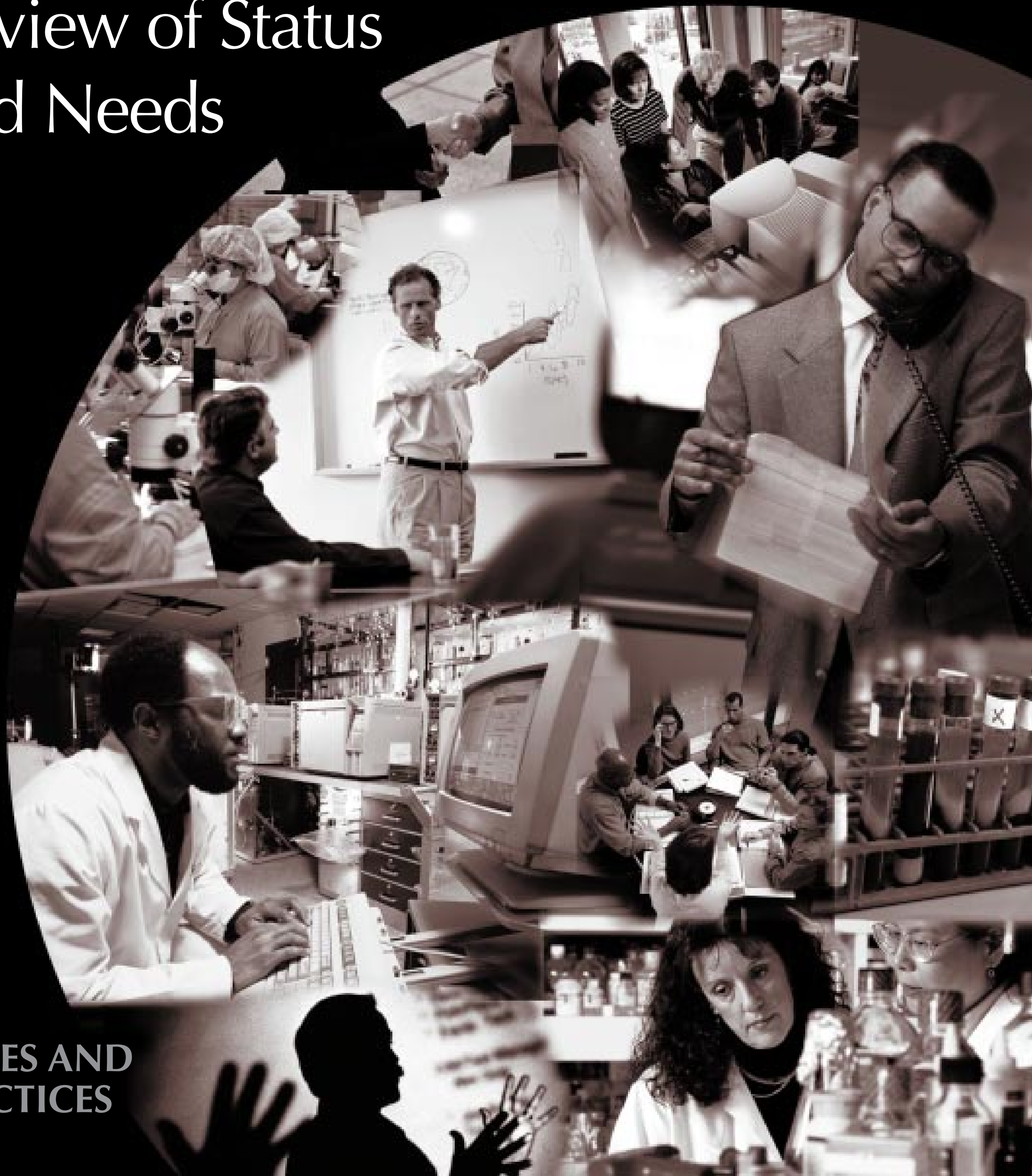
U.S. Department of Justice
Office of Justice Programs
National Institute of Justice

Forensic Sciences:

Review of Status and Needs



ISSUES AND PRACTICES

U.S. Department of Justice
Office of Justice Programs
National Institute of Justice

Forensic Sciences: Review of Status and Needs

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Foreword

Today, forensic science is facing many challenges that stretch its resources to their limits. The American Society of Crime Laboratory Directors (ASCLD) has a responsibility to identify means by which these challenges can be met. It has been more than 20 years since the last status and needs of the forensic sciences were studied. The need for a document that not only addressed the current challenges facing the forensic science profession, but offered possible solutions, became obvious.

At my request, Dr. Richard Rau at the National Institute of Justice (NIJ) formed a committee to accomplish this task. This committee was led by Kathleen Higgins, Director, Office of Law Enforcement Standards (OLES). This project was titled “Forensic Summit: Roadmap to the Year 2000,” and was funded by NIJ/OLES.

This document, *Forensic Sciences: Review of Status and Needs*, is the work product from a 2-day meeting held March 5–6, 1997. This meeting brought together 44 scientists and administrators with the common goal of helping the forensic science professions. These 44 professionals represented State, local, and Federal forensic science organizations and several Department of Energy (DOE) laboratories.

The four topic areas were:

- Training.
- Technology Transfer.
- Methods Research, Development, Testing, and Evaluation.
- Analytical Services.

The participants were each assigned to one of the four areas. Each group listed the current status and the needs in each of their areas.

I would like to formally thank all of the participants and sponsors for their support in this summit. A special note of thanks goes to Aspen Systems Corporation, who recorded the summit and assisted in the editing of this document.

Kevin Lothridge
Past President
American Society of Crime Laboratory Directors

Executive Summary

The work of forensic laboratories is varied and complex. Technical analyses performed must be able to forestall or defeat any challenge. To provide the best service possible to the criminal justice system, forensic laboratories must stay abreast of and have access to the latest technology and methods.

To assess the current state of forensic laboratories, the National Institute of Justice (NIJ), the National Institute of Standards and Technology (NIST)/Office of Law Enforcement Standards (OLES), and the American Society of Crime Laboratory Directors (ASCLD), held a joint workshop, Forensic Science Summit: Roadmap to the Year 2000, March 5–6, 1997, at NIST in Gaithersburg, Maryland. The purpose of the workshop was to determine the current status and needs of forensic laboratories on *training; technology transfer; methods research, development, testing, and evaluation;* and *analytical services.* The workshop also provided a forum to explore the use of national and Federal laboratory resources [e.g., Department of Energy (DOE), Department of Defense (DOD)] and how best to take advantage of this external support. Representatives from DOE attended the workshop to observe and learn how DOE could further contribute.

For technology transfer to be successful, there must be a true partnership between local or State forensic laboratories and national laboratories. Existing strengths that are fragmented and dispersed need to be consolidated. Over the years, a large amount of development work has been done at the national laboratories that some forensic laboratories may be aware of because of their geographic location, but the work may not be known to the entire forensic community. No formal process exists for technology transfer to forensic laboratories. The key is to identify technology currently in use or under development at national facilities that can be quickly transferred for use in the forensic field. Areas of technology at national laboratories that could be applied to the forensic community include robotics, remote sensors, supercomputers for computational power, and satellite communications.

In forensic science, as in other disciplines, cost-effectiveness and budgetary constraints are constant concerns. The technology must be affordable, reliable, and in some cases portable. The forensic community needs to be aggressive and creative in securing sources of funding to ensure that quality work is performed.

It is important to examine not only the needs of the forensic community, but also the consequences of not meeting those needs—how does it affect the criminal justice system and the public that the forensic laboratories serve. When police are not able to work cases efficiently, when court dates are postponed, then taxpayer money is not well spent, efficiency is reduced, and justice may not be served.

The training needs of the forensic community are immense. Training of newcomers to the field, as well as providing continuing education for seasoned professionals, are vital to ensuring that crime laboratories deliver the best possible service to the criminal justice system. Forensic scientists must stay up-to-date as new technology, equipment, methods, and techniques are developed. While training programs exist in a variety of forms, there is a need to broaden their scope and build on existing resources.

Casework—the support crime laboratories provide to those in the field—is the essence of forensic laboratory work. Casework support includes routine and traditional analyses common to all forensic laboratory settings, methods development particular to the requirements of specific cases, and the identification of analytical sources to perform work that is considered nonroutine.

Although many scientific and allied services apply to the forensic sciences field, there are nine common disciplines provided by the majority of municipal, county, and State forensic laboratories in the United States: Latent Print Examinations, Questioned Document Examinations, Firearms/Toolmarks and Other Impression Evidence Examinations, Crime Scene Response and Related Examinations, Energetic Materials (Explosives and Fire Debris Examinations), Postmortem Toxicology and Human Performance Testing, Forensic Biology and Molecular Biochemistry, Transfer (Trace) Evidence Evaluation, and Controlled Substance Examinations.

Common needs prevalent throughout most of these disciplines include standardization, validation, and the creation of information databases. However, each discipline has specific aspects and concerns such as sensitivity, efficiency, precision, portability, and effectiveness of sampling methods. Therefore, blanket standards generally cannot and should not be applied—they should be adapted and customized to each individual discipline and technique.

The development of new technologies brings new concerns for the future. If forensic scientists are to continue to provide valuable information and evidence efficiently, it is crucial for their needs to be addressed and resolved. This report can help further that agenda by serving as a guide on research and training priorities and on policy regarding criminal justice funding at the Federal, State, and local levels.

Training

Training for the forensic community, as in other professions, is an ongoing need. Training of novices and providing continuing education for seasoned professionals are essential to ensure that crime laboratories deliver the best possible service to the criminal justice system.

The training needs of the forensic community are immense. The major impact of training is on the professional level. Forensic scientists must stay up-to-date as new technology, equipment, methods, and techniques are developed. While training programs exist in a variety of forms, there is a need to broaden their scope and build on existing resources. Forensic professionals need to take advantage of the explosion in information technology and the ability to use it to exchange information and deliver training.

Training is essential but can be costly. The forensic community needs to be aggressive and creative in obtaining funding for training programs to ensure scientists keep abreast of the ever-changing trends and discoveries in the forensic science field.

Detailed below are categories of training, the needs that fall under each category, and the status of how those needs are currently being met.

Continuing Education for Operational Scientists

Training Needs

Operational scientists at the bench level need to keep up-to-date on new developments in the forensic field through continuing education, which has two components: theoretical and practical. They also need to have access to institutes of higher learning in order to continue their education and have the opportunity of obtaining graduate degrees. Such education not only helps develop their theoretical and practical skills but adds considerably to their credentials.

- **Theoretical.** It is often less expensive and more straightforward to provide theoretical training, for example, how a particular method or instrument works.

- **Practical.** Practical skills can be learned through:
  - Inservice (training that occurs as part of being on the job).
  - Short courses.

Current Status

Inservice Training. Currently, the extent and type of inservice training varies widely, depending on the laboratory and the State.

Short Courses. A number of institutions currently offer short courses on topics for forensic scientists. For example:

- **Forensic Science Research and Training Center (FSRTC).** FSRTC is part of the FBI Laboratory at Quantico, Virginia.
  - Offers extensive program of short courses.
  - More than 30 classes.
  - 800 students per year.
  - Free to participants.
  - Training normally done onsite at FSRTC; limited traveling to other sites.
  - Video teleconferencing (VTC) and satellite uplink capable.
  - Affiliated with the University of Virginia.

- **California Criminalistic Institute (CCI).** CCI is a unit of the California Department of Justice (CADOJ), under the Bureau of Forensic Services, and provides specialized training to forensic science professionals.
  - More than 50 classes.
  - Classes include crime scene and casework review.
  - 600 students per year.
  - In-State employees free; out-of-State participants pay $500/week (tuition) and per diem.
  - Classes normally onsite at CCI; some traveling to other sites within California.
  - Affiliated with the University of California at Davis.

- **Illinois State Police (ISP).**
  - 15 different courses per year.
  - Courses 1 to 2 weeks long.
  - Offers longer courses. Complete forensic discipline training (agency or individual specific).
  - $75 per day/student.
  - Courses normally onsite at ISP; some traveling to other sites.
  - Distance-learning capable.
  - VTC and satellite uplink capable.

◘ Closely affiliated with University of Illinois at Chicago; also affiliated with Southern Illinois University at Carbondale.

- **National Forensic Science Technology Center (NFSTC).** Located in central Pinellas County, Florida, NFSTC provides methods research, product development, and forensic education through onsite and teleconference programs.
  ◘ Recently formed.
  ◘ 15 classes a year planned.
  ◘ 5 classes in 1996 with 147 students.
  ◘ Fee-based, $125/day.
  ◘ Onsite at NFSTC and traveling to other sites. Philosophy is to take the course to the student
  ◘ Distance-learning capable.
  ◘ VTC and satellite uplink capable.
  ◘ Affiliated with University of Central Florida (UCF), and the University of South Florida (USF).

- Workshops also are offered through:
  ◘ Association of Firearms and Toolmarks Examiners (AFTE).
  ◘ International Association for Identification (IAI).
  ◘ Drug Enforcement Administration (DEA).
  ◘ American Academy of Forensic Science (AAFS).
  ◘ Regional forensic science associations.

