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Electronics and Electrical Engineering Laboratory

Office of Law Enforcement Standards

Programs, Activities, and Accomplishments

The Electronics and Electrical Engineering Laboratory

One of NIST's seven Measurement and Standards Laboratories, EEEL conducts research, provides measurement services, and helps set standards in support of: the fundamental electronic technologies of semiconductors, magnetics, and superconductors; information and communications technologies, such as fiber optics, photonics, microwaves, electronic displays, and electronics manufacturing supply chain collaboration; forensics and security measurement instrumentation; fundamental and practical physical standards and measurement services for electrical quantities; maintaining the quality and integrity of electrical power systems; and the development of nanoscale and microelectromechanical devices. EEEL provides support to law enforcement, corrections, and criminal justice agencies, including homeland security.

EEEL consists of four programmatic divisions and two matrix-managed offices:

Semiconductor Electronics Division

Optoelectronics Division

Quantum Electrical Metrology Division

Electromagnetics Division

Office of Microelectronics Programs

Office of Law Enforcement Standards

This document describes the technical programs of the Office of Law Enforcement Standards (OLES). Similar documents describing the other Divisions and Offices are available. Contact NIST/EEEL, 100 Bureau Drive, MS 8100, Gaithersburg, MD 20899-8100, Telephone: (301) 975-2220, On the Web: www.eeel.nist.gov

Cover caption: The Office of Law Enforcement Standards assists the criminal justice, public safety, and homeland security agencies make informed decisions when purchasing critical equipment, primarily by developing performance standards for that equipment, and develops tools, procedures and guidelines to help them do their work more effectively. Our logo (center) reflects some of the projects that we conduct: DNA research, arson research, forensic sciences and law enforcement weapons and equipment. Shown on the cover are pictures that represent some of the projects in our portfolio: development of standards for ballistic resistance of personal body armor and handcuffs and users' guides for chemical and biological protective equipment.

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U.S. DEPARTMENT OF COMMERCE
Donald L. Evans, Secretary

Technology Administration
Phillip J. Bond, Under Secretary of Commerce for Technology

National Institute of Standards and Technology
Hratch G. Semerjian, Acting Director

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Welcome

The **Office of Law Enforcement Standards (OLES)** helps criminal justice, public safety and homeland security agencies make informed decisions when purchasing critical equipment, primarily by developing performance standards for that equipment, and develops tools, procedures and guidelines to help them do their work more effectively. OLES is part of the Electronics and Electrical Engineering Laboratory (EEEL) of the National Institute of Standards and Technology (NIST). OLES, with a staff of 14, is located on the NIST campus in Gaithersburg, Maryland.

Mission

Since its founding in 1971, OLES' primary mission has been to develop minimum performance standards – technical performance criteria that can be used to evaluate equipment and determine whether it performs safely, effectively and dependably. A general description of OLES' standards development process is described in the section below.

Over the past 33 years, that mission and OLES' responsibilities to the nation have grown. Today OLES also develops reference materials (RMs) and standard reference materials (SRMs) for use in test procedures and to calibrate equipment. OLES authors equipment user guides, designs methods for examining evidentiary materials, and provides technical advice and assistance to agencies throughout the criminal justice, public safety and homelands security communities. OLES staff members hold memberships in scores of technical and scientific organizations, chair technical and policymaking committees in several of those organizations, and work closely with technical experts throughout the public and private sectors.

Organization

OLES is a project management organization that designs and manages standards-development and research projects on behalf of agencies such as the Department of Homeland Security (DHS), the National Institute of Justice (NIJ), and others.

Within OLES are six program areas: Weapons and Protective Systems; Detection, Inspection, and Enforcement Technologies; Chemical Systems and Materials; Forensic Sciences; Public Safety Communication Standards; and Critical Incident Technologies. These program areas conduct a vast range of projects related to protective clothing, communication systems, investigative aids, security devices, traffic enforcement equipment, vehicles, weapons and ammunition, detection of concealed weapons and explosives, forensic science, homeland security, and domestic preparedness.

Proposed and continuing projects within each program area for FY2005 are described in this publication.

Developing Performance Standards

Developing performance standards is OLES' primary activity, and the process OLES follows in that work provides a good illustration of the organization and its function.

Developing a performance standard begins when the criminal justice, public safety or homeland security community identifies the need for a certain type of equipment to perform at a certain level in the field. A bullet-resistant vest must stop a new type of ammunition. A metal detector must be sensitive enough for thorough screening of airline passengers. A respirator must allow first responders to work safely in a chemical, biological or radiological hot zone.

OLES talks to equipment users to refine our understanding of how the equipment is employed and under what conditions. OLES designs research projects to gather information from manufacturers and technical experts, and to evaluate the capabilities of equipment available on the market. OLES formulates a set of performance criteria that the particular type of equipment must meet to be considered adequate. Then OLES devises tests that can be used to determine if a piece of equipment meets the criteria. Together, the performance criteria and the test methods make up what is called a minimum performance standard.

The draft minimum performance standard is reviewed and commented on by practitioners, manufacturers, technical experts, government agencies and other parties with a professional interest in the standard. After required revisions, the minimum performance standard is published and distributed, along with a report that provides manufacturers and designers with detailed technical information about the standard, and a user guide to help agencies and their personnel understand the standard and properly select, use and maintain the equipment.

The projects listed in this publication are those that OLES has proposed for Fiscal Year 2005. The actual portfolio of projects is being negotiated as this publication goes to print.

For additional information about OLES, please visit us at http://www.eeel.nist.gov/oles.

Weapons and Protective Systems

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OLES' Weapons and Protective Systems program is responsible for some of the organization's most successful efforts. It provides ongoing technical support and research for the National Institute of Justice (NIJ) standard for ballistic-resistant body armor (bullet-resistant vests), which OLES first developed for NIJ in 1972. The body armor program is part of NIJ's successful Law Enforcement and Corrections Standards and Testing Program, through which companies may have their products voluntarily certified as compliant with the standard. Ballistic-resistant body armor has been credited with saving more than 2500 lives, and the program's evaluations of new materials and ballistic threats and its revisions of the standard help ensure the continued effectiveness of this technology.

The Weapons and Protective Systems program also develops and supports other equipment performance standards vital to the safety of law enforcement and corrections personnel, including stab-resistant body armor; ballistic helmets; riot helmets and face shields; bomb suits; metallic handcuffs; and firearms. It is evaluating new "smart gun" technologies and developing a test protocol for gunlocks, as well as working toward the country's first standard for armored cars to protect our nation's leaders, diplomats and visiting dignitaries.

This year, under the Weapons and Protective Systems program area, OLES will provide: 1) technical support for standards that are active under the NIJ Compliance Testing Program; 2) conduct and oversee research that will lead to revision of existing equipment performance standards to address the current state of technology or to improve test methodologies; and 3) conduct and oversee research that will lead to the publication of new equipment performance standards, test protocols, or technology assessments because the law enforcement and corrections communities have indicated the need for these. Projects in each of these three categories will now be described.

Cops' Bullet Proof Vests – Testing of ZYLON®-Based Body Armor: A Component of the Body Armor Safety Initiative

Goals

The objective of this project is to conduct a comprehensive testing program to address concerns with the ongoing ballistic-resistant performance of ZYLON-based body armor in response to the Department of Justice's Body Armor Safety Initiative, announced by Attorney General John Ashcroft on November 18, 2003. This initiative came in response to concerns raised by the public safety community and members of Congress regarding the performance of ZYLON-based armor. ZYLON is the trade name for a high strength ballistic fiber known as poly(p-phenylenebenzoxazole) (PBO).

Customer Needs

Neither the NIJ Standard–0101.04, "Ballistic Resistance of Personal Body Armor," nor the current Body Armor Compliance Testing Program were originally intended to address the ongoing performance of used ballistic-resistant body armor. Ensuring ongoing ballistic-resistant performance has always been the responsibility of the body armor manufacturer. The ZYLON-based body armor concern has heightened an industry-wide awareness that ongoing ballistic performance must be satisfactorily addressed. Determinations and findings of this testing program are expected to highlight significant problems with some samples of body armor, lead to improved body armor performance standards, and very likely produce fundamental changes in the Compliance Testing Program, ultimately benefiting the users of body armor. The primary benefit anticipated will be the implementation of ongoing conformity assessment methods that will give criminal justice and public safety officers greater confidence in the performance of body armor.

Technical Strategy

Multiple test efforts comprise this project: 1) Forest Hills Vest Study, 2) Ballistic Performance Tests to Determine ZYLON Degradation in Used Armor (which consists of up to three phases), and 3) Testing of Upgrade Kits. A brief summary of the test components follows. None of these testing initiatives will provide information on the mechanisms that lead to the performance degradation of armor. This will be addressed in the applied research effort described under a separate but integrated project.

Forest Hills Vest Study

In the Body Armor Safety Initiative, Attorney General John Ashcroft directed NIJ to conduct an immediate review of both new and used ZYLON-based bullet resistant vests to ensure that they are effective. The Attorney General also directed NIJ to

include in this testing effort the upgrade kits provided by manufacturers to retrofit ZYLON-based armor.

Prior to the Attorney General's announcement, OLES, at the request of NIJ, initiated a study to determine the cause of the bullet penetration of the ZYLON body armor being worn by a police officer in Forest Hills, Pennsylvania. This was the first known instance in which an NIJ-compliant armor model appears to have failed to stop a bullet that it was designed to defeat. The study of the Forest Hills vest penetration and the broader study of ZYLON-based body armor will assist in developing an appropriate standards and testing process for monitoring and ensuring the ongoing performance of NIJ-compliant body armor during its intended operational life. The following is a summary of the preliminary findings:

- The firearm and ammunition used during the shooting incident were examined to determine the expected bullet velocity. This examination indicated that the bullet velocity was not greater than the velocity used during NIJ compliance testing.

- The bullet materials (chemical and mechanical properties) were similar to the bullets normally used for compliance testing; however, some minor differences were observed in the geometry and deformation characteristics of the two bullet types.

- Tensile strengths of single yarns removed from the rear panel of the Forest Hills armor were up to 30 % lower than yarns from the "new" armors supplied by the body armor manufacturer for this study.

The reduction in tensile strength of the Forest Hills panel is considered significant, although other factors also may have contributed to the armor penetration (*e.g.*, shot location, shot angle, bullet rotational speed, armor stitching, etc.).

Since the ZYLON in the incident vest was found to be much weaker than expected, it is necessary to test armor that has been weakened to a condition matching that of the penetrated vest. Several potential degradation mechanisms that could account for the loss in mechanical strength were considered. An aging process was initiated to achieve uniform degradation of the materials. Polymer scientists from NIST established the conditions under which this aging is taking place. This aging involves holding the test specimens at elevated conditions of temperature and humidity, and periodically subjecting extracted yarns to tensile tests until the degraded properties are achieved.

After the weakened yarn mechanical properties are attained, the remainder of the ballistics series will continue. That experimental series is statistically designed to explore variations in bullet type, shot angle, vest conditions, barrel twist, and shot location to determine which factors, or combination of factors, leads to a greater risk of vest penetration.

Concurrent with this aging process, materials characterization testing will be performed by the NIST laboratories on yarn specimens from the rear panel of the officer's vest, yarn specimens removed periodically from the aging vest panels, yarn specimens removed from compliance test program samples, and yarn specimens removed from other body armor samples to explore whether any obvious chemical or physical differences exist. Tests will include mechanical properties testing and spectroscopic analysis to determine evidence of degradation and presence of residual surface contaminants from manufacturing processes. This examination is expected to provide a much better understanding of the most likely contributing factors that led to the penetration.

DELIVERABLES OF THE FOREST HILLS VEST STUDY:

- A report documenting findings from the Forest Hills Vest Study.

Ballistic Tests to Identify Evidence of ZYLON Degradation in Used Armor

There are nearly 240 different models of ZYLON-based ballistic-resistant body armor from 16 different manufacturers that have been found to comply with either NIJ Standard–0101.04 or –0101.03, "Ballistic Resistance of Police Body Armor." It is estimated that there are/were at least 300,000 ZYLON-based armors in field use. Drawing valid conclusions about all ZYLON-based armor performance requires a significant testing effort. A three-phase, statistically-based test plan was developed that will help ensure that a representative sampling of used armors (*e.g.* different manufacturers, threat levels, designs, environmental conditions, age, etc.) will be tested. A brief summary of these three phases follows.

Phase I – "Worst Case Testing"

A set of abbreviated ballistic tests (V50 and penetration) will be performed on a limited number of used ZYLON armors that were heavily worn and exposed to conditions that might adversely affect their ballistic performance (*e.g.*, heat, humidity, UV, age, improper care, and abuse). V50 testing is used

to determine if there is a shift in ballistic performance that might be indicative of armor degradation. This "worst-case" testing phase will quickly indicate whether performance issues exist with ZYLON armor in field use.

The vests will be subjected to normal ballistic penetration testing. The original compliance testing would have required six shots of one caliber (bullet type) on the ballistic panel, and a different ballistic panel would have received six shots of a second caliber (bullet type). This plan calls for the same two bullet types to be used, except both bullet types will be fired into the same panel; three shots of one caliber and three shots of the other. Furthermore, backface signature measurements (measurement of deformation of the ballistic material as a result of bullet impact) will be made for the first 0-degree shot of each bullet type, which again is consistent with the methods used in the NIJ Standards (-03 and -04 versions). The "penetration" tests are planned for the front panel of each vest. A "V50 ballistic limit" test is planned for each back panel. The results of these tests will be used to determine 1) if penetrations occur, and 2) if there has been a significant degradation in V50 measurements when compared to data obtained during original NIJ compliance testing.

Phase II – "Large Scale Testing"

The scope of the Department of Justice's Body Armor Safety Initiative is much broader than looking at only one model of ZYLON-based armor, and one cannot reliably assume that multiple used vests of the same model will perform similarly because their usage histories and environmental exposures will be different. For this reason, direct application of the NIJ standard for evaluating used armor has always been considered inappropriate. To overcome this limitation, this test program relies on randomly sampling ZYLON-based vests in use around the country and subjecting them to a modified ballistics test protocol that is similar to and consistent with the NIJ test methodology.

The purpose of this broad-based testing phase is to assess the ongoing performance of a broad "cross section" of ZYLON-based body armor in field use. Approximately 500 vests will be randomly selected from five different geographic regions, five different age categories, and four different manufacturer categories for a total of 100 sampling combinations or "bins." These vests will be subjected to a set of ballistic tests similar to those in Phase I. The results of these tests will be statistically evaluated and compared to baseline data obtained during original NIJ compliance testing. While this plan does not test all ZYLON-based armor, the design of the plan ensures that valid statistical conclusions can be made about ZYLON-based armor. The NIST Statistical Engineering Division (SED) stresses the importance of sampling randomly within each of these bins. Because the selection of vests will be random, the profile of the sample will look like a "cross section" of what is currently in service.

Failure rates obtained from the numerous six-shot front panel tests will be analyzed to determine if the failure rate exceeds that which might be expected from new armor. This approach establishes the current standard's requirements for 0-penetrations in 48-shots as the benchmark for "safety."

