Chapter 3 – Research and Data Collection in the Fire Service

"**Those who cannot remember the past are condemned to repeat it."**

George Santayana

Initiative 7 of the 16 Firefighter Life Safety Initiatives concerns data collection. This Initiative was included because far too often decisions in the fire service are made on suppositions, inferences drawn from personal experience, or hunches. The notion of a national research agenda reflects a growing professionalism in the fire service that members must apply their limited resources toward real and solvable problems. Research and data collection will go hand in hand as the national fire service research agenda is realized.

Although the idea of developing research agendas and designing data collection systems seems daunting, much of the work has already been done. Everyday, fire departments are able to access information about their local regions in order to made decisions about a myriad of important issues concerning training, equipment purchases, and, increasingly, firefighter health and wellness. It is relatively easy, for example, to find details on the local fire problem because information can be accessed from state and local databases. Easy, that is, if local fire departments have collected and reported data from their departments. Unlike almost anything else in the fire service, research and data are codependent partners with each and every 31,000 or more fire departments in the United States.

Research that has a direct impact on the fire service comes from a wide range of disciplines – engineering, kinesiology, medicine, the military, and many others. The data for the research is also collected from a variety of sources. These sources range from scientists studying chemical properties with the ultimate goal of improving the ignition resistance of materials (basic research), to engineers developing new fire safety systems for buildings (applied research), to firefighters recording the details of their last fire call into a database (data collection). Each of these tasks is very different, but as you will learn in this chapter, the scientist, engineer, and firefighter are dependent on each other making improvements to fire safety in the built environment.

The Need for Research in the Fire Service

Technology is constantly changing the world around us and how we work and live. This is true for the fire service as well. For example, the construction techniques and materials used to build a house over the past 50 years have changed. Engineered wood products have enabled long spans and open areas for improved use of living space in houses. In order to increase the energy efficiency of houses, insulation has improved, walls are wrapped in plastic to limit incursion of water and multi-pane windows are now the norm.

Figure 1. Modern houses use plastic sealing wrap to exclude water and multi-pane windows to improve energy efficiency.

The objects and materials inside our homes have changed as well. The information age has bought additional electronic appliances into homes and offices. Larger televisions, personal computers, cell phones, cameras, video games and battery chargers are in most homes.

The design and construction of furnishings has changed dramatically in the past fifty years. In the 1950's a wide range of synthetic materials called polymers became available for use in clothing, furniture, interior finish and insulation. Within a few years of their commercial introduction, the use of polyester, nylon, and polyurethane foam became common place in homes, vehicles and industry. Durability, comfort, and economics all play a role in the design and manufacturer of furnishings that people choose to buy. Today, flexible polyurethane foam is one of the most common materials used in upholstered furniture.

Starting in the 1960's new materials, such as aramid fibers (Nomex® and Kevlar®) and polybenzimidazole (PBI), were introduced that did not melt and had a high resistance to ignition. These materials are now in common use as part of fire fighters' protective clothing and equipment.

The use of self-contained breathing apparatus (SCBA) has improved conditions for fire fighters. The continued development of SCBAs with lighter materials, increased air supply, electronic monitoring and warning devices also have made working in a smoke filled building safer. Continued developments in the fields of electronics and sensing

have produced improvements in situational awareness for fire fighters in the form of thermal imaging and fire fighter tracking and accountability systems.

Figure 3.2 Testing the operational range of a thermal imaging camera.

All of these new materials, improvements in energy efficiency, and new construction methods have led to changes in the fire environment that a fire fighter will face. New materials and advances in technology are also able to offer improved protection to the fire fighter from thermal hazards and toxic gases. As the technologies mature and the costs are reduced, the fire fighter of the future may have lighter gear which affords superior safety and built in electronic systems which provide improved communications, thermal imaging/video and tracking capabilities.

Another consideration is the public service environment that you live and work in. We live in a data driven society. If there are to be increases made to department budgets, if there are changes to be made to a building code, if there improvements required in fire fighting protective equipment, then data is required to support the need for change. Without the data to support the need for more apparatus, or the need for improved fire code requirements, or the need to improve the design of life safety systems, the ability to change the status quo is reduced.

Data Collection in the Fire Service

In order to develop a solution to the fire problem, the problem must be understood. The basis of defining the fire problem in the United States is data collected by fire departments across the country. In the introduction to this chapter, it was discussed how global changes in technology, economics and standards of living have both positive and potentially negative impacts on the fire service. However, when an emergency occurs, it is the local fire department that is counted on to respond and improve the situation. This is also true relative to fire incident data collection. The data entered in to the National Fire Incident Reporting System by local fire departments provides the foundation for fire incident analysis and studies conducted by federal and state agencies as well as industry.

So what does a data snapshot of the fire problem in the United States look like? As an example of a typical question; how many fires do fire departments respond to everyday? According to the United States Fire Administration, fire departments respond to 4,250 fires on average every day. Further examination of the data shows that there are 11 civilian fatalities, 49 civilian injuries, and 200 firefighter injuries everyday. On average, one fire fighter dies on duty every three days.

National Fire Incident Reporting System (NFIRS)

The NFIRS system was established in 1976 by the National Fire Data Center of the United States Fire Administration. The goal of the system is to collect data relevant to the cause of the fire, damage caused by the fire (both to people and property), type of structure, fire protection system response and fire department response. In other words, the fire department reports provide answers to the questions of who, what, where, when and how for each fire they respond to. NFIRS also has a specific form to report details of a fire service casualty including the type of protective equipment used and a description of any damage. These reports are collected by the state and then forwarded to the U.S. Fire Administration where the results are compiled and analyzed.

