The U.S. Nuclear Regulatory Commission's Fire Risk Research Program - An Overview

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ABSTRACT

The U.S. Nuclear Regulatory Commission (NRC) has initiated a research program aimed at addressing gaps in current capabilities to perform realistic fire risk assessment. The intent of the program is to support an expanded use of risk-informed, performance-based methods for fire protection applications. This paper summarizes the current research plan for the program. The summary includes the program objectives, summary task descriptions, a summary of the overall program schedule and funding, and potential future activities. References are also provided for readers interested in additional details on fire risk assessment, fire research, and NRC's plans.

1. BACKGROUND

As stated in the U.S. Nuclear Regulatory Commission's (NRC's) policy statement on the use of Probabilistic Risk Assessment (PRA) [1], the NRC intends to increase the use of PRA technology in "all regulatory matters to the extent supported by the state of the art in PRA methods and data." Recent activities include the development of a general risk-informed[1] framework for supporting licensee requests for changes to a plant's licensing basis, described in Regulatory Guide (RG) 1.174 [3]; and efforts to make Part 50 of the Code of Federal Regulations more risk-informed.

In the area of fire protection, there is interest from both the NRC and industry in the use of PRA technology to deal with outstanding issues. Specific applications include the identification of plant-specific vulnerabilities, the evaluation of the acceptability of proposed changes to specific parts of a plant's program, the evaluation of the safety significance of certain fire protection issues (e.g., fire-induced circuit failures), and the evaluation of the safety significance of fire protection inspection findings. An industry consensus standard (NFPA 805), which uses risk information in evaluating a plant's fire protection program, is being developed under the auspices of the National

[1]According to Ref. 2, "A risk-informed approach to regulatory decision making represents a philosophy whereby risk insights are considered together with other factors to establish requirements that better focus licensee and regulatory attention on design and operational issues commensurate with their importance to public health and safety."

Fire Protection Association (NFPA). It is anticipated that the completed standard will use an approach that is compatible with RG 1.174.

When used in a risk-informed decision making framework, fire risk assessment (FRA) is useful in that it provides a systematic, integrated method for evaluating the importance of fire protection issues. However, the current FRA state of the art is not as mature as that for assessing the risk contributions of many other important accident initiators. As shown by a review of Individual Plant Examinations of External Events (IPEEEs) [4], variations in analytical assumptions can lead to orders of magnitude variations in estimates of fire-induced core damage frequency (CDF), and qualitatively different risk insights are possible. Such uncertainties can clearly affect a decision maker's confidence in the results of FRAs and, in hindsight, lead to suboptimal decisions.

Ref. 5 identifies a number of areas where improvements in FRA methods, tools, and data will improve the ability of FRA to support decision making. To address these areas, the Office of Nuclear Regulatory Research (RES) initiated a fire risk research program in Fiscal Year (FY) 1998.

This paper describes the current research plan for the RES fire risk research program. The paper covers the program objectives, summary task descriptions, a summary of the overall program schedule, and potential future activities. Additional details (e.g., task scopes and leads; interactions with other tasks, fire research programs, and fire safety activities) can be found in Ref. 6.

2. PROGRAM OBJECTIVES AND CHARACTERISTICS

The general objectives of the fire risk research program are as follows.

- Improve qualitative and quantitative understanding of the risk contribution due to fires in nuclear power plants.
- Support ongoing or anticipated NRC fire protection activities, including the development of risk-informed, performance-based approaches to fire protection.
- Develop improved fire risk assessment methods and tools (as needed to support the preceding objectives).

The technical objectives of the program are largely focused on the three elements of fire protection defense in depth (fire prevention, fire detection and suppression, fire mitigation), which have analogous elements in typical FRAs [7-10]. The objectives are, for the most part, aimed at developing an FRA state of the art which is, loosely speaking, comparable in quality to that for current PRA for other internal events. In particular, they are aimed at developing:

- improved estimates of the frequencies of challenging fires;
- improved fire modeling tools for risk significant scenarios, including guidance for proper application (accounting for limitations and uncertainties);
- mode-specific thermal fragilities for cables and other key components;
- guidance for identifying scenarios for which smoke effects may be risk significant;
- improved estimates of the probability of fire and fire effects containment (including active and passive barriers);
- configuration- and condition-sensitive fire protection system reliability estimates, including guidance for application;
- improved tools for assessing the risk impact of circuit interactions; and
- improved understanding of the implications of major fire events for FRA.

The program focuses on the development of evolutionary improvements on existing FRA approaches, or improved guidance for using these approaches, as opposed to the development of new methodologies. It emphasizes the improved use of existing information, and generally avoids the performance of new experiments. In cases where the technical issues cannot be adequately dealt with using these approaches, the program employs feasibility or scoping studies to support planning for more detailed studies. The program also takes into account the products and needs of parallel activities (e.g., the NRC ATHEANA program [11], the NFPA 805 standard development).

