Recommendations
of
The Research Advisory Council on Post-fire Analysis

A White Paper

THE
FIRE PROTECTION
RESEARCH FOUNDATION

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FOREWORD

This *White Paper* has been developed by the *Research Advisory Council on Post-fire Analysis,* a nationwide panel of experts in fields related to post-fire analysis, and other interested parties in industry and government. The fields of expertise brought to the Council include fire data analysis, fire prevention and suppression, fire research and testing, product safety and testing, insurance, education, chemistry, criminal investigation -- as well as fire origin and cause investigation.

The Council's mission is to meet regularly to review the state of the art and science of post-fire analysis, and -- as desired -- to make recommendations for further documentation, research and development. The Council's mission does not include making proposals to standards or regulations, participation in fire investigations, or carrying out the recommendations. It is rather to convene world-respected experts under an independent imprimatur, and thus to give its recommendations the greatest leverage. As one Council member said, "We will give our best to these, and then it's up to the stakeholders. Our role is to hold your coat." Thus, the Council organized its recommendations into cogent cases for needed work in five areas, and determined to synthesize them into a single *White Paper.* The Council next intends to generate a white paper on post-fire analysis and fire's environmental impacts, and one on post-fire analysis and business impacts, expanding on recommendations included in brief form here.

The Research Foundation convened the Council in 1998, one of seven international councils with similar missions in the areas of fire toxicity; fire detection futures; fire suppression futures; performance-based fire safety; aqueous film forming foams; and the NFPA 262 wire & cable fire test. Other councils are planned.

Council members and the Foundation are extremely grateful to Richard L.P. Custer, MSc., CFEI, for his diligence in capturing the Council's ideas in the several drafts that they have reviewed. The Foundation thanks Council members for their contributions of time and the resources to produce this work, making it available on request, free of charge. In fact, the reader is encouraged to contact any of the Council members for a greater understanding of the information, expertise and passion for improved post-fire analysis represented here.

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I.   Introduction

This is the first report on the *Post-fire Analysis Research Advisory Council's* deliberations. It reviews the status of the techniques and knowledge base of post-fire investigations, and presents recommendations addressing the research and development needs that the Council has identified.

Post-fire analysis comprises a wide range of activities. It aims to identify where and how a given fire or group of fires started and the factors contributing to fire loss. The collected knowledge can be applied to reduce the future costs of fire in terms of casualties, property damage and building regulations. Traditionally, most post-fire-analysis effort has been focused on the origin and cause of fires with emphasis on civil and criminal litigation. Most of the resources have been directed to investigation of fires with large financial or human losses. Often these major investigations take place well after the fire authorities have assigned a cause. In some instances, further investigation results in differing theories regarding cause.

Despite extensive investigation, data collected nationally rarely include details relating to the reasons for extensive loss or successful control.   Instead information is comprised mainly of reporting by the fire authorities. Statistics used as the basis for developing or changing building codes or selecting targets for fire protection programs frequently are inadequate.

Cause is identified by establishing the ignition source, the fuel ignited and the factors that brought them together. Causes are characterized as natural, unintentional, incendiary and unknown/undetermined. Many techniques used to determine cause are based upon the interpretation of damage patterns such as wood char morphology and depth, manner of glass breakage, and nature of smoke deposits. The color of smoke and the apparent speed of fire growth are also used to infer causal relationships.

Today's situation exists because the basis for identification of fire origin and cause has evolved from practical knowledge rather than scientific research. Over the past decade, however, the development of better understanding of fire science and factors related to fire growth and spread has led many investigators

to question these empirical techniques. In 1992, the first edition of NFPA 921 *Guide to Fire and Explosion Investigation*[1] was issued. The NFPA *Technical Committee on Fire Investigations* reviewed the bases for a number of traditional interpretations of fire scene evidence, including:

- Large shiny char blisters indicate fast fires and the presence of ignitable liquids.

- Small, flat and dull blisters characterize slow accidental fires.

- The angle of slope of the sides of a "V" pattern on a vertical surface suggests the intensity of the fire.

- Spalled concrete floor slabs are definitive of an ignitable liquid fire.

- Depth of char determines time of fire initiation.

- Dark or black smoke or rapid fire growth indicates the presence of ignitable liquids.

A salient finding of NFPA 921 is that patterns seen following fires can result from more than one set of conditions and thus may not indicate any one cause exclusively. Thus, NFPA 921 recommends a formalized approach to fire origin and cause investigation utilizing the scientific method of data collection, hypothesis development and hypothesis testing.