The data from U.S. Fire Administration is published in *Fire in the United States*, which is available for download from http://www.usfa.dhs.gov/downloads/pdf/publications/fa_325.pdf Everyone in the fire service should read these reports because they are truly a picture of how this nation is doing in terms of the broad fire issue. The analyses in these reports can then provide fire statistics to identify the day of the week that is most prone to a fire incident, or the time of day, or the room of fire origin and the first item ignited by a fire. These statistics are used by public and private sector organizations to develop fire prevention programs or standards (for example, the National Fire Protection Association®), fire research programs, product recalls, and insurance related data.

Currently, over 21,000 fire departments from all 50 states and the District of Columbia provide data to NFIRS. As a result, NFIRS is the world's largest, national, annual

database of fire incident information. This is a great testament to this federal, state and local voluntary partnership.

United States Fire Administration

The United States Fire Administration (USFA) is part of Federal Emergency Management Agency (FEMA), which is in the United States Department of Homeland Security (DHS). Part of USFA's mission is to collect fire data and develop analyses with the data to prioritize fire issues, to prioritize the needs of the fire service and to quantify the costs of the fire problem in the United States. NFIRS is managed by the USFA National Fire Data Center. This group generates the fire statistics for the United States and develops analyses with the data to highlight specific fire problems, the nature of the problems, and offers potential solutions based on the data trends. The studies can be downloaded from http://www.usfa.dhs.gov/statistics/ .

The data is also used to compare the fire problem in the United States with that in other countries to examine how the United States might improve. The figure below demonstrates that since 1980 the death rate due to fire in the United State had decreased from more than 35 people per million to less than 20 people per million. However our death rate due to fire is still higher than many other nations.

Executive Fire Officer Program (sidebar)

The United States Fire Administration, National Fire Academy Executive Fire Officer Program (EFOP) is a great way to conduct a research project to support the National Research Agenda and aid not only your fire department but potentially help fire departments across the country. Two of the objectives of the program are to provide senior fire officers with the tools to 1) become a proactive leader and 2) to understand the value of research and its application to the fire service. It is a four year program based on a series of courses two weeks in length. Participants must also complete several Applied Research Projects and a final research project in order to successfully complete the program. Projects which have earned the National Fire Academy Executive Fire Officer Program Outstanding Research Award can be reviewed and downloaded from http://www.usfa.dhs.gov/nfa/efop/applied_research/awards.shtm.

National Fire Protection Association®

The National Fire Protection Association® (NFPA®) is an independent, non-profit, voluntary-membership organization with the mission of reducing "the worldwide burden of fire and other hazards on the quality of life by providing and advocating scientifically based consensus codes and standards, research, training and education." The NFPA® has been operating since 1896. It's Fire Analysis and Research Division also collects data on fire incidents across the United States and produces studies and annual reports to examine specific fire issues.

This information is used to support the work of the NFPA® Technical Committees which are charged with developing a wide variety of codes and standards including those for fire fighter protective clothing and equipment. In addition to collaborating with USFA and using the NFIRS data, the NFPA® conducts an annual survey of approximately 3,000 fire departments across the country to develop estimates of the number of fires that public fire departments responded to, as well as the life and property losses that occurred during those fires. The results from the NFPA® studies can be accessed at http://www.nfpa.org/ under the Research Section.

Insurance Industry

As you might expect there are a wide array of entities in the insurance industry which collect and use fire incident data. Individual companies collect data on fire incidents which occur on properties that they insure. In some cases the insurance company may commit significant resources over and above what the local authorities provide to determine the cause of a fire as this may lead to subrogation against a product manufacturer or a service company that had performed work on the structure. Detailed information on the cause of a fire may also be supplied to the CPSC.

There are also organizations such as the American Association of Insurance Services which uses data to develop loss-cost rating analyses for more than 600 property and casualty insurers. Another provider of data and risk management information to insurance companies is the Insurance Services Office (ISO). ISO has two programs that they offer to insurance companies to help them assess the fire risk in a community.

Public Protection Classification Program ™ (PPC™) - Under this program ISO collects data on public fire departments regarding their communications and dispatch systems, physical resources, staffing, training and water supply. ISO then analyzes the data using their Fire Suppression Rating Schedule (FSRS). Based on the analysis, a Public Protection Classification rating is assigned. The ratings range from 1 to 10, with 1 being the best. The results of this evaluation can be used by the community to assess the resources that they are allocating to the fire service and determine if they are making appropriate choices. The results are also used by some insurance companies to determine the fire insurance premiums for the community. The better ISO ratings result in lower fire insurance premiums. ISO has collected data on more than 44,000 fire-response jurisdictions.

Building Code Effectiveness Grading Schedule ® (BCEGS®). Similar to the fire department evaluation, ISO examines the building codes that a community adopts and how the codes are enforced. Again the grading system goes from 1 to 10 with 1 meaning "exemplary commitment to building code enforcement." These results are then used by some insurance companies to determine insurance premiums especially with regard to natural disasters.

Some insurance companies focus solely on specialty areas such as industrial risk and therefore collect data relevant to factory, refinery or warehouse fires. Based on data collected from industrial fire incidents the insurance companies will conduct research to examine means of mitigating a specific hazard and advise their clients accordingly.

The Role of Local Fire Departments in Data Collection

Where does this data come from? It starts with fire officers across the country entering data after a fire call. This is one of the most critical steps in fire data collection. This is where someone who actually saw the fire and its results documents the incident. The fire incident data is typically entered into the National Fire Incident Reporting System (NFIRS). Once the NFIRS report is completed it is sent to the appropriate state agency and then forwarded to the U.S. Fire Administration. After further investigation, other reports may be filed to provide additional information. For example, if an appliance was identified as the cause of a fire and/or an injury or fatality, the fire department may also file a report with the United States Consumer Product Safety Commission (CPSC).

The data submitted by the local fire department forms the basis of fire related analysis and fire related decisions by both public and private sector organizations. The quality of the original data is critical to its usefulness. Therefore it is recommended that fire departments employ data quality procedures to ensure that the correct data is entered for their fire incidents.