- A variety of tertiary educational institutions offer undergraduate and graduate degrees in forensic science and other subjects relevant to contemporary forensic science.

Initial Training

Initial training applies to recent university graduates starting out in the forensic field. Forensic laboratories need to recruit graduates with the appropriate undergraduate scientific background and train them, which can be a significant drain on resources within the laboratories.

Training Needs

Initial training, like continuing education, has theoretical and practical components.

- **Theoretical.** Training can be done onsite at the scientist's laboratory or through distance learning.

- **Practical.**
    - Normally done onsite.
    - Other possibilities include compressed distance-learning methods, under which some training could be done at a participant's site. Participants would then come together at another site to actually apply the method and physically perform the analysis. Training could be done in compressed modules.

- **Supervised Casework.** Supervised casework is a major training need of individuals who come into the laboratory. It is normally provided inservice. It is a costly but important enterprise. Additional options for providing supervised casework could include:
    - Internships at an offsite laboratory.
    - Visiting scientist programs.

Current Status

- Initial training currently is largely on-the-job training.
- Uniform/consensus entry-level academic background requirements do not exist for all forensic disciplines. For example:
    - Questioned documents/firearms/latent fingerprints—no degree required.
    - With the exception of DNA, no uniform specific course work requirements.
- Delivery almost exclusively onsite at the laboratory (except Illinois State Police).
- There is need for visiting scientist/intern programs, but little or no funding available.

Professional Orientation

Training Needs

There is a need for all individuals employed in a forensic science laboratory to undergo professional orientation, which would include training in:

- Criminal justice system.
- Legal system.
- Ethics.
- Professional organizations.
- Basic philosophy of forensic science.

- Overview of disciplines of forensic science.
- Safety.

Current Status

- Formal courses are available in some jurisdictions—FBI, ISP, CADOJ, and Virginia State Division of Forensic Science. Average course length is 2 weeks.

First-Line Supervisors

Training Needs

- Quality Assurance.
- Case File Review.
- Basic Supervision Skills.

Current Status

- First-line supervision management training generally is not available, with some exceptions.
  - CADOJ provides nonmandatory, first-line supervisor training that includes quality assurance, safety, case review, and crime scene training. However, the department requires all supervisors to undergo a frontline leadership course, which is a component course that is mandatory at the State level.
  - There is some voluntary ASCLD-supported and delivered training sporadically carried out by regional associations.

Management

Although many crime laboratory managers have had adequate technical training, they often have not had the opportunity to undergo formal management training. Every crime laboratory manager should have the opportunity to undergo such training.

Training Needs

- Fiscal Management.
- Quality Systems Management.
- Project Management.

- Human Resource Management.
- Customer Service.

Current Status

- Some nonmandatory courses are available.
- The FBI-sponsored annual symposium on crime laboratory development includes management seminars.
- Management seminars offered by other organizations.

Quality Assurance

Every forensic scientist should undergo training in quality assurance, but the number of formal classes is limited.

Training Needs

- General.
- Good Laboratory Practice (GLP).
- Quality Systems.
- Laboratory Audits.
- Method Development and Validation.

Current Status

- CADOJ offers a 1-week quality-assurance course at CCI.
- FBI offers one course a year for 1 week.
- NFSTC offers a 2-day auditor training course. Fee based.
- ASCLD/LAB (Laboratory Accreditation Board) offers laboratory accreditation and laboratory inspectors training. Basic training (2-day course) and training for team captains (1-day course).

Effective Expert Testimony

Forensic scientists must be able to provide effective expert testimony.

Training Needs

- Public speaking.
- Presentation skills.

Current Status

- AAFS offers workshops.
- ISP offers basic and experienced classes lasting 3 days to 1 week.
- CADOJ offers a 3-day course.
- Occasional, sporadic attempts by other groups.

End-User Training

Forensic scientists need to educate their end users—those who use their services and therefore need to understand those services and terminology.

Training Needs

- Police.
- Bar.
- Judiciary.
- General public.
- Policymakers.

Current Status

- Training sporadic at Federal, State, and local levels.
- Judiciary/policymakers. Training is rare. (Virginia, for example, provides annual seminars for the judiciary.) ASCLD formerly provided training to judges.

Training the Trainer

The trainer is the best person to evaluate the training effectiveness of a program.

Training Needs

- Evaluate training effectiveness.
- Spot employee training needs.
- Plan training programs.
- Prepare training material.

Current Status

- Courses are available in instructional methodology but nothing specific for forensic science. However, the ISP provides an "in-house," 5-day course for forensic science facilitators regarding a video teleconferencing distance-learning training program.

Information

There is a need to make available to the forensic community as much centralized information as possible and provide guidance on how to access it.

Needs

- Database management.

- Reference collections. References are widespread with few centralized resources.
  - Databases.
    - Physical material being tested.
    - Results of the tests, analytical data.

- Literature.
  - Published papers and articles.
  - Abstracts of unpublished work.

- Casework interpretation information.

Current Status

- Reference collections.
  - Status needs to be assessed.
  - Databases (physical material).

• Reference databases are limited and local (e.g., CADOJ).

◙ National.

• No nationally accessible databases for physical materials exists.

• FBI rifling database. Characterizes general rifling characteristics of weapons.

- Literature. Services and availability local and sporadic. For example:
  - ◙ CADOJ: CCI “virtual library” with 10 000 citations. Conducts literature searches.
  - ◙ FBI: Forensic Science Information Resource System (literature retrieval system through which State and local laboratories and law enforcement agencies can obtain literature through the FBI).
  - ◙ ISP (Chicago): Librarian hired during first quarter of 1997 to set up a forensic library that will enable online methods of literature retrieval.

Academic Credit for Short Courses

Academic credit should be granted for short courses offered at other institutions. While several institutions’ programs are affiliated with universities, granting of university credit for courses is problematic. Currently, academic credit is not available for forensic-related short courses except through the FBI (affiliated with the University of Virginia), CCI (affiliated with the University of California at Davis in molecular biology), and NFSTC (affiliated with the University of Central Florida, University of South Florida).

Funding for Academic Institutions Providing Graduate-Level Forensic Science Research

Funding for accredited academic institutions providing graduate-level forensic science research in the form of scholarships and grants is an important training need. Currently, funding is nonexistent. Such funding facilitates the development and implementation of appropriate new technologies.

Delivery Systems

Needs and Current Status

Training can be delivered through a variety of methods either onsite at the laboratory (in-house) or offsite (external).

- In-house delivery methods.
  - Onsite at the laboratory (currently commonly used).
  - Video teleconferencing (current use limited—ISP uses this method).
  - World Wide Web based (rarely used).
  - Computer/interactive training (current use limited).

- External delivery methods. Currently available through:
  - Commercial companies.
  - Universities.
  - State institutions.
  - FBI/DEA/ATF (Bureau of Alcohol, Tobacco and Firearms).
  - NFSTC.
  - Professional organizations (workshops).

Recommendations Regarding Training

The following recommendations are based on the training status and needs identified above.

- The profession should accredit/certify forensic academic training programs/institutions.

- The profession should set national consensus standards of education in the forensic sciences.

- Independent, communitywide, consensus standard-setting bodies should be established and funded (e.g., technical working groups), since training is based upon such standards.

- NIJ should fund forensic academic research and development programs.

- ASCLD should intensify its effort to provide appropriate training for managers and supervisors.

- All new employees should undergo professional orientation (including managers new to the field).

- **All forensic scientists should have formal quality-assurance training.**

- All forensic scientists should have formal expert witness training.

- The profession should provide end-user training to the following:

- Police.
- Bar.
- Judiciary.
- General public.
- Policymakers.

- The profession should make a concerted effort to compile databases for literature, reference materials, and analytical data.

- The profession should utilize existing and explore other delivery systems for forensic science training.
  - LABNET. LABNET is a recently added feature of the FBI laboratory and is used to communicate information between laboratories.
  - JUSTNET (Justice Technology Information Network). JUSTNET (*http://www.nlectc.org*) serves as an information gateway, via the World Wide Web, to information on new technologies, equipment, and products of interest to the law enforcement and corrections communities.
  - LETN (Law Enforcement Television Network). LETN provides quality training, education, information, and news to the law enforcement community via satellite and the computer-based STTAR (Specialized Training, Testing, and Recordkeeping) workstation.
  - DOE/other Federal sources.

- Computer-interactive training materials should be developed for forensic science.
  - CD-ROM.
  - World Wide Web based.

- Distance-learning centers accessible to forensic laboratories should be identified.
  - Possible resources include the United States Distance Learning Association, which has a home page on the Internet (*http://www.usdla.org*). Also, in most States there are consortiums that are generally university based with secondary and primary schools hooked up into STTAR networks.

- All training needs should be funded using a combination of the following:
  - Direct Federal funds.
  - Fines and forfeitures.
  - Foundation grants.

Technology Transfer

Introduction

The term “technology transfer” encompasses a broad range of activities that a general definition is difficult to construct. Various groups and institutions use a number of different definitions. The Federal Laboratory Consortium defines technology transfer as “the process by which existing knowledge, facilities, or capabilities developed under Federal research and development funding are utilized to fulfill public and private needs.”

The Office of Management and Budget’s definition of technology transfer is given in Circular No. A-11 (1994) as follows:

> Technology Transfer consists of efforts and activities intended to result in the application or commercialization of Federal laboratory-developed innovations by the private sector, State and local governments, and other domestic users. These activities include, but are not limited to:
>
> - Technical/cooperative interactions (direct technical assistance to private-sector users and developers; personnel exchanges; resource sharing; and cooperative research and development agreements).
>
> - Commercialization activities (patenting and licensing of innovations and identifying markets and users).
>
> - Information exchange (dissemination to potential technology users of technical information, papers, articles, reports, seminars, etc.).

Operational and analytical issues currently serve as the impetus for the introduction of new technologies into forensic laboratories. Operational concerns focus on increased efficiency, productivity, or “smarter” ways of performing the job. This mechanism is driven predominately by the need to process overwhelming caseloads with limited personnel and/or equipment. Analytical concerns are based on techniques having increased sensitivity or on new, nondestructive methods of analyzing evidence.

One of the characteristics associated with the technology transfer process involving the national laboratories and the forensic community is the considerable gap in understanding between what technology could do (its potential) and what it actually does (the reality). Often, the perception of forensic scientists is that the technology developed in national laboratories is too complex or the technology is limited in scope of application (e.g., it is case specific). Among the reasons for this misconception is the lack of communication between the source of the technology (national laboratories) and the user (forensic laboratories).

One reason why there is not more interest in the national laboratories and industry in general is that the purely commercial aspects of developing technology are not readily apparent. Although the researcher is driven by dedication to solving the particular problem, increasingly, research programs are being shaped by the attractiveness of reaping the potential financial rewards of commercialization of a product or process. Collaborative research agreements between the national laboratories and universities or industrial partners in areas other than forensic science often lead to inventions that are granted patents and technologies that can be licensed.

Although there are well-established technology transfer mechanisms at national laboratories (technology transfer offices), no formal transfer process has been recognized by the forensic community, probably because existing research efforts in forensic laboratories, if they exist, are fragmented and dispersed. In certain instances, scientists at a particular forensic laboratory may be aware of the technologies being developed at a national laboratory within close geographic proximity to the forensic laboratory; however the forensic community at large may be totally unaware of the technology and its applications.

Technology transfer from national laboratories into the forensic community has for the most part been limited to surveillance technologies and other defense-related areas. Little in the way of advanced sampling, laboratory robotics, or instrumentation has found its way into forensic laboratories.

Types of Transfer

Technology can be transferred through:

- **People.** Postdoctoral students or researchers moving into industry or other laboratories.
- **Information.** Publication in journals, books, reports, and lectures at seminars and workshops.
- **Hardware.** Equipment, instruments, devices, and computers.
- **Software.** Development of algorithms to complement existing technologies.

Technologies can be classified as:

- **Dual-use.** The reuse of technology from a Federal laboratory in a follow-up application. A technology that may have been originally developed for a defense-related or energy application but can be used in another are without modification or further development.

- **Pin-on.** The movement of technology from a research and development laboratory to a first-time application.

- **Spin-off.** A technology, typically a product or process that can be adapted or "spun off" as a separate entity.

Existing Mechanism for Transfer

The transfer of technology from national laboratories into the forensic community has traditionally occurred in the following manner:

- Individual(s) at either the national or forensic laboratory have expressed interest in a technology and contacted one another (outreach). The inquiry is often driven by an individual's interest in a particular technology.

- The researcher (source) informs the forensic scientist (user) of the current applications of the technology and its attributes.

- The user determines whether the technology is applicable to forensics.

- Both parties perform a detailed assessment as to the feasibility of transferring the technology to the forensic community.

- If the technology is found to be applicable, a source of funding is identified (Federal, State, and local grants).

- A collaboration or "partnership" is established between the forensic laboratory and the national laboratory possibly in conjunction with a university.

- The technology is transferred to the forensic laboratory, a pilot study is conducted and if necessary, additional research and development is performed.