Testing carried out at the National Institutes for Standards and Technology (NIST) validated this approach. It demonstrated that fire patterns can, in fact, have multiple sources[2][3][4]. NIST investigated these fire patterns in the light of some basic liquid accelerant and room fire scenarios. Many more variables that can affect evidence at fire scenes have yet to be investigated, including effects of burn time, materials involved, ventilation and fire fighting techniques. *Prima facie* evidence previously used is now deemed inadequate or inconclusive; however, new methods and technologies have not yet evolved to aid in fire scene investigation.

National fire statistics can give a general picture of the factors affecting fire losses but may not provide sufficient detail to assess adequately the effectiveness of specific fire code requirements. For example, statistics alone cannot determine the effect of regulation of combustibility of interior finishes on fire losses. Advantages of automatic sprinklers versus fire-rated construction can only be evaluated in broad terms. This is particularly true when fire resistance has been reduced because of the use of automatic sprinklers. Additionally, effects of specific fire protection designs used cannot be assessed since design and performance details are sparsely reported.

These questions must be answered if we are to develop more cost-effective building regulations and evaluate the effects of performance-based design. For the most part, the successful performance of fire protection features may be

under-examined in fire investigations since it can result in fires too small to report to the fire department or even to the insurance companies. These fires might not be investigated at all.

In November 1997 the federal Bureau of Alcohol, Tobacco and Firearms sponsored the *International Conference on Fire Research for Fire Investigation*[5] that bought together national and international fire researchers and fire investigators to identify the current state of the art and technical gaps in fire investigation. The conference issued a *Proceedings* identifying research and development needs.

Among the cited research and development needs included:

- Fire incident reconstruction -- laboratory methods for testing of ignition source hypotheses
- Validation of pattern analysis – patterns on walls and ceilings and patterns resulting from liquids on floors
- Determination of burning rates for different items and development of a burning rate data base
- Means to validate identification of electrical faults as an ignition source
- Impacts of flashover on fire patterns and other indicators
- Effects of ventilation on fire growth and origin determination
- Validation of fire models
- Fire investigator occupational health and safety

Training and education needs included:

- Specific training in understanding fire patterns, use of models
- Protocols for collection of data at the fire scene
- Training and certification for laboratory personnel
- Certification programs for investigators
- Methods and means for training the trainers

A full list of all the identified needs is reported in the conference *Proceedings.*

II.   Discussion

To organize the discussion, the Research Advisory Council has identified five broad areas where progress is needed in post-fire analysis. These are:

- *Origin and Cause Investigation Methods*
- *Deaths, Injuries, Property Losses and Building Costs*
- *Education, Training and Dissemination*
- *Environmental Impacts of Fire and Fire Protection*
- *Business Impacts*

The first area relates to cause determination. The second addresses post-fire analysis methods to assess the effectiveness of codes, standards and fire safety design on controlling fire losses. Education and training are needed to raise the awareness and capability of post-fire investigators.

The two other identified areas are nontraditional, but becoming more visible. Fire is now recognized as an event in the open environment: Smoke impacts air. Runoff impacts water.   Finally, consumer confidence and tenant concern about fires in tall buildings might affect the construction and rental market. This is an unobvious impact of fire on business.

The issues associated with these last two areas will be introduced in this document but are sufficiently broad based and complex that they will be the subjects of more detailed study in a subsequent white paper.

For each of these areas, the following topics will be addressed:

- **Problem** – a general statement of the problem(s) associated with post-fire analysis
- **Impact** – identification of potential impact of advances in specific problem areas
- **Research and Development** – needs and recommendations
- **Stakeholders** – identification of those groups most likely to benefit from advances

III.   Recommendations

Origin and Cause Investigation Methods

Problem:
There is a lack of scientific foundation for many methods used to identify the area of origin and the cause of fires. The interpretation of patterns can be extremely difficult due to the complicated effects of the type and form of the materials burning, the building geometry and ventilation and the fire fighting actions taken. This can lead to confusion and conflicting indications. Two investigators may have different causal theories based on observation of the same patterns.