In addition to the national impact of the data your department collects, the data can be used locally as well. For example, your department can examine types of fires and portions of your response area with a high incidence of fire to focus your prevention efforts and public outreach. Your department can also compare your local data to the national averages. Categories such as response time or number of firefighter injuries may be used to support the case for improved resources in your department or a means to identify equipment and training needs.

Research and Investigation for the Fire Service

In the United States, there are many Federal Agencies that work together with the fire service and private industry to generate research data to develop standards, codes, and guidelines aimed at improving fire safety. As you will see in the following section, some of the research data is collected from investigations of fire incidents, while other data is collected from experiments and tests conducted in laboratories. The one constant across all of the research organizations is that their research priorities are driven by the availability of reliable fire incident data.

Another constant is the need for research funding. One of the key federal organizations in providing funding for fire service research is the U.S. Department of Homeland Security (DHS). DHS has several components which provide support to many of the

organizations listed below. For example the Directorate for Science and Technology is funding research on fire fighter locator system technology and the next generation of self contained breathing apparatus. Descriptions of the work done by the Directorate can be found at: http://www.firstresponder.gov.

Another example is the Assistance to Firefighters Grant Program within the DHS Federal Emergency Management Agency (FEMA). This program may be most widely known for grants that are used to provide equipment to fire departments to improve their capability to protect the public and themselves. This program also provides Fire Prevention and Safety Grants a portion of which are focused on Firefighter Safety Research and Develop projects. As you read though this section you will notice that they have been involved in the sponsorship of a significant amount of recent and current fire service research.

The United States Fire Administration (USFA) is another key DHS component that provides the leadership on many fire service issues. In addition to the critical data collection and analysis functions listed in the previous section, USFA has supported a significant body of fire service research and technology transfer, working with fire service organizations, industry and other federal agencies. As you read through the broad spectrum of research laboratories listed below, you will notice that in a larger number of cases USFA was a co-sponsor of the research. However any projects listed just represents a small fraction of what USFA has accomplished for the fire service in the past 30 years. Access to USFA reports, National Fire Academy Classes and other information can be found at http://www.usfa.dhs.gov/.

Consumer Products Safety Commission (CPSC)

CPSC is an independent Federal Regulatory Agency, which was created by Congress in 1972, to protect the public against unreasonable risks of injuries associated with consumer products. CPSC works toward their goal by developing voluntary standards in conjunction with industry groups to issue and enforce mandatory standards, recall products, alert the general public about recalls and hazards thorough numerous types of media sources and conduct research on potential hazards.

None of this would be possible without the information (data) collection systems that CPSC has in place to identify hazards. CPSC collects data on consumer product-related injuries and deaths, as well as economic and hazard exposure information. They also investigate specific cases to gain additional knowledge about injuries or hazards and how the reported product was involved.

CPSC collects the data thorough a variety of mechanisms including: the National Electronic Injury Surveillance System (NEISS), review of death certificates, news reports, legal filings, fire department reports and input from the public. As an example of how this works we will briefly examine the NEISS. It is a network of approximately 100 hospital emergency rooms across the county. The emergency rooms fill out a report on all consumer product related injuries and, as part of a collaboration with the Centers for

Disease for Control (CDC), all trauma related injuries and submit it to CPSC. In some cases, the reports are submitted within 24 hours of the injury. Approximately 360,000 consumer product related injuries are documented with this system each year.

CPSC staff review the data in order to identify emerging trends or specific products that may be the cause of the injuries. This can result in follow-up field inspections, investigations or testing of the product in question in the CPSC's laboratories in order to collect more data on a particular incident.

In the event that a cause is identified, then the CPSC uses a variety of media to inform the public of the hazard. These include local and national media coverage, publication of numerous booklets and product alerts, a web site, a telephone Hotline, the National Injury Information Clearinghouse, and CPSC's Public Information Center. Depending on the problem, CPSC would also be alerting and working with the product manufacturers, suppliers and retailers to address the issue.

While CPSC deals with a wide variety of hazards, one of the focal areas of their strategic plan is to reduce fire deaths. In 2007, a mandatory mattress flammability standard went into effect. Mattresses that comply with the new "open flame" standard (16 CFR Part 1633) will generate a smaller fire size and a slower fire growth rate, thus reducing the possibility of flashover.

In order to accomplish passage of this Federal Standard, CPSC examined the fire incident data generated by fire departments across the country and worked with the National Institute of Standards and Technology (NIST) to develop the measurement science needed to produce and support the standardized test method. Then they had to estimate the impact that this mandate would have on the fire safety problem and perform an economic analysis. CPSC estimated that this mattress standard could potentially save 240 to 270 lives per year and eliminate 1,150 to 1,330 injuries per year. Information on CPSC's programs and research can be accessed from www.cpsc.gov and www.recalls.gov.

National Institute of Standards and Technology (NIST)

As part of the U.S. Department of Commerce, NIST (formerly the National Bureau of Standards from 1901 through 1988) is a non-regulatory federal agency with the mission to promote U.S. innovation and industrial competitiveness by advancing measurement science, standards, and technology in ways that enhance economic security and improve our quality of life. There are many laboratories within NIST that conduct research which contribute to improved fire safety for building occupants and fire fighters.

NIST researchers study building materials, computer-integrated construction practices, fire science and fire safety engineering, as well as structural, mechanical, energy, and environmental engineering. Products of the laboratory's research include measurements

and test methods, performance criteria, fire models, and technical data that support innovations by industry and are incorporated into building and fire standards and codes.

NIST has been conducting fire research since its founding in 1901. In the early years, this research focused on fire resistance properties of building materials. Furnace testing of columns and walls made of wood, gypsum, brick, concrete and steel were conducted in conjunction with Underwriters' Laboratories, Associated Factory Mutual Fire Insurance Companies, the National Board of Fire Underwriters and the American Institute of Steel Construction. The testing of structural members was a major activity at NIST into the 1960's.