- Feedback is solicited from the user about the merits or disadvantages of the technology.

Although this mechanism has been moderately successful in a very limited number of situations, it is inadequate for meeting the current and future needs of forensic laboratories.

Potential obstacles to technology transfer include:

- Insufficient knowledge of the market, including awareness of demand and overly high expectations (profits vs. expenses).

- Inadequate communication on behalf of the laboratories, inertia and low commercialization potential, and missing links between source, intermediates (if applicable), and users.

- Formal or legal regulations, fiscal legal impediments, protection of intellectual property (license and patent protection), secrecy, and requirements on standardization of procedures.

- Fear of the unknown product or process.

- Factual circumstances such as time and space limitations.

The following sections represent a “roadmap” relating the current needs of forensic laboratories to proposed mechanisms for technology transfer. These are designed to provide insight into needs and problems associated with the transfer of technology. The topics discussed are not intended to provide a comprehensive summary of all aspects of technology transfer from national laboratories to the forensic community, but only to highlight key issues.

Immediate Needs

Existing technologies at the national laboratories that could be applied to the immediate needs of the forensic community include:

- **Databases.** Compilations of large volumes of information (DNA, firearms, fingerprints, trace evidence, etc.) that would be available for dispersal.

- **Hazardous waste disposal.** Technology that would allow for the safe handling, storage, and disposal of hazardous chemical, biological, or nuclear evidence.

- **Imaging.** Techniques for the detection of fingerprints and other physiological fluids that would replace and/or complement physical or chemical methods.

- **Microscopy.** Advanced techniques (confocal, etc.) for examining firearms/toolmarks and other trace evidence.

- **MEMS (micro-electro-mechanical-systems)/nanotechnology.** Miniaturization of devices (sensors and instruments) that could be used for remote sensing. Micromachines, for example a miniature bomb robot that could fit into very small areas.

- **Robotics.** Robots with enhanced capabilities or “smart robots” could be used in the field or in laboratory settings. Next-generation robots include those using artificial intelligence and equipped with probes having the dexterity of the human hand.

- **Remote (field) sensors.** These devices are based on microchip technologies that could be used to detect contraband narcotics, explosives, and other trace evidence.

- **Satellite imagery.** High-resolution photographs and digital images could be used for the reconstruction and enhancement of exterior crime scenes.

- **Software.** Artificial intelligence/neural network-based algorithms that could be used for computer-based training, data processing, and analysis.

- **Supercomputers.** These machines (parallel processors) are useful for analyzing large amounts of data very quickly and could be used to analyze highly complex crime scenes (blood splatter) or to search data banks (fingerprint, DNA, firearms, etc.) rapidly.

The Technology Transfer Process

The goal of this section is to propose a process whereby the forensic community can consistently identify, evaluate, develop, and put into use new and/or improved products, processes, and services based on technologies available or under development at the national laboratories.

Objectives

The following objectives must be met to provide a viable mechanism for technology transfer:

1. **Develop strategies to identify and share research and technical information between forensic and national laboratories.**

The transfer of knowledge is an important prerequisite for the application of research findings. It is essential that accurate technical information be available to all concerned. Managers and scientists at forensic laboratories interested in learning about new technologies could use the following resources to identify sources of research and solicit information about what technologies are available.

Professional societies such as the AAFS, ASCLD, and the American Chemical Society (ACS), among many others, represent a large and diverse segment of the forensic, industrial, and academic community. Most of these organizations disseminate information to their members and the public through a variety of print and electronic media.

Sources of information on the needs and interests of forensic laboratories include:

- Peer-reviewed publications (journals).
- Publications available from Federal Bureau of Investigation and Drug Enforcement Administration laboratories (*Crime Lab Digest* and *Microgram*).
- National and regional meetings of forensic societies.
- Workshops and symposia.
- Internet sites (ASCLD homepage).
- Internet chat rooms.
- Personal contacts.
- Site visits.

Sources of information on technologies available at the national laboratories include:

- Peer-reviewed publications.
- Internal publications available to the public domain.
- Publications from cooperative research agreements.
- Patents and licenses.
- Internet listings (national laboratory homepage).
- Personal contacts.
- Site visits.

Mechanisms of information transfer. For the technology transfer to be effective, it is essential that accurate technical information shapes both the mechanism and the process that creates it.

- Build upon the existence of informal communication channels between the national laboratories, forensic laboratories, universities, and companies in the same geographical area.

- Establish personal contacts between technical staff and management of forensic laboratories and the technology transfer liaison at the national laboratories.

- Establish a mechanism to guide joint activities, perhaps through visiting scientists who would spend time at both facilities.

2. Establish a project appraisal procedure for the selection of technologies at the national laboratories.

The process must classify and prioritize available technologies. Having selected a technology, an assessment of the technology must be performed according to a mutually agreed upon set of criteria. The criteria for selection should include the following:

- **Accuracy and precision.** The results must met certain minimum specifications.

- **Affordability.** The technology has to be affordable. All laboratories have some budgetary constraints regardless of the size of the organization.

- **Applicability.** The technology must be able to meet the needs of the forensic science community.

- **Methodology.** The technology must be based on generally accepted principles in forensic science.

- **Sensitivity.** Highly sensitive techniques are desirable for analyzing very small quantities of evidence. However, if the technology is too sensitive, low levels of contamination can create problems and become a limitation.

- **Timeliness.** In general, for the technology to have widespread utilitarian value within the forensic community, it must be developed within a reasonable period of time.

- **Portability.** This may be utilized as one of the criteria if the technology in question could possibly be used at crime scenes.

3. **Conduct a pilot study in the laboratory and, if applicable, in the field.**

4. **Obtain feedback from the user.**

5. **Evaluate the findings and generate a report.**

6. **Communicate the results back to the source.**

7. **Make recommendations.**

8. **Decide to either implement or abandon the technology.**

Recommendations

The following recommendations, if implemented, are intended to lead to a permanent mechanism to coordinate, guide, and evaluate the technologies at the national laboratories.

- **Prepare a directory of technologies available at the national laboratories.**

Compile a directory of current projects at the national laboratories, including a listing of key contact personnel. Classify the technologies as being case specific or generic (i.e., applicable to routine analyses). A directory should be published annually and the information made available over the Internet.

- **Prepare a directory of key contacts in the national laboratories and the forensic community.**

Individuals at the national laboratories must be kept informed of the changing needs of the forensic community. There is a need to identify key contacts at the national laboratories, forensic laboratories, private corporations, the academic community, and law enforcement agencies. A directory should be published annually and the information placed on the Internet.

- **Establish a steering committee and technical advisory focus group.**

NIJ and ASCLD should cosponsor a forensic science steering committee. The committee would determine the needs of the forensic community and would form technical advisory focus groups. Each focus group would be responsible for a particular technology. The members selected for the focus groups would represent the laboratories and academic community. The members of the focus groups would have the technical expertise to identify which technologies are available and also possess the requisite skills to determine the feasibility of commercial development. The steering committee would have the responsibility for convening meetings for the focus groups. At these meetings, advice and reactions would be solicited from each participant regarding the scope and expectations of the new technology, the manner in which the technology should be developed and implemented, and the strengths and weaknesses associated with any existing technology.

The focus groups shall have two purposes: (1) To gather information and advice from Federal, State, and local forensic laboratories that would be most affected by any technology transfer initiatives, and (2) to bring together individuals with diverse backgrounds, perhaps for the first time, to address technological issues of mutual interest. This interaction could stimulate new ideas and areas for future development.

The information and recommendations from the focus groups would then be evaluated by the steering committee and proposed in a framework that would be acceptable to the national laboratories.

- **Form strategic (working) partnerships.**

Working partnerships represent the association of a diverse group of individuals with a common interest. Partnerships bring a combination of experience and expertise that promote activities that distribute the risks and costs but most of all enhance the overall likelihood for success and the sustainability of the project. All projects involve some degree of risk. Risks can be technology itself, the development process, finance, and legal issues. By choosing to establish strategic partnerships, the partners contribute different but complimentary resources to the project and thereby implicitly establish a process to minimize risk.

All parties must articulate a well-defined mission statement that is practical and dedicated to deploying available resources strategically among all partners. The mission must be accompanied by a rigorous but flexible strategic plan for tracking and monitoring milestone achievement of goals. Above all, the participants involved must understand the objectives, resources, motives, and limitations of the partnership.

Identify a partnership organization to encourage, guide, coordinate, and help finance the use of new and emerging technology in forensic laboratories. NIJ could play an important role in promoting such partnerships by identifying critical need areas, by providing seed money, and by promoting relationships between public agencies (the DOE) and forensic laboratories. While partnerships between universities, industry, and government agencies (national laboratories) can be discussed and agreed to, their true potential can be realized only to the extent that they can be embodied in an organization that can act reliably over time.

Solicit information and advice from private-sector firms. These groups include technology-intensive companies and manufacturers of analytical instruments.

There is a need to address university research based at national laboratories and to concentrate on those segments that would most likely have major applications in forensic science.

Most importantly, partnerships will require that the individuals involved in the forensic laboratories, national laboratories, universities, government, and the private sector come to be better informed of the needs and resources each has and understand their different views, yet appreciate their common interests.

- **Identify sources of funding.**

Capital is essential at all stages. Government can play the role of catalyst by providing seed capital through Federal or State grants, but leadership in providing funding must increasingly come from the private sector. Commercialization of a technology is ultimately a private-sector affair. The basic principles of supply and demand must be part of the foundation upon which the partnership is built. Industry must be proactive and must be allowed to be proactive in moving commercially viable innovations from research in the national laboratories into the forensic community. Mechanisms should also be developed to encourage innovation and support commercialization based on technologies in national laboratories through the formation of industry/university consortia.

Ultimately, however, all parties should be prepared for the “if you build it they may not come” scenario.

Methods Research, Development, Testing, and Evaluation

Methods research, development, testing, and evaluation (RDT&E) activities are vital to the provision of effective forensic science laboratory services. Among other considerations, RDT&E activities assist in the:

- **Validation** of technologies prior to initial or enhanced forensic applications.
- **Determination** of appropriate methodological standards.
- **Improvement** of analytical figures of merit (e.g., resolution, sensitivity) for forensic techniques.
- **Extension** of current methods to new forensic applications.
- **Identification** of new analytes of forensic interest.
- **Discrimination** of potential sources of evidentiary materials.
- **Elucidation** of new characteristics and properties of materials having forensic importance.
- **Reduction** of destructive steps included in the routine analysis of evidence.
- **Enhancement** of productivity, portability, and interoperability of forensic methods.
- **Dissemination** of appropriately validated databases.
- **Optimization** of technology for transfer to, and incorporation in, forensic laboratories.
- **Support** of ongoing training efforts and the identification of new training requirements.
- **Creation** of performance specifications for equipment and material used in examinations.
- **Assurance** of safety and security during remote-deployment and laboratory-based operations.

Although many scientific and allied services are applicable to the forensic sciences field, there are nine common disciplines provided by the majority of municipal, county, and State forensic laboratories in the United States, as follows:

- **Latent Print Examinations.**
- **Questioned Document Examinations.**
- **Firearms/Toolmarks and Other Impression Evidence Examinations.**
- **Crime Scene Response and Related Examinations.**
- **Energetic Materials (Explosives and Fire Debris Examinations).**
- **Postmortem Toxicology and Human Performance Testing.**
- **Forensic Biology and Molecular Biochemistry.**
- **Transfer (Trace) Evidence Evaluation.**
- **Controlled Substance Examinations.**

Each of these disciplines has been divided into three categories for discussion purposes: (1) the current status of the discipline, (2) systematic methods used in the discipline, and (3) forensic scientists' needs. Once the status and methods are discussed, specific areas are identified where new or enhanced developments in forensic science are necessary.

Common needs of most of these disciplines include standardization, validation, and creation of information databases. With regard to standardization, it is important to realize that each discipline has specific concerns regarding sensitivity, efficiency, precision, portability, and effectiveness of sampling methods. Therefore, standards generally cannot and should not be all-encompassing—they should be adapted and customized to each individual discipline. In a phrase, "It is possible to develop standards without achieving standardization."

The development of new equipment and technologies brings with it new concerns for the future. If forensic scientists are to continue providing valuable information and evidence in a timely and cost-effective manner, it is crucial that their needs be addressed and resolved.

Latent Print Examinations

Current Status

For many years, courts have accepted the work performed in latent print examinations because they understand that friction-ridge detail in individual fingerprints is empirically unique. Nonetheless, two efforts are now under way to increase the understanding of fingerprint features and content. There is a modest effort to better comprehend the genetic basis and relative importance of specific print features and a significant effort to characterize and understand the chemical content of latent prints. The latter effort will ultimately allow examiners to design more sensitive visualization techniques. Latent print examiners currently use RDT&E activities that include the visualization, recording, and recovery of latent prints; comparison of prints; storage and retrieval systems; and automated comparison systems.

Criteria used during print comparisons to determine individualizations vary throughout the world. Although there are some jurisdictional exceptions, in the United States examiners are not generally required to find a specific number of comparison points to determine an identity between two prints.

