STATE-OF-THE-ART RESEARCH IS THE FUTURE OF FIRE INVESTIGATION

by

Daniel Madrzykowski
Building and Fire Research Laboratory
National Institute of Standards and Technology
Gaithersburg, MD 20899, USA

Reprinted from SIU Awareness, Vol. 15, No. 1, 18-23, March 2001.

1901-2001
NIST CENTENNIAL.

NIST
National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

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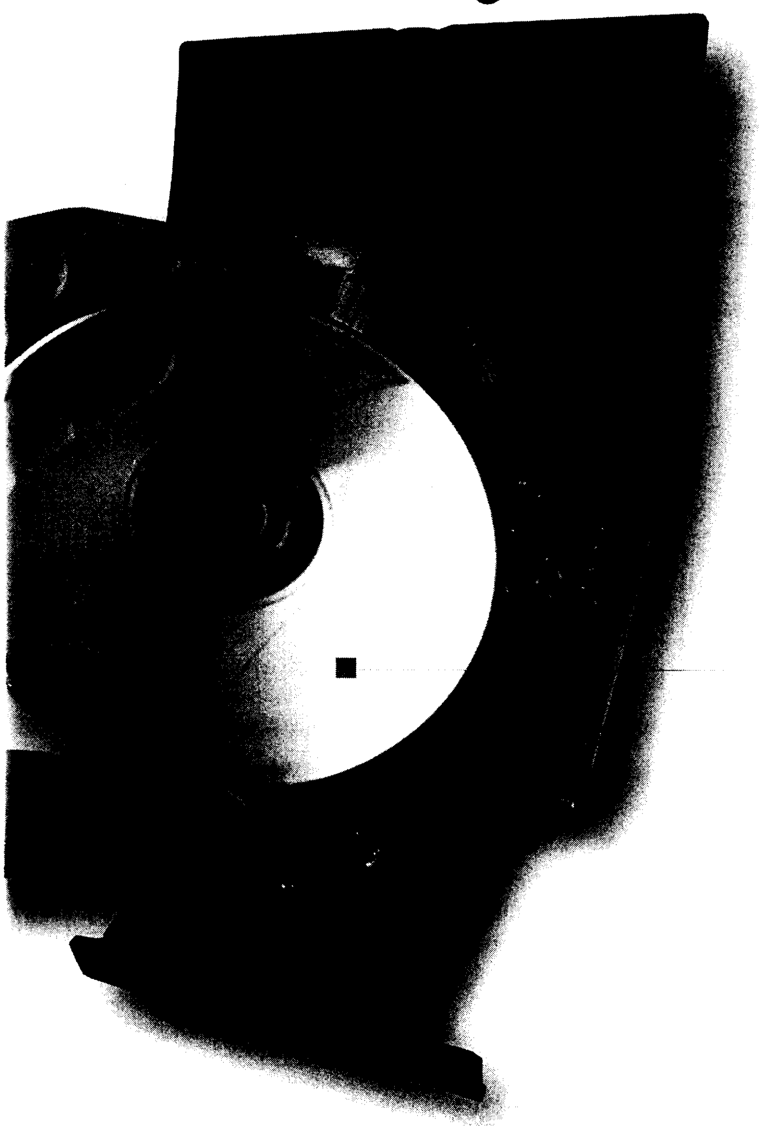

As the legal climate for arson and fire investigations becomes more demanding, the need for a rigorous scientific foundation is growing. Fortunately, federal research efforts are already starting to close the gap.

Imagine arriving at a fire scene. You examine the area, working your way to the room of **origin.** As you survey the burned-out room, something doesn't add up. The heavy burn pattern on the wall and the ceiling is remote from the apparent spill pattern on the floor.

After taking digital images of the room and loading them into your strap-on portable computer, you "stitch', the separate images together to form a virtual fire room. Assigning a reference dimension to your image allows the computer to develop an input file for a mathematical fire simulation. You continue to refine your digital image, defining surfaces so that the computer model attaches values, such as ignition temperature or heat release rate per unit area, to each.

Next, identify the doorways, hvac vents and windows to complete the geometry of the model. Trace the demarcation lines of thermal damage on the image. Finally, define an ignition source; place the ignition fire and press the submit button.