The 1970s were a time of great change in fire research in the United States. In 1973, the report, "America Burning" was issued. The report called for the creation of the U.S. Fire Administration, The National Fire Academy and the Center for Fire Research. As a result the Center for Fire Research was formed at NIST. While the research at NIST had been focused in large part on protecting buildings from fire, the impact of "America Burning," changed the focus to protecting people from the fire.

"Important areas of research are being neglected. The state-of-the-art in firefighting, in treatment of burn and smoke victims, in protecting the built environment from combustion hazards, points to the need for a major expansion of research and development in these areas. Progress in most of these areas is hindered by a lack of fundamental understanding of the behavior of fire and its combustion products… One basic goal of research should be to improve understanding of the dynamics of fire-not of flames alone, but of smoke, heat, toxic gases, and oxygen depletion, which together cause more deaths than flames do." *America Burning*

Today the Fire Research Division at NIST continues to focus on research aimed at reducing the loss of life and property due to fire. Finding new ways to measure fire phenomena leads to better understanding of how to prevent or control fires. Many times new measurement techniques lead to the development of standardized test methods. NIST has a long history of developing test methods to measure flame spread, smoke generation and heat release rate. These test methods are then used to examine or develop fire resistant or reduced flammability materials. NIST has recently developed standard test methods for the less fire-prone cigarettes and mattresses. Currently, nano-composite materials are being examined as a means to reduce the flammability of plastics.

Figure. 3.3. The National Institute of Standards and Technology routinely conducts research on fire behavior ranging from bench scale experiments like the cone calorimeter up to real-scale experiments such as this acquired structure burn.

NIST is the leader in the development of fire models which are able to predict the movement of fire gases and heat through a building and estimate the response of various fire protection systems. Wide varieties of models have been developed over the years and are available from NIST at no charge. The two current state of the art fire models are the Consolidated Fire and Smoke Transport (CFAST) and the NIST Fire Dynamic Simulator (FDS). Both of these models can be used to predict the movement of smoke and heat through a building. They can also be used to examine the activation time of smoke alarms and sprinkler systems. Both of these models can use a visualization model, Smokeview, to present the model results. These models are critical to the use of performance based fire safety design and are also used in fire investigations.

<<Comparison of a photograph from a full-scale experiment and the result of a Fire Dynamic Simulator/Smokeview simulation that were used to study The Station Night Club fire, in which 100 people lost their lives.>>

The Fire Research Division also conducts full-scale fire experiments in their large fire research laboratory as well as in acquired structures. These experiments are needed to conduct fire model validation, smoke alarm and sprinkler activation experiments, fire reconstructions and fire fighting tactics experiments.

NIST fire models, reports, and test data can be downloaded from www.fire.nist.gov. FIREDOC, the search engine for the Fire Research library can also be accessed from the website listed above. More than 72,000 documents are in the searchable database.

Fire Fighting Technology Research at NIST

One of the main research areas within the Fire Research Division is advanced fire service technology. The objective of the program is to provide the measurement science and performance metrics to enable the development and implementation of new technology necessary to improve the effectiveness and the safety of fire fighters and emergency responders. This includes development of science-based standards and testing protocols, enabling an information rich environment, fire fighter training tools, and application of innovative technologies. In support of these objectives, NIST works with a wide range of federal, state, and local government partners, fire departments, and private sector organizations to facilitate the transfer of BFRL research into the hands of fire fighters, training officers, incident commanders, and other emergency responders.

A few of the projects recently completed or currently being conducted are outlined below to demonstrate the types of research being conducted and the high level of activity with the other government agencies and the fire service.

Integrated PASS Device Test Apparatus Development

In 2005 and 2006, NIST published reports on the performance of thermal exposure sensors in Personal Alert Safety System (PASS) devices and on the thermal environment considerations for electronic equipment used by the fire service. The thermal exposure research in concert with field observations by the NIOSH Fire Fighter Fatality Investigation and Prevention Program identified issues with the decrease in alarm signal volume at high temperatures. This led to the revision of the thermal test requirements of NFPA 1982, Standard on Personal Alert Safety Systems, which went into effect in July of 2007. NIST is continuing the thermal exposure research and is developing a new thermal test loop which can be used to test a range of personnel protection equipment including integrated PASS devices.

Performance Metrics for Thermal Imaging Cameras

Thermal imaging cameras (TICs) have become an important tool for firefighters and other first responders. However, due to the lack of performance standards for TICs, a wide variety of designs and capabilities are provided to fire fighters with little consistency in reported performance. In order to understand the performance characteristics of TIC during fire fighting applications, it was critical that a set of performance metrics and standard testing protocols be developed to allow the fire service to evaluate the TICs capabilities.

With the support of the USFA and DHS, NIST has been working closely with the NFPA Technical Committee on Electronic Safety Equipment and the U.S. Army's Night Vision Laboratory to develop test methods to support and enable thermal imaging camera performance standards. Given that a TIC is composed of a number of components that affect what a fire fighter "sees", this effort has gone beyond the NIST Fire Research Division and has tapped the expertise of the NIST Physics Laboratory as well as the

NIST Electronics and Electrical Engineering Laboratory. Firefighters were key participants in some of the evaluations of the TICs. NFPA's Technical Committee on Electronic Safety Equipment has incorporated these metrics and test protocols into a new standard, *NFPA 1801, Standard on Thermal Imagers for the Fire Service.*

Wind-driven Fires in Structures

A series of 14 experiments were conducted in a 7-story building to evaluate the ability of positive pressure ventilation fans, wind control devices and external water application with high-rise nozzles to mitigate the hazards of a wind driven fire in a structure. Each of the 14 experiments started with a fire in a furnished room. The experiments were conducted by NIST, the Fire Department of New York City (FDNY), and the Polytechnic Institute of New York University with the support of the DHS/FEMA Assistance to Firefighters Research and Development Grant Program and the USFA.