Systematic Methods

The attempts used in visualization are sequential and generally involve the use of alternate light sources, physical (powder), and chemical treatments. The exact sequence of the techniques depends on many case-specific factors, and documentation is recommended after each visualization step has been performed. Techniques used to recover visualized prints include direct lifts, photography, and digital imaging, depending on the matrix and the particular circumstances involved.

The quality and number of unique features observed through microscopic comparisons between known and recovered (questioned) prints can help examiners determine whether or not the prints form an identity. Automated search and retrieval systems, such as the Automated Fingerprint Identification System (AFIS), also assist examiners by allowing them to select known prints to compare with recovered (questioned) prints. AFIS has several competing systems, and interoperability efforts among these systems are ongoing but have not yet been completed.

Needs

Standardization of comparison criteria. There does not necessarily need to be a known number of "points" of comparison that allow an examiner to state an identity between a questioned and known print. However, minimum criteria and reporting standardization based on empirical studies and a consensus process among qualified examiners would significantly enhance the reliability of findings. In addition, setting such minimum guidelines would provide a more objective basis for competency testing following initial training of examiners. It is recognized that it is not simply the number of points of comparison available that lead to a reliable identification. The quality of the comparison relies as much on spatial relationships between, and the specific types of, minutiae (and the frequency of occurrence of these minutiae in the "population" of prints) as on sheer number of points.

Validation of the basis for print individualization. How can examiners prove that each individual has unique fingerprints? There are certainly statistical models that support this contention. Friction ridge print evidence has historically been "understood" to hold individuality based on empirical studies of millions of prints. However, the theoretical basis for this individuality has had limited study and needs a great deal more work to demonstrate that physiological/developmental coding occurs for friction ridge detail, or that this detail is purely an accidental process of fetal development. Studies to date suggest more than an accidental basis for the development of print detail, but more work is needed.

Improved recovery and visualization methods. The value of a print relies on the clarity and completeness of recovered detail. The chemical composition of fingerprints is reasonably well understood, although more work could be used to determine whether or not physiological states (agonal processes or flight response, for instance) can alter the normal composition of components in the secretions that comprise most latent prints. In the best of cases, the methods used for visualizing and recovering latent prints are systematically applied. Examiners consider the need for contrast, preservation of underlying matrices, substrate dynamics, contributions of one visualization step to subsequent steps, and the ease of recording when determining the exact number and types of visualization steps to pursue. More work is needed to fully understand the dynamics of these variables, as well as to properly preserve and "recover" the developed print. Specific efforts are needed to improve the recovery of prints left on victims' bodies.

Determination of the relative importance of print features. There is empirical evidence that suggests that certain print minutiae are more rare than others [see generally the work of D.A. Stoney and J.I. Thornton, *Journal of Forensic Sciences* 31(4), (October 1996): pp. 1187–1216 and 1217–1234; and *Journal of Forensic Sciences* 32(5), (September 1997): pp. 1182–1203]. More research is needed to demonstrate if this empirical suggestion has a complete theoretical basis and/or statistical significance. Specific testing of this hypothesis may allow examiners to quantify the significance of a match between unknown and known prints in a more definitive way. This knowledge may also lead to improved algorithms for automated search and match programs, improved productivity for print examiners, and also strengthen the forensic defensibility under the conditions of increased court scrutiny expected in the future.

Detection of associative evidence in prints. Studying associative evidence such as DNA, sex determinants, alcohol, drugs, stress markers, donor age determinants, and print age determinants would help examiners detect physical characteristics of the person(s) who left the prints, as well as temporal characteristics that may have influenced the person's behavior or activities at the time the prints were deposited. Such information of enhanced identity (e.g., DNA) or temporal content may significantly strengthen the connection between a suspect and the crime or crime scene, especially in the absence of a fully definitive recovered print. Information of this kind could provide specific information to better allow investigators to narrow the focus of the investigation on particular suspects, areas of search, and times. This may seem farfetched, but the sensitivity of modern instrumental approaches continues to provide new levels of information content when applied to classical evidence of other kinds. There is no reason to believe that latent prints are immune from this exciting potential.

Interoperability and improvement of search and retrieval systems. Interoperability among the various AFIS systems would ensure that examiners are getting the most complete, up-to-date information when conducting searches of questioned prints against the local, statewide, national, and international databases of prints. The algorithms on which current methods are based must be enhanced and such enhancements will rely on improved understanding of the basis for print individuality and statistical significance of specific minutiae found. Simple interoperability of current systems has not yet been achieved, which represents a significant operational and investigative cost for the international forensic community. There is arguably no more important *immediate* need than this interoperability.

Shared databases for use in training and harmonization efforts. The “print examiner” community has made efforts to harmonize information available for training. Specific needs for improved tools include better databases of “known nonmatches.” Collecting nonmatches and widely disseminating them using a standard format (similar to that used for AFIS), will enhance training of new examiners and proficiency of senior examiners. Unusual findings and other field curiosities and improved systematic methods for visualization and recording of developed prints may be similarly disseminated. The same means can facilitate the development of digital photographic methods and enhancement methods for prints on visually complex matrices.

Questioned Document Examinations

Current Status

Questioned document examination, which encompasses forgeries, tracings, and disguised handwritings, is currently in a state of upheaval. Courts in several jurisdictions recently questioned the scientific basis of handwriting “identifications.” In addition, criteria for using writing or typing comparisons to determine individualizations are not standardized, making validation of positive identifications very difficult. Computer software programs for matching documents via handwriting analysis may be able to provide an objective basis for this type of examination. However, these pattern recognition programs are not necessarily available to the entire forensic community. Another factor contributing to this discipline’s chaotic state is an ongoing change in the way that documents are created and transmitted. Like the comparison of prints and firearms/toolmark impressions, many components of questioned document examination involve expertise that may only be garnered through experience.

The development and expansion of electronic communications also have created new areas of need within the discipline. As a result, examiners may require RDT&E activities for cases involving comparison of handwriting; comparison and measurement of document features such as papers, inks, and toners; identification or elimination of source instruments such as word processors, typewriters, copiers, or printers; computer manipulation of images to assist in the review of documents; and recovery of altered information such as shredded and burned documents.

Systematic Methods

Macroscopic and microscopic comparisons of recovered (questioned) and known writings are used to determine any unique features present in both writings. These comparisons incorporate authentic writing sources (including requested and acquired standards) to allow for consideration of inter and intraindividual variability during examination. The resultant quality and number of unique features observed guide the examiner in deciding whether or not the same individual may have written both documents. The manner of forgery may be of interest when a questioned writing is excluded from having been written by a particular individual. Additionally, chromatographic and spectroscopic methods may be used on inks, papers, and other features of a document to elicit additional information about its age and source.

Machine-produced documents may be examined to determine characteristic features of the letters, fonts, inks, toners, papers, and artifacts of the printing process. Comparison of such features using questioned and known-source documents can assist examiners in determining whether or not a suspected machine may have printed a questioned document. Embossing may also yield characteristic features that allow for similar comparisons.

Needs

Validation of the scientific basis for handwriting examination. This component is extremely important because work performed in this discipline is ineffective if it cannot stand up in court. While other areas of research also need to be addressed to improve the examination practices for questioned documents, priority must be placed on demonstrating the scientific basis for identifications claimed during handwriting comparisons. Basic research on the psychomotor skills involved in handwriting are needed. Demonstration of an adequate basis for handwriting identifications could be obtained through the use of blind studies. These studies must present a fair challenge to the community of examiners but also must be structured to allow for the estimation of error rates and statistical significance of observed features.

Harmonization of comparison criteria. Comparison criteria currently vary throughout the world. Once studies on the fundamental underpinnings of the discipline are completed, the resultant findings should be used to develop a set of criteria that may be systematically applied as uniformly as possible. This harmonization will enhance many aspects of the discipline and provide a stronger scientific basis to handwriting identifications.

Improved nondestructive methods for determining characteristic features of documents. Nondestructive methods must be improved for use in the characterization of inks, toners, and papers. Multiple tests using current methods may destroy critical areas of documents, and it is anticipated that future scrutiny of evidence will require greater allowance for secondary (reference) testing of intact evidence whenever possible. These methods also will assist in meeting the challenges of image enhancement noted below.

Image enhancement methods for writing or printing on visually complex matrices. The matrices on which writing, typing, and printing occurs has become more complex over the past few decades. Improved manufacturing processes and the addition of postconsumer materials into raw material feedstocks has added to the complexity of papers. In addition, purposeful addition of visually complex features to currency and checks adds to the difficulties facing the examiner. The development of digital imaging equipment and application of computer enhancement methods could provide important tools to the examiner in cases involving these unusual matrices.

Image enhancement methods for linking documents to machines. The technologies employed for creating documents has changed dramatically over the past 20 years. Instruments such as typewriters, printers, copiers, and facsimile machines no longer solely use offset processes—the staple of document creation since the invention of machine-assisted writing. Instead, a host of thermal, micromechanical, and chemical processes generate the images produced on modern processed documents. To assist examiners in discovering, recording, and cataloging unique features of modern documents, it is important that more powerful imaging and image enhancement instruments be developed. The products from the use of these instruments—digital images of adequate clarity and detail—will allow for rapid transmission of data among examiners as well as archival storage and retrieval.

Shared databases of writing and machine-document exemplars for use in training and harmonization efforts. These databases provide the basis for development of systematic methods and more rigorous demonstration of the scientific basis for writing and document comparisons. As with firearms and toolmarks and latent prints, examiners of questioned documents rely upon experience and judgment when determining the importance of apparent writing nuances or document features. Databases containing “known nonmatches” allow for challenges of examiners during initial training and may be used to augment the ongoing proficiency of more senior examiners as well. As the complexity of instruments that create documents increases, these shared databases will also play a significant role in reducing redundant research and development efforts. Significant findings in one laboratory must be rapidly communicated to all appropriate examiners, leading to more uniform and consistent results among laboratories and greater forensic defensibility.

Firearms/Toolmarks and Other Impression Evidence Examinations

Current Status

Courts routinely accept identifications of firearms, tools, and other implements through the comparison of microscopic impressions on questioned and authenticated specimens. However, recent developments suggest the need for additional studies to enhance understanding of the scientific basis of such identifications.

Like the disciplines of fingerprint and document examinations, this discipline also involves expertise achieved predominantly through experience.

Systematic Methods

Microscopic comparisons of questioned and authenticated impressions are used to determine the presence of any unique features. The quality and number of unique features observed guide the examiner in determining if a particular firearm, tool, or other implement may have produced the questioned impressions. Many examiners rely on intralaboratory peer review for assistance in cases involving difficult interpretations or when comparisons lead to an identification. Documentation of unique features is recommended when possible, although it may be difficult when features on nonplanar surfaces are involved.

Two automated search and retrieval systems, IBIS (Integrated Ballistics Identification System) and DRUGFIRE, are available to help examiners select known firearms-related impressions for comparison with recovered (questioned) impressions. These systems are now competitive, but efforts are under way to increase their compatibility. There has been reasonable success to date in using these systems with cases involving breech-face markings and firing-pin impressions; however, newer technology now allows examiners to capture and compare striae within land and groove impressions on recovered bullets.

Needs

Validation of the basis for impression evidence identifications. An excellent review of the "state-of-the-science" of firearm and toolmark identification criteria was recently published [see R.G. Nichols, *Journal of Forensic Sciences*, 42(3) (1997): pp. 466–474]. This review details the fact that significant research exists that empirically supports the unique identification of firearms and tools based on the alignment of microscopic striae from a questioned mark with those made during test firing or marking with suspect weapons and tools, respectively. However, examiners do not routinely reference the available literature when testifying to these identifications, and there are some "gaps" in the knowledge set with respect to the relative frequency of—and therefore importance to be assigned to—particular types of microscopic features from various tools and weapons. Extension of the available knowledge is necessary to provide more formal support for these identifications.

Development of portable nondestructive analytical approaches for characterizing the elemental composition and other features of bullet impact areas. Examination of bullet-impact areas often necessitates examiners going to the location where the bullet or its impression is discovered, such as a particular building, residence, or outdoor location. It is not always possible for examiners to remove evidence for testing in a laboratory (for example, a bullet impression in an interior or exterior wall), especially if doing so will destroy or alter the evidence. Therefore, it is vital for examiners to develop portable, nondestructive techniques that will enable them to conduct comprehensive, onsite testing of bullet-impacted surfaces so that evidence can be identified and presumptively evaluated at the scene. A related need for portable "range-of-fire" determinations exists, and may utilize similar approaches.

Incorporation of a "z-dimension" imaging component into pattern-recognition systems. Current algorithms for characterizing microscopic striae principally map the image in two dimensions (x- and y-). While these algorithms may provide adequate information for some applications, improvements are still needed. This is especially the case for impressions made on nonplanar surfaces (such as bullets). The depth of the striation provides an additional dimension that is currently ignored in the image-capture systems, primarily because the imaging equipment is not designed for such determinations. Incorporation of this third dimension for characterizing striae would provide much greater discriminating power to the algorithm. In addition, such an approach would increase productivity when using automated search and retrieval systems (IBIS and DRUGFIRE), because the number of matches recovered in the search would be minimized.