The V50 ballistic limit test results for the 04-standard models also will be examined to determine if there is a consistent shift in ballistic-resistance performance when compared to the baseline V50s that were generated when that armor model was tested for compliance to the 04-standard. This testing phase will also be integrated with the applied research project, and vests showing signs of degraded performance (based on V50 results) or yielding penetrations during routine testing will be examined further in a variety of chemical and physical tests. In addition, vests that show little signs of change will also be sampled for further study.

Because the scale of testing is fairly large (ballistic tests on 1000 panels – 2 panels per vest), OLES will be issuing a contract(s) to commercial test laboratory(ies) to conduct this testing. Logistics associated with this contracting process are currently being addressed. The acquisition of appropriate body armor test specimens represents a significant logistic hurdle. The resources of the Bulletproof Vest Partnership program will be relied upon to obtain body armor in field use and to make arrangements for compensation to participating agencies.

Phase III – "Additional Testing"

After analysis of the data from Phases I and II, it may become necessary to perform additional tests. The data from the first two phases will be looked at from many perspectives to determine whether any definitive conclusions can be drawn regarding ZYLON degradation and potential contributing factors. If the incidence of failure indicates a "potential" problem under a certain combination of factors (*i.e.*, Manufacturer X; Model Y; Age greater than Z years; specific design features, etc.), addi-

tional testing may be needed to validate whether there is a true problem. It is envisioned that this testing, if necessary, would be similar in size/scope to Phase I.

DELIVERABLES OF THE ZYLON BALLISTIC TESTS:

- A report stating whether there are indications of ZYLON degradation, evidenced by increased rates of bullet penetrations, as determined from the Phase I "worst case" tests.
- A contract establishing a mechanism for accomplishing the Phase II tests.
- A report summarizing the findings of the Phase II ballistic tests on 500 random samples of body armor.
- If Phase III is conducted, then a report summarizing the results will be produced.

Testing of Upgrade Kits

One body armor manufacturer has offered upgrade kits for use with certain models of body armor. The Body Armor Safety Initiative directs that the performance of these upgrade kits be assessed. Vests that are considered to be "degraded" will be tested with the upgrade kits to determine if the combination of the two can consistently prevent bullet penetrations when tested in accordance with a test protocol that is similar to that used in Phase I testing described earlier. Additional tests will be conducted to estimate the relative gain afforded by inclusion of the upgrade kit. This will be estimated from V50 tests done with and without the upgrade kits.

DELIVERABLES OF THE TESTING OF UPGRADE KITS:

- A report summarizing findings of ballistic tests on upgrade packages.

Cops' Bullet Proof Vests – Applied Research to Understand Degradation Mechanisms/Review of Ballistic and Stab Standards: A Component of the Body Armor Safety Initiative

This general project area is a direct result of the Department of Justice's Body Armor Safety Initiative. This general project area complements the ballistic testing project area. While the ballistic testing projects address some of the concerns with the ongoing ballistic-resistant performance of ZYLON-based body armor, they will not lead to an understanding of what improvements are needed to address armor design, material selection, ongoing quality assurance, and conformity assessment issues, all of which have become apparent as a result of the initial examination of the Forest Hills incident. This general project area addresses those concerns. This general project area consists of two major components. Each component consists of two subprojects. Each of these subprojects will be presented as a stand-alone project:

- Applied Research Program
  - "Investigation of Body Armor Failure: Identification of Factors Contributing to the Degradation of Polymers in Ballistic Fibers."
  - "Correlation of the Mechanical and Chemical Properties of Polymeric Materials with Ballistic Resistance of Personal Body Armor."
- Review of Standards and Testing Program
  - "Improvements to Quality Assurance and Armor Testing Methods."
  - "Blunt Trauma Research and Development of an Improved Test Methodology."

The objective of the projects under the Applied Research Program is to provide a thorough understanding of the degradation mechanisms that affect ballistic-resistant body armor so that improvements can be made to the NIJ body armor standard, and advancements can be made in ballistic-resistant technologies. Two polymers groups at NIST are undertaking studies to identify body armor degradation mechanisms, establish sensitivities of the ballistic materials to environmental stressors, identify chemical changes and reactions responsible for strength loss, and initiate the development of standardized chemical or physical protocols for assessing, screening, and predicting the service life of fibers used in ballistic applications.

The objective of the projects under the Review of Standards and Testing Program is to identify improvements to the NIJ body armor standard and its associated Compliance Testing Program. These improvements are expected to define rigorous conformity assessment procedures to ensure acceptable long-term ballistic performance of soft body armor, and define improved test methods for evaluating body armor.

Investigation of Body Armor Failure: Identification of Factors Contributing to the Degradation of Polymers in Ballistic Fibers

Goals

The objectives of the proposed research are to: 1) identify chemical changes and reactions respon-

sible for strength loss in poly(phenylenebenzobisoxazole) (PBO) fibers; 2) to identify the exposure variables, acting individually or in combination, that initiate and accelerate these chemical changes and reaction(s); 3) to study and model fiber degradation kinetics; and 4) to initiate the development of a standardized chemical or physical protocol for assessing, screening, and predicting the service lives of fibers used in ballistic applications.

Customer Needs

Identification and comprehensive understanding of the chemical reactions responsible for the loss of mechanical strength in PBO ballistic fibers will lead to improvements in the selection of durable and reliable fibers used in body armor. The development of a scientifically-based protocol for screening, testing, and comparing the long-term performance of new and existing fibers for use in ballistic applications will have long term benefits in identifying fibers having improved long-term ballistic performance.

Recent field failures of body armor manufactured from PBO fibers have underscored the need to study the service life of these ballistic fibers under a variety of environmental and operating conditions. Manufacturer-supplied data, as well as tests conducted by other commercial research laboratories and governmental labs, have indicated that PBO fiber (which is relatively new in the ballistic armor arena) undergoes degradation in tensile strength following exposure to temperature, moisture and light. Degradation on this level has not yet been observed with more established materials such as Kevlar or Spectra fiber. An extensive and ongoing review of the scientific literature has revealed that neither systematically controlled experiments involving relevant environmental factors, nor detailed chemical analysis of the mechanisms and kinetics of fiber degradation, have yet been carried out. The proposed research will address these issues.

Technical Strategy

Phase I: Identification of Chemical Indicators of PBO Fiber Tensile Strength Loss

The initial six-month phase of the proposed research will focus on the identification of chemical indicators of PBO fiber tensile strength loss; systematic characterization of PBO fibers; procurement of needed equipment; and development of an experimental design for Phase II of the proposed research. In the initial portion of Phase I, a number of PBO materials will be characterized and their chemical properties compared. Materials to be analyzed will include, but not be limited to, yarns extracted from 1) the back panel of the Forest Hills vest that failed in-service, 2) new vests, 3) vests that have been used in the field, and 4) virgin spool yarn. In addition to identifying chemical and physical differences between the specimens, this phase will allow us to determine which analytical techniques are the most sensitive in detecting chemical changes that reflect subsequent losses in mechanical strength. The analyses that will be performed and their expected capabilities are as follows:

- Molecular Spectroscopy (infrared, UV-visible, x-ray, NMR, Raman): To assess differences in fiber chemistry, *e.g.*, determine if any hydrolysis has occurred, as well as detect possible degradation products or impurities.

- Atomic Spectroscopy (emission spectrometry, atomic absorption spectroscopy): To identify the presence of trace elements such as phosphorus from residual polyphosphoric acid.

- X-ray Diffraction, Neutron Scattering: To determine if any differences in crystallinity or crystal structure exist between various fiber specimens.

- Moisture Absorption (thermogravimetric analysis, moisture sorption analysis): To measure equilibrium moisture content and to measure kinetics of water absorption as a function of temperature and humidity.

- Water and Organic Solvent Extraction: To identify soluble degradation products, fiber additives or sizings, residual polyphosphoric acid, etc., as analyzed by gas chromatography-mass spectrometry (GC-MS) or infrared spectroscopy.

- Dynamic Mechanical Thermal Analysis: To obtain information on fiber modulus, damping and thermal transitions.

- Tensile Testing: To measure the tensile strength, modulus and elongation of the fibers/yarns.

To determine whether environmental factors such as temperature, humidity and ultraviolet (UV) exposure produce measurable changes in the fibers, virgin yarn will also be subjected to a short-term high temperature, high humidity and high intensity UV-visible radiation exposure in our UV weathering chambers. Chemical, physical and mechanical analyses as described above will be carried out on the exposed specimens as a function of time.

Phase II: Changes in Fiber Properties as a Function of Temperature, Relative Humidity, and Spectral Radiation

We plan to initiate a statistically designed experiment on PBO and other commercially available ballistic fibers, focusing on, but not limited to, the individual and combined effects of temperature, humidity and ultraviolet-visible radiation. The ballistic fibers will be tested in specially designed test fixtures in the integrating sphere-based weathering device, and changes in chemical, physical and mechanical properties will be analyzed via the most sensitive chemical techniques identified in Phase I. Materials will be exposed to different treatments throughout FY2005 and FY2006, with fiber analyses occurring concurrently. As the experimental data becomes available, a scientific model will be derived and refined to explain the experimental observations.

Materials that will be tested include single fibers, yarns and woven fabrics. Temperatures and relative humidities that span the range of normal use will be used as factors in the study, as well as more extreme temperatures and relative humidities that may be encountered during storage and immersion. UV-visible spectral intensity and UV-visible spectral distribution are also important environmental factors. Of particular interest is to determine and model the degradation kinetics as a function of these environmental factors acting alone and in combination. Another interest is to identify the wavelengths of light that contribute the most to photodegradation, if it is indeed observed. This study will provide information on the antagonistic relationships that could exist between temperature, humidity, UV as well as other environmental and processing variables that are not known at this time.

Specific chemical, physical and mechanical measurements that will be carried out will be determined following the completion of Phase I (FY2004 research). Mechanical testing in this phase will be carried out on yarns using a standard test frame equipped with a fiber tensile testing accessory, and on single fibers with the single fiber testing apparatus in the Polymers Division. If fabric specimens are of sufficient size, ballistic testing can also be carried out on the woven fabrics after exposure on the integrating sphere.

The results that are obtained will provide critical data towards gaining an understanding of the factors responsible for the degradation of ballistic fibers, and will also lead to the development of reliable and effective methods for screening and accelerated durability testing. Ultimately, both savings in costs and lives can be realized.

DELIVERABLES

- Report on chemical analysis of failed and new vests.

Correlation of the Mechanical and Chemical Properties of Polymeric Materials with Ballistic Resistance of Personal Body Armor

Goals

To prevent catastrophic failure of personal body armor by developing tests and standards of assessment for the reliability of the active polymeric materials that comprise them.

Customer Needs

It is known that virgin PBO fibers can offer ballistic performance that is superior to other fibers on the market (*e.g.*, Kevlar). This potentially leads to protective systems made with PBO fibers that are thinner and therefore are more comfortable to wear. Recent incidents and experimental data from industry, however, suggest that the ballistic performance of PBO fibers is reduced by exposure to hydrolysis and UV-photolysis environmental. Some other fibers have also been shown to have the same susceptibility; therefore, a more detailed investigation is warranted.

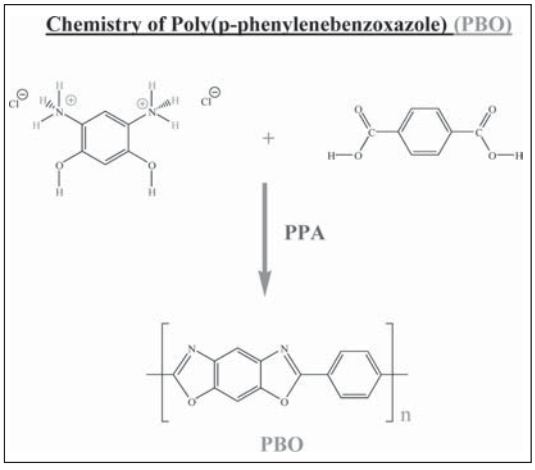

Figure 1. Chemistry of preparation and structure of poly(p-phenylenebenzoxazole) (PBO) fibers. Fibers made from the reaction of 1,3-diamino-4, 6-dihydroxybenzene (DADHB) dihydrochloride with terephthalic acid (TA) with poly(phosphoric acid) (PPA) as a catalyst.

Technical Strategy

We will expose virgin PBO fibers to controlled hydrolysis and UV-photolysis conditions, using testing equipment that is purchasable by industrial organizations (*e.g.*, zenon lamp, oven with humidity control). Using analytical techniques, including the single fiber (SF) test, nuclear magnetic resonance (NMR) spectroscopy, Fourier Transform Infrared (FTIR) Spectroscopy, multi-angle laser light scattering (MALLS), and electron spin resonance (ESR) spectroscopy with radical trapping, we will characterize the impact of the degradation processes on PBO material properties. These results will be compared with those obtained from the UV weathering chamber studies in the related research project. Finally, we will correlate the combined results with those obtained from ballistic resistance tests to identify optimal measurement methods for determining overall ballistic resistance from fiber/yarn samples.

On a parallel track, we will study model compounds that mimic the linkages and structure of the PBO fiber. To determine the role of residual acid on the degradation process, we will also include poly(phosphoric) acid (PPA) in the model testing matrix (see Figure 1 for PPA's role in the synthesis of PBO). These results will be used to quantify the degradation rates by UV and hydrolysis, which will allow us to determine whether UV or moisture is more damaging to the PBO system and allow its quantitation in polymeric materials. We will employ these results in developing test methodologies that aid in the certification of PBO-based protective equipment.

Results from the above test matrix will then be used to develop methodologies that quantify the rate of degradation and its impact on the ballistic performance of PBO fibers. Other techniques not previously identified may be required at this point. Based on what we have learned, the performance of other ballistic fibers will be quantified.

DELIVERABLES

- All exposed and virgin fibers characterized by the best available analytical techniques, to include NMR, FTIR, etc.
- Hydrolysis and UV-photolysis failure mechanisms for PBO fibers determined.
- Impact of hydrolysis and UV-photolysis on PBO material properties, *i.e.*, modulus, tensile strength, strain-to-failure, and molecular weight, quantified.
- Since the above three material properties are used to determine the ballistic performance of fibers, the change in the properties with degradation should give a quantitative estimate of how the protective equipment will perform via the ballistic performance parameter, U*.

$$U^* = \frac{\sigma_{uts}\varepsilon_f}{2\rho}\sqrt{\frac{E}{\rho}}$$

where

σ_{uts} = fiber ultimate axial tensile strength

ε_f = fiber ultimate tensile strain

ρ = fiber density

E = fiber modulus (assumed to be linear elastic)

- Results of literature reviews in current knowledge base regarding PBO degradation and analyses of possible failure mechanisms.
- Report summarizing the results of the following tests:
  - Initial tests performed on virgin PBO fibers and PBO fibers from vests (Forest Hills Officer's vest and vest that has been in storage) to look for spectral differences using Nuclear Magnetic Resonance (NMR) and Fourier Transform Infrared (FTIR) spectroscopies. (Test results obtained from at least 5 different locations.)
  - Initial Single Fiber (SF) tests on virgin PBO fibers and PBO fibers from vests to look for differences in strain-to-failure, modulus, and ultimate tensile strength. Test results obtained from (40 to 50) fibers from 5 different locations
- Review article on hydrolytic and UV stability of benzoxazole ring structures, which is of particular interest due the fact that the benzoxazole ring is the key structural component in PBO.
- Issue report summarizing:
  - Complete spectral test results (NMR & IR) on virgin PBO fibers and PBO fibers from vests, including effects of humidity and UV radiation on virgin PBO fibers.
  - Complete SF test results on virgin PBO fibers and PBO fibers from vests, including effects of humidity and UV radiation on virgin PBO fibers
  - Results of preliminary tests on virgin PBO fibers and PBO fibers from the vests to establish the efficacy of using multi-angle laser light scattering to monitor the rate of degradation and to look for differences between the samples.
- Journal article/conference proceeding draft prepared summarizing correlations between spectral, single fiber, and ballistic resistance tests.
- Journal article/conference proceeding draft prepared summarizing effects of moisture and humidity on virgin PBO fibers characterized through spectral analysis and single fiber tests.
- Model compound 3 synthesized.
- Journal article submitted on parallel hydrolytic/UV degradation study of model compounds (including the effects of residual acid).
- If MALLS experiments were determined to be a feasible method for monitoring fiber degradation, then journal article will be submitted.
- Standard test method developed for characterizing ballistic PBO fibers.