In those cases where the extent of fire development is limited to one room or perhaps one or two items, the location of the point of origin may be obvious by observation of the fire damage patterns. At the other extreme is found the massively destroyed fire scene often referred to as a "black hole." In this case, the investigator sees patterns that represent the summation of all the damage for the duration of the fire and the "overhaul" or final extinguishment phase of the fire department operations and it may be impossible to determine the order in which the patterns evolved. In between lies a continuum where the value of patterns decreases as that magnitude and duration of the fire increases. If patterns are to be used for origin and cause determination, forensic methods to identify the specific source of a pattern need to be developed and rigorously vetted. This can be particularly important for identifying patterns caused specifically by burning ignitable liquids or other incendiary materials where potential arson is at issue.

Impact:
Two areas of potential major impact would be criminal litigation (for arson fires) and civil litigation (for product involvement in unintentional fires). In both cases, more detailed, more accurate and more confident determination of origin and cause should lead to more successful litigation of valid cases and less frequent initiation of invalid cases.   Better procedures could also result in less disagreement on facts between investigators, which should lead to faster, less expensive resolution of cases. But all of this requires not just better procedures but also the broadest possible information dissemination, training, education, and certification. We need to have better ways to generate and use information, we need everyone to understand and use those better ways, and we need to know that they do.

The quantitative impact is particularly clear for arson fires. In a typical year, arson is estimated to result in half a million fires reported to US fire departments and roughly \$2 billion in direct property damage, together with hundreds of deaths. Roughly one-third of the fires are confirmed as incendiary, another one-

third are only categorized as suspicious (characteristics consistent with incendiarism but no positive determination), and the other one-third are the arson share of fires with no cause determined at all. Only the one-third confirmed as incendiary go on to police investigation, and only one-sixth of that group leads to an arrest.

Better origin and cause determination would be expected, therefore, to triple the number of arson cases sufficiently documented to justify police investigation. Better origin and cause determination could very well provide enough additional forensic detail to improve the solve-by-arrest percentage, as well, and improve the percent of arrests that lead to conviction. At present, NFPA estimates that only 2% of set fires lead to a conviction[6], and every step in the investigative process offers opportunities to greatly improve that percentage through better forensic procedures.

Improved methodologies for origin and cause determination would also provide greater confidence, and possibly greater quality, in statistics on fire problems. Limited special studies have indicated that fire reports are subject to a substantial but unbiased error rate. That means there is a high rate of errors, but the errors favor no particular characterization, so the errors tend to cancel out when reports are aggregated for statistics. However, many professionals are more focused on some types of errors rather than others, and so remain concerned about the high rate of errors per report and are distrustful of statistics from such a database. Reducing the rate of errors, therefore, will provide greater confidence in statistics, both by reducing the statistical uncertainty associated with the error rate and, perhaps more importantly, by reducing the perception of inaccuracy. Any resulting changes in statistical patterns would result in greater quality as well, but the improvement in confidence would be very valuable, even if the statistical patterns are largely unchanged.

Data exists on actual ignition and fire performance of many major product types, but not specific brands or functional design types. Even when identified and reported to the Consumer Product Safety Commission or similar agency, which is rare, the data is not available for general use. In addition, much product fire testing focuses on standard tests that may not reflect the full range of end-use configurations or applications. Improved data can help identify specific problems with materials, products or test methods. An example of how this can work is found in the case of halogen torchier lamp fires involving curtains and drapes that resulted in revised requirements to UL Standard 153 *Portable Electric Lamps*[7].

Stakeholders:
Improved origin and cause determination particularly affects the law enforcement, fire fighter and insurance communities. For law enforcement, better and more rigorous methods can result in higher arson conviction rates. The fire fighter community benefits from improved product safety and a better understanding of performance in fire, which translates to improved fire fighter

safety. For the insurance community, the outcome would be reducing losses by having a stronger basis for pursuing arson/fraud and subrogation activities.

Improved origin and cause determination affects those writing fire prevention regulations by providing a better basis for targeting regulations and for inspection and public education programs.

Improved origin and cause determination also affects writers of building codes, in that fire scenarios involving specific functional areas of buildings, or specific occupancies, could be identified and reflected in code development.

Research and Development Needs:
Developing the experimental data to resolve these problems can be extremely expensive due to the large number of variables involved and the costs associated with the needed large scale testing. For this reason, very specific research targets need to be identified with potentially high return. In order to accomplish this high cost effort, it will most likely be necessary to share the costs among stakeholders.

Since knowledge of the origin of a fire is, in nearly all cases, essential to determining cause, a high priority should be placed on new or improved methods for identifying the point or area of origin including burn pattern analysis. Such new or improved methods should be developed, peer reviewed and published to meet the challenges of the recent court tests under the Daubert[8] and Kuhmo Tire[9] rulings. These rulings have tightened the requirements for both scientific and technical data used as evidence, and the opinion basis of expert testimony. Both these rulings have come into play as tests of the admissibility of evidence and opinions in fire litigation.