Statistical analysis of performance of algorithms used in automated pattern recognition (search/retrieval) software. The harmonization of IBIS and DRUGFIRE will yield a common data set to allow for the facile interchange of image data captured on either system. However, both systems could be improved if the statistical basis for individualization of firearms-related striae was better characterized. Just as with automated fingerprints, the algorithms used in IBIS and DRUGFIRE return candidates after searches demonstrate consistent features between questioned and databased ("known") cartridges and bullets. However, the performance of these two systems has not been fully characterized to determine the relative importance of certain redundant or random microscopic features to the search result.

Crime Scene Response and Related Examinations

Current Status

The forensic aspects of crime scene response have not received adequate attention or funding. This needs to be remedied in a timely manner because the quality of evidence recognition, documentation, collection, and preservation are critical to the quality of results from resultant analyses. In addition, crime scene personnel must be protected from exposure to hazardous materials such as biological, chemical, and etiologic agents, but this important concern has received very little consideration.

Systematic Methods

The methods used in crime scene response and related endeavors are quite diverse and should logically correspond to each individual case and the specific types of evidence recovered.

Needs

Small, rugged, chemical analysis instruments for onsite preliminary or confirmatory analysis in investigations involving drugs, explosives, and hazardous materials. Current methods for presumptive testing of materials at the scene do not allow for the preliminary detection of the full complement of substances for which such testing is important. For drugs and explosives, these portable methods significantly enhance the productivity of the investigative/forensic science interface, because the materials forwarded from field investigations are more routinely verified in the laboratory than when no screening is available. The potentially wide distribution of explosive residua in a postblast scene demands rapid localization of the areas and particular items of evidence bearing such traces, so that the investigation can be suitably focused to avoid the deleterious effects of weather and human activity. With hazardous materials, another important reason for onsite testing is to limit the exposure of scene personnel to injury or illness caused by these materials.

Sample location, identification, capture and stabilization technology "in a kit," suitable for recovery of trace particulate, liquid, chemical, and biological evidence, with immediate partitioning of samples for secondary testing. Following on the discussion of the onsite chemical analysis instruments above, a further refinement of the collection approach is needed. A "kit" should be developed that could not only be used in the presumptive detection or identification of various types of evidence at a crime scene, but that also allows for the retrieval and storage of evidence to protect it from contamination so that it can be brought back to the laboratory for further, more detailed examinations.

Portable and remote hazardous materials detectors for alerting/protecting crime scene personnel. Portable and remote detectors can be very beneficial, not only in gathering information but also in protecting crime scene personnel. Portable detectors could show examiners the location and types of hazardous materials present at a particular crime scene, while remote detectors would allow personnel to obtain crime scene information from a distance in cases where hazardous materials are present or suspected. Both types of detectors would prevent field personnel from being unnecessarily exposed to hazardous materials while still allowing them to obtain vital information from a crime scene. Placement of similar equipment in ongoing or permanent monitoring practice could be used to alert personnel to dangerous changes or new, unsafe conditions.

Microrobotic platforms to support crime scene visualization, safety assessments, and sampling. The development and use of microrobotic equipment would further enable examiners to investigate potentially dangerous crime scenes without putting themselves at risk. Robots could perform sampling tests of questioned materials to determine any hazardous components and further focus the investigation on areas of highest contamination or interest. These same robots could be fitted with remote sensing equipment for extending the use of equipment when barriers (weather, line-of-sight for spectrometers, etc.) exist for conventional use. The safety of field personnel and minimization of evidence destruction from human intervention could be maintained through the use of microrobotic equipment.

Computerized crime scene mapping supported by global positioning systems (GPS) and multimedia capture technologies for three-dimensional crime scene visualization, memorialization, and location of evidence. Current attempts at constructing the "digital crime scene" have been accompanied by relatively high cost and a lack of standardization. The goal of research and development in this area is to provide a highly accurate record of the position and the morphology (or other salient features) of evidence discovered at the crime scene. This information must be available in a three-dimensional map, to include objects discovered underground or in multiple floors of buildings, and include digital photographs that reliably and with adequate resolution provide for memorialization with high integrity. These protocols also must be developed to lower the overall cost (manpower and materials) of crime scene processing. Systems must be developed that allow investigators to demonstrate that images have not been inappropriately manipulated, and to fully incorporate features needed in later review for information not immediately obvious to scene investigators.

Energetic Materials (Explosives and Fire Debris Examinations)

Current Status

The identification of bulk explosives is relatively simple compared to the recovery and detection of residues of explosives in postblast debris. Very few laboratories routinely analyze postblast debris. Critical questions may exist when attempting to interpret positive findings, due to the sensitivity of approaches available. In addition, the possibility for inadvertent transfer from contaminated surfaces to other surfaces or people can further complicate or confound interpretations. Therefore, collaboration between laboratory examiners and investigators is often critical in making proper casework interpretations.

Fire Debris analysis is a subdiscipline of trace analysis that is in good standing because there is sufficient published work on the analysis and interpretation of the material involved. Standard guides for the examination and interpretation of chemical residues in fire debris have been published through the consensus process of ASTM Committee E–30 on Forensic Science. Research in recent years has been directed toward the improved capture and detection of compounds that can be used as fire accelerants. Significant work also has been devoted to the differentiation of pyrolysis products from ignitable liquid residues. These standardization documents are often quoted in the scientific literature, helping to meet the requirements of the legal community.

Systematic Methods

Laboratory analysis of explosives involves characterization of energetic materials in either bulk or postblast form. “Low explosives” (for example, smokeless powder, flash powder, or match heads) are commonly used as charge materials in improvised devices such as pipe bombs. Bulk low-explosive materials are analyzed using microscopic, spectroscopic, and chromatographic methods to characterize the content of admixtures (such as flash powders and improvised mixtures) and single-component forms (such as smokeless and black powders). Careful observation of the physical morphology of recovered, commercial low explosives may allow them to be linked to a particular manufacturing source. “High explosives” include traditional military and commercial blasting materials. Bulk high-explosive materials also are routinely identified using chromatographic and spectroscopic methods.

Sufficient matrix materials may be present to allow for characterization of possible sources of the material if analyses are focused on this need. Courtroom acceptance of these results has been routine.

Analysis of postblast debris starts with macroscopic and microscopic viewing and segregation of appropriate materials; then sieving and another microscopic evaluation are conducted, if appropriate. Debris may need to be extracted using aqueous or organic solvents, with concentration and clean-up prior to chromatographic and spectroscopic examination. Unfortunately, the analysis and interpretation of postblast debris is difficult, because high concentrations of extraneous materials are often present with the low-level traces of explosive residues.

Fire debris examination involves containment of debris in vapor-tight containers. The common examination procedure at the laboratory involves concentration of volatile traces on adsorbents, followed by elution of adsorbed residua and chromatographic examination. For complex debris, gas chromatography-mass spectrometry may be needed to adequately discriminate between ignitable liquid residues and pyrolysis products from matrix materials.

Needs

Improved methods for assessing the size, construction, and composition of improvised explosive devices from macro-effects at postblast scenes. The current tools available to investigators in assessing the size, construction, and composition of improvised explosive devices (IEDs) from effects observed at postblast scenes rely on very small data sets. For some types of IEDs, there have been no systematic demonstrations of the macro-effects of these devices. Many bombings involve IEDs every year, yet the proper investigative focus cannot be assigned without more fundamental knowledge of the effects to expect from different IEDs. Testing of various designs, having a variety of sizes and in a variety of common applications (such as in vehicles and buildings incorporating different construction elements), is critical to improved postblast scene investigation outcomes.

Enhanced clean-up techniques for postblast debris. Because postblast debris is usually comprised of a large amount of extraneous materials such as building or vehicle remnants and a small amount of explosive device remains, advanced technologies are needed to effectively separate out the relevant materials so they can be properly identified and preserved. This is particularly important when sifting through large areas of damage, because examiners need to ensure that crucial evidence is not lost or destroyed during the debris cleanup and removal processes.

Method development for recovery of explosive and ignitable liquid residues from a variety of matrices. To complement more effective cleanup processes in the laboratory, techniques need to be developed that allow residues to be recovered from many different matrices such as building remnants, air, soil, and human remains. Since there may only be a small amount of evidence that survives an explosion or fire, it is very important for examiners to have the necessary technology to recover this evidence regardless of the type of surface on which the residues are found. This is especially important in aerospace and other more complex environments, in which the degree of damage is often very high, and fabrication materials are often unusual or esoteric and comprised of advanced composites.

Enhanced field detection capabilities and mapping technologies for bomb scene investigation assistance. Previous discussion on advances needed for crime scene response is certainly applicable with postblast and fire scenes. However, this need is magnified for these scenes because three-dimensional mapping of the position of recovered traces of explosives or ignitable liquid residues can be used to estimate the size and operation of explosive and combustible devices or materials. Therefore, enhanced capabilities not only provide greater accuracy in recording the position of the evidence, but may actually materially contribute to the interpretation of the size and composition of devices and explosive or ignitable liquids used in the generation of observed effects.

Improved onsite materials science and metallurgical analytical capabilities to assess, discriminate, and validate the effects of improvised explosive devices versus alternative causes. Portable equipment for onsite examination and analysis of postblast debris and structural components of targets (such as buildings and vehicles) needs to be developed. Such equipment will allow investigators to more accurately and quickly determine whether an explosion was due to an improvised device or was caused by other factors. The findings from these portable devices could help investigators and examiners understand and more rapidly focus investigations on the causes of explosions. In addition, they may provide more rapid preliminary identifications of source materials.

Improved sensitivity in the detection of ignitable liquid residues in fire debris. Minute traces may be all that remains of ignitable liquids used to start an arson fire. Canine detection approaches and improved portable detection devices may have better sensitivity to these traces than current laboratory-based methods. Although the lowering of limits of detection brings an attendant requirement for improved rules for the interpretation of findings, these sensitivity enhancements are critical.

Desorption advances for enhanced automation. Most laboratories providing fire-debris analysis services use a static or dynamic adsorption/elution step to recover traces of ignitable liquids. The elution (“desorption”) step in this process of sample preparation must be automated to improve laboratory productivity. Automated methods for the chemical and thermal desorption of explosive residues from debris would significantly enhance the productivity of laboratory explosives analyses as well. Such advances could also lead to improved portable devices for field recovery of residues.

Algorithms for interpretation of complex fire and bomb debris analytical data. Methods need to be developed that enable investigators to systematically examine bomb debris and fire scene data to estimate the size and content of components or amount of ignitable liquid involved. As noted above for IEDs, controlled explosions and fires are needed to provide the data for these algorithms. Examinations of scenes would be more efficient if investigators had specific guidelines on which to rely, as long as these guidelines are based on appropriate, accurate data. Significant collaborative input should be used in the design of these experiments, because controlled explosions and fires are extremely expensive to conduct and may generate staggering amounts of data.

Continued validation of the current methods by intralaboratory studies. Proficiency testing materials for use in fire debris and explosive-related subdisciplines are notoriously difficult to manufacture and control. In addition to difficulties posed for manufacturers of these materials, these tests do not adequately test critical aspects of the examination such as the proper selection of debris for testing, recovery of residues from complex matrices, or interpretation of data in realistic scenarios. Intralaboratory studies (as partially described above regarding algorithms for interpretation of data) must be designed and implemented to address the shortcomings of conventional proficiency testing approaches.

Postmortem Toxicology and Human Performance Testing

Current Status

Although courts routinely accept laboratory determinations in both postmortem and human performance testing, interpretive controversies still exist in several areas of toxicology. One important problem is that normal, “impairing,” and lethal concentration ranges for drugs and toxins in human body fluids and tissues are not well known. The critical need is for data from well-controlled studies of individuals taking normal doses of drugs, or involved in normal occupations with attendant “normal” exposures to nondrug toxins. Concentrations of these substances and their metabolites in fluids or tissues from a deceased individual could then be compared to postmortem expected values to determine the likelihood that death was due to an overdose, or that the substance adversely contributed to the death. Similarly, comparisons could be made for investigations of impaired performance in cases involving living subjects.

Unlike many criminalistics subdisciplines, this discipline has national certification standards both for personnel and for laboratories. Toxicologists also generally have advanced academic degrees in analytical sciences or pharmacology and several years of experience.

Systematic Methods

The general approach to toxicological determinations include screening of fluids and/or tissue homogenates from human subjects using highly sensitive analytical methods that may have low specificities but high sensitivity. Such methods may include immunoassays, microchemical methods, and other low-cost approaches. The identities and quantities of suspected toxins from these screens are confirmed using alternative technologies that are more selective and employ different technologies than those used in the screening process. Common confirmatory techniques include gas and liquid chromatography-mass spectrometry.