• Results of similar studies on Kevlar fibers and other systems of interest published.

Improvements to Quality Assurance and Armor Testing Methods

Goals

NIJ Standard–0101.04 was published in September, 2000, and improved with a minor revision, referred to as "Revision A," in June, 2001. The standard is actively managed and regularly reviewed to stay current with any new developments. OLES plays a critical role in this process and remains current with other relevant body armor research efforts being conducted by others. The objective of this project is to further strengthen the NIJ body armor standard and associated Compliance Testing Program by incorporating improved test methods in a new version of the standard and establishing an ongoing conformity assessment program.

Customer Needs

A critical review of the incident in Forest Hills and subsequent discussions with the criminal justice and public safety communities have made clear the need for more oversight of ongoing body armor performance. Gaps exist in the current ballistic-resistant body armor standard and related Compliance Testing Program. Some of these gaps exist because neither the NIJ Standard–0101.04 nor the Compliance Testing Program were originally intended to address the ongoing performance of used ballistic-resistant body armor. Other gaps are inherent in the standard because the standard addresses only "certification" of a "model" of body armor, meaning that the model design meets certain minimal performance requirements. Ensuring that future production units comply with these requirements is not addressed by the standard; instead, it is the responsibility of the body armor manufacturer to prove, and the purchasing authority to require, that new production units of body armor comply with certain performance requirements. There is much confusion about these issues among body armor users and procurement officials. Addressing these issues will lead to fundamental changes in the testing program.

By addressing the gaps described, the criminal justice and public safety communities will benefit because they will be assured that ongoing production units of body armor are inspected for conformity to ballistic-resistance requirements. The manufacturing industry will also benefit from improvements in the standardized test and measurement methods.

Technical Strategy

Solutions to the gaps identified will take into account input from public safety agencies, organizations, and associations; manufacturers; and standards and testing organizations. Additionally, findings from the studies that examine ZYLON-based armor and preliminary results from NIST's other applied research efforts will provide further insight leading to recommendations that address the gaps.

With the emphasis on general Quality Assurance issues and Testing and Measurement issues, there will be heavy involvement and reliance on the statistical and conformity assessment disciplines at NIST. Among the areas to address under Quality Assurance are laboratory accreditation programs, used armor monitoring, and ongoing performance assessments of certified models. Among the areas to address under Testing and Measurement Improvements are V50 test methodologies and uncertainty analysis, investigations of V50 tests vis à vis penetration tests, improvements in velocity measurements, software development to structure testing and automatically perform data analysis, and the introduction of advisory statements that address concerns with factors (for example, ultraviolet radiation and moisture) that may be detrimental to some body armor materials. Other efforts are being planned to investigate additional improvements that could be incorporated into the standard, such as impact sensors, multiple shot resistance, flex testing, and alternative backing materials, but details on those studies will be presented in the future.

DELIVERABLES

• Identification of key issues not currently addressed by existing standards.

• Briefings to law enforcement, corrections, public safety, and industry personnel on proposed changes to the NIJ standard and testing program.

• A modified NIJ body armor standard.

• Plans for the establishment of an improved conformity assessment system.

Blunt Trauma Research and Development of an Improved Test Methodology

Goals

This effort will focus on the development of an enhanced technique for the evaluation of soft body

armor using biomechanical tests with modern instrumentation and the creation of a robust test methodology for the evaluation of injury risk from Behind Armor Blunt Trauma (BABT).

Customer Needs

An area identified in the current NIJ standard that requires further attention is related to test fixturing and the backface deformation performance requirement that is often associated with the threat due to BABT. Deformation of the body armor during the ballistic impact event may lead to injuries behind the armor. Though the NIJ standard has been successful in defining a test methodology and performance requirements that led to effective body armor systems, the biomechanical basis for using clay deformation to characterize BABT is uncertain. First, unlike the clay, the human thorax is generally viscoelastic. It is unlikely the response is appropriate for widely varying rates of deformation. The current test methodology was validated using goat experiments performed over 30 years ago. The test is also not likely to be appropriate over wider ranges of clay deformation. In addition, the standard does not account for the "penciling effect." This impact does not penetrate the skin, but results in deep deformation over a small area. The "penciling effect" may be frequently seen in soft body armor backing.

Optimization of soft body armor systems requires a more biofidelic coupling of the body armor and the fixture on which it is mounted for testing. Shear deformation properties of clay are substantially different than the shear properties for the human thorax. Thoracic deformations having the same deformation depths, but different cavity volumes may have significantly different risks of serious injury, and the standard does not address this possibility. In addition, deficiencies identified with the clay system argue for the development of a robust technique for BABT injury assessment. Beyond the existing NIJ standard, there exists no generally accepted injury criterion for thoracic BABT.

Technical Strategy

Development of the enhanced technique for evaluating body armor will involve:

- Identification of a suitable biofidelic surrogate for BABT assessments of soft body armor, perhaps a dummy that is robust, gives a repeatable physical response, and responds in a human-like manner. Generally, a surrogate should be as simple as possible while still representing the relevant human response. In the current NIJ standard, the surrogate is the clay.

- Identification of a relevant engineering measurement – a physical parameter such as force or acceleration – that may be used to quantify the physical response of the dummy. Dummies may be instrumented so that a measurement indicative of the severity of the ballistic impact can be measured. For instance, the current engineering measurement in the NIJ standard is clay deformation.

- Establishment of an injury risk evaluation, which is accomplished by correlating the engineering measurement and an injury model. The injury risk evaluation is expected to be based on mid-thoracic injury tolerance levels. For example, in the NIJ standard, the injury risk evaluation is based on a maximum clay deformation of 44 mm.

- Validation of the injury model, which is accomplished by correlating the injury risk evaluation to a physical model of injury. An injury risk model is without value unless it can be successfully validated using: 1) epidemiology or physical reconstruction of actual injury events, 2) an animal injury model, or 3) a cadaveric human injury model. Development of a relationship between a robust surrogate for injury and a validated injury model is crucial in the success of this approach. Without a robust injury model based on animal testing, cadaveric testing, and/or epidemiology, the testing performed with a dummy surrogate will be invalid. The injury model for the NIJ standard includes animal tests that have been scaled to human values.

With the development of an instrumented surrogate, a two-step process for evaluating body armor will be considered. The potential for bullet penetration would be assessed first on a surrogate with minimal cost risk (*i.e.*, should a penetration occur, valuable instrumentation would not be lost). Following the penetration assessment, further tests on an instrumented surrogate would assess the potential for BABT impact injuries for those body armor systems that pass the penetration tests.

DELIVERABLES

- Issue final report, including recommendations for revisions to NIJ standard.

NIJ Standard–0106.01, "Ballistic Helmets"

Goals

The objective of this project is to revise the NIJ "Ballistic Helmets" standard and establish new performance levels and test methods based on ballistic impact biomechanics research.

Customer Needs

The new standard will lead to improved helmet designs that will increase the probability of user survivability. It will also provide a standard in which the user community has confidence. Customers will also find that more test laboratories will be able to perform this testing because of changes to the equipment required for testing.

The current NIJ helmet standard is more than twenty years old, was not regularly updated, and was not based on ballistic impact biomechanical principles. Research conducted in the "Study of Head Injuries During Ballistic Loading of Helmets" by the University of Virginia Impact Biomechanics Center (under contract to the U.S. Army Soldier and Biological Chemical Command's Natick Soldier Center (NSC)) indicated that requirements in the existing standard may not ensure adequate protection for individuals wearing ballistic protective helmets meeting the standard. Additionally, relatively few helmets are certified to the existing standard due to a number of reasons: NIJ does not administer a formal Compliance Testing Program for ballistic helmets; the test equipment is difficult to obtain; and the performance levels are outdated and have not kept pace with those defined in the ballistic-resistant body armor standard. The new standard will reduce the risk of serious injury due to ballistic impacts, as well as standardize testing and performance requirements based on modern ballistic impact biomechanical principles.

Technical Strategy

■ Work will continue under the Biokinetics contract. Numerous issues will be addressed: 1) the current revision only addresses threats up to level II, while existing helmet technologies can readily provide higher levels of protection; 2) the threat definitions in the current revision are different from those in the recently updated ballistic-resistant body armor standard; 3) instrumentation for assessing helmet performance has improved dramatically; and 4) head trauma research has led to a better understanding of injury mechanisms and injury risk criteria. A newly developed ballistic helmet test rig will be used to validate the improved test method.

■ A draft revised standard will be written and sent out for comment and review.

DELIVERABLES

- Validation tests conducted under contract.
- Test equipment and instrumentation.
- Draft revised standard.

NIJ Standard–0108.01, "Ballistic Resistance of Protective Materials"

Goals

The objective of this project is to revise the NIJ standard that establishes minimum performance requirements and methods of test for ballistic resistant protective materials.

Customer Needs

Law enforcement agencies rely on the NIJ Standard–0108.01 to ensure the quality and reliability of ballistic resistant materials used for personal protection purposes. These materials are of many types, and can be found in shields, ballistic resistant plates, and vehicle armor.

The current revision of the standard, NIJ Standard–0108.01 was released in September 1985. It added ballistic threat level IIIA and established threat level classifications that were consistent with other NIJ standards for ballistic protection. Since that time, an extensive amount of work has been done leading to the improved body armor standard, NIJ Standard–0101.04. The current NIJ Standard–0108.01 does not reflect any of the improvements that were recently introduced into the ballistic resistant body armor standard, and harmonizing the test methods and threat levels of the two ballistic standards is important.

Technical Strategy

■ The review of the draft revision of the standard will be completed. The revision will include: 1) introduction of a V50 ballistic limit test methodology; 2) updating of the ballistic threats; and 3) specification of formal test procedures that require a uniform reporting style.

■ A validation test matrix will be developed and materials to support the tests will be procured.

■ A determination will be made whether to include testing of transparent materials in the revised standard or to develop a separate performance standard for those materials.

■ All test methods will be validated through experimental testing.

■ The draft standard will be submitted to user and technical committees for review and comment.

DELIVERABLES

- Revised draft standard, including comments.
- Validation test matrix.
- Summary report of validation tests.
- Final version of revised standard.

Development of a Frangible Ammunition Selection Guide and Performance Standard

Goals

"Frangible ammunition" is ammunition loaded with a bullet that is designed to shatter into small pieces on impact with hard structural surfaces. The purpose of this project is to provide an in-depth understanding of bullets and soft armor materials leading to models and computer simulations of bullet/armor interactions. Special attention will be directed at frangible and other special materials/designs that pose a potential threat to existing armor. To achieve this objective we will also develop a dynamic material properties database for bullet and armor materials, including high rate and heating effects.

This project consists of three parts: 1) producing a Selection Guide of existing frangible ammunition; 2) performing ballistic testing of frangible ammunition against various targets and developing modeling and simulation capabilities to better understand bullet and armor deformations and interactions; and 3) developing a performance standard for frangible ammunition.

Customer Needs

Key performance requirements of frangible rounds are that they remain effective against their targets without causing significant collateral damage due to over-penetration of the target or ricochets. This project will ensure that the frangible ammunition used by criminal justice and public safety officers meets minimum safety, quality, and performance requirements. Additionally, changes to the NIJ ballistic-resistant body armor standard may be necessary to ensure adequate protection from these emerging threats. Protective equipment product designers will design better equipment faster, taking into account the material properties of the equipment and the threats to the officers. Government and industry researchers evaluating new threats will have improved evaluation tools with the new models developed as part of this project.

Criminal justice and public safety agencies are interested in frangible ammunition because of its value in certain situations. For example, frangible ammunition is ideal in some tactical applications to minimize collateral damage. In other cases, some training facilities are "lead-free," and most frangible ammunition can be utilized at these facilities because the materials used in the construction of the bullet are often devoid of lead so that the bullet possesses low ductility and can be readily shattered. Frangible ammunition is currently used by several government agencies, state and local law enforcement agencies, and other public safety agencies.

With increasing demand for frangible ammunition, more products are becoming available on the open market. Some recent reports have suggested that frangible ammunition may pose a serious penetration threat to conventional soft body armor. This highlights the need for further understanding of the potential threats posed by this ammunition to soft body armor. There are far too many different types of bullets and armor material parameters to experimentally assess all threats. However predictive modeling or computer simulations can provide guidance to narrow the range of physical experiments to a manageable number. Final approval of a particular design will always be done with actual testing in accordance with NIJ Standards. The models will assist in predicting the effectiveness of the protective devices as well as limiting the number of tests in the design and evaluation stages.

The modeling and simulation of impact problems such as bullets hitting a protective shield or armor rely on dynamic material properties of the materials involved. Traditionally the research into high rate dynamic materials properties has been directed toward military types of armor plate and penetrating projectiles. The methods used in military research may be very helpful in analysis of protective equipment for law enforcement personnel; however, the materials used in most law enforcement equipment are very different. Effective models for soft armor studies are only just beginning to be developed and more research in this area is needed. Further work in this area will examine system vulnerabilities and identify solutions to improve officer safety.

Technical Strategy

This effort began in mid-calendar year 2002. Because of increased national attention being directed at this issue, a higher level of effort was expended on this project to obtain some preliminary assessments of the relative threat posed by frangible ammunition to soft body armor and to determine the types and extent of use of this type of ammunition. Work from various agencies and other groups has been compiled and reviewed. A survey was conducted to determine the extent of use and purpose of frangible ammunition in many law enforcement agencies. Patent searches were conducted to better understand fundamental differences between various types of frangible bullet constructions. A frangible ammo test matrix was developed and preliminary tests against conventional soft body armor were conducted. Initial results suggest a potentially serious problem.

Exploratory studies were conducted to determine if some property of the bullet (such as compressive strength) might correlate to observed behavior against armor. For starters, a simple slow-rate compression test using a universal test machine to compare different bullets having similar geometries was tried. Results were encouraging, but it became apparent that understanding the dynamic properties of these materials was crucial to understanding their impact behavior, and modeling and simulation capabilities in this area would prove extremely beneficial to understanding how body armor works against conventional threats as well. The research plan has been revised to address these important areas for investigation.