Methods for analyzing burn patterns concerning their meaning in the early growth history of the fire are also important. In particular, how does one determine when in the course of the fire event a particular pattern was made and how it might relate to a given potential ignition scenario? One possible approach would be to study from an engineering/combustion perspective the top 10 incendiary ignition scenarios and determine whether there are separate characteristics or groups of characteristics that are unique to a given scenario.

Research also needs to address the effects of ventilation and airflow, either natural or induced by fire fighting activity, on fire patterns. Knowledge of ignition, early fire growth, flame spread and smoke generation as related to the genesis of fire patterns needs to be developed and integrated into the models being used to interpret fire patterns and test origin and cause theories. Methods should be explored that could identify physical or trace evidence specific to the origin of a pattern that could be established by analytical procedures at the fire scene or in the laboratory.

Research and Development Recommendations:

- Examination of existing instrumentation and analytical methods for possible use in identifying the presence of ignitable liquid residues at fire scenes.
- Development and testing of a methodology for locating the area or point of origin of fires having major destruction.
- Identify "top ten" incendiary ignition scenarios and develop a series of "characteristic" features that would aid in discriminating among them.
- Advance the capabilities of Computational Fluid Dynamics fire modeling, particularly as applied to fire ignition scenarios and fire pattern development and interpretation.

Deaths, Injuries, Property Losses and Building Costs

Problem:
Traditionally, post-fire analysis has been limited to determination of origin and cause except in cases where litigation is involved. In these situations, attention typically focused on the failure of a product or building design feature that resulted in death, personal injury or property loss. It is also useful to determine the factors that resulted in successful outcomes of fire incidents. In many instances the investigation into the factors resulting in those losses takes place long after the incident when the building has been restored or the site has been cleared.

Changes to codes often derive from major high profile incidents involving large life loss or property losses. The fire safety aspects of building codes are largely directed toward life safety, although concern for property losses is increasing. As we continue to evolve the nature and structure of the fire safety provisions of our building codes, it is important that a better understanding is developed of how the existing code provisions are performing in practice for different occupancies. In short, we need to know under what circumstances the code-mandated fire protection requirements are working, and what are the circumstances under which they are not.

In order to generate this information, it is necessary to collect and analyze data at fire scene to identify the fire protection features of the building, and assess the effectiveness of those features in controlling the spread of fire and its products, and the reasons for the success or failure.

Some interest in this area has been expressed by the American Institute of Architects, which has proposed that teams of fire service personnel, architects, fire protection engineers and code officials investigate building fires to assess fire protection performance. Limitation on funding, rather than lack of interest, has been a barrier to ongoing activity in the United States. Some international pilot programs of this type have been reported in Australia.

A major need in this area is a broadly accepted protocol with guidelines for analysis to ensure consistency of the reported data.

Impact:
The overall impact of successful work in this area would lead to more effective prescriptive fire protection requirements in the codes by providing a basis for making changes in existing requirements, and provide information for consideration in the performance-based design process. Additionally, the data collected would provide quantitative input for risk analysis in fire protection design.

Changes to the code could result in more effective use of the resources expended in meeting prescriptive code requirements. Changes could result in lower fire protection costs in buildings.

Provide the basis for expansion of NFPA 921 NFPA 921 *Guide to Fire and Explosion Investigation* to include guidance for evaluating fire protection performance and inclusion of needed data in NFPA 901 *Standard Classification for Incident Reporting and Fire Protection Data.* Alternatively, a new project might be established by NFPA in this area.

It should be noted that there is a strong potential for liability issues to be associated with studies in this area.

Stakeholders:
Improved knowledge of the actual performance of prescriptive code requirements is of value to those writing building codes. The data can be used to assess existing requirements and help evaluate proposed changes.

Fire protection engineers would benefit by using performance and reliability data to assist in evaluating candidate performance-based designs.

Improved effectiveness of fire protection requirements should result in lower fire losses. Stakeholders benefiting from this result would be the insurance industry in terms of reduction in loss payments and governments with respect to maintenance of their tax base through reduction in fire losses.

Builders and building owners benefit from possible savings in reduced construction costs and insurance rates.

Manufacturers and installers of fire protection systems would benefit from generic data about performance of systems, using this information to improve product performance through design, installation and maintenance.