The satellite modem sends your input fire to a remote computing site and the model is analyzed. A series of potential solutions to your problem is downloaded to your portable computer for you to watch. The fire simulations help you visualize what may have happened, which may lead to a "best fit" scenario or guide you in continuing your investigation. Sounds far fetched? Even impossible?

Research is currently under way that could deliver this type of technology within the decade. Researchers at the National Institute of Standards and Technology's (NIST) Building and Fire Research Laboratory (BFRL) are working with the U.S. Fire Administration (USFA); the Bureau of Alcohol, Tobacco and Firearms (ATF); and the U.S. Department of Justice to provide a more scientific basis for the investigation of fire. This article will provide an overview of where the state of the art research is and where it may lead us.

Science vs. arson

Arson is one of the top causes of fires and fire deaths in the United States, causing annual direct dollar losses of approximately **$3.6** billion, according to the USFA. Ongoing arson investigation and prosecution will obviously play a crucial role in reducing that figure.

It has been said that fire investigators will have to work differently if their expert testimony is to be admissible in court (See "Arson, scientific evidence and the Daubert case," August 1998, and "The experts' new clothes: Arson 'science' after Kumho Tire,', July 1999, www.firechief.com). Because of the *Daubert* and *Kumho* Tire decisions, expert testimony must be technically defensible.

In other words, if something can't be proved based on scientific principles or recreated in an experiment, then it might not be admissible as evidence in court. When this is coupled with the National Fire Protection Association's (NFPA) estimate that only **two** percent of set fires lead to conviction, it's obvious why the fire investigation community is looking to improve its capabilities by building a better scientific foundation for fire investigation.

Knowledge built on technically defensible data is only one part of what's needed to successfully investigate a fire scene. **A** well-trained and well-equipped investigator is critical to the process. To that end, efforts have also been undertaken to provide high-quality fire investigation training to a wide audience. In addition, field-testing is being conducted to develop cutting edge hardware for investigators.

Computer-based training

As previously featured in the September issue of *SIU Awareness,* a standardized, state-of-the-art fire investigation training package was the goal of the public-private partnership that developed interFIRE VR. The ATF spearheaded the partnership that included the USFA, the NFPA and American Re-Insurance Co. Experts from the International Association of Arson Investigators, NIST, **and** the law firm of Butler, Burnette and Pappas also contributed to developing the material for the training package.

InterFIRE VR is a CD-ROM–based interactive training program that was developed using the latest in PC-based virtual reality technology to present lessons of best practices in fire investigation.

The program has three work sections, which include a series of video clip – based tutorials, a reference file and the "scenario."

By Daniel Madrzykowski, p.e.,

Fire Safety and Engineering Division Building and Fire Research Laboratory, National Institute of Standards and Technology Gaithersburg, Md.

Originally published in *Fire Chief* magazine

Arson intervention and mitigation strategy

A joint project of the USFA and the Tennessee Valley Authority Police (see Reference 2), Arson Intervention and Mitigation Strategy (AIMS) is intended to enhance fire investigation by:

- Standardtzing the process of scene documentation,
- Increasing the communications and data transfer capability of investigators at the scene, and
- Providing electronic references and computer fire modeling capability to investigators.

The program supports field investigators' need to collect, record and document information or images to simplify case information management. The system also enables rapid data exchange to allow for on-scene interaction with personnel remote from the fire site.

The hardware and software core of the AIMS project is called the Transportable Rapid Information Package (TRIP). The hardware consists of a laptop computer that's integrated with a GPS receiver, color printer, document scanner, evidence label printer, digital cameras (still and video), cell phone and wireless networlung.

TRIP can be used to process and dtstribute information, data and images from the fire scene; to retrieve information from the National Fire Incident Repository System (NFIRS) and FBI Uniform Crime Incident Reports; or provide remote access to reference materials or to fire libraries such as the Fire Research Information Service at NIST.

TRIP's functional capabilities are summarized in Table 1, and the technological improvements to the fire investigation and case information management are summarized in Table 2.

Fire investigation research

While the training and applied efforts listed above can increase investigators' slulls and enhance their field capabilities, the field of fire investigation has another underlying weakness: the lack of a comprehensive body of data or knowledge to which fire investigators can refer. Needs in this area include an appropriate understanding of fire dynamics, real-world ignition thresholds, the effects of ignition sources, heat-release rate and flame-spread data for a wide variety of commercial products and material assemblies, and the generation of fire patterns, to name a few.