Some long-lead time armor materials were procured – shoot pack samples constructed from a variety of different soft armor materials are now available. Plans for an expanded study were developed so that a broader range of the different types of frangible ammunition and armor systems were included:

- Perform conventional Kolsky bar tests, including high-speed video, of bullet materials (frangible as well as conventional bullets). Perform a series of novel dynamic diametral compression tests that generate a tensile failure using the Kolsky bar apparatus.

- Compare dynamic mechanical properties to those (compressive strength or shear strength) obtained under quasi-static conditions. Determine which correlate best with observed penetration performance against armor.

- Study methods of testing soft body armor fibers at high loading rates and develop capability for generating high-rate mechanical properties data for a variety of ballistic-resistant materials.

- Perform literature search and interact with outside experts to assess the state-of-the-art in modeling bullet/soft armor interactions. Implement state-of-the-art computer model of soft armor/bullet interactions and develop a plan for improvement.

- Begin ballistic penetration performance tests of frangible ammunition against a variety of targets using new shoot packs.

- Develop a draft "Selection Guide for Frangible Ammunition" that will identify existing frangible ammunition types, models, calibers, and sources. The guide will also discuss critical issues that users should consider when they select ammunition. The guide will provide a reference for selection and purchase of frangible ammunition for various criminal justice and public safety applications.

- Continue with ballistic penetration performance tests of frangible ammunition against a variety of targets.

- Continue development of first generation finite element model of the bullet/soft armor interactions.

- Complete tests on various bullet materials and develop a database of these materials.

- Fabricate a single soft body armor fiber testing apparatus for high rate behavior.

- Incorporate test methods developed for ammunition performance characterization into a performance standard for frangible ammunition. This may lead to the implementation of a formal Compliance Testing Program, through which frangible ammunition could be formally tested against the standard.

- Using the dynamic properties database, evaluate existing constitutive models for use in the finite element model. Using the new fiber testing apparatus, measure the high rate behavior of pristine and degraded body armor fibers. Perform appropriate tests of real systems and use high-speed video recording methods to evaluate and improve first generation bullet finite element models.

- Perform appropriate experiments and measurements for evaluating the finite element modeling using the NIST-developed constitutive equations for fibers and bullets. Based on the improved un-

derstanding of the interactions of bullet and soft armor, develop a road map for future studies.

DELIVERABLES

- A preliminary test report describing ammunition performance against standard soft body armor targets.
- Stress-strain curves for frangible and conventional bullet materials.
- Brief report on the effectiveness of diametral compression testing in providing fracture behavior of frangible bullet materials.
- A progress report describing dynamic tensile testing of single soft armor fibers.
- A report reviewing current status of soft armor computer models and status of implementation of a model useful for studying bullet deformation and armor interactions.
- A draft of the "Selection Guide for Frangible Ammunition".
- Database of mechanical properties of frangible bullets and comparisons with conventional bullets. The database will include examples of measurements, including high-speed videos, of deformations and fractures to aid in the understanding of the processes involved.
- Demonstrate an operating single fiber dynamic testing apparatus and provide examples of data that will be obtained.
- Demonstrate a first generation computer model of bullet/soft armor interactions.
- Based on the database of the bullet materials provide constitutive equations needed in the finite element models for bullet behavior.
- Provide a database of soft body armor materials of both pristine and degraded fibers using data from the NIST laboratories and other sources.
- Demonstrate a finite element model of bullet deformation using constitutive equations developed at NIST and compare with high-speed video of actual tests.
- Draft a performance standard.
- Provide constitutive equations of soft body armor fibers needed for finite element models.
- Demonstrate a full FEA model of bullet/soft armor interactions using NIST developed bullet and fiber constitutive equations.
- Report comparing results of simulations with experiments of real situations. Report will include a road map for continued improvement of the modeling by using comparisons with experiments.

NIJ Standard–0104.02, "Riot Helmets and Face Shields"

Goals

The objective of this project is to review NIJ Standard–0104.02 and issue an improved revision.

Customer Needs

With the anticipated improvements, it is expected that more riot control equipment will be tested against the standard, leading to improved products and an increase in standard-compliant models, which will benefit the user community.

NIJ Standard–0104.02, "Riot Helmets and Face Shields," was last reviewed in October 1984. Since that time, technological improvements incorporated into helmets and face shields offer better protection, and research has led to a better understanding of head and neck injuries. An improved performance standard that incorporates these considerations into it will allow law enforcement and corrections personnel to specify and procure improved equipment that offers higher levels of protection.

Technical Strategy

- Review other national standards dealing with helmets.
- Review threat levels and use of ISO "headform." Consult with other standards bodies to discuss their rationale for and experiences with the ISO headform.
- Research existing flammability resistance test methods for potential inclusion in this standard.
- Research impact resistance methods for potential inclusion to assess the performance of the "tails."
- Identify outside support to provide assistance with revising standard.
- Establish performance levels consistent with the latest injury threshold research.
- Develop revised test procedures and validate through testing.
- Finalize revised standard and issue it for comment and review.

DELIVERABLES

- Reviews completed and summarized in intermediate status report.
- Revised test procedures.
- Validation test report.
- Finalize revised standard and issue it for comment and review.

Accomplishments of Weapons and Protective Systems

■ Provided technical leadership for the Attorney General's Body Armor Safety Initiative.

- Advanced the understanding of issues associated with the penetration of the Forest Hills body armor.

- Determined that there are performance deficiencies with at least some ZYLON-based body armor samples in field service.

- Evaluated upgrade kits for some ZYLON-based body armor models.

- Supported the Attorney General's Body Armor Summit.

- Advanced the understanding of PBO degradation mechanisms and specific armor design features that might increase the risk of exposure of PBO to undesirable environmental factors.

- Developed preliminary test and measurement methods for assessing changes in PBO. Methods are based on assessing certain chemical and mechanical properties.

- Developed specific recommendations for improving the NIJ body armor standard in the near term, and identified areas requiring further study.

■ Developed improved test methodologies for assessing ballistic helmets.

Publications

G.A. Holmes, K.D. Rice, and C.R. Snyder, "Ballistic Fibers: A Review of the Thermal, Ultraviolet, and Hydrolytic Stability of the Benzoxazole Ring Structure," submitted to *Journal of Materials Science*, (June 2004).

Detection, Inspection, and Enforcement Technologies

As America's homeland security efforts intensify, the work of OLES' Detection, Inspection and Enforcement Technologies program becomes increasingly important.

Two continuing projects focus on testing and improving the capabilities of current walk-through and hand-held metal detectors. Work completed last year on the conductivity and permeability of weapons-grade metals is currently available for interpreting detection limits. Likewise, methods for producing phantom materials that emulate human tissue were recently developed for experimentally investigating issues of electromagnetic compatibility and safety for wearers of personal medical devices (PMEDS) in the rf fields produced by metal detectors.

Another effort focuses on the completion of a performance standard for the portable x-ray systems used by bomb technicians to disarm improvised explosive devices. A complementary project tests commercial-off-the-shelf models for compliance with the forth-coming standard.

Investigations of the electromagnetic properties of building materials are being pursued so that better systems can be improvised for communications between First Responders in emergency situations and for locating victims that may be trapped beneath building rubble.

The Detection, Inspection and Enforcement Technologies program is also developing evaluation standards for advanced human recognition systems that will allow qualitative performance testing of recognition products over a wide range of watch-list and access-control applications.

In the enforcement arena, standards for traffic speed-measuring devices are constantly being updated to keep pace with the enhancements manufacturers install on their products to catch speed offenders on our nation's highways and roads. In addition, a new standard is being prepared for the ubiquitous intersection safety systems that capture images and speeds of red light violators.

NIJ Standard–0601.02, "Walk-Through Metal Detectors for Use in Concealed Weapon and Contraband Detection"

Technical Contact:
George Lieberman

Staff-Years:
3

Goals

The objective of this project is to continue work to improve the latest revision of the Walk-Through Metal Detector (WTMD) performance standard, design and implement improvements to the robot used for WTMD performance tests, revise the NIST report that describes the test equipment, and provide technical assistance to the Compliance Testing Program.

Customer Needs

The new standard, the Compliance Testing Program, and the equipment performance report will provide important information to WTMD manufacturers, lead to improved WTMD designs, and serve to educate the user community about important performance characteristics and operating parameters of WTMDs.

Increasing attention is being given to security, and great confidence is placed in walk-through metal detectors to detect items that might pose a threat to public safety. Routinely, one can find these devices being used to screen correctional facility populations and their visitors, as well as to screen people for admission to airport terminals, courthouses, schools, sports stadiums, amusement parks, and political events, and this is only a partial list. It is essential for the WTMD to be adjusted properly to sense the types of threat objects of interest, and that it perform this detection function accurately and reliably. The WTMD performance standard fills an important void in that it is the only reference developed specifically for these products that ties together many important performance requirements (electrical safety and vulnerability, electromagnetic compatibility, detection performance, and environmental resistance). Users of WTMDs can purchase compliant products with confidence.

Historically, WTMD manufacturers were not compelled to design their products to meet a broad array of performance requirements, but rather only a subset of requirements to meet basic electrical safety and perhaps electromagnetic emissions

requirements. With the last revision of the standard, NIJ established a Compliance Testing Program for WTMDs and made it available to manufacturers so that they can begin to assess their designs against the full array of performance tests and make adjustments to improve the designs to address vulnerabilities that might be exposed during testing. It is important to address issues that have been discovered during the first year of the WTMD Compliance Testing Program and to report the results of the testing program so that users will benefit from this information and further improvements can be made to the standard.

Since the first series of tests under the Compliance Testing Program, numerous requests have been made by manufacturers and procurement authorities to have units tested against the standard. Presently there are no commercial laboratories recognized by NIJ to do this. Also, during the first series of tests, several areas for improvement were noted.

In consultation with an industry group, NIST developed what has now become the current version of the NIJ "Walk-Through Metal Detector" performance standard, NIJ Standard–0601.02. A formal WTMD Compliance Testing Program based on this standard was initiated in mid-FY2002 and completed in FY2003. NIST worked closely with the National Law Enforcement and Corrections Technology Center (NLECTC) and a commercial test laboratory to implement the WTMD Compliance Testing Program, through which several models of commercially available WTMDs were tested. This test program has proven very valuable, both in terms of generating data on products of interest and in terms of pinpointing areas in the standard that could be improved further. Comments and suggestions for further improvements to the standard were, and continue to be, collected from industry.

This project will provide the technical support needed to implement an ongoing Compliance Testing Program. Work will also begin on the next revision of the standard, which will include the procurement of three WTMDs for validation testing purposed. Mentioned in the handheld metal detector project are robot specific improvements that also carry over to this effort. Additionally, a separate publication is planned that describes the test equipment and test objects in detail.

Technical Strategy

- Provide technical support to NIJ and the NLECTC, which administers the Compliance Testing Program, to re-establish the testing program.
- Revise standard, including the following: 1) removing text and figures describing test objects and auxiliary test equipment designs; 2) updating references to other standards; and 3) procuring three WTMDs and evaluating performance test protocols of standard.
- Publish new document that includes build details for the robot and embedments (while the test object design is a requirement, the embedment is not necessary); it is used to facilitate reproducible test and provide safety. This will involve: 1) removing test object embedments from the standard; 2) redesigning the embedments to allow placing test objects closer to metal detectors (we have observed that for some metal detectors, the distance between the test object and metal detector was too great); and 3) inserting drawings and specifications for the parts in the supplemental document. Additionally, the test equipment design descriptions will be placed in the supplemental NIJ document, as these descriptions are a suggestion and not a requirement.
- Modify the OLES robot. Of special interest is the addition of hardware to minimize test object bounce and to improve positional accuracy. Software modifications are also planned to improve the measurement process.
- Modify the NIJ robot. Commercial labs performing these tests will need this robot. Modifications need to be made to the robotic controller or a new software package must be developed to provide the flexibility needed in testing a broad range of detector geometries. Initial testing revealed limitations in the software package supplied with it. An assessment will be made to determine the most effective route toward improvement – either a hardware change or a software change.

DELIVERABLES

- Revised standard.
- Separate document containing equipment recommendations, which will either be a revision of NISTIR 6530, "A Measurement System for Characterizing the Detection Performance of Metal Detectors: Design and Operation," or a new, but similar, publication.

NIJ Standard–0602.02, "Handheld Metal Detectors for Use in Concealed Weapon and Contraband Detection"

Goals

The objective of this project is to continue work to improve the latest revision of the Hand-Held Metal

Detector (HHMD) performance standard, design and implement improvements to the robot used for HHMD performance tests, revise the NIST report that describes the test equipment, and provide technical assistance to the Compliance Testing Program.

Customer Needs

The new standard, the Compliance Testing Program, and the equipment performance report will provide important information to HHMD manufacturers, lead to improved HHMD designs, and serve to educate the user community about important performance characteristics and operating parameters of HHMDs.

With increasing attention being given to security, hand-held metal detectors are often used to supplement the interrogation provided by walk-through metal detectors (WTMDs), especially if the WTMD gives a positive alarm. The HHMD allows the security screener to pinpoint areas of primary concern and to inspect them more closely to detect items that might pose a threat to public safety. These devices are found nearly everywhere that WTMDs are found, and they are often the last inspection devices used to screen someone; therefore, it is critical that they perform their intended function accurately and reliably. As is the case with WTMDs, manufacturers of HHMDs were not compelled to design their products to meet a broad array of performance requirements, but this standard and a coordinated Compliance Testing Program will fill that void. With the new revision of the standard and the Compliance Testing Program, manufacturers will be able to assess their designs against the full array of performance tests and make adjustments to improve the designs to address vulnerabilities that might be exposed during testing. Users of HHMDs will be able to purchase compliant products with confidence.

In consultation with an industry group, NIST developed what has now become the current version of the NIJ "Hand-Held Metal Detector" performance standard, NIJ Standard–0602.02. A formal Compliance Testing Program based on this standard has not been initiated; however, some internal tests have proven very valuable in terms of pinpointing areas in the standard that could be improved further. Comments and suggestions for further improvements to the standard continue to be collected from industry.

This current project will provide the technical support needed to implement an ongoing Compliance Testing Program. Work will also begin on the next revision of the standard and on making improvements to the robotic test system. Additionally, a separate publication is planned that describes the test equipment and test objects in detail.

Technical Strategy

- Provide technical support to NIJ and NLECTC, which will administer the Compliance Testing Program. Assist in identification of laboratories that can conduct tests in the standard and work closely with NLECTC to implement the HHMD Compliance Testing Program.

- Revise standard, including the following: 1) removing text and figures describing test objects and auxiliary test equipment designs; 2) implementing minor changes to certain test procedures to reduce test time and cost; and 3) updating references to other standards.

- Publish new document that includes build details for the robot and embedments (while the test object design is a requirement, the embedment is not necessary); it is used to facilitate reproducible test and provide safety. This will involve: 1) removing test object embedments from the standard, 2) redesigning the embedments to allow placing test objects closer to metal detectors (we have observed that for some metal detectors, the distance between the test object and metal detector was too great); and 3) inserting drawings and specifications for the parts in the supplemental document. Additionally, the test equipment design descriptions will be placed in the supplemental NIJ document, as these descriptions are a suggestion and not a requirement.