3. TASK DESCRIPTIONS

The technical tasks included in the fire risk research program are listed in Table 1. This section provides, for each task, a description of the background for the problem being addressed and the technical objectives.

3.1 Tools for Circuit Failure Mode and Likelihood Analysis

When dealing with fire-induced damage to electrical cables, two important effects are the loss of function or spurious actuation of equipment associated with the cables. In FRAs, the latter failure mode is typically assumed to be caused by "hot shorts," i.e., short circuits involving a powered conductor.

Hot shorts can be a significant direct and indirect risk contributor. In one advanced reactor design FRA, hot short scenarios (leading to medium or large LOCAs due to spurious valve operation) contribute over 95% of the predicted fire-induced CDF for that design.

Complications in procedures designed to address the potential of equipment damage due to hot shorts contribute to the significant fire risk contribution at another boiling water reactor plant.

Table 1. Fire Risk Research Program Technical Tasks, FY 1998-2000

Lead Org.	Task Title
SNL	Tools for circuit failure mode and likelihood analysis
SNL	Tools for fire detection and suppression analysis
SNL	IEEE-383 rated cable fire frequency analysis: feasibility study
SNL	Fire modeling toolbox: input data and assessment
SNL	Experience from major fires
SNL	Industrial fire experience
SNL	Frequency and characteristics of switchgear and transformer fires
SNL	Fire barrier reliability model development and application
UMd	Integrated model and parameter uncertainty
TBD	Frequency of challenging fires
TBD	Fire model limitations and application guidance
NRC	Risk significance of turbine building fires
NRC	Penetration seals
NRC	Risk significance of multiple unit interactions
NRC	Use of advanced fire models in fire risk assessment

SNL = Sandia National Laboratories
TBD = to be determined
UMd = University of Maryland
USNRC = U.S. Nuclear Regulatory Commission

From a methodology standpoint, a major concern is that hot short analyses performed for FRAs are generally simplistic. The probability of a single hot short is commonly based on a generic probability distribution derived subjectively in Ref. 12 from a limited amount of information. (The distribution, assumed to be lognormal, has a 5th percentile of 0.01 and a 95th percentile of 0.20; its mean value is 0.07.) The probability of multiple hot shorts is typically obtained by multiplying this probability an appropriate number of times. The latter procedure ignores the potentially significant impact of dependencies, both aleatory and epistemic. Furthermore, both it and the original single hot short distribution do not explicitly reflect such potentially important issues as the circuit design, the function of the cable, and the characteristics of other cables in the vicinity.

The objectives of this task are as follows:

- To develop an improved understanding of the mechanisms linking fire-induced cable damage to potentially risk significant failure modes of power, control, and instrumentation circuits.

- To develop improved methods and data for estimating the conditional probabilities of key circuit faults, given damage to one or more cables.

- To develop representative estimates of the conditional probabilities of key circuit failure modes applicable to currently operating U.S. nuclear power plants. The estimation process will include an identification and quantification of the key uncertainties in the estimates.

- To gain risk insights concerning fire-induced circuit failures, especially those associated with cable hot shorts.

- To identify areas where additional work needs to be done to improve understanding of the risk associated with fire-induced circuit failures.

3.2 Tools for Fire Detection and Suppression Analysis

FRA analyses of the effectiveness of fire detection and suppression efforts require estimates of the reliability of automatic suppression systems. One concern with current approaches involves the use of generic non-nuclear industry estimates for system unreliability. These estimates do not account for variations in such plant- and scenario-specific factors as sprinkler head location relative to the fire, sprinkler system design, and room congestion. The use of generic suppression system reliability estimates may also be optimistic in studies employing severity factors[2] because the estimates are not conditioned on the fire severity.

A suppression analysis also requires estimates of characteristic delay times (e.g., the time to initiate fire suppression, the time to final suppression). More precisely, since these times should be modeled as random variables, estimates of the parameters of the aleatory distributions for these times are required. Event data have been used in the estimation process (e.g., see [10,13]). However, the data are limited and are not always sufficiently defined to support direct estimation of key parameters. Model-based approaches (e.g., [14]) can be used to specialize event-based generic distributions to account for scenario-specific features, but difficulties arise when addressing the uncertainties in the models. (Note that fire models which are conservative with respect to fire damage predictions may be non-conservative with respect to fire suppression.) Expert judgment provides another way to account for plant-specific features (e.g., [15]). To date, however, such approaches have not integrated the results of the expert elicitation with actual event data.