The air flow for 12 of the 14 experiments was intensified by a natural or mechanical wind. Each of the tactics were evaluated individually and in conjunction with each other to assess the benefit to fire fighters, as well as occupants in the structure. Wind created conditions that rapidly caused the environment in the structure to deteriorate by forcing fire gases through the apartment of origin and into the public corridor and stairwell. These conditions would be untenable for advancing fire fighters. Each of the new tactics was able to reduce the thermal hazard created by the wind driven fire. Multiple tactics used in conjunction with each other were very effective at improving conditions for fire fighter operations and occupant egress.

Firefighter Safety and Deployment Study

The objectives of this study are to measure the effects of crew size (two-, three-, four- and five-persons per fire apparatus) and apparatus arrival time on the fire conditions within a two-story "residence". Researchers will observe and time 22 different tasks performed on the fire ground as well as measure temperatures and oxygen levels in the "residence."

A broad coalition of stakeholders is participating in the Firefighter Safety and Deployment study, including (in alphabetical order): the Center for Public Safety Excellence, NIST, Fairfax County (Va.) Fire and Rescue Department, International Association of Fire Fighters, International Association of Fire Chiefs, Montgomery County (Md.) Fire and Rescue Service, the Urban Institute, and Worcester Polytechnic Institute. The project is supported through the DHS/FEMA Assistance to Firefighters Grant Program.

The results from these fire ground experiments will complement a fire incident survey involving 400 fire departments from across the country. Based on these data sets, the researchers will develop and validate a computer model that will allow local government

decision makers to conduct “what if” analyses in order to help them make informed choices about the deployment of resources for public and firefighter safety.

NIST hosts another web site that focuses on fire fighting technology research, www.fire.gov. In addition to updates on current research projects; reports and videos from completed projects can be downloaded from the site.

National Institute for Occupational Safety and Health (NIOSH)

The National Institute for Occupational Safety and Health is a part of the Centers for Disease Control and Prevention (CDC) of the U.S. Department of Health and Human Services. The mission of the NIOSH Fire Fighter Fatality Investigation and Prevention Program (FFFIPP) is to conduct investigations of fire fighter line-of-duty deaths to develop recommendations for preventing future deaths and injuries. The program does not seek to determine fault or place blame on fire departments or individual fire fighters, but to learn from these tragic events and prevent future similar events.

The program, which started in 1998, is divided into two main areas of study; traumatic injury deaths and Cardiovascular Disease Deaths (CVD). The traumatic injury deaths are investigated per the Fatality Assessment and Control Evaluation (FACE) model. Incidents investigated under this model include; burns, diving accidents, electrocutions, falls, motor vehicle accidents and structural collapse incidents.

Heart attack and stroke are two of the most common types of line of duty deaths for fire fighters – accounting for almost half of the firefighter deaths in this country annually. FFFIPP investigations of CVD examine both the individual's risk factors for coronary artery disease and workplace factors. Workplace factors include what conditions the fire fighter was exposed to in terms of physical effort, exposure to hazardous chemicals and thermal stress. In addition, NIOSH assesses the fire department's fitness and wellness program, as well as any screening program for coronary artery disease.

Since the program started more than 400 investigation reports have been produced. Based on the trends discovered in the investigations, NIOSH has issued special reports on topics such as; "Preventing Injuries and Deaths of Fire Fighters Due to Structural Collapse," and "Fire Fighter Fatality Investigation and Prevention Program: Leading Recommendations for Preventing Fire Fighter Fatalities, 1998–2005." All of the completed investigations and the special reports can be downloaded from http://www.cdc.gov/niosh/fire/.

Structure Fire Claims the Lives of Three Career Fire Fighters and Three Children– Iowa, Report, NIOSH Death in the Line of Duty Report 2000-04 (sidebar?)

On December 22, 1999, fire fighters from a career fire department responded to a structural fire at a local residence. The fire was started when a stove turned on shortly after 0800 hours, ignited the materials setting on the stove top. A 49-year-old Shift Commander (Victim #1), a 39-year-old Engine Operator (Victim #2) assigned to drive Aerial Truck 2, and a 29-year-old Engine Operator (Victim #3) assigned to drive Engine 3 lost their lives while performing search-and-rescue operations for three children who were trapped inside the burning structure. These fire fighters were part of a five-person crew who were on duty at the time of the alarm.

NIOSH in collaboration with local authorities, International Association of Fire Fighters, the Bureau of Alcohol Tobacco and Firearms, NFPA and NIST investigated the incident. NIOSH conducted an inspection of the victims' Self-Contained Breathing Apparatus (SCBA) and turnout gear. With NIOSH support, NIST used a computer based fire dynamics model to simulate the flow of fire gases through the building. Findings of the investigation included discussed the need for adequate staffing, the need to perform size-up, the need for good communication and fire ground accountability. The fire model demonstrated that 1) smoke is fuel and 2) the speed that fire can spread throughout a structure once one room has gone to flashover and given the needed ventilation is rapid.

Figure 3.4. NIST FDS/Smokeview fire model simulation of the flame spread through the structure in the Iowa LODD incident.

National Personal Protective Technology Laboratory (NPPTL)

This laboratory was created within NIOSH in 2001. The mission of the NPPTL is to prevent work-related injury, illness and death, by advancing the state of knowledge and the application of personal protective equipment. To accomplish this the lab draws on expertise from many scientific disciplines. While the lab advances technology for many industry needs such as health care workers or miners, they maintain a research focus on first responders. Areas of research for fire fighters include; improving the safety and functionality of fire fighting PPE, developing end-of-service-life indicators for PPE, and improved test methods for respirators.

The NPPTL works in conjunction with the NIOSH Fire Fighter Fatality Investigation and Prevention Program by investigating the performance of Self Contained Breathing

Apparatus (SCBA) and other PPE following fire fighter fatalities. Findings from the fire fighter fatality and injury data assist with the prioritization of research efforts and goals.