Needs

Nondestructive analytical techniques with reduced interferences from biological materials. One of the problems with analyses in this subdiscipline is that testing tends to use destructive methods that result in critical evidence being destroyed during the toxicological investigation. Therefore, nondestructive techniques need to be developed so that multiple tests can be performed on a small amount of biological fluid or tissue. Examiners would also benefit by being able to test for alternative substances after testing for the original target substance(s) was completed. Nondestructive techniques would also enable retesting for an identified substance if some controversy arose later about the original laboratory's toxicological findings.

Well-controlled studies of the effects of drugs on the operation of motor vehicles and complex equipment. Although many studies exist that describe how alcohol impairs human behavior and performance, drug-related studies tend to concentrate on how drugs affect human behavior but not on how they affect the performance of complex tasks such as driving motor vehicles or operating complex machinery. Studies need to be conducted with subjects who perform realistic complex functions, such as driving, before and after receiving a drug or placebo. In these studies, appropriate biological fluids need to be collected throughout the study, concentrations of drugs and metabolites must be determined, and the correlation of affects on individual performance with these concentrations estimated.

More accurate methods for determining time of death. One of the biggest problems that medical examiners face is accurately determining a person's time of death. Current objective methods for determining time of death include measuring body temperature, determining selected changes in body chemistry, or assessing growth stages of infesting insects in deceased individuals. Each of these measures is highly variable, which increases the uncertainty in predicting the time of death. More effective methods need to be developed and authenticated under realistic conditions.

Automated and inexpensive methods for extraction and detection of drugs and other toxins. Cost and time for testing must be reduced in order to stay within limited laboratory budgets. One way to reduce manpower and increase testing speed is to develop automated methods, especially for more recently studied matrices such as hair, sweat, and saliva. There is also a need to develop screening methods that are inexpensive and more specific for target substances. These methods must lend themselves to automation. Current automated screening methods produce many false positive results, which then require performance of expensive, labor-intensive confirmation tests.

Central database of postmortem "incidental" drug findings in deaths unrelated to drugs. When examiners are investigating the cause of death (other than drug related) of an individual, they look for evidence that specifically deals with how or why the person was killed. However, in the course of their investigations, examiners may discover additional, "incidental" information related to drugs or other substances in this individual. Although this information may not be directly relevant to the cause of the death, it may provide insight into the manner of death, or the chemistry and composition of the human body. It is important that this information be disseminated in such a way that examiners throughout the world could access it and learn from it. One way to accomplish this would be through the creation of a central database containing information about such incidental findings. Any new information could prove beneficial in helping examiners to understand expected levels of toxins, endogenous compounds, or the identity of substances that could interfere with routine tests. Trends in incidental findings may also be quite useful in tracking emerging drugs or toxins of concern, information which could be relayed to medical examiners and public health officials as appropriate.

Forensic Biology and Molecular Biochemistry

Current Status

During the past 5 years, quality-control and quality-assurance program improvements have been realized by forensic DNA laboratories. These improvements have not only enhanced the reliability of the methods employed, but laboratories have also increasingly found the criminal justice system receptive to admissibility issues. Forensic laboratories also have benefitted from extraordinarily valuable resources obtained through efforts supporting a valid scientific foundation for DNA use in casework. One of the most impressive advancements is the concerted effort to disseminate foundational, scientific data through a variety of media including publications, national and international meetings, workshops, laboratory internships, and extensive laboratory collaborations.

The end product of forensic DNA analysis is data that is admissible in court. Therefore, a clear need exists for laboratories to access current and advanced DNA technologies in a timely and cost-effective manner. However, most forensic laboratories are hindered from using state-of-the-art DNA technology by relentless casework backlogs, lack of personnel, and budgetary constraints. Although a general framework has been established for implementing DNA analysis in casework, there is a need for faster, more efficient analytical equipment if DNA technology is to be used at its optimum level.

Systematic Methods

Forensic DNA analysis allows for the biologic comparison between an individual's genetic makeup and biological evidence found at a crime scene. Because virtual identity is possible through the statistical representation of a DNA profile, it is essential that the DNA genetic markers allow for the highest quality of discrimination. This is achieved by increasing the number of well-characterized DNA loci; the more DNA markers that can be labeled and defined, the easier it will be to make definitive comparisons between individuals and crime scene stains.

Most cases submitted for laboratory work involve suspected biological materials that must first be characterized as being human or nonhuman and then as having evidentiary importance. Presumptive and conclusive microchemical and biochemical tests are made on suspected stains to determine what potential type of stain is involved (such as blood, seminal residua, or saliva). Afterwards, the stains may be subjected to conventional serological tests and DNA testing using either restriction fragment length polymorphism (RFLP) or polymerase chain reaction (PCR) based techniques.

With the advent of PCR in forensic science, the possibility of mass analysis of multiplexed loci has been realized. Individual laboratory decisions regarding the source of the genetic markers, allele detection systems, critical validation studies, casework implementation, and most important, interpretation guidelines, are now made easier by the efforts of the DNA Advisory Board, the Technical Working Group on DNA Analysis Methods (TWGDAM), availability of accreditation, and general private and public technical support groups.

Needs

Robotics for the extraction of biologic fluids and tissues, including differentials for semen stains. Methods for extracting biological fluids and tissues (such as hair, bone, and teeth) are currently very time consuming, but this problem could be remedied through development and use of robotics. Robotics platforms can be programmed to perform certain routine but necessary tasks, which would enable examiners to concentrate their efforts in other areas. A critical need exists for robots for performing differential extractions of semen stains. This particularly tedious step is essential to the preparation of evidence for DNA testing in rape and sexual assault cases.

Genetic analysis of botanical materials for tracking and other investigative assistance. Biological evidence may be discovered on many types of surfaces at a crime scene and may include botanical materials such as plants, leaves, grasses, pollens, phytons, and other microorganisms. Methods need to be developed so examiners can routinely detect and analyze this information and use it to determine potential suspects as well as the path (such as through woods, fields, or along streambeds) the suspect might have taken before, during, and after committing the crime.

Access to microchip technology to enhance and advance DNA testing methods. Preliminary results of research on microchip array techniques suggest that these methods will one day eliminate the need for electrophoresis in DNA analyses. A good deal of the work currently under way is being performed by private industry. These companies have recognized the potential of microchip technology in DNA-based medical diagnostics, paternity testing, and forensic identity analyses. Research in the public sector is needed to complement these commercial advances and ensure that appropriate forensic applications are developed and that realistic validations are performed using appropriate forensic challenge scenarios and materials.

Application of DNA testing to biological materials from animals. A substantial number of forensic cases submitted to laboratories provide the opportunity for applying DNA testing methods to animal hairs, bloodstains, and other biological matrices. These materials demand modification of existing methods of testing, and databases of population frequencies of various discovered loci in the myriad of animal species must be developed.

Complete assessment of additional STR marker systems. It is estimated that more than 40 000 potential short tandem repeat (STR) loci may be available for humans. At this time, less than 20 have been fully evaluated for forensic applications (although the number is increasing almost daily). The most common goal of DNA examinations is to conclusively identify or exonerate a single individual as being responsible for an unknown biological stain or material. This can be best accomplished by choosing the combination of STR loci that provides the greatest freedom from the effects of environmental degradation, high productivity during analysis, and maximum discrimination when results are interpreted. Clearly, there is a substantial amount of research to be performed in this area.

Additional methodologies for the characterization of mtDNA sequences. Mitochondrial DNA (mtDNA) offers the examiner the power of DNA analysis in biological materials (such as hair, teeth, and bone) which do not contain nuclear DNA. MtDNA tests are currently more expensive and difficult to perform than conventional RFLP or STR DNA testing, and given the potential for budgetary constraints and the huge demand likely to arise when more laboratories provide mtDNA services, significant development is necessary for these tests. In addition, extension of applications of mtDNA analyses in more unusual types of evidence, such as unusable latent partial prints and automobile steering wheels, could provide significant new information for law enforcement investigations.

Repository for DNA samples with microheterogeneity for proficiency and training purposes. There should be a collection of information about microheterogeneity (also known as “heteroplasmy”) in individuals that examiners could access to help them interpret casework results. This collection is especially important in the proper application and interpretation of mtDNA results. For example, studies have shown that the mtDNA results for hairs collected from a single individual can be different for different hairs, although the differences generally arise in a single location in the sequence. It has also been demonstrated that microheterogeneity tends to occur somewhat consistently—in “hot spots” along the sequence— so information about these hot spots can be vital for the proper interpretation of casework data.

Lab-Net links for interactive data interchange among caseworkers. Lab-Net links should be established that allow examiners working throughout the world to share and discuss information with each other. Although there may be security concerns and privacy issues that will limit the topics of discussion, this forum would help examiners learn from each other and help promote the continuous quality-improvement process that this discipline has recently enjoyed.

Sampling devices for stabilizing evidence during in-field collection. Equipment needs to be developed that will allow crime scene personnel to routinely collect and package evidence and maintain appropriate temperatures until the laboratory processing begins. There are many issues of contamination and degradation that must be addressed in virtually every case involving biological evidence. The development of sampling devices that will stabilize evidence, when coupled with appropriate training for crime scene investigators, can significantly reduce the potential for deleterious change or contamination of this evidence.

Transfer (Trace) Evidence Evaluation

Current Status

Trace evidence materials include transfer evidence of all types except biological fluids. Although there is an extensive list of possible transfer materials, the main types observed in crime laboratories are paints, hairs, fibers, glass, and building materials. The use of trace evidence has declined in recent years, primarily because forensic laboratories are devoting resources to technologies such as DNA analysis that provide stronger conclusions. This cutback in resources increases the casework demand upon analysts and limits their participation in the volunteer processes of method development, standardization, validation, and interlaboratory studies. This is unfortunate, because the benefits of these standard-setting and validation activities cannot be overstated. Two groups currently working on these issues are the Technical Working Group on Materials (TWGMAT) and the American Society for Testing and Materials (ASTM) Committee E–30 on Forensic Sciences.

Recent publications on glass indicate significant heterogeneity within the glass population. Studies that comprehensibly characterize subtypes of materials, such as vehicle windows, allow examiners to form opinions that experienced forensic scientists intuitively know to be stronger than “the Q *could have* come from the source.” Ultimately, it is greatly beneficial to the investigative process when such stronger opinions are forensically defensible. To this end, current efforts in materials characterizations include the creation of databases containing analytical variables such as the elemental composition of glass and coatings.

In the coatings (paints and polymers) area, the FBI and Royal Canadian Mounted Police (RCMP) have undertaken a comprehensive effort to characterize commercial coatings. This effort will create and validate a database to assist forensic scientists in sourcing, comparison, and interpretation issues. Although it is not a population database, this representative database will be very useful to practicing examiners.

Systematic Methods

The nature of the evidence (that is, the variety of materials and matrices that can be submitted as evidence and the variety of methods for the analysis of those materials and matrices) makes analysis in this discipline complex. Each type of trace material requires a unique systematic approach, and even these approaches are significantly predicated on the size and morphology of the evidence being examined. As a result, considerable background knowledge and interpretation are necessary when opining on the meaning of a positive association.

Needs

Standardization of trace analysis methodologies. Trace evidence examiners recognize that there is no single, foolproof method or series of procedures that will provide optimum results in every case. However, these examiners also recognize that the lack of appropriate standards may lead to problems such as inappropriate destruction of evidence, unreliable results, and nontransferable representative databases of material characteristics. Initial work by ASTM and TWGMAT has led to several standards and guides for the systematic analysis of gunshot primer residue and glass, and more standards are under development at this time. These efforts must continue in order to maximize the reliable information obtained during examinations and facilitate the transfer of information among examiners.

Enhancements of nondestructive techniques for elemental and molecular analysis of materials. Trace evidence typically provides very small samples for examination. From this evidence the examiner must extract as much information as possible, yet maintain sufficient sample for retesting or confirmatory methods, as appropriate. There are several nondestructive techniques available for use with trace evidence, but most of them suffer from sensitivity or selectivity problems in these applications. Significant research and development is needed to improve these techniques or develop new methods.

Development of portable and automated systems for improved detection of trace materials. By its nature, trace evidence can be very difficult to locate. The examiner's job is often tedious and is prone to errors of omission (missed collections of trace materials from evidence) because it is hard for anyone to maintain full concentration for extended periods of time. There are commercially available instruments that can scan a tape-lift for fibers or hairs, as well as determine the reflectance spectrum for detected fibers, but similar instruments are not available for other types of trace materials. Development of these systems could provide significantly enhanced productivity and more thorough collections of important trace evidence. In addition, the availability of a portable instrument of this type could improve the collection of crime scene evidence bearing important trace materials. However, it would be important in such applications to provide field personnel with appropriate training.

Assistance in the design and review of proficiency tests in materials comparisons. Evaluation of trace materials requires sophisticated analyses and substantial background knowledge and interpretation skill. It would be helpful for examiners to have proficiency tests that have been adequately characterized and that were developed using more rigorous guidelines for manufacturing. This will require substantial effort on the part of senior examiners in this discipline, with assistance from specialists in materials science, statistics, and manufacturing process design.