A limited amount of work has been started by a variety of federal agencies to address the fire investigation community's research needs. Summaries of these research programs include:

USFA burn pattern tests

In conjunction with NIST, the USFA conducted a series of full-scale fire experiments to study the development of fire patterns (See Reference 3). The experiments were conducted in rooms built in a laboratory, as well as in rooms in residential structures, using different fuel loads during the course of the study. A committee of fire investigators designed the experiments, and a team of seasoned fire investigators conducted the post-fire analysis.

Many patterns were produced and documented during the course of the experiments. The report showed that fire patterns are influenced by a variety of variables, two of which have a major influence on the resulting fire patterns: ventilation and flashover. The results from this report have provided the direction for further fire pattern study.

NIJ full-scale room burn pattern study

Under the sponsorship of the National Institute of Justice (NIJ), the BFRL, and the Office of Law Enforcement Standards at NIST conducted a series of experiments with the University of Maryland, Maryland Fire & Rescue Institute (See Reference 4). These experiments focused on a single-room configuration with a similar set of furnishings in each experiment.

TABLE I — TRIP Functional Capabilities

Basic virtual office unit	Laptop with color scanner, printer and Microsoft professional office software tools
Fire reports	Field data collection of information needed for NFIRS, NIBRS and fire modeling
Interviews	Written field witness interviews using prompted questions
Evidence collection	Photography by digital and video cameras, printing of evidence labels
Fire scene diagramming	Computer-assisted drafting of building floor plans and fire scene
Mapping and GPS	Plotting the fire scene location on a digital map using GPS
CD-ROM library	Retrieval of fire reports, NFPA fire codes, and NFIRS data profiles and NIST Models
Network conferencing	Wireless network with other TRIP units with video desktop conferencing
Telecommunications	Cellular and pager communications, faxing of reports from scene

TABLE II — Technological Assesment Matrix

MAJORGOALS	CURRENT PRACTICES	CURRENT CHALLENGES	TRIP PHASE I SOLUTIONS
Case Management	[illegible]	[illegible]	[illegible]
Incident Reporting Systems	Complete separate NFIRS and NIBRS forms	Reduce reporting duplication	Collect data, print NFIRS and NIBRS reports
Fire Investigation Unit Management	Cases assigned and closed as needed	Develop case solvability scoring	Incorporate case solvability factors
Litigation and Prospective Support	Cases based on written files	Automate case files	Case-based data search and retrieval
Investigative Efficiency and Productivity	Case assignments by call-out	Measure efficiency	Tri-motion studies

Four experiments were conducted. Two replicate experiments were ignited with a small flame on upholstered chair. (In replicate experiments, identical scenarios are run more than once to demonstrate the repeatability of the results). The other two experiments used a 0.95-liter (1-quart) spill of gasoline on the floor of the room as the first item ignited.

In both of the first two experiments (un-accelerated ignition), flashover occurred at approximately 5 minutes, 40 seconds. The experiments that used gasoline ignition reached flashover at approximately 1 minute, 15 seconds. In all of the experiments, fire suppression was started approximately 3 minutes after flashover began.

The temperature and heat flux times were measured for each experiment and are provided in the report. In two of the experiments, oxygen, carbon dioxide and carbon monoxide were also measured. In addition, the rooms and furnishings were studied and photographed after each experiment. Comparisons between the replicate experiments yielded many similarities in the data, the burn patterns and the condition of articles in the burn rooms, such as "pulled" light bulbs. (The evidence suggests that light bulbs pull in the direction of the greatest heat, but not necessarily toward the fire's origin).

Unfortunately for investigators, the replicate experiments also produced some significant differences in the severity of burning, locations of patterns and types of patterns present. For example, with the exception of the burn patterns on the wall above the upholstered chair, the walls yielded significantly different patterns. Fire patterns, therefore, may not be such reliable indicators, as many fire investigators believe.

As in the USFA research, ventilation seems to be the prime cause of the difference in fire behavior within the rooms that led to the different burn patterns. Based on the results of these studies, further research has been started to decouple the phenomena that occur in full-scale room fires and gain a better understanding of fire pattern development.

Liquid fuel spill/burn pattern study

NIST has conducted a study examining gasohe spills and the burn patterns caused by them (See Reference 5). The NIJ sponsored the first phase of the study, which measured the physical size of the spill relative to the amount of gasoline spdled.