Research and Development Needs:
The primary work needed in obtaining performance data about building fire protection features is in the development and testing of a protocol and guidelines for assessing performance. The resulting work should address the issues such as what the performance objectives are for the fire protection measures to be evaluated, how success or failure is measured, identification of a common basis for comparing the various fire protection measures.

Research and Development Recommendations:

- Development, testing and implementation of protocols and guidelines for specific data collection studies rather than adding to the overall detail and complexity or general fire reporting.
- Carry out a series of specialized studies of particular issues such as…
  - Performance of specific fire safety measures (egress, compartmentation, detection, automatic suppression etc.).
  - Comparisons of effectiveness of systems such as automatic sprinklers vs. fire resistant construction.
  - Number of exits needed from buildings.

Education, Training and Dissemination

Problem:
Lack of dissemination of information has been much of the problem behind the comparatively slow advance in fire investigation. NFPA 921 NFPA 921 *Guide to Fire and Explosion Investigation* has had a major effect on the level of knowledge available to practitioners. Most of the information adopted in NFPA 921 is not new. It was available, dispersed throughout the fire science and engineering literature. But it was not readily available in a unified, readable format.

Having information available does not necessarily mean that it will be used or used properly. A well-developed model curriculum with instructional methods and technologies tailored to the materials to be presented is one solution. These should include distance learning alternatives and simulation/virtual reality technology, where appropriate.

Work in this area will have to address the need for education and training on a variety of levels in the public sector ranging from fire officers and entry-level investigators to advanced training for experienced fire service personnel and code officials. Education and training is also needed for fire investigators in the private sector including scientists and engineers. The target audience backgrounds also vary widely with education reaching the graduate degree level and professional activities from fire fighting and code enforcement to architecture and engineering. Types of training resources, availability of those resources, and the perception that training may not be needed should be considered in the curriculum development. As model or standardized training is developed, the content of existing certification programs may be influenced leading to standards for licensure.

Impact:
Successful improvements in education and training would lead to wider application of advancements in fire investigation and assessment of performance of fire protection requirements.

This would further lead to improved confidence in fire statistics and expanded use in code development and performance-based fire protection design.

Stakeholders:
The benefit for all of the following stakeholders can be the expanded availability and relevancy of educational and training materials and methods:
- Public and private fire investigators
- Fire protection educational community
- Fire service
- Fire protection engineers
- Insurance industry
- Code officials

Research and Development Needs:
The primary need in education, training and dissemination is in the area of transfer of research and technological advances to target audiences. Curricula and training materials developed should be developed by peer review and consensus processes to establish credibility to the content and approaches.

Development Recommendations:

- Develop interactive CD training package for assessing performance of fire protection features.
- Develop textbooks that transfer research results to practical applications in understandable language.
- Develop curricula for target audiences of various education and skill levels.
- Develop distance learning programs in conjunction with accredited educational institutions.
- Develop simulation/virtual reality training for fire scene investigation to include both origin and cause and fire growth analyses.

Environmental Impacts of Fire and Fire Protection

Problem:
In recent years, fire incidents have resulted in significant impacts on the environment. Contaminated water and fire suppression agent runoff has threatened water supplies[10]. Burning of large amounts of petroleum products and waste tires has created extensive air and water pollution. Incidents involving swimming pool chemicals have released large quantities of corrosive material into the atmosphere resulting in major damage and evacuation of exposed populations[11].

Concern has also been raised about the products of combustion in ordinary fires in domestic and public occupancies. Problems can occur in any large fire whether it is an industrial plant, a warehouse, a retail establishment or even a large residential complex.

In response to these concerns, consideration is now being given to the development of regulatory solutions to deal with these potential problems[12]

While it is clear that fire effluents can have local and possibly widespread effects, the magnitude of the overall problem has so far eluded even rough estimation. Protocols for assessing effects of fire effluents on environmental conditions have not been well developed. Methods for prevention of environment impacts from fire, and standards for environmental remediation and building re-habilitation have not been addressed. Safety procedures for fire fighters during suppression, investigation activities, overhaul and clean up are needed.

Impact:
Realistic, science-based approaches and solutions would result in better understanding of the magnitude and urgency of the problems, and would lead to reduced potential for water and air pollution from significant events. Safety for fire fighters, investigators and clean-up personnel would be improved.