Department of Defense

The research laboratories and activities of the different branches of the DoD are significant to the fire service, although to an extent classified and beyond the scope of this chapter. However, it is important to note their contributions here. Significant strides in behavioral health have also been developed by the military dealing with such issues as post-traumatic stress.

The thermal imaging camera (TIC) that is prevalent in the fire service today was developed for military purposes, adapted to military firefighting and then after significant testing by the U. S. Navy made its way to the commercial market and the civilian fire service. The U.S. Army's Night Vision and Electronic Sensors Directorate continue to work toward advances in technology which may make future thermal imagers; smaller, lighter, and less expensive while maintaining a high image quality and durability.

The U.S. Army Soldier Systems Center conducts research on protective clothing for the military. Again as technologies or materials were developed for reducing the threat of fire, biological or chemical hazards to soldiers, these materials have been transferred for use by first responders. These are just a few examples of the type of technology transfer that occurs from DoD research activities which benefit the fire service.

Private Foundation-Based Research

Private foundations exist in many forms and support research at a variety of levels. Three international/national foundations are discussed in this section. The common thread connecting the three foundations listed below is the core fire safety mission.

Fire Protection Research Foundation (FPRF)

The aim of the Fire Protection Research Foundation (FRPF) in Quincy, Massachusetts, is an independent non-profit whose mission is to plan, manage, and communicate research in support of the NFPA®. Specifically to design and support research projects which provide the type of information that NFPA's Technical Committee members and others can use to better support fire safety codes and standards. These projects are funded by interested stakeholder companies and organizations as well as federal grants. Each project has a technical panel that provides technical expertise and user input from sponsors, the research community, the fire service, NFPA technical committees, and other stakeholders. Its web site is located at www.nfpa.org.

The FRPF has had significant impact in the research areas of halon alternatives, smoke alarms, automatic fire sprinkler technology and risk assessment. With the support of the

DHS Assistance to Firefighters Grant Program, FPRF in co-operation with NIST, USFA and an international panel of fire chiefs conducted a series of experiments to examine new firefighting tactics to address wind driven conditions in structure fires. The study demonstrated how rapidly wind driven fires can generate un-survivable conditions even for fully protected firefighters. New tactics with equipment such as wind control devices and applying water for suppression from the floor below the fire were demonstrated to have benefit. These laboratory based experiments prepared the way for a study that was conducted in a 7 story building on Governors Island in New York City. As a result of the experiments, FDNY has changed their tactics for fires in fire resistant construction, multiple dwelling unit buildings and is incorporating the use of positive pressure ventilation fans, wind control devices and high-rise nozzles into their new tactics.

FPRF has also been conducting research with North Carolina State University and NIST on structural fire fighter protective clothing in support of proposed "stored energy" test which may be added to the suite of test methods in NFPA 1971 to determine the thermal capacity of the PPE. The foundation has also conducted studies on the "breathability" of turnout gear. These reports and many others can be downloaded from the foundation's website at
http://www.nfpa.org/categoryList.asp?categoryID=242&URL=Research/Fire%20Protection%20Research%20Foundation

In addition, FPRF has recently published a 5 year research agenda that can be found at http://www.nfpa.org/assets/files//PDF/Research/A_Five_Year_Research_Strategy.pdf.

National Fallen Firefighters Foundation (NFFF)

The National Fallen Firefighters Foundation (NFFF) works with DHS, FEMA, USFA, DoJ, NIOSH, NIST, other federal agencies, industry partners, fire service organizations, training organizations and fire departments across the country in their efforts to reduce the number firefighter deaths. NFFF has generated a National Fire Research Agenda. This document is used as a guide for researchers across the country, to assist in developing research priorities. The foundation, with federal sponsorship has supported research on firefighter friendly and effective seat belt design.

The Everyone Goes Home® web site (www.everyonegoeshome.com) has a wealth of firefighter-safety-related data and information that includes a research database and a learning media center. The NFFF, parent organization of the Everyone Goes Home® Program, supports a wide variety of educational efforts to ensure that firefighters have the information they need on the fireground to operate in a safe manner.

Society of Fire Protection Engineers (SFPE) Educational and Scientific Foundation

The mission of the SFPE Educational and Scientific Foundation is, "To advance the science and practice of Fire Protection Engineering internationally, by advocating and supporting engineering research, technology transfer and education." Fire protection engineers work to ensure that the built environment has appropriate fire safety systems and design in order to limit the loss of life and property. Hence research sponsored by the foundation to examine new methods of design, improved protection materials, modeling smoke movement or studying combustion gases all have an impact on fire fighters' working environment. Information about the foundation, a list of grants awarded and access to heritage documents such as *Americas Burning* can be accessed from http://www.sfpe.org/About/Foundation.aspx.

University- Based Research

Research programs dealing with fire service safety issues have increased because of the availability of various grants. Colleges such as the University of Maryland, Worcester Polytechnic Institute, Indiana University, and University of Illinois have broad based fire research programs. Other colleges such as North Carolina State University, Harvey Mudd College, and the University of Texas also conduct fire safety research in the U.S. along with several universities worldwide.

Center for Firefighter Safety Research and Development at the University of Maryland

The Center brings together the strengths of the University's Maryland Fire and Rescue Institute and the Fire Protection Engineering Department to advance technologies aimed at reducing firefighter deaths and injuries. The Center also draws on the expertise of other assets of the University including the Small Smart System Center, the Electrical and Computer Engineering Department, and the Department of Kinesiology. In addition to the technical and training expertise of the Center, the University of Maryland, one of the largest research institutions in the world, has programs that can provide assistance for the development and commercialization of technologies that are developed for firefighter safety.

With the support of the DHS Assistance to Firefighters Grant Program, the Center has completed research programs which have resulted in improved health and safety guidelines for firefighter training and hydration. The Center is also conducting research in the areas of firefighter tracking and accountability, thermal environment monitoring systems for fire fighter use and exercise programs designed specifically to account for the broad range of strength requirements for structural firefighting. Further information on the Center for Firefighter Safety Research and Development and the Health and Safety Guidelines can be found at http://www.mfri.org/fireresearch/index.html.