Several floor coverings were used in the experiments: vinyl tiles, wood parquet, dense-loop polyolefin carpeting and cut-pile nylon carpeting. The floors had no walls around them, to eliminate compartmentation effects, and were positioned under a smoke hood instrumented to measure the heat release rate. After the initial spill pattern measurements were made, the spills were ignited. The resulting burn patterns were measured and heat release rates were determined.

The results from this report provide fire investigators with a means to predict the quantity of spdled gasoline needed to produce a burn pattern of a given size on a number of common flooring materials. Heat release rate data for each experiment is provided for use in fire model calculations.

In each of the carpeted floor experiments, a "doughnut" pattern remained where quantities of gasoline were present. This phenomenon, which results from the liquid accelerant actually insulating and cooling the carpet, is consistent with the experience of many fire investigators.

Additional Liquid burn pattern experiments are being planned in buildings of opportunity. The experiments conducted at NIST will be repeated in rooms to examine the effects of the compartment and then the additional effects on the floor pattern of furnishings in the room. These experiments, sponsored by NIJ and USFA, are scheduled for completion later this year.

"Fire" in a computer

Fire investigators have used computer fire models for many years. Typically, these have been simple numerical correlations or "zone models," such as ASET-B, FPETOOL or FAST. These

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models can be used to calculate a characteristic temperature for the hot gas layer in a room and define the position of the hot gas layer height.

Recently, NIST has developed and issued a new model called the Fire Dynamics Simulator (FDS), that's based on computational fluid dynamics (CFD). **A** CFD model requires that the room or building of interest be divided into small rectangular control volumes or computational cells.

The model then computes the density, velocity, temperature, pressure and species concentration of gas in each cell (based on the conservation laws of mass, momentum, energy and species) to model the movement of fire gases. FDS uses the material properties of the furnishings; walls, floors and ceilings to simulate fire growth and spread. **A** complete description of the FDS model can be found in Reference 6.

A second program, called Smokeview, is a scientific visualization program that was developed to display the results of an FDS model simulation. Results can be displayed as snapshots or as two or three-dimensional animations (See Reference *7).*

The Fire Safety Engineering Division at NIST recently used these programs to assist the District of Columbia Fire and Emergency Medical Services Department in examining the fire dynamics of **an** incident that claimed the lives of two firefighters and burned other firefighters (See Reference **8).** The FDS model was developed using the building geometry, material thermal properties and an approximate timeline of the fire department actions.

The model outputs were checked against physical damage from the fire scene and information from the department's Reconstruction Committee. The committee then used the model to examine the best representation of the fire as it occurred, as well as a fire simulation with different ventilation.

While the use of this technology is just beginning, with further research and validation FDS and Smokeview may be able to recreate fire patterns, thus providing the investigator with valuable information on the development and spread of the fire in question. Work is ongoing to take the use of the models in this direction. The simulations also have the potential to be used as training tools to demonstrate a fire's dynamic effects.

The federal government has begun to increase the amount of fire research aimed at fire investigation by funding the creation of the **ATF** Fire Research Laboratory in **Beltsville,** Md. While the laboratory won't be completed until 2002, some of the ATF laboratory staff are already in place and working with BFRL staff at NIST under a cooperative agreement. **As** you can see, a number of research efforts in fire investigation are moving forward, and the tools that fire investigators have to do their job are increasing. Perhaps the scenario that was presented in the opening paragraphs isn't as far away as we might **think.**

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Available from Publications Center, USFA, 16825 S. Seton Ave., Emmitsburg, Md. 21727, 800-561-3356, or visit their Web site at **www.usfa.fema.gov/usfapubs.**

All other publications available from NIST, 100 Bureau Drive, MS 8641, Gaithersburg, Md. 20899, or visit their Web site at www.fire.nist.gov, or contact madrzy@nist.gov. ■

Dan Madrzykowski is the leader of the Large Fire Research Group at the National Institute of Standards and Technology, Gaithersburg, Md. He is involved with research in the areas of fire investigation, firefighter protective clothing and equipment, sprinkler systems, and fire suppression agents such as Class A foams and gelled water. Madrzykowski is a member of the International Association of Arson Investigators, serves on several NFPA technical committees and chairs the Society of Fire Protection Engineers' task group on computer model evaluation. He earned his master's in fire protection engineering from the University of Maryland.