Coordination of available expertise for unique case problems. Trace evidence data interpretation is currently affected by many different variables, such as where the examiners received their training, in what methods they were trained, and the availability of appropriate instruments. There is a primary need to develop interpretation standards to ensure that examiners provide consistent and complete conclusions from a given set of developed data. In addition, coordination is needed on a national level to provide useful assistance in interpreting unique case problems. One possible solution could involve the creation of a central national laboratory where examiners could perform extensive research and materials characterization and disseminate this information to the international forensic community. This approach would also improve the forensic defensibility of testing results because interpretations would have a stronger empirical basis.

Development and coordination of databases. Because transfer evidence encompasses so many different types of materials, several databases are needed to coordinate and track this information and to allow examiners to retrieve and review the information when necessary. Coordination of existing databases also is important; for example, manufacturers sometimes maintain databases of their product-testing results which, although proprietary, could assist examiners in understanding the components and features of certain types of materials. The following are two specific databases that could greatly assist examiners in this discipline:

- **Glass database.** This would entail the creation, validation, and publication of a database characterizing an appropriate population of glass samples by elemental composition, morphological features, and spectral characteristics if appropriate.

- **Fiber sources database.** This could assist examiners in determining the types of fiber being examined through the compilation of morphological characteristics, spectral and elemental data, how commonly the fiber is distributed, products from which the fibers may be initially transferred, and the company or country of origin.

Controlled Substance Examinations

Current Status

The determination of controlled substances is the most common service delivered by forensic laboratories all over the world. Multiple examinations are required to identify the drug(s) present in submitted evidence. These examinations can incorporate microscopic, microchemical, chromatographic, and spectroscopic methodologies. (Some jurisdictions require quantitative estimation of the purity of drug(s) present in exhibits.) Although most laboratories use similar examination methods, there is no standardization on the exact number, type, or conditions employed for tests performed in this discipline. For example, there is some disagreement on the use of microcrystalline tests to confirm the presence of a drug. The disagreement centers around the lack of documentation available for peer review, and the lack of a scientific basis for conclusions of identity drawn from a description of gross crystal formation. Reports from laboratories are routinely accepted into court without testimony by examiners—the attorneys stipulate to the results.

Field testing is performed in many jurisdictions. When performed by qualified personnel, these presumptive tests complement law enforcement efforts by decreasing the time to arraignment and by frequently lowering adjudication burdens due to plea-bargaining agreements. All other factors being equal, laboratories tend to have lower controlled substance caseloads in jurisdictions where field testing is performed. Field testing is not without controversy, however, because its accurate application depends on the quality of training received by the individuals conducting the testing. Law enforcement personnel are also assisted in their investigations of drug offenses by canines trained to detect controlled substances.

Systematic Methods

Controlled substance exhibits are first weighed and described, and then presumptive tests are performed. Confirmatory testing is then performed; the most common approach utilizes either gas chromatography-mass spectrometry or infrared spectrophotometry, although liquid chromatography may be needed to detect thermally labile or polar drugs. Finally, case records are compiled, usually consisting of hard copies of the analytical data, preprinted “check sheets” for fast internal reporting, and the formal laboratory report.

Special modification of these methods is required when dealing with residues of drugs on paraphernalia or other evidence. In these cases, the evidence may be swabbed in order to collect the residues from the evidence. A liquid extract or eluate from the swab is then tested using either conventional presumptive and confirmatory techniques, or may require the use of a more sensitive method such as ion mobility spectrometry.

Needs

Standardization of methods. There are two distinct standardization needs in this discipline. One involves general standardization of the number, type, and conditions employed for tests on controlled substances. The other pertains to specific chromatographic/electrophoretic standardization for chiral mixtures, biopharmaceutical products, and other complex materials.

Inclusive automation of sampling and analytical methods to increase productivity. Forensic scientists spend a great amount of effort on controlled substance examinations that could be better spent in areas such as crime scene response, explosives examinations, and DNA testing. In order to increase available time and resources, it would be extremely beneficial for examiners if automated methods were developed for sampling and analyses, especially in bulk drug cases. Cases involving residues are inherently more difficult to automate, but also are much less frequently encountered in the majority of forensic laboratories.

Remote sensing equipment for enhanced field testing and investigation applications. There is a need for improved remote sensing equipment that investigators could use to detect the presence of controlled substances, solvents, reagents, and synthetic precursors. This would help narrow the field of search and interdiction, especially in large geographical areas or buildings such as airports, hotels, and schools.

Nondisruptive ("through the packaging") sampling. If technologies were developed that allowed for nondisruptive sampling methods, examiners would be able to detect the presence of controlled substances without opening the suspected container. This could increase productivity and reduce the possibility of cross-contamination in the laboratory.

Enhanced understanding of canine detection mechanisms leading to instrumental approaches for field deployment. When properly trained (both the dog and the handler), canines are able to detect controlled substances with surprising accuracy and sensitivity. Research is needed to better understand the exact mechanism and target(s) of the canine detection response. This research would not only allow for improved training for canines, but would also facilitate development of instrumental methods that mimic canines.

Analytical Services

Analytical service is the support crime laboratories provide to their clients. It is the essence of forensic laboratory work and represents the end product of the laboratory's efforts. Analytical service includes routine and traditional analyses common to all forensic laboratory settings. It also includes methods development particular to the requirements of specific cases, as well as the identification of analytical sources to perform work that is considered nonroutine.

There is room for improvement and enhancement of casework services. Such improvement and enhancement would be illustrated by additional services, increased efficiency, and greater cost-effectiveness. It is critical to examine not only the needs of the forensic community, but also the consequences of not meeting those needs—how does it affect the criminal justice system and the public that the forensic laboratory serves. When police are not able to work cases efficiently, when court dates are postponed, taxpayer money is not well spent and efficiency is reduced. An important question to consider is whether local and State laboratories, if they are overloaded with work and have a case backlog, should outsource cases to Federal laboratories. A list of resources available to accomplish casework also is needed.

Discussed below are the following issues in casework:

- Current status of analytical services.
- Review of product delivery requirements.
- Assessment of casework applications.
- Alternatives to consider in response to today's needs.

Current Status of Analytical Services

The first step in assessing the current status of casework is the identification of clients and the unique needs of those clients. Those needs determine the services that are provided. Clients include:

- Police/law enforcement.
- Judiciary.
    - Courts.
    - Prosecution.
    - Defense bar.

Police

The greatest need experienced by the police is for investigative support, which is divided into two areas: nonsuspect casework and cases with suspects.

- **Unidentified suspect casework.** These cases include work related to rape, burglary, homicide, and other crimes where there is no suspect. Forensic scientists have the ability to assist in these cases through tools such as DNA databases, the automated fingerprint identification system (AFIS), and cartridge/bullet imaging databases. Although this work is important, follow-through on nonsuspect cases may not occur because existing staffing levels are inundated with working cases with suspects. Ideally, these cases should be worked within 30 days of the crime, during the active police investigation. Laboratories must respond to the pressure of upcoming trials; cases without trial dates often are put on the back burner due to caseload demands. An additional investment in staffing to work unidentified suspect cases would be a very cost-effective way to reduce wasted police investigative time and reduce recidivism through the identification of perpetrators.

- **Cases with suspects.** These cases receive more attention. Police need results during the active investigation phase of a case, generally within 30 days after a crime is committed. Unfortunately, results often are not available quickly, again due to heavy caseloads. Failure to meet this need diminishes law-enforcement efficiency.

- **Technical training.** Technical training is another area where police need the support of the forensic community. Instruction needs include crime scene processing, field testing, and recruit training. While more training is needed, time spent by scientists training police is time taken from actively working cases. The allocation of resources for training negatively affects case output. At the same time, the lack of training opportunities exacerbates the case backlog situation.

Judiciary

The needs of the judiciary (the courts, prosecution, and defense bar) for casework support touch on the following areas:

- **Drug-related crimes.** Drug-related crimes and drug analysis frequently require a high percentage of a crime laboratory’s total resources, in some labs as much as 50 percent. However, drug analysis, while often politically popular, does not identify the perpetrator of a crime. Drug analysis competes with other cases for resources, including the investigation of violent crimes.

- **Trial preparation.** Crime laboratory test results and reports are needed by both the prosecution and the defense for trial preparation. The forensic scientists who testify as expert witnesses also need to prepare. It is essential to provide adequate background for court personnel, whether for the State government or the defense. If test results are not prepared in a timely fashion, trials can be delayed.

- **Speedy trial requirements.** Most States have a speedy trial requirement, details of which vary from jurisdiction to jurisdiction. In general, crime laboratory results are needed within 30 days of an arrest so as not to hamper or bog down the process.

- **Court dockets.** Court dockets are overloaded. The system is clogged with continuances and compromised by plea bargains. These backlogs often are attributed to the forensic community because of its inability to respond in a timely fashion due to its own backlogs.

Coping Mechanisms

What coping mechanisms do forensic scientists and laboratories use to help meet the needs of their clients?

- A priority system that ensures cases with suspects and those going to trial receive attention. Important cases pending arrest unfortunately are delayed or deferred.

- Overtime for laboratory personnel must be authorized due to overwhelming demands for results.

- Cases may be transferred to another laboratory within a system to equalize the backlog among laboratories.

- Laboratories may decline to process low-priority cases.

- Streamlining methods to promote efficiency also need to be examined. Care must be taken to ensure that streamlining would not be to the detriment of the quality of the work being performed. District attorneys may need to become more selective in the cases they choose to prosecute.

Review of Product Delivery Requirements

The issue of product delivery requirements grows in importance when work is outsourced to other laboratories. Product delivery requirements are in place to ensure quality products, timely delivery, and a valid assessment of a provider's qualifications. The forensic community must be assured that a usable product will be obtained. If a test is performed and a result obtained, that result must be prepared to pass peer scrutiny, regardless of the reputation of the laboratory performing the examination. Since results often are used in adversarial situations, the stakes are too high for anything less. Product delivery requirements consist of the following elements:

- **Evidence control.** Evidence control is measured by the presence of chain-of-custody procedures and the assurance of the evidence-integrity processes. Such processes include attention to seals, marking, and secure storage.

- **Analytical procedures.** Analytical procedures are defined as generally accepted procedures (as specified in Frye), scientifically valid methods (as outlined in Daubert), and appropriate procedural documentation.

- **Quality assurance and quality control.** The importance of maintaining strong quality assurance and quality control cannot be overemphasized. Appropriate controls and standards must be in place, including instrument calibration, traceability, and reliability. Technical peer review is an important tool. Testimony monitoring is also very valuable. Having a technical problem resolution process in place is key to the quality-assurance and quality-control process—if there is a mistake, what action should be taken? Proficiency testing, which should be reviewed by management and approved by the ASCLD/LAB, also can play a significant role in this product-delivery requirement.

- **Personnel qualifications.** Personnel qualifications are measured in a number of ways: certification, appropriate educational background, relevant training, and completion of competency training.

- **Physical plant requirements.** Physical plant requirements include attention to details such as controlled and limited access. This is accomplished not only through key control but also by secured entry/exit.

- **Legal process.** The legal process has a great impact on product delivery. Not all laboratories perform the same services; services vary from agency to agency and jurisdiction to jurisdiction. Statutory authority determines which services are performed. Procedural requirements include subpoenas, discovery, court orders, and the speedy-trial requirement. Expert court testimony for civil, criminal, grand jury, and petit jury comes into play in this area. Members of the forensic community also can be called on to participate in pretrial conferences.

Assessment of Casework Applications

Casework applications are divided into those considered routine and those that are nonroutine. Routine is defined as those applications provided by most crime laboratories or those that are readily available. If routine applications are not provided, it is due to either choice or necessity. Nonroutine applications are those not available in most crime laboratories and may be "one-of-a-kind" examinations. Applications considered routine include:

- Drug analysis.
- Toxicology.
- Serology/DNA.
- CODIS (Combined DNA Index System).
- Trace evidence (e.g., fiber, paint, glass, gunshot residue explosives, hair, metals, and plastics).
- Firearms (e.g., firearm identification, toolmarks, serial number restoration, and ballistic imaging database).
- Documents.
- Latents (e.g., development, identification, and AFIS).
- Photography.
- Crime scene processing.
- Image analysis.

Nonroutine applications include:

- Unusual drug cases such as "designer drugs."
- Unusual toxicology, including exotic drugs and poisons.
- Microscopic identification for nonroutine applications (e.g., unknown particles).
- Common source determination (e.g., metallurgy, oils/grease, drugs, and explosives).
- Mitochondrial DNA (e.g., hair).
- Nonhuman DNA.
- Computer forensics.
- Computer forgeries.

- Voice identification.
- Pathology specialties.
- "One-time" analyses of all types.

An important consideration for forensic scientists to keep in mind is that what is nonroutine today may well be routine tomorrow. At one time DNA analysis was considered exotic and was rarely used. Today it is a staple in the investigative process. Nonroutine applications, such as those involving trace evidence, also can turn into miniresearch projects that can help future cases.

Alternatives to Consider in Response to Today's Needs

In fashioning responses to the challenges faced in providing casework support, members of the forensic community are encouraged to consider the following:

- **Expert systems**. Expert systems would capture the collective experience and knowledge that exist within the forensic community and build on this foundation to ensure continuous growth by reducing the knowledge loss that occurs due to attrition of members.