Worcester Polytechnic Institute

The WPI Fire Protection Engineering Department offers research based Master of Science and Doctor of Philosophy degrees. The research areas addressed cover the breath of fire research and engineering, such as: flame spread and material flammability, performance based design, compartment fire dynamics and fire modeling. An electronic collection of theses and dissertations can be found at: http://www.wpi.edu/Pubs/ETD/browse/by_department/f.html. Titles include: "Evaluation of New Test Methods for Fire Fighting Clothing," " Theoretical Analysis of Light-weight Truss Construction in Fire Conditions," and "Building Evaluation for Manual Suppression."

In December of 1999 a tragedy in the City of Worcestor highlighted the immediate need for improved firefighter tracking capability. On that cold night, six fire fighters lost their lives in an attempt to locate victims in a cold storage warehouse. Two fire fighters had become disoriented in the dense smoke and complicated building geometry. Four other fire fighters in a search and rescue also became disoriented. The loss of these fire fighters and the recommendation from NIOSH about the need to develop technology to track fire fighters on the fire ground, led the WPI Electrical and Computer Engineering Department to begin research in the area of firefighter location and tracking.

With support from the National Institute of Justice (the research, development, and evaluation agency of the U.S. Department of Justice) and DHS, WPI has held international workshops where attendees, representing academia, private sector and public sector laboratories, present and compare their fire fighter tracking systems. WPI has made significant advances on completely portable firefighter tracking systems with their development of improved antennas, processing hardware and software.

WPI will team up with U.S. Army Natick Soldier Research, Development, and Engineering Center (NSRDEC) in Natick, MA. to conduct a national test of all existing indoor tracking and monitoring systems. For further information on the WPI Precision Personnel Locator Project please go to the following website: http://www.ece.wpi.edu/research/PPL/.

Indiana University

The focus of the research conducted by the Indiana University Firefighter Health and Safety Research program is to develop a better understanding of the physiological and psychological demands of firefighting. The program goal is to reduce fire fighter line of duty deaths by developing a healthier firefighting force. The Indiana University Firefighter Health and Safety Research program is currently conducting research is the areas of firefighter sleep patterns and the related risk factors for developing cardiovascular disease and toxic gas environment exposure in structural fire fighting.

In 2005, 54% of the fire fighter LODDs were attributed to stress or overexertion including heart attacks, cerebrovascular events (stroke) or other types of cardio-respiratory system collapse (heat exhaustion etc.). Indiana University in collaboration

with the Indianapolis Fire Department and supported by the DHS Assistance to Firefighters Grant Program conducted a study which measured heart rates, blood pressures and respiratory rates of firefighters during fire fighting operations. This study was the first to provide data on the magnitude of the increase and duration of these values.

Other correlations from the study included assessments of the fire fighters' capacity to perform the required work, the impact of the size of the structure and fire on the physiological response of the fire fighters and the impact of ambient weather conditions. The findings of the study show the importance of health monitoring programs, physical training programs and proper hydration. In fact the Firefighter Physiology Reports states, "Dehydration exacerbates the cardiovascular stress associated with thermoregulation and can debilitate even the most fit firefighter." The report can be downloaded from http://www.indiana.edu/~firefit/pdf/Final%20Report.pdf.

Indiana University in conjunction with the Indiana Volunteer Firefighters, have developed a video based physical fitness assessment and training program, titled "Fit to Fight." It can be downloaded from http://www.indiana.edu/~firefit/index.shtml?n1=home.

University of Illinois

The Illinois Fire Service Institute leads the fire fighter research efforts at the University of Illinois and partners with a wide range of experts from departments throughout the University, fire departments across the state and industrial partners. The Illinois Fire Service Institute has on-going research in the areas of fire fighter health and wellness, incident management, and tools and equipment research.

With support from the DHS Assistance to Firefighters Grant Program, the Illinois Fire Service Institute has completed a study on the role of heat stress and the personal protective ensemble on firefighter fatalities and injuries. Key findings of the report, "Firefighter Fatalities and Injuries: The Role of Heat Stress and PPE," showed that 18 minutes of simulated firefighting activity caused a increased heart rate, increased core temperature, and increased blood platelet numbers and activation (which results in faster clot formation). In other words, the studies provided improved insight into the mechanisms of the onset of a cardiovascular event and the increased risk, based on simulated firefighting activity. The full report can be downloaded from http://www.fsi.illinois.edu/documents/research/FFLSRC_FinalReport.pdf.

The universities listed above have large multi-discipline research programs, however there are many more schools that conduct fire fighter research in specific areas. North Carolina State University, College of Textiles' Textile Protection and Comfort Center (T-PACC) has a long history of conducting research which has resulted in improvements to fire fighter protective clothing and changes to NFPA® standards. Schools such as

Harvey Mudd College in California which is developing a vibration based monitoring system to provide an early warning of structural collapse for firefighters. Another example is the University of Texas at Austin which has partnered with the Austin Fire Department to conduct research on the use of Positive Pressure Ventilation. A multi-media presentation of this research is available at http://www.me.utexas.edu/~ezekoye/rsch.dir/PPV.html.

Universities around the world also conduct research for the fire service. Some examples are as follows:

Lund University, Sweden - Its Department of Fire Safety Engineering conducts a broad range of fire related research which include: emergency response management, demand for extinguishing media in manual fire fighting, and fire control operations. Many of their research papers may be downloaded in English from http://www.brand.lth.se/english/publications/.

University of Edinburgh, Scotland – The University sponsors the Building Research Establishment Centre for Fire Safety Engineering and is a world leader in the area of fire research. Its publications can be downloaded from http://www.era.lib.ed.ac.uk/handle/1842/1152.