Stakeholders:
The identification and management of environmental impacts of fire would affect:

- Fire fighters and fire origin and cause investigators
- Building owners and managers
- Materials and product manufacturers
- Insurance industry
- Environmental authorities and organizations
- Civilian defense
- Public health authorities and organizations

Research and Development Needs:

Research is needed to quantify the magnitude of environmental issues, and to support development of improved incident management and information tools.

Research and Development Recommendations:

- Develop and test of protocols for post-fire analyses to identify the nature and extent of the environmental effects of fire.
- Carry out a series of targeted studies of the physical and economic impacts and major risk scenarios during and after a fire.
- Develop fire protection strategies that include control of environmental impacts and implement them through the consensus design standards system.
- Develop fire department procedures for preplanning and fire incident management of environmental impacts.
- Establish a rational basis for assessing environmental impacts of fire.

NOTE: The environmental impacts of fire will be the subject of a future detailed white paper to be issued by this Council.

Business Impacts

Problem:
The economic impact of fire has been addressed in a number of ways over the years. Losses can generally be grouped into two major categories: direct losses and indirect losses. Direct losses relate to the damage produced by the fire such as property losses due to flame and smoke. Indirect fire losses arise from a fire incident but are not related to replacement of lost or damaged property. The most common example is business interruption where loss of sales or services results in loss of income and can result in business failure. In addition to property insurance many companies also carry business interruption insurance (BI) to address just this situation.

Estimates of direct fire losses are prepared by the NFPA, the United States Fire Administration, and various insurance companies and organizations. Insurance companies can partially determine indirect losses based on BI claims. In general, however, indirect losses are an under-researched topic[13]

The full economic impact of fire is not well known because indirect losses are not well known. Beyond BI losses are impacts including permanent loss of customers during the interruption as they find alternate sources of supply. Suppliers to the affected business sustain lost profits as well.

The recent World Trade Center incidents have resulted in loss of tenant and public confidence in the safety of high buildings. It has been reported that tenants are moving to lower floors of buildings and that some developers are now reassessing their interest in future tall building projects. For those businesses with BI coverage, major incidents can exceed the coverage. Loss of investor confidence can arise based on the perception that a business may not recover.

The economic cost of fire must be considered in the context of a cost-plus-loss model. Costs include providing protection by engineering, building code compliance and fire service, improvements in flammability resistance of products and materials and planning for business continuity. Costs of insurance premiums are also part of the picture.

Losses include lost salary due to temporary or permanent job loss. Other poorly documented indirect losses include short- and long- term medical, and disability costs and lost income for injured and deceased victims.

Impact:
Better understanding of the full nature and extent of fire losses could lead to better quantification of the risk of losses and establishment of ways to predict their occurrence and magnitude. Greater knowledge can lead to better business continuity and disaster recovery planning, faster recovery of sales and services and lower BI losses.

Better information on the nature and costs of injuries and deaths could lead to improved insurance coverage. Studies of consumer and investor attitudes relative to the fire-worthiness of buildings, and factors relating to the likelihood of business failures after fires would provide input to fire safety planners and the public.

Stakeholders:
Those groups that benefit from work in this area would include:

- Building owners and developers
- Insurance industry
- Owners, stockholders and employees of directly affected businesses and Industries
- Owners, stockholders and employees of indirectly affected businesses and industries
- Fire victims and their families

Research and Development Recommendations:

Some examples of projects addressing the economic impact of fire include:

- Broad study of the economic effects of fire in a cost-plus-loss model.
- Studies targeted at specific aspects of the cost-plus-loss model to provide the basis for development of solution strategies.
- Preparation of case studies of successes and failures of business continuity planning and disaster recovery.
- Preparation of strategies and planning guides for managing economic impacts of fire for a wide range of users from industry to the general public.

NOTE: The business impacts of fire will be the subject of a future detailed white paper to be issued by this Council.

IV. Conclusions

- Given the high cost of research, funding is most likely to require input from multiple stakeholders including government (legislative, law enforcement), manufacturing, building design and construction, building management and insurance.
- Given its wide use in the United States and its reference in training programs and court decisions, NFPA 921 *Guide to Fire and Explosion Investigation* is the appropriate vehicle for dissemination of project results relating to standard practices of origin and cause determination. Education and training methods and certification needs should be met concurrently.
- Investigative practices not related to origin and causes are needed to assess means for improvement of life safety and property protection from fire.
- Expanded training and education relating to post-fire investigation and dissemination of the resulting data and information are needed to reach all the identified stakeholders including legislative bodies and the general public.
- White Paper topics covering environmental and economic impacts of fire should be further expanded.

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