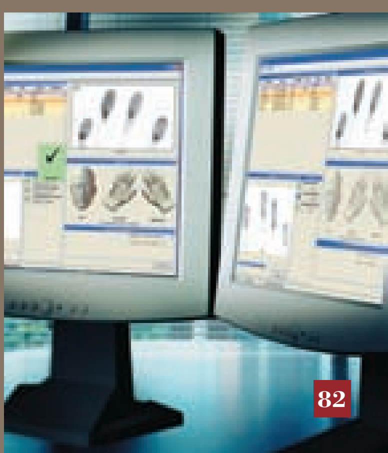

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In God We Trust, X-Ray Everything Else!

Standards for X-Ray and Gamma-Ray Security Screening Systems

By Larry Hudson, Steve Seltzer, Paul Bergstrom, and Frank Cerra

A suite of technical performance standards for all of the nation's security systems that screen using x-rays or gamma-rays is nearing completion. Specifically, these standards address aspects of imaging quality and radiation safety, and each specifies test artifacts, test methods, and, in some cases, required minimum performance levels. All modalities are treated: transmission and backscatter geometries as well as computed tomography (CT). The goal is to provide governmental users and industrial partners with uniform methods to compare technical aspects related to performance and standard gauges that will stimulate and quantify future technological improvements.

Since the 1920s, the National Bureau of Standards, now the National Institute of Standards and Technology (NIST), has been a world leader in promoting accurate and meaningful measurements, methods, and measurement services. Among other things, NIST develops, maintains, and disseminates the national standards for ionizing radiation and radioactivity, thereby providing credible and absolute measurement traceability for the nation's medical, industrial, environmental, defense, homeland security, energy, and radiation-protection communities. This experience and infrastructure, which includes fundamental research and radiation-transport modeling, enabled NIST to respond to rapidly emerging homeland security needs in the area of x-ray and gamma-ray security screening. In particular, efforts are nearing completion on the development of a suite of national voluntary consensus standards that span the use of x-rays and gamma rays in the screening of carried items at checkpoints, airline baggage, trucks, cargo containers, human subjects, and abandoned objects suspected of containing bulk explosives.

Funded by the Department of Homeland Security, and in alliance with the American National Standards Institute (ANSI), the development process began by recruiting working groups with representation from end users of x-ray security screening systems (primarily governmental), the manufacturers of the equipment, national research and development laboratories, and other expert stakeholders. Current best practices were considered for possible codification. Agencies and laboratories that were able to contribute key ideas because of years of extensive experience included the then Federal Aviation Administration's Transportation Security Laboratory, the Thunder Mountain Evaluation Center, the U.S. Secret Service, and U.S. Customs and Border Protection (CBP). In some cases, vendors chose to contribute proprietary in-house test methods and objects for adoption.

The Checkpoint

Nearly everyone by now recognizes the checkpoint—with its x-ray system, fed by a conveyor belt on which we place our carry-on luggage, computers, briefcases, parcels, bags, coats, and even shoes—that one must pass through to enter a secured area. Nearly 800 million passengers per year at U.S. airports pass through such checkpoints to enter the boarding area. Millions more experience checkpoints to enter secure courthouses, some schools, and sporting and entertainment venues. Although metal detectors are used to screen for possible weapons hidden

Technical Performance Standards for X-Ray and Gamma-Ray Security Screening Systems

Image Quality

ANSI N42.44, "American National Standard for the Performance of Checkpoint Cabinet X-Ray Imaging Security Systems"

ANSI N42.45, "American National Standard for Evaluating the Image Quality of X-Ray Computed Tomography Security-Screening Systems"

ANSI N42.46, "Measuring the Imaging Performance of X-Ray and Gamma-Ray Systems for Cargo and Vehicle Security Screening"

ANSI N42.47, "American National Standard for Measuring the Imaging Performance of X-Ray and Gamma-Ray Systems for Security Screening of Humans"

National Institute of Justice 0603.01, "Portable X-Ray Systems for Use in Bomb Identification and Interdiction"

Radiation Safety

ANSI N43.16, "Radiation Safety Standard for Vehicle and Cargo Security Screening Systems Using X-Ray or Gamma Radiation"