- Modify the OLES robot. Of special interest is the addition of hardware to minimize test object bounce and to improve positional accuracy. Software modifications are also planned to improve the measurement process.

- Modify the NIJ robot. Commercial labs performing these tests will need this robot. Modifications need to be made to the robotic controller or a new software package must be developed to provide the flexibility needed in testing a broad range of detector geometries. Initial testing revealed limitations in the software package supplied with it. An assessment will be made to determine the most effective route toward improvement – either a hardware change or a software change.

DELIVERABLES

- Revised standard.
- Identification of laboratories.
- Separate document containing equipment recommendations, which will either be a revision of NISTIR 6530, "A Measurement System for Characterizing the Detection Performance of Metal Detectors: Design and Operation," or a new, but similar, publication.

Development of Evaluation Standards for Face Recognition Systems

Goals

The objective of this project is to design methods for the evaluation of systems that identify humans in imagery and define the standards for the collection, dissemination and use of imagery databases.

Customer Needs

Databases and software implementations of evaluation metrics allow quantitative performance testing of human recognition products over a wide range of watch-list and access-control applications.

In prior fiscal years, NIST has been funded to conduct data gathering efforts, which have resulted in a human identification database. Using the database, NIST has developed the measurement methods for analyzing performance of facial recognition systems. The methods have proven sufficiently generic such that fingerprint recognition systems (single finger and Automated Fingerprint Identification System (AFIS)) can be evaluated in much the same manner. Indeed the measurement techniques and performance statistics are applicable to a wide range of biometrics, and non-human recognition tasks.

This effort is funded by the NIJ. Two distinct imagery databases have been used for the NIST face tests. First, a NIST-gathered collection of volunteer images constitutes a database of multi-modal, multi-site, and multi-biometric collection. Second, 6.8M operational images from the Department of State give very large-scale performance numbers that are predictive of deployed performance in visa processing applications.

Technical Strategy

NIST will continue work to support the evaluation of human recognition systems. This will be a three-pronged approach:

- Given that face recognition systems have been shown to benefit from multiple captures (and/or views) of the face, NIST is conducting a study to quantify this effect, and to ensure that the standard face interchange format supports the inclusion of multiple images.

- NIST will participate in the U.S. standards committee INCITS M1 (national) and ISO/IEC SC37 (international) standards processes in two areas: 1) establishing face and fingerprint interchange standards (this is close to completion), and 2) performance testing. This latter activity is primarily a codification of the offline testing conducted at NIST for face (http://www.frvt.org) and fingerprint (http://fpvte.nist.gov). The major result will be prescriptive methods for measuring false accept and true accept rates for one-to-one verification and one-to-many open-set identification applications.

- NIST is working jointly with the Department of Homeland Security on face recognition aspects of the US VISIT port-of-entry traveler verification system. Particularly NIST will assess the image quality of the images that can be captured using installed equipment, determine its suitability for the recognition activities planned, and make recommendations on the basis of our findings.

DELIVERABLES

- Working Draft M1 and ISO testing standards.
- Final Draft face and fingerprint interchange formats.
- Image quality assessment methods for face recognition.
- Studies of face+face and face+fingerprint fusion, its effectiveness, and ergonomic and economic viability.

Portable X-Ray Systems for Bomb Disarmament and Search

Goals

To modernize the currently obsolete standard for portable x-ray systems used in bomb disarmament operations and then test commercial-off-the-shelf (COTS) systems for compliance with this revised standard.

Customer Needs

Law enforcement officers engaged in counter-terrorism activities may be called upon to determine whether a suspicious letter received by a prominent individual, or an abandoned package found in a public place, contains an improvised explosive device (IED). Time permitting, a portable x-ray system enables that determination to be made and, depending on such factors as the construction, type and amount of explosive, and detonation

mechanism, to lead to a course of action to disarm, disrupt or otherwise mitigate the explosive blast.

Technical Strategy

Due to vast improvements in x-ray generation, imaging and microprocessor technology, and stricter radiation safety requirements imposed by other agencies, there is a heightened, if not urgent, need to modernize the current 32-year-old Justice Department standard: NILECTJ- STD 0603.00. To facilitate that effort, a collaboration was undertaken with the Police Scientific Development Branch (PSDB) of the Home Office in the United Kingdom (UK). The PSDB has considerable expertise and experience in the testing and deployment of portable x-ray equipment. PSDB facility at Sandridge is also very comprehensive, including a large lead-lined laboratory and various x-ray generators, and the staff are familiar with the general requirements of x-ray imaging systems and generators and the associated (UK) health and safety issues.

Together with the PSDB, two workshops were conducted at NIST involving bomb squad practitioners, instructors and physical scientists familiar with the technology. The outcome was a draft that was subsequently reviewed by manufacturers and experts from various professional associations of bomb technicians and investigators. Their recommendations were incorporated into a final draft, which is being prepared for approval and promulgation. As this is occurring, the PSDB will commence preparations for testing COTS x-ray systems for compliance with the standard. The standard together with results from the testing program are intended to provide a powerful procurement tool for bomb squad acquisitions.

DELIVERABLES

- An NIJ/PSDB standard for portable x-ray systems for bomb disarmament and search.
- A report containing compliance test results for COTS portable x-ray systems.

Technologies for Traffic Speed and Red Light Enforcement

Goals

To develop and maintain performance specifications which assure the accuracy and reliability of speed-measuring devices and systems used by law enforcement, and to assist the International Association of Chiefs of Police (IACP) with administering an independent testing laboratory program establishing a consumer products list for each type of speed-measuring device.

Customer Needs

Police traffic radar devices have been used in this country to detect speeding motorists since the 1940s. Since then, radar devices have evolved from clumsy, stationary models into sophisticated, microprocessor-enhanced units capable of monitoring vehicle speeds in either direction from moving patrol cars, and into automated across-the-road systems that automatically capture images of speed-offending vehicles. The successful application of radar technologies to speed enforcement has spawned interest in the development of laser technologies, such as lidar devices and hand-held photolidar systems that photographically document speed violations, as well as an interest in intersection safety systems that not only record red light violations but also the vehicle's approaching speed. Against this bewildering array of technically complex speed-enforcement tools, law enforcement administrators are forced to make difficult procurement decisions.

Technical Strategy

Through the development of minimum performance standards, and testing programs administered by the IACP, baselines are established for acceptable device and system performance. Citizens, courts and law enforcement officers should be assured that those product models, determined by test to comply with the specifications, will provide the high quality of service they require. To further this program, it is recommended that equipment buyers incorporate these performance specifications into their procurement documents, requiring units offered for purchase meet or exceed the requirements of the performance specifications. This is intended to encourage manufacturers to produce better devices and systems. Since device features are constantly evolving, the specifications are subjected to continuing review.

DELIVERABLES

- Maintain up-to-date minimum performance specifications for traffic speed-measuring devices and systems.
- Develop an intersection safety system standard and a traffic simulator for compliance testing.
- Assist the IACP with administration of its device and system Compliance Testing Program.

Dielectric Measurements of Building Materials

Goals

Accurately measure the electromagnetic properties of a broad range of building materials and develop a modeling technique that, based on these properties and the dimensional dispositions of any building's structural elements, can be used to optimize the communication system setup by First Responders during emergency situations.

Customer Needs

First responders in emergency situations need optimized communication systems for a variety of building structures. They not only need to communicate effectively with each other, but also need to know whether safe entry or egress is possible in parts of buildings. These building structures may be characterized as those for office and living use, or as those having specialized functional roles such as telecommunications centers, gas or explosive repositories, or underground rooms and bunkers.

Technical Strategy

Concrete is one of the most commonly used building materials, since it is inexpensive, durable, convenient, and has high mechanical strength. The electromagnetic properties of concrete vary with frequency and critically influence the performance of communication systems used by First Responders. Because the mechanical properties of poured or cast concrete are considerably improved with the use of rebar wire meshes, the effects of the rebar wire, as well as that of the concrete itself, must be considered to properly analyze the efficacy of communication signals amidst the concrete structural elements of buildings. As other building materials also affect signaling and their effects vary with frequency, it becomes equally important to accurately assess the electromagnetic properties of a wide spectrum of commonly used building materials, over a broad frequency range.

Our strategy has been to develop accurate methods for measuring the broadband electromagnetic properties of building materials and then to apply these techniques to assess the electromagnetic properties of prepared building materials. The collected data are being used to create a NIST-traceable measurement database and for the development of national reference standards for evaluating the electromagnetic properties of building materials. Next, the measured electromagnetic properties are being incorporated into a modeling technique for simulating and optimizing electromagnetic communications through any multi--wall or multi-floor building structure, given the disposition and dimensions of the structural elements comprising the building.

DELIVERABLES

- Electromagnetic property measurements for a wide spectrum of building materials, including concrete and rebar, over a broad range in frequency.
- The fabrication, analysis and experimental testing of a number of accurate, non-destructive RF and microwave measuring systems.
- A database of dielectric materials.
- A practical modeling technique that can be used by First Responders to assess communication systems for any building structure.
- Publications in the form of NIST Technical Notes and/or articles in professional journals.

Accomplishments of Detection, Inspection, and Enforcement Technologies

- Facial Recognition Vendors Test 2000 and 2002, http://www.frvt.org. Supplemental report on FRVT 2002 was released January 2004.

- A new color, high resolution, release of the Facial Evaluation Recognition Test (FERET) face database (superseding the greyscale version 500 copies of which were issued between February 2001 and September 2003) was released in October 2003.

- INCITS 1602-D, Biometric Performance Testing and Reporting, Part 2: Technology Testing and Reporting, August 2004.

- ISO/IEC, Text of Working Draft 19795-4, Biometric Performance Testing and Reporting – Part 4: Specific Test Programmes, October 2004.

- ANSI, INCITS 385-2004, Face Recognition Format for Data Interchange, May 2004.

- The final draft of the standard for portable x-ray systems is being prepared for submission to the NIJ for printing and promulgation.

- The program to test COTS portable x-ray systems is about to commence.

- The following standards for traffic speed enforcement devices and systems were significantly revised and recently released for distribution:

  - Speed Measuring Device Performance Specifications: Down-the-Road Radar Module, June 1, 2004.

- Speed Measuring Device Performance Specifications: Across -the-Road Radar Module, June 1, 2004.

- Speed Measuring Device Performance Specifications: Lidar Module, June 1, 2004.

■ The scope and capabilities of the IACP testing laboratory at the Institute for Police Technology and Management at the University of N. Florida have been expanded in the areas of radar device, lidar device and photolidar system testing.

■ A new IACP facility has been established at San Diego State University for testing conventional radar devices and across-the-road radar systems.

■ Broadband coaxial open-circuit transmission line techniques were developed and then used to accurately measure the dielectric properties of non-reinforced concrete from 100 MHz to 5 GHz. These measurements were performed as a function of cure time for the concrete, which had aggregate compositions to simulate typical building yield strengths of 4500 psi.

■ An electromagnetic model for concrete was developed that can be used to predict electromagnetic signaling as a function frequency, total water content, bulk/surface water ratio, chemical salinity, porosity, and temperature.

■ Surface resistance measurements of steel beams from the World Trade Center (WTC) and steel used in rebar wire meshes for reinforcing concrete were completed. Room-temperature data were reported for various WTC steel alloys at frequencies from 1MHz to 100 GHz. Conductivities were determined from the surface resistance measurements.

■ Non-destructive techniques for characterizing laminar dielectric building materials at selected frequencies from 700 MHz to 10 GHz were developed and applied to a number of commonly used building materials. An in-progress summary of the measurements, together with measurement uncertainties, has been reported.

■ A measurement system for determining the electromagnetic properties of building materials at K-band frequencies (20GHz –30GHz) is being developed for future building material testing.

■ A simplified technique, employing the NIST-measured electromagnetic properties of building materials, has been developed for optimizing an improvised communication system for use between First Responders in emergency situations. It includes signaling through concrete floors or through (multiple) exterior walls. It can also be used to design a communication system for remote interrogation of chemical or biological sensors to ascertain safety of entry or egress.

■ A NIST Technical Note is in preparation.

■ A time-domain system was developed and used to measure large sheets of building materials.

Publications

J. Baker-Jarvis, "Dielectric measurements of building materials," URSI/APS meeting, Monterey, CA, April 2004.

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R. G. Geyer, "A chain matrix model using intrinsic building material electromagnetic properties for evaluation of electromagnetic signaling in buildings," NIST Technical Note in progress.

R. G. Geyer, J. R. Baker-Jarvis, M. D. Janezic and R. K. F. Kaiser, "Carbon-loaded polymer composites used as human phantoms: Theoretical models for predicting low frequency dielectric behavior," NIST Technical Note 1529, June 2003.

C. Grosvenor, R. Johnk, N. Canales, D. Novotny, J. Baker-Jarvis, and M. D. Janezic, "Electrical material property measurements using a free-field, ultra-wideband system," Proceedings of IEEE/CEIDP (Conference on Electrical Insulation & Dielectric Phenomena), Boulder, CO, October 2004.

C. Grosvenor, B. Davis, R. Johnk, D. Novotny, and N. Canales, "Measuring the dielectric properties of materials using an ultra-wideband, time-domain measurement system," NIST Technical Note in progress.

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M. D. Janezic, R. F. Kaiser, J. Baker-Jarvis, and G. Free, "DC conductivity measurements of metals," NIST Technical Note 1531, January 2004.

M. D. Janezic, E. F. Kuester, and J. Baker-Jarvis, "Broadband complex permittivity measurements of dielectric substrates using a split-cylinder resonator," *Microwave Symposium Digest*, 2004 IEEE MTT-S International (Fort Worth, TX, June 6-11, 2004), vol. 3, pp.1817-1820.

B. Riddle, J. Baker- Jarvis, J. Kruptka, "Complex permittivity measurements of common plastics over variable temperatures," *IEEE Transactions on Microwave Theory and Techniques*, vol. 51, no. 3, March 2003, pp. 727-733.

Chemical Systems and Materials

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5

OLES' Chemical Systems and Materials program concentrates on research and standards related to chemical technologies used by the criminal justice and public safety communities. The increasing use of less-than-lethal chemicals such as pepper spray (oleoresin capsicum, OC) raises questions about the safety and effectiveness of products currently on the market. The program is examining pepper spray canister products to determine their ingredients, potency, and dose characteristics. This work, coupled with OLES' previous studies to evaluate the dose-related effects of pepper spray on the human body, is in preparation for developing the first standard for pepper spray products.

With regard to standards, the forensic science community has an inherent need for standard reference materials (SRMs) and reference materials (RMs). Currently NIST supplies industry, academia, government, and other users with over 1300 reference materials of the highest quality and metrological value. SRMs are used for three main purposes: to help develop accurate methods of analysis (reference methods); to calibrate measurement systems; and to assure the long-term integrity of measurement quality assurance programs. To provide this support in the forensic science laboratories, OLES has initiated projects that will create SRMs and RMs where the community determined that a void exists.