The preceding discussion addresses estimation issues in suppression analysis. Modeling issues which are not quantitatively addressed by most FRAs include: the impact of smoke and loss of lighting on the effectiveness of manual fire fighting and the effectiveness of compensatory measures (e.g., fire watches) for temporary fire protection deficiencies.

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[2] "Severity factors" are commonly used in FRAs to model the fraction of reported fires that have the potential to cause damage to components not involved in the initial fire.

The objectives of this task are as follows:

- To develop improved methods and data for estimating the reliabilities of automatic and manual suppression activities.

- To develop estimates of these reliabilities applicable to currently operating U.S. nuclear power plants.

- To identify and quantify key uncertainties in these estimates.

3.3 IEEE-383 Rated Cable Fire Frequency Analysis: Feasibility Study

One key issue in FRA concerns the frequency of self-ignited fires involving cables certified by the IEEE-383-74 flame test. Tests have shown that electrical ignition of fires involving these cables is difficult (e.g., see Ref. 16). A practical FRA question is, for compartments containing only rated cables, what is the frequency of cable fires? Is it sufficiently low that the analysis only need consider transient-fueled fires? As shown by the results of a number of IPEEEs, differences in analysis assumptions can lead to qualitatively different risk insights.

Nuclear power plant data for self-ignited cable fires are sparse; the number of reported events is small and the event descriptions rarely include much detail about the types of cables involved. Information is needed on: a) relevant events from other facilities and industries, and b) scenarios leading to fire initiation.

The objectives of this task are as follows:

- Determine if there is an adequate technical basis for asserting that the frequency of self-ignited fires involving IEEE-383 rated cables is too small to consider in nuclear power plant FRAs.

- Failing the above, determine the feasibility of developing a practical, improved methodology for estimating the frequency of such fires.

- Identify the work needed to develop and implement this methodology.

3.4 Fire Modeling Toolbox: Input Data and Assessment

Some of the key uncertainties in the prediction of the hazardous environment induced by a fire, and of the response of critical equipment to this environment, are due to sparseness of basic data concerning: a) the flammability and damageability characteristics of the equipment under fire conditions, and b) the validity of currently available physical models for predicting the fire-induced environment.

Numerous experiments have been performed to collect various data relevant to the thermal behavior and effects of fires in nuclear power plants. However, there are three problems with these data. First, in some cases, the data have not been processed to allow their use by analysts. Second, the experiments were not usually performed with the needs of fire modeling in mind. (This means that direct measurements of key model parameters may be lacking.) Third, weaknesses in the experimental processes (from an FRA modeling perspective) have not been characterized. The latter two concerns do not mean that the experimental results are useless; they do mean that data processing will require not only transcription of raw data into appropriate media and formats, but also characterization from an FRA perspective.

Some work has been performed on non-thermal effects of fire. This work has led to identification of potential failure modes of electronic equipment due to smoke effects (e.g., [17,18]). It has not yet led to characterizations of the fragilities of key equipment that can be directly used in FRAs. Additional work is needed to develop these fragilities.

The objectives of this task are as follows:

! Collect and characterize available experimental data potentially relevant to the prediction of electrical cable flammability and thermal fragility.

! Collect and characterize available experimental data potentially relevant to the prediction of the thermal fragility of other potentially risk significant nuclear power plant components.

! Collect and characterize available experimental data potentially relevant to the assessment of model uncertainties in current fire environment models.

! Process and publish the SNL base line fire model validation data (see Ref. 19) in a format suitable for its use by analysts to validate fire models used in FRAs.

! Generate experimental data needed to assess the smoke fragility of potentially risk significant nuclear power plant components.

! Collect and characterize available experimental data potentially relevant to the assessment of fire heat release rates.

3.5 Experience from Major Fires

A number of safety significant fires have occurred in U.S. and international nuclear power plants (e.g., see Refs. 20 and 21). While these events have been studied from a fire protection point of view, current FRAs tend to make limited use of the information obtained from these events. For example, counts of events are used to estimate fire frequencies, but the descriptions of many events have not been seriously studied to determine if changes in the FRA models or even basic FRA structure are warranted.

The objectives of this task are as follows:

- Identify key fire risk and FRA insights from serious U.S. and international nuclear power plant fires.

- Develop recommendations for FRA improvements and areas for further investigation.