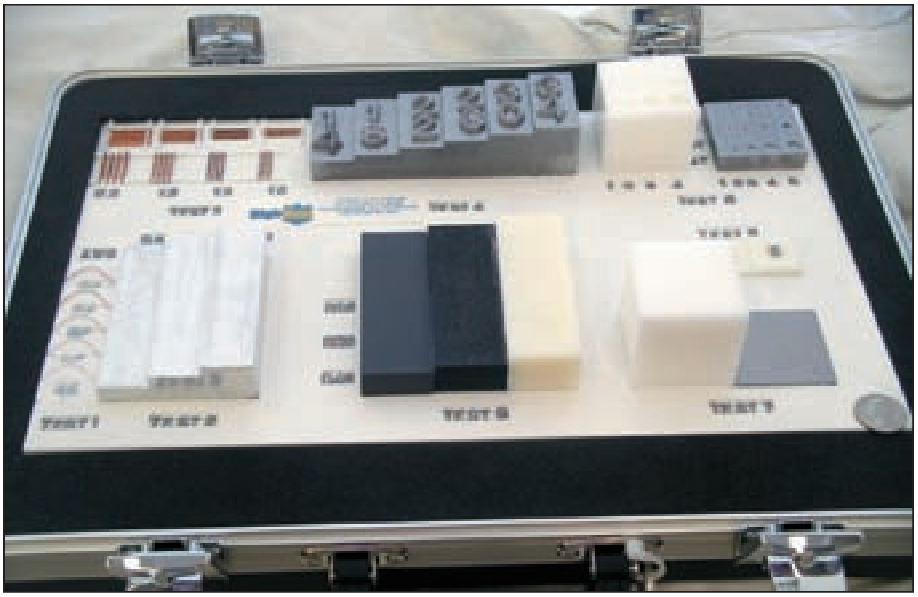
ANSI N43.17, "Radiation Safety for Personnel Security Screening Systems Using X-Ray or Gamma Radiation" (revision of N43.17-2002)

on the body, the x-ray scanners are used to scan the contents of carried items without having to open containers for a time-consuming visual inspection. In addition, such equipment is often used to screen incoming parcels in mail and shipping receiving rooms.

The detection of threat and illicit material using these x-ray screening systems of course depends on the operator's ability to recognize an ever-expanding array of threat objects from an often-cluttered x-ray image filled with innocent objects. This inspection must be as quick and unintrusive as possible to minimize delays through the checkpoint and thus the associated social and economic costs.

Common sense suggests that the better the quality of the x-ray image, the better the detection performance. A new standard—Institute of Electrical and Electronics Engineers, Inc. (IEEE)/ANSI N42.44, "American National Standard for the Performance of Checkpoint Cabinet X-Ray Imaging Security Systems"—addresses detection performance. Specifically, the new standard builds upon an older standard—ASTM F792, "Standard Practice for Evaluating the Imaging Performance of Security X-Ray Systems"—and an associated test object useful in determining the resolution, penetration, and material differentiation of these systems. (See Figure 1.) The new ANSI/IEEE standard, in addition to correcting some inconsistencies in the ASTM practice, establishes minimum imaging performance requirements in each of the

FIGURE 1. ASTM F 792 Test Object



nine imaging tests associated with the ASTM test object. Through normative reference to existing standards, it also incorporates pertinent requirements for electrical and mechanical safety, electromagnetic compatibility and susceptibility, and radiation safety for these environments.

A well-defined test method and a set of minimum acceptable image-quality standards, as established in this standard, will provide value to both users and manufacturers of these x-ray imaging security systems. Buyers and prospective users of checkpoint x-ray systems will have test methods that facilitate performance comparisons among systems and will be assured of minimum acceptable imaging-performance requirements. This performance is achievable with current state-of-the-art production checkpoint x-ray systems. Manufacturers will have a better understanding of the needs, wants, and expectations of the user community and a clearer understanding of the minimum set of imaging goals. In addition, the standard can be used in acceptance tests for checking actual performance against manufacturers' test claims and for monitoring system performance over time to check for degradation that could compromise security. Some applications, such as aviation security, will no doubt require image-quality standards higher than the minimum performance established in this standard. Reporting under this standard will convey the better performance and will assure all parties of consistent and reliable performance data.

Computed Tomography

The Government Accountability Office reports that Transportation Security Administration funding related to aviation security has totaled about $20 billion since FY04. Much of this is directed toward the inspection of the some billion pieces of luggage that are checked each year in the United States for transport in the holds of commercial airliners. At present, each undergoes inspection using the multiview CT technique, providing three-dimensional information to automated explosives-detection algorithms. (See Figure 2.)

Due to the highly sensitive nature of explosives detection in aviation security, the scope of ANSI N42.45, "American National Standard for Evaluating the Image Quality of X-Ray Computed Tomography Security-Screening Systems," is limited to test artifacts and test methods. The final test article, which is expected to be adopted by DHS's Transportation Security Laboratory for factory acceptance testing, will be composed of a novel set of x-ray phantoms designed specifically for CT security (as opposed to medical) screening. It will gauge the following image quality metrics: CT-number consistency, beam hardening and scattering, object-length accuracy and presentation, atomic number and density uniformity, CT-to-projection image registration, slice-sensitivity profile, modulation transfer function, and streak artifacts.