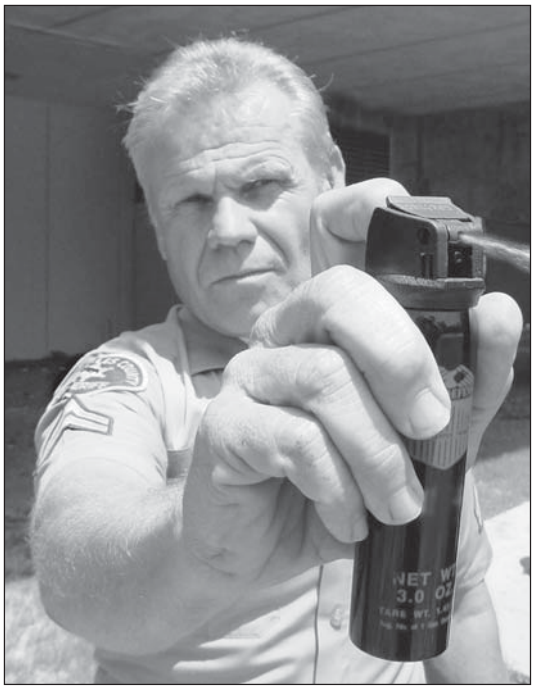
The criminal justice community and employers in both the private and public sectors have expressed strong interest in less invasive tests than those now used to detect illegal drug use. In response, the Chemical Systems and Materials program has recently completed research projects investigating two alternatives: sweat-based drug testing techniques and saliva as a drug testing specimen.

In 1999, the program issued the first NIJ standard for protective gloves for law enforcement and corrections users. Today it continues to provide technical support to the NLECTC at Rockville, MD, for its glove testing program based on that standard.

Oleoresin Capsicum Canister Study

Goals

OLES has initiated a study involving sampling and analyzing the contents of commercial pepper spray canisters from five different manufacturers, to make quantitative measurements of the internal pressure, concentration of active agent(s) capsaicinoid compounds present in the aerosol spray, the propellants and carriers. The study will also include shelf-life stability studies of the canisters (devices) at specified environments, aerosol firing tests, spray range tests, and drop tests to gauge device mechanical safety and stability. It is hoped that data from this type of study will suggest improvements and serve as the basis for minimum voluntary labeling and performance standards. The work will be performed at the Chemical Science and Technology Laboratory (CSTL) at NIST.



OLES is helping to characterize and establish performance standards for pepper spray.

Customer Needs

Oleoresin Capsicum (OC) is an extract of hot peppers. In addition to its use in food and pharmaceuticals, it is an active ingredient in the aerosol sprays used by law enforcement agencies to subdue non-cooperative individuals through skin contact, eyes, and inhalation. The pungency of taste and pain associated with this material are the result of a family of compounds known as "capsaicinoids." The major capsaicinoids present in OC are Capsaicin (CAP), dihydrocapsaicin (DIHCAP), nordihydrocapsaicin (NORDIH), homocapsaicin (HOMO), and dihydrohomocapsaicin (DIHHOMO).

Law Enforcement agencies that have used OC over the last 10 years have found that administering this to those resisting arrest results in effective incapacitation – reversible in 15–20 minutes – 85–90 % of the time. The reasons for the 10–15 % failure include low concentration of OC in the canister, poor delivery owing to low pressure, bad aim, variability of subject responses or a combination of these factors. OLES at NIST is particularly interested in addressing some of these product failure issues that face the law enforcement community to help them perform their functions more safely and effectively.

The pharmaceutical effects of the topical application of these compounds to skin and mucous membranes stimulates the production of and subsequent desensitization to pain. Studies in animals have indicated this effect arises from the binding of specific parts of the particular molecule to receptors in nerve endings. The generation of pain appears to be a temporary phenomenon only, and is not the result of damage to tissue. The pungency of capsaicinoid compounds and preparations containing them is widely expressed in terms of "Scoville Heat Units" (SU). The SU value is the dilution at which a pungency can just be detected by a trained taster. Since the production of pain and the sensation of pungency probably arise through similar physiological pathways, such as the interaction with nerve receptors, it might be assumed that the effects would have some correlation. Another way of expressing capsaicinoid potency is the "mean pain potency" (MPP), which is the concentration required to produce a certain response when a solution is applied to the eye of a rat. Thus, it is an inverse indicator; that is, the smaller the number the higher the potency. It must be noted, however, both the SU and the MPP are subjective measurement systems and, therefore, do not lend themselves to either quantitative determination of potency or an accurate determination of structure-activity relationships for each of the capsaicinoid compounds, alone or in a mixture.

Although CN and CS, commonly known as "tear gas," have been used for riot control for many years, they are not suitable for use against individuals as OC is. Recent findings have shown that OC is an effective incapacitant, reducing assaults against officers, injuries to officers and suspects, while reducing the number of complaints filed against cities regarding use-of-force by law enforcement officers. At the same time, however, a number of areas of concern have surfaced with regard to the use of OC. These areas include legal and policy issues, technical issues such as product specification and performance, medical issues such as the safety and toxicity of OC, especially with regard to long term use of OC, and operational issues such as training and safety procedures for users. OLES is particularly interested in addressing the "technical issues" aspects of this problem.

Technical Strategy

At the present time, the commercial "pepper spray" products in the market are not well defined. There is no specification of active ingredients and manufacturers use a wide range of formulations and labeling schemes: 1) they do not show whether they are using natural or synthetic OC; 2) they do not identify the concentrations of the OC ingredients in the formulation; 3) some combine OC with other active ingredients such CS and CN; 4) they use different carriers such as water, isopropyl alcohol, freon and other halogenated solvents without the data to show how the OC ingredients potency and effectiveness correlates with the carrier system; and 5) there is no data to show the correlation between the concentrations of the different capsaicinoids and how that correlates with the performance and effectiveness of OC.

The project will examine a number of canisters from particular lots and manufacturers that have been used in confrontations by measuring propellant pressure, OC concentration and other properties of the canister which correlate with the reason for the failure. NIJ Standard–0110.00, "Barrier-Penetrating Tear Gas Munitions," which deals with testing hand-held aerosol tear gas weapons, will be used as a guide in measuring spray pattern of canisters.

Evaluation of Equipment for Detection of Drugs and Alcohol in Saliva

Goals

A variety of approaches have been devised for detection of drug abuse. Recently considerable attention has been focused on using oral fluids, commonly known as saliva, as a medium for detection of alcohol and drug use. Commercial vendors offer a variety of systems for this market, ranging from simple strips that display a color change to sophisticated instruments. All of these tests are promoted as rapid and simple and are intended for on-site use. As with any test designed to be simple, rapid and at low cost, there are concerns about the specificity and sensitivity of these saliva testing materials. As the results of these tests may have

legal ramifications, it is critical that the tests perform as claimed by the vendors of the test equipment.

OLES assessment of use of saliva as a non-intrusive forensic test may lead to more accurate drug testing results.

Customer Needs

Saliva interests the law enforcement, prison, and the court systems because it is a relatively easy liquid to use with conventional drug screening and confirmation techniques. It can be collected – by spitting or swabbing – simply and in a less invasive and less embarrassing manner than blood or urine. Many illegal drugs, including heroin, cocaine and amphetamines, can be detected in saliva. And because saliva is derived from blood, drug levels found in oral fluids should reflect those present in the blood and urine.

There is a wealth of background literature on the collection, analysis and interpretation of many drugs in oral fluid as reported in NISTIR 7139, "The Evaluation of Saliva/Oral Fluid as an Alternate Drug Testing Specimen," July 2004. Oral fluid appears to have promise as a specimen for testing in the criminal justice system. This study is one of the latest results of a 30-year collaborative effort between NIJ and NIST to develop standards and guidelines for equipment used in the law enforcement and criminal justice systems.

The word "saliva" is commonly used to describe the complex combination of oral fluids produced by the three major and several minor saliva glands plus other constituents present in the mouth. Sometimes called "mixed saliva," the fluid moistens mucus membranes of the mouth and upper respiratory tract. It also contributes to digestion and helps cleanse the mouth. Adults typically produce more than 1,000 milliliters of saliva daily, including about 5 milliliters per minute while spitting and .05 milliliters while sleeping. Beyond saliva, researchers are also testing hair and sweat to determine if they can be used to detect illegal drug use.

Before saliva can become an accepted test for illegal drugs, several problems have to be resolved and limitations overcome. Current testing methods usually measure the metabolites or chemical breakdown products of illegal drugs rather than the parent drugs themselves. Unfortunately, those parent drugs are found in saliva more often than the metabolites. Eventually, however, this may be helpful since parent drugs can be extracted from a saliva sample more easily than the metabolites.

Technical Strategy

NIST will acquire a variety of saliva test systems and will subject these systems to a rigorous evaluation of their specificity and sensitivity. For systems that promise quantitative results, results will be compared with those obtained using proven GC/MS and/or LC/MS methodology. Known amounts of alcohol and/or the other drugs of abuse that are claimed to be detected will be added to drug-free saliva. The various devices will be tested using these spiked saliva samples to determine if the quoted detection limits are achievable. GC/MS or LC/MS measurements will be used to confirm the concentration of the analytes. In addition, other substances that might be present in saliva will be added to determine the specificity of the saliva tests. These will include some common, over-the-counter medications that are taken orally as well as other substances that might occur in saliva. If a test fails to perform as promised, it will be retested to ensure that the failure was repeatable.

DELIVERABLES

- Set up GC/MS and LC/MS methods for drugs and alcohol in saliva.
- Complete testing of GC/MS and LC/MS methods used for validation.
- Complete acquisition of commercial saliva testing materials.
- Complete sensitivity testing.
- Complete specificity testing.
- Complete project report.

Accomplishments of Chemical Systems and Materials

- Purity tests on the standards by differential scanning calorimetry (DSC), ultraviolet absorbance at 280 nm, LC with UV absorbance detection at 210 nm, and LC with electrospray ionization and mass spectrometric detection was completed.

- Two insulated boxes were constructed to serve as environmental chambers for the storage of canisters containing flammable propellant.

- A device was built to permit sampling of the contents of a pressured canister by piercing the wall of the canister.

- A device for use in the range tests, impact pattern tests, and number of bursts tests was built to position and fire the canisters remotely through actuation of a solenoid.

- A device was designed and built to hold and release canisters for the drop test. This device is also operated electrically through application of a solenoid, and will permit remote actuation. The device was designed to impart minimum torque on the canister upon release, to maintain the original orientation.

- Bureau of Alcohol, Tobacco and Firearms (ATF) brought a failed canister to and several specimens of the same brand to the NIST test range for spray tests and were failed. The failed canister had a spray range and pattern different than the others.

Publications

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Forensic Sciences

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Staff-Years:
15

In today's world, forensic procedures have an incredible range of applications. Department of Homeland Security applies them when evaluating threats to our nation and relies on their precision when investigating terrorist actions. Government and private crime laboratories have stepped into the limelight as a result of high profile cases and primetime television shows. Because of this increased visibility laboratories must meet the most stringent laboratory requirements. The OLES Forensic Sciences program works to ensure laboratories have the necessary tools or documentation to assist in obtaining accurate results that will hold up in court.

The expanse of forensic applications requires a multi-disciplinary approach, and thus work in this area has been distributed across NIST laboratories. For example, projects involving high-tech (computer) crime are based in the Information Technology Laboratory (ITL). These projects address issues such as: the evaluation of investigative software, the prevention of inadvertent modifications of electronic files under investigation and the development of a National Software Reference Library (NSRL) that helps computer analysts to quickly identify suspect files on a hard drive. The Chemical Science and Technology Laboratory (CSTL) has been assigned all aspects of DNA research, blood-and-breath alcohol analysis and the creation of biological standard reference materials (SRMs). The Precision Engineering Division has been assigned all projects addressing bullet and cartridge cases and the Building and Fire Research Laboratory (BFRL) handles all projects related to burn pattern recognition, measurement and simulation of ignition sources, and computer simulations of actual fire events.

Standard Reference Test Data Set for Computer Forensics

Goals

The objective of this project is to provide a validated test that can be used by computer forensic analysts and management to evaluate/calibrate equipment prior to case use and to meet accreditation requirements.

Customer Needs

Application of established forensic protocol and procedures are now being applied to computer forensics. Part of the procedures require "controls" or "traceable reference materials" to be used during case analysis. At the time of this publication, no such validated product exists. Therefore, to assist with this requirement, NIST is in the process of evaluating the needs of the community and creating the necessary product.

Technical Strategy

NIST converses with individuals knowledgeable in the field to determine the type of test needed and in what format. Some basic issues to resolve are:

- Distribution method. One possibility is compressed images on CDs or DVDs that could easily be transferred to digital media for imaging.
- Source for the Data Sets. NIST could produce some, but there are existing data sets that NIST could verify, package and distribute.
- Determine what features to include in the data sets. Target strings in files, slack space, unallocated space and file system metadata.

DELIVERABLES

- An actual test provided on CD/DVD/hard drive media.

Computer Forensics Tools Testing (CFTT)

Goals

The objective of this project is to verify the operation and output of automated programs, generally termed tools, used to examine computer evidence and to provide documented evaluation for judicial proceedings.

Customer Needs

Computer forensic investigators and analysts require documented evaluation of currently available software/tools that advertise forensic capabilities. This step is essential to support collection, analysis, examination and court testimony of digital evidence. NIST is highly suited to provide an unbiased determination of a tool's capability and therefore to verify the results produced by these tools, NIST was asked to provide expertise in developing test suites and a testing framework to structure the testing of the products in use. The information provided by NIST as a neutral party would be used to determine several factors: whether specific tools should be used in forensic examinations; how the

tools should be used; and the limitations of the tools' capabilities.

Technical Strategy

To assist the computer forensic community NIST has conducted functionality tests on specific software and hardware products. The selection of a specific software/hardware product and its functionality (*e.g.*, imaging) is accomplished through specific listserv announcements and select federal agencies. The actual test results are provided in a report form and posted on two different Web sites: http://www.cftt.nist.gov and http://www.ojp.usdoj.gov/nij/sciencetech/welcome.html.

DELIVERABLES

- Published documents describing the overall concept and framework for testing computer forensics tools. Details for the Law Enforcement agency on how to use this information is also provided. Electronic documentation can be found at: http://www.cftt.nist.gov.

National Software Reference Library (NSRL)

Goals

The objective of this project is to provide a validated database of known software, file profiles, and file signatures ("fingerprints") in different hash formats.

Customer Needs

The computer forensic analyst is confronted with the examination of thousands of files per hard drive and in many instances numerous hard drives per forensic case. In addition, all methods and tools utilized in an examination must meet stringent accreditation and judicial requirements.

Technical Strategy

To support the computer forensic investigator or analyst, a validated automated filter program has been created that will either assist in the elimination of thousands of legal files that have no intrinsic forensic value, or provide a quick identification of a specific file of interest. This capability can significantly reduce the amount of examination time required on behalf of the analyst.

Legal requirements may also dictate that the computer forensic analyst produce the basis for the hash values used in an examination, or the specific software version used to obtain the hash. To meet this, NIST retains the actual commercial product that was tested in an in-house library.

DELIVERABLES

- The master database is the primary deliverable (see http://www.nsrl.nist.gov for further information).
- An extracted database that is available to users in CD format. The CD can be purchased through the NIST SRD Office on a subscription basis.