- **Neural networks.** Neural networks would automate routine interpretation, which would provide a great enhancement to current training efforts. Neural networks would be a collection of examiner's aids that would enhance the scientist's interpretive ability, not supplant it.

- **Regionalization.** Regional specialty centers could be developed for outsourcing unique work. If a case had an exotic instrumental requirement, it could be referred to a center specializing in this service. Regional and commercial centers also could be formed for the outsourcing of routine work, such as marijuana identification. Such centers would ensure economies of scale. They also could provide services such as fully automated drug analysis and fire debris analysis.

- **National Outsource Clearinghouse.** Outsourcing must be considered as a way to cope with the backlog of work experienced by most forensic laboratories. At the same time, laboratory managers must be confident that the laboratories to which they transfer cases are able to perform credible work. A national outsource clearinghouse could assist managers as they seek to channel nonroutine case requests to appropriate solution centers. Such a clearinghouse would further aid the forensic community by establishing and monitoring routine and nonroutine analysis criteria. The development of a "Call 1–800–FORENSIC" number would ensure that laboratories throughout the Nation would have equal access to the most appropriate services. Finally, the establishment of governmentally recognized “centers of excellence” would promote the quest for excellence within the forensic community.

Department of Energy Perspective

One purpose of the workshop was to explore the kind of help national Federal laboratories can provide to State and local forensic laboratories. Representatives of the U.S. Department of Energy (DOE) attended the workshop to observe and learn how the Department, especially the Office of Research and Development, can further contribute to the forensic community to ensure the broadest support possible.

The Office of Research and Development (NN–20) comes under the Office of Nonproliferation and National Security. DOE's national laboratory system represents a technical base in a variety of areas. While there are significant opportunities to apply DOE technology strengths to law enforcement problems, there are areas in which DOE does not have experience, such as casework, how the criminal justice system works, or investigative procedures.

Major program areas of NN–20 include:

- Proliferation (Long-Range) Detection.
  - Multi-/hyperspectral imaging.
  - Chemical analysis by laser interrogation.
  - Data analysis.

- Treaty Monitoring.
  - Comprehensive test ban.
  - Fissile materials cutoff.
  - Satellite instrumentation.

- Materials Diversion/Detection/Deterrence.
  - Warhead dismantlement.
  - Special Nuclear Materials (SNM) tracking.
  - Safeguards.
  - Radiation detection.
  - Nuclear smuggling.
  - Law enforcement support.
  - Nuclear materials analysis/forensics.
  - Cooperative/remote monitoring.
  - Counterproliferation (weapons of mass destruction).
  - Broad area search and analysis.

Problems within State and local crime laboratories are diverse and vary from laboratory to laboratory and from location to location. Suggested actions to help include:

- Access to national databases to help eliminate some of the differences that currently exist among various laboratories and locations. Increased standardization should continue to be a priority.

- Because of regional differences, DOE should continue to foster local relationships between DOE laboratories and nearby State/local crime laboratories.

- The Office of Research and Development (NN–20) should serve as a "clearinghouse" or point-of-contact for research and development and technology transfer between DOE and law enforcement to ensure the broadest and most uniform coverage.

- A mechanism for technology transfer needs to be defined.

- Many current DOE programs may only require a slight shift in focus to benefit the law enforcement community. Dual-use is applicable. Opportunities exist for transferring ideas, technologies, and technical skills that have been applied in a number of areas. For example:

    - Portable Isotope Neutron Spectroscopy (PINS). PINS was developed at the Idaho National Environmental Engineering Laboratory for the interrogation of unexploded ordnance. The system, which is portable, provides a noncontact, noninvasive, nondestructive method for determining whether an artillery shell contains normal high explosives, chemical agents, or other material. The system was fielded in the Washington, D.C. area when some World War I ordnance was discovered at a construction site. It also has been deployed in Australia with some World War II munitions. This technology could be readily adapted to the interrogation of unknown packages or containers at a crime scene.

    - Team Leader. Team leader, a concept developed by Pacific Northwest National Laboratory, is a portable computer-based system providing treaty inspectors with site information coupled with global positioning system (GPS) and communication support. Team Leader automatically integrates the physical location of the inspector with map overlays of an area (visible to the inspector in a heads-up display), together with audio, visual, and other sensor information that is acquired by the inspector as he or she moves about the location. This system could have law enforcement applications for gathering and cataloging evidence at a large crime scene or for guiding a raid on a complex facility.

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Glossary

Note: Most glossary definitions are taken from *Criminalistics, An Introduction to Forensic Science (Sixth Edition)*, by Richard Saferstein, and from the American Society of Crime Laboratory Directors/Laboratory Accreditation Board glossary.

Black Powder	Normally, a mixture of potassium nitrate, carbon, and sulfur in the ratio of 75:15:10.
Blind Sample	A proficiency test sample for which the analyst is unaware of the test nature of the sample at the time of analysis.
Chemical Property	Describes the behavior of a substance when it reacts or combines with another substance.
Class Characteristics	Properties of evidence that can only be associated with a group and never with a single source.
Combustion	The rapid combination of oxygen with another substance accompanied by the production of noticeable heat and light.
Controlled Substances (functional area)	The identification of controlled drug substances either in pure, legal, or illicit dosage forms. (Analysis for alcohol in blood, breath, or urine may be included in this functional area if it is the only toxicological analysis performed by the laboratory.)
Controls	Tests performed in parallel with experimental samples and designed to demonstrate that a procedure worked correctly.
Crime/Forensic Laboratory	A laboratory (with at least one full-time scientist) that examines physical evidence in criminal matters and provides opinion testimony with respect to such physical evidence in a court of law.
Crime Scene Response and Related Activities	Anything dealing with evidence collection and crime scene analysis.
Critical Reagent	Reagents such as commercial supplies and kits that have an expiration date. *See* reagent.
Database	A collection of related information about a subject organized in a useful manner that provides a base or foundation for procedures such as retrieving information, drawing conclusions, and making decisions.

Deflagration	A very rapid oxidation reaction accompanied by the generation of a low-intensity pressure wave that can have a disruptive effect on the surroundings.
Detonating Cord	A cordlike explosive containing a core of high-explosive material, usually PETN. Also called primacord.
Detonation	An extremely rapid oxidation reaction accompanied by a violent disruptive effect and an intense, high-speed shock wave.
Digital Imaging	A process through which a picture is converted into a series of square electronic dots known as pixels. Manipulation of the picture is accomplished through computer software that changes the numerical value of each pixel.
Discipline	*See* functional area.
DNA (functional area)	The identification and comparison of deoxyribonucleic acid (DNA) detected in “known” and “questioned” biological samples.
Endothermic Reaction	A chemical transformation in which heat energy is absorbed from the surroundings.
Exemplar	*See* “known” standard.
Exothermic Reaction	A chemical transformation in which heat energy is liberated.
Explosion	A chemical or mechanical action resulting in the rapid expansion of gases.
External Proficiency Testing Program	Test program whose management and/or control is outside the laboratory system.
Firearms/Toolmarks (functional area)	Examination and comparison of evidence resulting from discharge and/or use of firearms; comparison of marks made by various tools.
Flash Point	The minimum temperature at which a liquid fuel will produce enough vapor to burn.
Functional Area	A major area of casework for which a laboratory may seek accreditation.

Glowing Combustion	Burning at the fuel air interface. Examples are a red-hot charcoal or a burning cigarette.
Heat of Combustion	The heat evolved when a substance is burned in oxygen.
High Explosive	Explosive with a velocity of detonation greater than 1, meters per second. For example, dynamite and RDX.
Hydrocarbon	Any compound consisting only of carbon and hydrogen.
Ignition Temperature	The minimum temperature at which a fuel will spontaneously ignite.
Individual Characteristics	Properties of evidence that can be attributed to a common source with an extremely high degree of certainty.
Internal Proficiency Testing Program	Proficiency testing program whose management and control is within the laboratory.
Known Sample Technique	A quality-assurance procedure in which a previously identified substance is submitted to a laboratory for examination to determine the reliability of the laboratory's procedures.
Known Standard	A specimen of an identified source acquired for the purpose of comparison with an evidence sample; synonymous with exemplar.
Latent Fingerprint	A fingerprint made by the deposit of oils and/or perspiration. It is invisible to the naked eye.
Latent Prints (functional area)	Comparison of latent print impressions regardless of method of development.
Low Explosive	Explosive with a velocity of detonation less than 1000 meters per second. For example, black powder and smokeless powder.
Method	The course of action or technique followed on conducting a specific analysis or comparison leading to an analytical result.
Open Proficiency Testing Program	A quality-assurance program where the examiner is aware that the sample is a test.

Oxidation	The combination of oxygen with other substances to produce new products.
Oxidizing Agent	A substance that supplies oxygen to a chemical reaction.
Peer	An individual having expertise in a specific functional area gained through documented training and expertise.
Peer Review	The review of casework for technical correctness by a peer. *See* technical review.
Physical Evidence	Any object that can establish that a crime has been committed or can provide a link between a crime and its victim or between a crime and its perpetrator.
Plastic Fingerprint	A fingerprint impressed in a soft surface.
Polymerase Chain Reaction (PCR)	A technique for replicating or copying a portion of a DNA strand outside a living cell. This technique leads to millions of copies of the DNA strand.
Polymorphism	The existence of more than one form of a genetic trait.
Practical Training	Hands-on training in a forensic method in which participants apply methods and perform analysis.
Procedure	The manner in which an operation is performed; a set of directions for performing an examination or analysis; the actual parameters of the methods employed.
Proficiency Tests	Tests to evaluate the competence of analysts and the quality performance of a laboratory; in open tests, the analysts are aware that they are being tested; in blind tests, they are not aware. Internal proficiency tests are conducted by the laboratory itself; external proficiency tests are conducted by an agency independent of the laboratory being tested.
Protocol	A directive listing the procedures to be followed in performing a particular laboratory examination or operation; the overall plan for analysis of a particular type of evidence.
Pyrolysis	The decomposition of organic matter by heat.

Quality Assurance	Those planned and systematic actions necessary to provide sufficient confidence that a laboratory's product or service will satisfy given requirements for quality.
Quality Audit	A management tool used to evaluate and confirm activities related to quality. Its primary purpose is to verify compliance with the operational requirements of the quality system.
Quality Control	Internal activities or activities according to externally established standards used to monitor the quality of analytical data and to ensure that it satisfies specified criteria.
Quality Manager	An individual (however named) designated by top management who has the defined authority and obligation to ensure that the requirements of the quality system are implemented and maintained.
Quality Manual	A document stating the quality policy and describing the various elements of the quality system and quality practices of an organization. It will also reference and note the location of additional material relating to a laboratory's quality arrangement.
Quality System	The organization structure, responsibilities, procedures, processes, and resources for implementing quality management. Includes all activities that contribute to quality, directly or indirectly.
Questioned Documents (functional area)	Examination of any type of printed, typed, or written material for the purpose of identifying the source, determining alterations, or determining other means of gaining information about the item or the circumstances surrounding its production.
Questioned Sample	An evidence sample to be examined for the purpose of comparison or identification.
Reagent	A substance used because of its chemical or biological activity.
Reexamination Technique	A quality-assurance technique whereby a previously examined sample is reexamined by a different person.
Reference Standard	A sample acquired or prepared that has known properties (e.g., concentration, chemical composition) for the purpose of calibrating equipment and for use as a control in experiments.

Reliability	Possessing the quality of being dependable. May refer to personnel, materials, or equipment.
Restriction Fragment Length Polymorphisms (RFLP)	Different fragment lengths of base pairs that result from cutting a DNA molecule with restriction enzymes.
Ridge Characteristics	Ridge endings, bifurcations, enclosures, and other ridge details, which must match in two fingerprints in order for their common origin to be established. Also called minutiae.
Serology (functional area)	The identification and/or comparison of genetic markers in body fluids (or stains) with those from "known" and/or "questioned" samples.
Smokeless Powder (double base)	An explosive consisting of a mixture of nitrocelluose and nitroglycerin.
Smokeless Powder (single base)	An explosive consisting of nitrocellulose.
Spontaneous Combustion	A fire caused by a natural heat-producing process in the presence of sufficient air and fuel.
Sublimation	A physical change from the solid directly into the gaseous state.
Technical Review	Review of bench notes, data, and other documents that form the basis for scientific conclusions. *See* peer review.
Theoretical Training	Conceptual or abstract, such as training in school classes.
Toolmarks Examination (functional area)	*See* firearms/toolmarks.
Toxicology (functional area)	Analysis of biological samples for the presence of drugs and other potentially toxic materials.
Trace Evidence (functional area)	Any analytical procedure utilizing either chemical or instrumental techniques not specifically covered in other functional areas, including, but not limited to, fire debris, paint, glass, hair, fibers, and other varieties of trace evidence.

Validation	The process of performing a set of experiments that establish the efficacy and reliability of a technique or procedure or modification thereof.