FIGURE 2. Reconstructed CT Image

Courtesy of Analogic Corporation

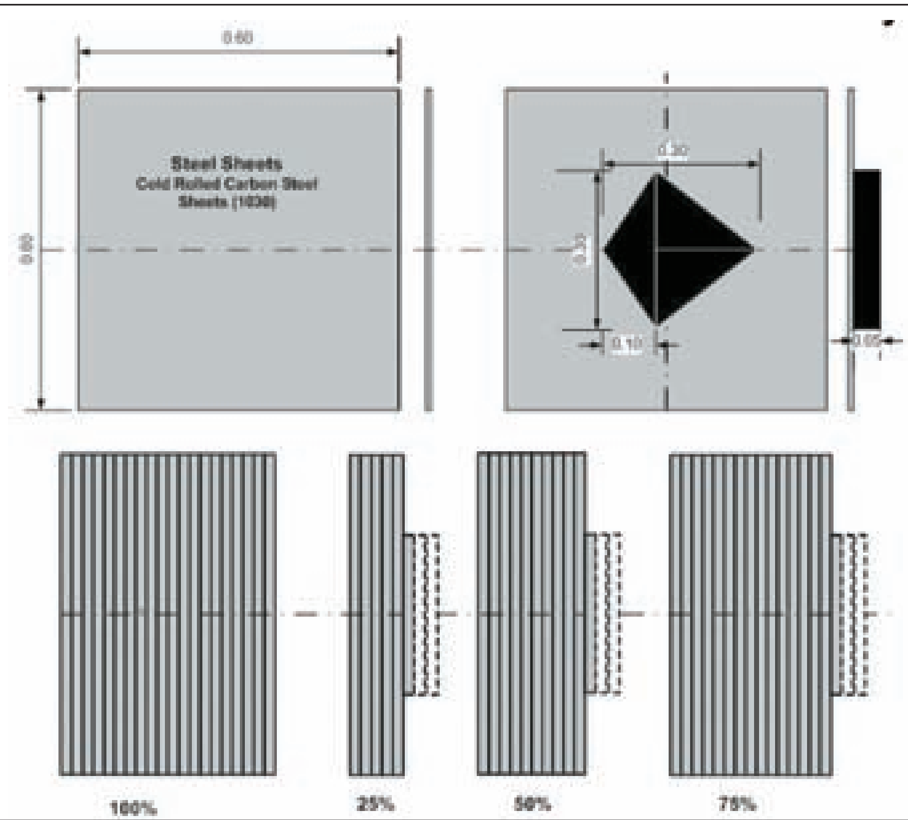
Cargo Vehicle

Daily, an average of 80,000 cargo containers arrive at the borders of the United States. About two-thirds come through seaports, while the remainder arrive by truck or by rail. A substantial number of x-ray and gamma-ray systems are already deployed at the borders to inspect some fraction of this traffic. These systems assist the officers of CBP in their attempts to interdict contraband and people illegally entering the United States. There is an increasing interest in using these systems to detect weapons of mass destruction and special nuclear material. In addition, Congress has mandated that all cargo containers entering the United States must be inspected in the future. With the need to deploy many additional inspection systems with more powerful capabilities, it is all the more important that these systems be subjected to a common test method in order to consistently compare their performance. Currently, no national standard test procedures are available for such comparisons.

ANSI/IEEE N42.46, "Measuring the Imaging Performance of X-Ray and Gamma-Ray Systems for Cargo and Vehicle Security Screening," is intended to fill this gap. This standard defines test methods for both the transmission and backscatter modes to measure the main image quality metrics of concern in imaging present-day cargo systems. These metrics are simple penetration, spatial resolution, wire detection, and contrast sensitivity. Because the purview of this standard ranges from palletized cargo to trucks and cargo containers, these methods were designed with flexibility in scaling. Given the diversity of systems and applications, no minimum level of performance is specified. Rather it is expected that the standard will provide a basis for vendors to report the capabilities of their systems in a manner that can be directly compared with other systems being considered for the same application. Figure 3 depicts a proposed test of the penetration and contrast sensitivity of a cargo-screening system. The requirement entails determining the direction of an arrow through increasing thicknesses of steel shielding.

This technical performance standard is complemented by another effort in progress, ANSI/Health Physics Society (HPS) N43.16, "Radiation Safety Standard for Vehicle and Cargo Security Screening Systems Using X-Ray or Gamma Radiation." Together, these standards will provide a solid basis for understanding and comparing the performance and safety of radiation-based cargo and vehicle security inspection systems.