Standard Bullet and Casing Reference Materials

Goals

The objective of this project is to provide virtual signature standards and material standards for both bullets and casings to be used with equipment that captures images for comparison purposes.

Customer Needs

Firearm analysts currently utilize in-house standards for equipment calibration and inter-laboratory methods for examiner evaluation. Laboratory accreditation requirements and federal mandates are dictating the use of traceable reference materials in an effort to establish measurement uniformity.

Technical Strategy

The standard bullet has undergone extensive testing and is nearing its final stages of evaluation. However, prior to release, the standard bullet will be made available to a select group of firearms examiners for a six to twelve-month study. The results of this study will be used to determine laboratory protocol for use of the standard bullet and to determine a range for score evaluation. Casings are currently undergoing evaluation to determine the best method for production.

DELIVERABLES

- RM (Reference Material) 8240, Standard Bullets.
- Report stating the practicality of using the NIST algorithm for bullet signature comparisons.

Refractive Index Glass Standard Reference Material

Goals

The objective of this project is to replenish the depleted NIST standard reference material that is required by forensic laboratories that conduct glass analysis to meet standard operating procedures.

Customer Needs

To meet quality assurance and accreditation requirements, traceable reference materials must be used when analyzing forensic evidence. The depletion of the NIST glass refractive index standard reference material (SRM) caused some laboratories to seek other options to meet accreditation requirements. Therefore, the forensic community needs a new glass refractive index SRM.

Technical Strategy

Glass samples have been specially annealed to remove residual stress birefringence to ensure uniform optical quality. A 5-decimal place index of refraction values will be extracted from the measurements and glass prism samples (7 in total) will be subjected to index of refraction measurements. Tests are planned to see how high a temperature can be achieved before thermal gradients in the sample become too large for accurate measurements of index. Density measurements will be the final step in the testing process.

DELIVERABLES

- A glass standard reference material available for purchase, which can be found at https://srmors.nist.gov or http://ts.nist.gov/ts/htdocs/230/232/232.htm.

DNA Related Projects

Goals

The objective of these projects are to provide technical support to state and local forensic DNA laboratories regarding the underlying science of available DNA products. To promote advances into new technology and provide the necessary documentation required to use the technology in criminal investigations.

Customer Needs

State and local forensic DNA analysts do not have the time or the funds to conduct research into new technologies or evaluate newly released products. In addition, the incorporation of new products into a laboratory's standard protocol requires the laboratory to conduct lengthy validation. To alleviate most of the time and cost constraints, NIST undertakes the necessary tasks.

Sixteen capillaries enable high DNA throughput, allowing more samples to be simultaneously analyzed. © 2002 Robert Rathe

Technical Strategy

NIST provides ready access to reference material, new technology and tutorials through a service called strbase, which can be found at http://www.cstl.nist.gov/biotech/strbase/NISTpub.htm. Through this service analysts have resources at their fingertips.

NIST will continue research in such areas as: analysis of degraded DNA through the use of miniSTRs autosomal SNP typing and mitochondrial coding region SNP assays, continue evaluating the applicability of Y-chromosome analysis through the use of Y-SNP markers and Y-STR markers and multiplex assays, evaluate and improve tools that will aid state and local crime laboratories in the areas of gel electrophoresis, quality assurance and quality control software, and variant allele cataloging and characterization.

DELIVERABLES

- To continue to provide service to all state and local DNA laboratories through presentations, publications, Web site postings and release of new technologies.

Accomplishments of the Forensic Sciences Program

■ National Software Reference Library: Reference Data Set version 2.5 became available June 2004, providing 8,758,741 unique SHA-1, MD5 and CRC32 values for 21,257,017 files.

■ Issued the following Standard Reference Materials (SRMs):

SRM 1828b Ethanol-Water Solutions: Blood-Alcohol Testing: Six Levels

SRM 1847 Ethanol-Water Solutions: Breath-Alcohol Testing: Three levels

SRM 2285 Arson Test Mixture in Methylene Chloride

SRM 2891 Ethanol-Water Solutions: (nominal 0.02 % by mass)

SRM 2892 Ethanol-Water Solutions: (nominal 0.04 % by mass)

SRM 2893 Ethanol-Water Solutions: (nominal 0.08 % by mass)

SRM 2894 Ethanol-Water Solutions: (nominal 0.1 % by mass)

SRM 2895 Ethanol-Water Solutions: (nominal 0.2 % by mass)

SRM 2896 Ethanol-Water Solutions: (nominal 0.3 % by mass)

SRM 2897 Ethanol-Water Solutions: (nominal 2 % by mass)

SRM 2898 Ethanol-Water Solutions: (nominal 6 % by mass)

SRM 2899 Ethanol-Water Solutions: (nominal 25 % by mass)

SRM 8107 Additives in Smokeless Gunpowder.

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J. Song, L. Ma, E. Whitenton and T. Vorburger, "2D and 3D Surface Texture Comparisons Using Autocorrelation Functions," *Proceedings of the 6th ISMTII (International Symposium on Measurement Technology and Intelligent Instruments)*, November 28-29, 2003, Hong Kong.

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Forensic Examination of Digital Evidence: A Guide for Law Enforcement, NCJ 199408, April 2004, Special Report, National Institute of Justice.

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Public Safety Communication Standards

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18

The ability of law enforcement and public safety agencies to communicate and exchange data in critical situations is fragmented by equipment incompatibilities and the lack of standards to provide a common, nationwide approach to telecommunications and information sharing. To resolve the situation, NIJ developed the CommTech (Communications Technology) Program – formerly known as AGILE – to develop and implement interoperability standards.

The OLES Public Safety Communications Standards program is dedicated to supporting CommTech. The program is developing standards for voice, data, image, and video transfers, drawing on existing standards, discussions with end users regarding their requirements, and participation in IT and wireless standards committees. To meet the needs of law enforcement and public safety agencies until standards are in place, the program is evaluating commercial devices and services that can provide interim interoperability.

The ability of an officer to communicate with other local agencies and emergency responders is critical to efficient and safe operations.

Standardization Efforts Related to Telecommunication and Information Technology Interoperability

Goals

The objective of this project, as part of the CommTech Program, is to provide engineering support, scientific analysis, technical liaison, test design and implementation to allow the identification, development and validation of interoperability standards for the Justice/Public Safety/Homeland Security community, and other communication system products and services supporting wireless telecommunications and IT needs. Further, provide technical assessments and evaluations of existing and emerging commercial products and services that may provide interim solutions for various interoperability scenarios.

Customer Needs

With the explosion of telecommunications and information technologies has come a disturbing trend – a lack of interoperability among systems. This has been demonstrated most dramatically in the justice/public safety community, as police and other agencies (fire departments, emergency medical services, etc.) failed to communicate with each other during multi-jurisdictional events (such as the Oklahoma City bombing and the September 11 attacks). Even when high-profile local, state, or regional calamities do not occur, daily interoperability problems continue to plague justice/public safety agencies nationwide.

Efforts for the CommTech Program have continued in earnest for IT and wireless telecommunications interoperability standardization, as well as technology evaluation. Regarding IT standardization activities, coordination was sustained with the Office of Justice Programs (OJP), NIJ, the Bureau of Justice Assistance (BJA), the GLOBAL Infrastructure/Standards Working Group (I/SWG) and its technical committees (including those working on Infrastructure/Architecture, XML [eXtensible Markup Language], Justice Standards Clearinghouse, Emerging Technologies, and Governance issues).

Effective communication is a critical aspect of both law enforcement and corrections operations. Dispatch is the nerve center of the agency.

Work was planned and conducted with individuals representing various practitioner groups at the local, state, federal, tribal, and international levels. To facilitate progress of national-level committees, strategic and tactical planning documents for OJP, I/SWG, and its technical committees were developed. The justice XML data dictionary and schema that were developed through GLOBAL (with OLES help) have been accepted as a draft standard for use by all practitioner groups. OLES has already begun to provide training to the NLECTC system in standard XML implementation techniques.

Interoperability standardization activities for wireless communication applications were also sustained. Direct and concentrated involvement with Project 25 and Telecommunications Industry Association (TIA) TR 8 standards committees has continued, especially in the development of inter-RF subsystem interface (ISSI) specifications. Additionally, a recent and significant product has been developed on behalf of CommTech and the COPS (Community Oriented Policing Services) office, and vetted through the public safety community – the *Statement of Requirements (SOR) for Public Safety Wireless Communications and Interoperability*. In conjunction with SAFECOM, this document was released and is the recognized definition of requirements for the public safety community. In FY2005, the SOR will be addressed by a nationwide architectural framework for telecommunications interoperability and information sharing. Standards will ultimately specify all aspects of the framework's components, operation, and performance.

Technology evaluation and engineering support have continued across a wide breadth of technical topics and interoperability issues. An interoperability laboratory has been operating to investigate and characterize wireless, IT, and hybrid (wireless/IT) system and network products, prototypes, and conceptual approaches. Testing was completed on a communications repeater that interfaces both with conventional radio frequency (rf) and Internet protocol systems, and on an interim interoperability device. Interoperability testing of Project 25 equipment produced by different manufacturers continues, with portable, mobile, base station, and repeater gear being included.

Technical Strategy

The current phase of the project can be seen as falling into the following functional support areas:

Information Technology Interoperability Standardization

OLES will continue to work closely with the GLOBAL I/SWG to validate users' information-sharing requirements; validate the current assets and plans of local, state, federal, tribal, and international Justice/ Public Safety/Homeland Security agencies; update the characterization of current and emerging technologies; validate internal and external factors that may impact standardization options; establish and validate data models and schema for sharing information among agencies; and validate the strategic plan for moving the entire standardization process forward. In addition, provide overall planning and operational support to the GLOBAL I/SWG and its committees. Provide detailed technical review and analysis of IT standards developed by standards development organizations, and recommend standards to the I/SWG and its committees that may facilitate architectural alternatives advanced by the I/SWG for information sharing. On an ongoing basis, validate (through simulation and/or demonstration/testing) that the chosen standards are compatible, fit together as an entire package, and specify effective and efficient interfaces for local, state, federal, tribal, and international systems.

Technology Evaluation and Engineering Support

Provide technical observations, analyses, demonstrations, and testing as part of technical evaluation activities aimed at determining the utility of commercial interoperability products and services. Technical evaluation efforts will address products and services identified by NIJ, but also those various technologies determined (through OLES research) to have great potential as interim interoperability solutions, over the short and long-term. Recommend emerging technologies worthy of NIJ grant assistance, as required. Respond to the immediate needs of the CommTech Program by performing other research and applied engineering activities as requested. These activities may include strategic and tactical planning, system engineering, technical analysis, economic benefit studies, etc. Develop formal documents such as guides or handbooks, and also presentations, white papers, and other documentation to support existing program tasks and/or proposed initiatives. Evaluate proposals, designs, approaches, and other technical overtures submitted/offered to NIJ, as requested.

Wireless Telecommunications Interoperability Standardization

Work closely with those chosen to represent the wireless telecommunications users within the Justice/ Public Safety/Homeland Security community and SAFECOM to validate users' requirements; validate the current assets and plans of local, state, federal, tribal, and international justice/public safety agencies; update the characterization of current and emerging technologies; validate internal and external factors that may impact standardization options; and validate the strategic plan for moving the entire standardization process forward. In addition, provide overall planning and operational support to those representing the wireless telecommunications users as they function within such standards bodies as Project 25/TIA TR8, Project MESA, etc. Provide detailed technical review and analysis of standards developed by standards development organizations, and recommend standards to those representing the wireless telecommunications users. On an ongoing basis, validate (through simulation and/or demonstration/testing) that the chosen standards are compatible, fit together as an entire package, and specify effective and efficient interfaces for local, state, and federal systems. Provide close technical liaison with GLOBAL I/SWG and its committees to ensure that data transfer issues are addressed consistently by the wireless and IT standardization activities, and that the two activities ultimately converge. Provide coordination with Federal Initiatives aimed at developing and implementing wireless telecommunication interoperability strategies, *e.g.*, Project SAFECOM.

DELIVERABLES

• Revised Statements of Requirements (SORs) for both IT and wireless telecommunications applications, architectural framework documents, NIJ standards, reports, guides, guidelines, handbooks, white papers, and other products required to advance the CommTech Program and other interoperability-related efforts within NIJ.

Accomplishments of the Public Safety Communication Standards

- Provided training on the Justice XML Data Model, including the data element dictionary, schema, and applications, to hundreds of public safety practitioners, and management and staff of the National Law Enforcement and Corrections Technology Center (NLECTC).
- Developed the *Minimum Specification for Interoperability* for SAFECOM that was accepted and publicized by the Department of Homeland Security.
- Selected and Chaired the Security Working Group of the National Public Safety Telecommunications Council.
- Provided detailed technical education to the program managers and staff of the CommTech and SAFECOM Programs regarding technologies and applications offered to the programs.
- Developed technical approaches and contributions to Project 25 and Project MESA that advanced the definition of user requirements and critical interface standards.
- Conducted over 3600 individual interoperability and performance tests on equipment manufactured to Project 25/ TIA 102-Series standards.
- Assisted CommTech, COPS, and SAFECOM management by developing the technical strategy for formally achieving telecommunications interoperability, deriving the process and procedures for involving local, state, and federal public safety practitioners in the strategy, and creating position papers and outreach documents that will help high-level Government officials better understand the methodology.

Publications

The following documents provide significant input to the standardization of telecommunications interoperability for the public safety community:

Statement of Requirements for Public Safety Wireless Communications and Interoperability, Version 1.0, March 10, 2004, DHS/SAFECOM, AGILE Program, NIST/OLES (see http://www.safecomprogram.gov).

Scope and Mission Statements for TR8.8, Technical Contribution to Telecommunications Industry Association (TIA) TR8 Committee to establish the Wireless Broadband Networking Committee, July 2004 (accepted).

Known Wireless Attacks (Myths and Reality), Technical Contribution to GLOBAL Justice Information Sharing Initiative, Security Working Group, August 2004.

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Critical Incident Technologies

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40

Long before the September 11, 2001 attacks and the war on terrorism, OLES was heavily engaged in America's domestic preparedness and homeland security efforts. The Critical Incident Technologies program, established as a separate program area in 2001, consolidated existing projects with new initiatives under a single administrative banner. The Critical Incident Technologies program expanded significantly in FY2003 and FY2004. During this period, primary funding for the program switched from NIJ to the Office for Domestic Preparedness (ODP) in FY2003; in 2004 the funding was again transferred, this time to the Science and Technology (S&T) Directorate of the Department of Homeland Security (DHS). The Critical Incident Technologies program currently manages the bulk of the standards development efforts for the DHS Science and Technology Directorate's Standards Portfolio.

The projects within the Critical Incident Technologies program area can be divided into three main areas: 1) the First Responder Chemical, Biological, Radiological, Nuclear and Explosive (CBRNE) Protective and Operational Equipment Standards Development Program; 2) the DHS Standards Portfolio Chemical and Biological Countermeasures, Critical Infrastructure Protection, Biometrics, Cyber and Interoperable Communications Standards Development Program; and 3) NIJ funded Critical Incidents projects. Each of these program areas and the corresponding projects will be discussed in more detail.