University of Canterbury, New Zealand - Its Civil and Natural Resources Engineering Department has a Fire Engineering program which is supported in part by the New Zealand Fire Service. A variety of research papers ranging from the benefits of fire extinguishers to reviews of fire fighting water requirements are available for downloading from http://www.civil.canterbury.ac.nz/fire/fe_resrch.shtml.

Industry Based Fire Research

There are a number of private sector laboratories around the country that conduct fire research. Much of the data generated by industry is proprietary and is therefore not available to the public or the fire service. However, industry based research provides a valuable service to the public. Many manufacturers conduct research in a wide variety of fields to ensure that their products are safe before they are sold to the public. This is inherently good.

Private testing and research laboratories, such as FM Global and Underwriters Laboratories® provide a wide range of services to manufacturers, to insurance companies, and the fire service. Through their testing and certification of building materials, electrical equipment, and fire protection equipment, to name just a few categories, the private laboratories are an integral part of the building and fire code process. History has shown has that the evolution of the building, electrical, and fire codes, along with the improved demonstrated safety of products has resulted in improved fire safety. Two of the largest fire testing and research laboratories in the Unites States are discussed below.

FM Global

FM Global in Johnston, Rhode Island, is a commercial insurance company, which conducts fire research in order to assess risks, approve safety equipment, and provide appropriate fire protection for their insured properties. FM Global's Fire Technology Laboratory has a floor area of more than 108,000 square feet making it the largest facility of its kind in the world. The facility is sized to allow full-scale warehouse high rack storage fires. The fire experiments typically focus on measuring the heat release from different materials and configurations of those materials and then determining and testing the appropriate protection requirements. The findings of these research efforts form the basis of engineering guidelines published as FM Global Property Loss Prevention Data Sheets. The sheets are available to fire service professionals from http://www.fmglobalcatalog.com/Default.aspx. Even though most of FM Global's focus is on commercial fire hazards, they conducted much of the original work in the area of sprinkler sensitivity, under the sponsorship of the U.S. Fire Administration, which led to the development and acceptance of residential sprinklers.

Underwriters Laboratories® (UL®)

UL® in Northbrook, Illinois, is an independent, not for profit, product safety certification organization that has been developing standards and testing products since 1894. In 2008, UL® evaluated more than 19,000 types of products for safety. UL® has laboratory, testing and certification facilities around the world. UL® may be best known to consumers by the labels and marks that are on products that it has certified. In order for the product to have the mark, it had to pass rigorous tests. Throughout UL® history there focus has been on improving fire safety.

UL® offers complimentary copies of their Building and Fire Related product directories to code officials. Much of the information that is of importance to fire fighters about a structure, such as the fire ratings of floors, walls and doors, or the types of fire protection systems that are installed in the building can be traced back to a UL® test method and listing.

UL® tests structural fire fighter protective clothing and equipment and wildland fire fighting gear against the appropriate NFPA® standards. In addition, UL® has a program for testing fire department ground ladders, aerials and fire pumps to ensure that the equipment still complies with the appropriate standards and that the equipment is safe to use. With the support of the DHS Assistance to Fire Fighters Grants programs and USFA, UL® has provided a series of on-line fire safety courses for the fire service available at no charge. The courses are based on research that UL® has conducted in the areas of lightweight construction, Class A foams and fire behavior. The on-line courses can be accessed from http://www.uluniversity.us/home.aspx.

Summary - Supporting the National Research Agenda and Data Collection System

As new technologies and changing economics continue to impact our lives, new fire challenges will also arise. Something as simple as the introduction of a new type of light bulb for use in the home has in the past led to a series of fires, a product recall and a product redesign and improved test standards. In 2008, high gasoline prices resulted in people hoarding gasoline in their apartments and others choosing to distill their own bio-fuels in the basements of their homes. New fire challenges will keep occurring. Data sharing aids in the rapid discovery of such trends so that the fire service can keep up with them.

Data plays a significant role in our daily lives. It is behind decisions of companies, government agencies, lawmakers. A national fire incident data collection system like NFIRS can provide great vision. It provides us with the information to know that on average, fire causes the death of 11 people in the United States everyday. The data show us that there are approximately 1.6 million reported fires every year with a direct dollar lost in excess of 14 billion dollars. It is important to use the data to understand the nature of the fire problem so that the fire service in concert with the research organizations, local government and the population you service can work to reduce the high cost of the fire problem in the United States.

It is clear that the fire service has a role in supporting the data collection system by participating in NFIRS. But the fire service also has several roles in supporting the National Research Agenda. In many of the research summaries presented above you will see that fire service organizations or fire departments were involved in the planning and conduct of experiments. It is important for fire fighters and fire chiefs alike to encourage and participate at this level.

When the data facts are available, no one person can make reasonable suppositions about how to protect firefighters from ongoing and new dangers. Experience has shown that when researchers and the fire service work together on a project with the common desire to improve life safety for fire fighters and civilians, great things can happen.

Summary

To meet Initiative 7, fire service personnel must gather data from a wide variety of sources to make informed decisions regarding local fire issues, equipment acquisitions, training, firefighter health and wellness, and many other topics. Some of this data is collected by agencies such as the U.S. Fire Administration (USFA), the National Fire Protection Association® (NFPA®), the insurance industry, and local fire departments.

Numerous organizations exist that conduct fire and fire-service-related research and investigation. Examples of these organizations include the Consumer Products Safety Commission (CPSC), National Institute of Standards and Technology (NIST), National Institute for Occupational Safety and Health

(NIOSH), U.S. Department of Defense (DoD), and many universities. Armed with the knowledge collected and stored within these various organizations, the fire service can begin to help prevent firefighter injuries and deaths.

About the Author: Daniel Madrzykowski, P.E. serves as a Fire Protection Engineer in the Fire Fighting Technology Group/Fire Research Division of the National Institute of Standards and Technology (NIST) in Gaithersburg, Maryland