FIGURE 3. Steel Penetration and Contrast Sensitivity



Body Scanners

X-ray systems are now available for screening humans, exposing them to an extremely low level of radiation. Unlike conventional metal detectors, these systems can detect non-metal as well as metal weapons. The Transportation Security Administration has begun a pilot program to test x-ray body scanners as part of their continuing effort to improve the effectiveness and efficiency of passenger screening. Other governmental institutions, such as prisons, customs, and the armed services, also have used or are considering using the body scanners. This relatively new technology has a potential for significant expansion in today's security environment.

X-ray screening of humans presents two key challenges:

- Systems must be safe and effective.
- They must afford a level of privacy appropriate for each screening situation and in line with societal standards.

To address safety and effectiveness, NIST is facilitating the development of two related standards: ANSI/IEEE N42.47, "American National Standard for Measuring the Imaging Performance of X-Ray and Gamma-Ray Systems for Security Screening of Humans," and ANSI/HPS N43.17, "Radiation Safety for Personnel Security Screening Systems Using X-Ray or Gamma Radiation." The latter is a revision of N43.17-2002, which had a limited scope.

The ANSI/IEEE N42.47 standard will establish a set of imaging parameters and associated measurement methods. Minimum performance requirements will be specified for each parameter. Because of fundamental differences between the two basic technologies employed, backscatter and transmission, separate test objects will be developed for the two types of systems. (Figure 4 shows x-ray images from a backscatter body scanner, and Figure 5 shows a transmission x-ray image of a person with threat objects.) In addition to image quality requirements, N42.47 will include a complete set of performance requirements by referencing existing standards. These normative references will include provisions for electrical, mechanical, and radiological safety; electromagnetic compatibility; and electromagnetic susceptibility. This should make the standard a valuable tool for manufacturers, users, and potential buyers of the systems. Manufacturers may use the standard in the design, testing, and specification processes. For users, the standard will provide basic test methods for acceptance testing and monitoring performance degradation over time. Users may also build upon the requirements of the standard to satisfy their own special needs. Potential buyers will benefit from a uniform set of parameters for comparing available products and from a complete set of requirements to aid with purchase specifications.

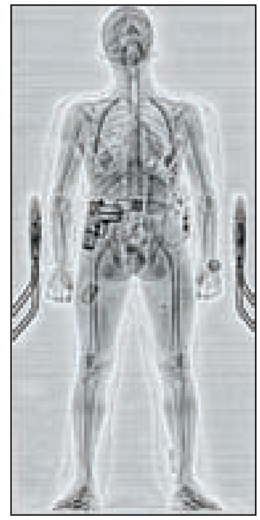
The ANSI/HPS N43.17 standard provides requirements associated with radiation safety of body scanning systems. It includes dose limits and requirements for manufacturers and users of systems that employ backscatter and transmission geometries. This expanded standard will also

FIGURE 4. X-Ray Images from a Backscatter Body Scanner

Courtesy of AS&E, Billerica, MA

consider portals and vehicle scanners used for human screening. Transmission technology works on the same principle as digital radiography in medicine, using radiation that passes through the body to form an image. Backscatter technology uses radiation that bounces off the body to detect objects hidden under clothing and requires much lower levels of radiation (typically 30 to 100 times lower). One backscatter image requires roughly the same amount of radiation an person receives on average from natural sources every 15 minutes (or in about 1 minute of flying at high altitude).

FIGURE 5. Transmission X-Ray Image of a Person with Threat Objects



Courtesy of SecurePath LLC

Because of the disparity in potential dose and other safety considerations, the N43.17 standard will have two sets of requirements. The safest systems will be classified as general-use systems, following recommendations from the National Council on Radiation Protection and Measurements. Systems requiring stricter controls will be classified as limited-use systems. The standard seeks to limit the annual effective dose to an individual from all types of systems in one screening site to 0.25 microsievert. This is consistent with national and international standards of radiation protection and is a fraction of the typical annual dose from natural sources.

About the Authors

Larry Hudson has 20 years of federal service with NASA and NIST. Research interests include precision x-ray metrology, imaging, and standards; curved crystal x-ray spectroscopy; and medical, industrial, and security applications of x-ray technology. Dr. Hudson is the primary liaison for NIST to the Department of Homeland Security for bulk explosives detection and standards for x-ray and gamma-ray security screening and is the facilitator for the ANSI N42.45 and National Institute of Justice 0603.01 working groups.

Other key NIST contributors include Steve Seltzer (ANSI N42.44), Paul Bergstrom (ANSI N42.46), and Frank Cerra (ANSI N42.47 and N43.17).