Goals

The primary goals of the program are to:

1) Enhance public safety by promulgating standards for CBRNE protective and operational equipment that ensure minimum performance, quality, reliability and interoperability;

2) Disseminate standards and subsequent performance evaluations to the public safety community to help them make informed equipment purchases and to guide manufacturers, developers, and the test and evaluation community to ensure product compliance; and

3) Link equipment certification and compliance with minimum performance standards to federal equipment grants programs.

Customer Needs

The objective of this project is to provide the criminal justice and public safety community a suite of national CBRNE protective equipment standards and to facilitate the adoption of these standards. Implementation of these standards is important to ensure procurement and use of equipment that achieves a minimum acceptable level of performance. To accomplish this mission, relationships have been established and maintained within the user communities to the point where the user representatives play an integral role in all facets of the standards prioritization and development process. One primary means of accomplishing this is through Memorandums of Understanding with many agencies to include the Interagency Board (IAB) for Equipment Standardization and Interoperability. The IAB, which consists of Committees and Sub Groups from the user community, initially identified respiratory equipment as the first priority for development within the program.

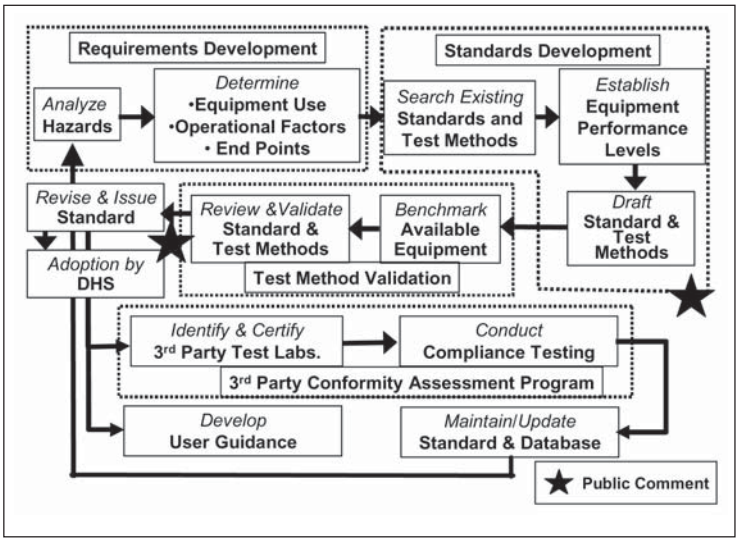
A typical protective mask for first responders, law enforcement officers, corrections officers, and EMS providers.

Technical Strategy

Critical Incident Technologies Standards Development Process is described in the following description and illustration.

Requirements Development. The first step is to develop the requirements for the standard. These are based on the requirements of the user – what does the responder need the equipment to do, under what conditions, and conduct a threat and haz-

ard analysis. A number of factors need to be addressed such as: What is the threat that is to be countered? What is the use of the technology, is it a detector, protective clothing, communications equipment? What environmental conditions need to be considered such as temperature, humidity, flame impingement, etc.? What is the key endpoint that must be measured, is it detection of specific agents at a range of concentrations, allowable breakthrough for protective clothing? A hazards analysis must be conducted, perhaps through the use of modeling or simulations. The details of this analysis may be classified, but the resulting inputs to the standards development process should be unclassified.



Critical Incident Technologies Standards Development Process

Standards Development. The next step is the development of the performance standard and test methods to evaluate the performance of the equipment to the standard. Maximum use is made of the voluntary consensus standards development process, the development and promulgation of the standards through recognized Standards Development Organizations (SDO) such as ASTM International, the National Fire Protection Association (NFPA), and other such organizations. A review of existing standards and test methods is conducted to identify: 1) standards and test methods that meet the requirements as identified, or 2) standards and test methods that if modified could meet the requirement, or 3) if no such standards and test methods exist, then identify the appropriate SDO for development and promulgation of the standard. A team of subject matter experts is assembled to conduct research and develop the input for submission to the appropriate SDO. It is important that the test methods to evaluate compliance to the standard are linked to the performance standard. The end result is the development of draft performance standards and test methods, submitted to the appropriate SDO.

Test Method Validation. Once the draft standard and test method have been developed, the next step is to procure commercially available products, and test them to the draft standard. This process validates the test method, in that the test methods can be translated to the test facility, and it benchmarks currently available equipment. If the standard is such that no equipment can meet the standard, then the standard must be closely scrutinized. This was the case in the development of the CBRN Self-Contained Breathing Apparatus (SCBA) Standard. No currently available SCBA was able to meet the standard due to the new threats, chemical warfare agents, that the systems were exposed too. Engineering modifications were made to the systems by the manufacturers, and currently there are over 50 different SCBA models certified to the NIOSH CBRN standard. If however, the preliminary benchmarking indicates that no equipment can meet the standard, even with modifications by the manufacturer, then the performance requirements and the test methods must be reevaluated.

Revise and Issue Standard. After identifying all concerns, the standard is issued or promulgated by the appropriate SDO. One key component of this program is the adoption of these standards by the Department of Homeland Security. This ties compliance to appropriate standards with the federal grants programs, in compliance with Homeland Security Presidential Directive (HSPD) 8 (National Preparedness).

3rd Party Conformity Assessment Program. The development of performance standards and test methods to evaluate performance to these standards does not ensure that the equipment going to the responders does indeed meet these standards. Programs must be put in place to use the test methods to evaluate conformity to the appropriate standards. The details of these conformity assessment programs will vary, depending on the type of technology being evaluated, the consequence of

non-conformance to the standard, whether the standard promulgated by a particular SDO contains provisions for conformity assessment, and a number of other factors. Appropriate third party test facilities must be identified that satisfactorily conduct the testing, and the appropriate test management and certification program must be established.

User Guidance. The standards and associated test methods by necessity are very specific and technical documents. The capabilities and limitations on the performance of the technology must be translated in terms that are understandable and useable by the end users of the equipment. They must know whether the system has been tested against Toxic Industrial Chemicals (TICs) or just against Chemical Warfare Agents. They must know what type of respirator is appropriate for what use. Development and distribution of this type of information is essential for the user, the procurement official, and in the development of concepts of operation and training programs.

Maintenance of Standard. There must be provisions for the review and update of the standard. As experience is gained in the use of the standard, as new technologies and test methods become available, or in the case of unforeseen problems with the standard and test method, the standard will require periodic revisions. Most SDOs have procedures to accomplish these tasks, and this will be one of the considerations in selecting the appropriate SDO for the development and promulgation of a new standard. A list of compliant equipment must be maintained and available for the user community. One such portal is the Responder Knowledge Base, funded by the Memorial Institute for the Prevention of Terrorism.

Public Comment. This process is not conducted in a vacuum. Public comment from users, developers, manufacturers and other concerned individuals and organizations is critical in the development of the standards. There are a number of points within the process where such comment will be actively solicited.

First Responder CBRNE Protective and Operational Equipment Standards Development Program

This program is the continuation of an ongoing comprehensive, multi-year program to develop an integrated suite of national standards for first responder chemical, biological, radiological, nuclear and high yield explosive (CBRNE) protective and operational equipment. This program was established in 1999 and initially focused primarily on chemical and biological protective equipment but the scope of the program has grown to reflect the national needs, and the needs of the first responder community. In FY2003 the program was expanded to begin work on radiation and explosives detection standards, decontamination standards, and to reflect an increased level of funding. In FY2004 the program will incorporate standards development for operational equipment needed by the first responders to sustain operations and provide general support during CBRNE incident response.

A chemical/biological protective suit.

This program area is divided into eight main tasks:

1) CBRN Respiratory Protection Standards. This includes the development of standards for CBRN respiratory protection equipment. The standards are developed and promulgated through the Na-

tional Institute for Occupational Safety and Health (NIOSH) National Personal Protective Technology Laboratory (NPPTL) with technical support and assistance provided by the Edgewood Chemical Biological Center (ECBC) and the Natick Soldier Center. To develop these, the following tasks will be continue to be performed: 1) determine applicability of existing industrial and military warfare agent standards; 2) develop key chemical/biological design and performance requirements; 3) modify and/or develop terrorism agent-specific test methods; and 4) prepare final evaluation, testing, and certification standards. This program is conducted by the NIOSH National Personal Protective Technology Laboratory (NPPTL).

2) CBRNE Protective Clothing Standards. This covers the development of standards for CBRNE protective clothing. In many cases, results of research will be input into existing standards programs, such as with the National Fire Protection Association (NFPA). Efforts in this area support development of standards for CBRN protective clothing, and development of a bomb suit standard. This approach should offer a wider array of garments and ensembles that would be attractive and suitable for use, as well as to meet a wider range of needs as may be defined or anticipated by all members of the emergency response community, including law enforcement and public service. In addition to the NFPA this program will be working with the recently formed ASTM committee E54.04 (Personal Protective Equipment for Homeland Security Applications) to publish non-firefighting chemical and biological protective clothing standards. FY2004 was the fourth of a scheduled five-year program. However, support has been added for FY2006 to address the two additional standards proposed to be delivered in FY2006.

3) First Responder CBRNE Detection Equipment Standards. This supports development of detection equipment standards for emergency responders to identify and quantify hazards. This is to allow the responders to make the appropriate decisions for the selection of protective equipment, decontamination requirements, and for overall incident management. Based on earlier efforts performed by the U.S. Army Soldier Biological and Chemical Command, the Detector Standard Effort will leverage off work performed under the Domestic Preparedness Program, the Military Detector programs and the Respirator and Personnel Protective Equipment Standards' efforts. Specifically, this effort will use the health and hazard assessments, provided through the respirator and personnel protection equipment standards' efforts, to make a determination of the chemical agent detection levels necessary.

4) First Responder CBRN Decontamination Standards. This effort supports development of decontamination standards to support the initial response to an incident. The equipment minimum performance standards are critical to the many emergency first responder communities who have received or are in the process of receiving CB equipment grants funding from the U.S. Department of Homeland Security. The need for decontamination standards for solutions and equipment continues to be an important issue within the emergency response community. The purpose of this effort is to provide minimum performance criteria and standards for chemical and biological decontamination equipment for use by the emergency response community. While all equipment must be used correctly in order for it to perform effectively, this is an especially big issue when the equipment is designed for decontamination. Therefore, in addition to the equipment performance standards it is paramount that procedures be evaluated, in conjunction with the equipment evaluation, to ensure the necessary performance.

5) First Responder CBRNE Operational Equipment Standards. Operational equipment includes the other equipment needed to respond to an incident, outside of the categories of personal protective, detection and decontamination equipment. An effort was started in FY2004 to develop performance metrics for Urban Search and Rescue Robots. The objective of this program is to develop standards for minimum requirements, performance evaluation, and interfaces for Urban Search and Rescue (USAR) robot systems. USAR robot standards will accelerate the *development* and *deployment* of robots for urban search and rescue missions, enhancing the effectiveness of search and rescue teams and reducing risks to rescue personnel in collapsed structures. Search and rescue robots are an inherently dual-benefit technology – as useful in responding to natural disasters as they are in searching for victims at the site of a terrorist attack.

6) First Responder CBRNE Communication Equipment Interfaces. The standards for the broader area of interoperable communications are the scope of this effort, and are being addressed through such activities as Project SAFECOM within the DHS. This effort looks at the interfaces between communications equipment and the pro-

tective ensemble, and other more limited aspects of the incident environment.

7) CBRNE Protective and Operational Equipment Systems Integration. This task is to provide technical support and integration of standards, and interoperability of multiple systems.

8) First Responder CBRNE Equipment Compendia. This continues the development, revision and integration of equipment compendia, initially started by NIJ. These compendia offer a vast selection of over the counter equipment to include MSA data to provide users an idea of what equipment is available for procurement and any manufacturers claims on performance. Additionally, the development of user-friendly decision aid systems and selection care and maintenance (SCAM) guides will also be published to provide additional guidance to the users. The SCAM guides provide information derived from the development of the equipment standard such as appropriate uses and limitations of the equipment, selection guidelines, maintenance and decontamination guidelines, and other critical information.

DELIVERABLES

• Major deliverables include quarterly and annual progress reports, ongoing hazard threat analyses reports, draft and final performance standards, hosting of public hearings on proposed standards, contributions to interagency groups, staffing and equipping a suitable test laboratory, publication of user guides, and other relevant products and reports required to fully implement the CBRNE Standards Development Program.

Accomplishments of the Critical Incident Technologies

This program began in 1999. The following major milestones achieved to date include:

■ CBRN Self-Contained Breathing Apparatus Standard (SCBA), December 2001. Fifty different models of respirators from six major manufacturers have been certified to date. Certification testing is ongoing. CBRN Air Purifying Respirator Standard, March 2003. Certification testing is currently ongoing.

■ CBRN SCBA retrofit kit approval, March 2003. This allows previously purchased non-CBRN certified respirators to be upgraded to the CBRN standard.

■ CBRN APR and Self Contained Escape Mask Standard, October 2003. Certification testing is currently ongoing.

■ Adoption of these standards by the Interagency Board for Equipment Standardization and Interoperability, the Office for Domestic Preparedness, and by the Department of Homeland Security. In addition, the National Fire Protection Agency is referencing the NIOSH CBRN respirator standards in the NFPA standards.

■ Standards for four different types of radiation detection equipment were developed and promulgated through IEEE. These standards were adopted by the Department of Homeland Security in February 2004. Testing is being conducted at DOE National Labs.

■ Using simulations developed as a result of the user input, determined the appropriate chemical agent concentrations a protective suit must endure in either the hot or the warm zone. Initially this mode was developed using GB and HD, as they were the agents the respirators are being challenged against, however, additional agents are being studied as they may pose a greater percutaneous threat.

■ To ensure the protective ensembles protect the user to an extent that there are minimal negative health effects and no lasting health effects, the health community performed a health hazard assessment, "Evaluation of Chemical Warfare Agent Percutaneous Vapor Toxicity: Derivation of Toxicity Guidelines for Assessing Chemical Protective Ensembles", July 2003, by Annetta Watson, Dennis Opresko and Veronique Hauschild.

■ Ongoing efforts continue on the draft of a chemical vapor detection standard which include any additional tests or procedures based on the user requirements or the interferents study. Input will be provided in accordance with ASTM, or other standards organization timelines.

■ Guides for First Responders providing comprehensive listings of personal protective equipment, chemical and biological detection equipment, chemical and biological decontamination equipment and emergency first responder communication equipment. These guides have been published in hard copy format and are available for download from the OLES Web site at http://www.eeel.nist.gov/oles/ and user friendly electronically searchable CD-ROM.

■ Work with vendors of test equipment and their customers to determine the type of reference material that will provide the most realistic tests of explosives detection equipment.

■ Three Decontamination Reports were finalized during FY2004. The items are as follows 1) Defining quantity and specific body site location of liquid chemical warfare agents that may be deposited on personnel located near a terrorist event; 2) Chemical kinetics study recommending optimum contact times, decontaminate concentration and negative effects of certain contaminate /decontaminate reactions; and 3) Report containing preliminary determination of chemical contamination residual allowable by the medical community.

Office of Law Enforcement Standards Organization (810.02)

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