3.6 Industrial Fire Experience

Reportable nuclear power plant fires are not frequent events; the average occurrence rate is on the order of 0.3 per plant-year [22]. The frequency of potentially risk significant fires is considerably lower. Thus, current FRA characterizations of the relative likelihood and progression of nuclear power plant fire scenarios are largely model- rather than experience-based. To reduce the uncertainties in these characterizations, it should be useful to review the experience from non-nuclear industrial fires involving equipment and occupancies similar to those found in nuclear power plants. Such a review can provide useful qualitative information (e.g., how well do operators perform in degraded environments) as well as indications of the relative likelihood of different scenarios. As discussed in Ref. 23, it is not expected that the review will necessarily lead to quantitative data that can be directly used in estimates of fire scenario frequencies; the non-nuclear information sources appear to be in such a form that resource requirements for such an effort would be considerable.

The objective of this task is to collect and evaluate industrial data relevant to the analyses of specific nuclear power plant fire scenarios.

3.7 Frequency and Characteristics of Switchgear and Transformer Fires

Fires involving low- to medium-voltage (# 6.19kV) electrical switchgear (including motor control centers) are often important contributors to fire risk. However, there is considerable uncertainty as to how switchgear fires should be modeled (as a hazard to other components in the area). Many IPEEEs have selected a relatively low heat release rate for their switchgear fires, as compared with the full range of results obtained from Sandia National Laboratories (SNL) electrical panel fire tests [24,25]]. The value used (69 kW) represents the burning of a single bundle of IEEE-383 qualified cables; fires involving more fuel will naturally be greater in magnitude. There is also considerable uncertainty concerning the heat release rates of indoor transformer fires.

Besides data uncertainties, a concern with current FRAs is that they treat switchgear and transformer fires essentially as pool fires. They do not account for the events leading up to the fire. In particular, if the fire is started by an electrical fault, the scenario can involve the overheating and ignition of cables far removed from the component. In the case of oil-filled transformer fires, an energetic fault can lead to a spray of burning oil rather than a pool. Furthermore, the blast and missiles from an energetic fault can cause direct mechanical damage to nearby components.

The objectives of this task are as follows:

- Develop frequency-magnitude relationships for switchgear and transformer fires.

- Develop a simple method for addressing the non-thermal effects of switchgear and transformer energetic faults.

3.8 Fire Barrier Reliability Model Development and Application

The treatment of local fire barriers varies in current FRAs. Approaches include: a) fully crediting the barriers if they are included in a fire barrier surveillance program [14]; b) using simple heat transfer models (not a common approach); c) crediting barriers for delaying fire-induced damage and ignition based on experimental results for a limited number of barrier systems [10]. The first approach doesn't allow for the finite probability of failure of the barrier. The second and third approaches do not account for key factors (e.g., mechanical construction details, material behavior under fire conditions) which affect performance of many current barrier systems. The third approach also uses experimental results in situations not directly covered by the experiments (e.g., different fire severities, geometries).

Intercompartment fire barriers are typically fully credited when the barriers separate fire areas. Some studies employ reliability estimates for specific barrier elements (penetration seals, dampers, doors); these estimates are quoted in Refs. 9 and 15. Many studies fully credit barriers between fire zones under certain conditions (e.g., see [14]). Again, the first approach doesn't allow for the barrier to fail. Regarding the second and third approaches, the formal technical bases for the estimates/conditions are unavailable.

The objectives of this task are as follows:

- Develop a screening model for predicting the performance of local fire barriers under exposure fire conditions. The model will address probabilistic issues (e.g., barrier construction and installation) as well as phenomenological issues (e.g., exposure fire severity).

- Estimate the probability of failure (on demand) of fire dampers, fire doors, and penetration seals for challenging fire scenarios.

3.9 Integrated Model and Parameter Uncertainty

In general, methods for estimating “parameter uncertainty,” i.e., uncertainty in the model output due to uncertainties in the model parameters, are well known and routinely applied in many situations. On the other hand, there currently is no consensus concerning formal methods for estimating “model uncertainty,” i.e., the additional output uncertainty due to modeling approximations. Ref. 26 presents many viewpoints on how model uncertainty should be defined and addressed in general situations.

In the case of fire model prediction, simulation codes are available to predict the dynamic behavior of variables that are, in principle, measureable. Furthermore, limited amounts of experimental data potentially useful for estimating output model uncertainty are also available. However, the experiments do not cover all possible situations to which the model will be applied. This can affect the applicability of any experimentally-derived output model uncertainty distribution. Further, the values of the model parameters needed to simulate the experiments may not be well known. (Note that the experiments are not necessarily performed for the sake of model validation.) It may therefore be unclear as to how much of the difference between model predictions and experimental data is due to the parameter uncertainty and how much is due to the model uncertainty.

A relatively simple approach for quantifying uncertainty in model predictions in the presence of model uncertainty and parameter uncertainty is proposed in Ref. 27. However, this approach has not been fully tested. Furthermore, the relationship between the approach and the fundamental frameworks discussed in Ref. 26 has not been investigated.

Work on this task is being performed as part of a cooperative research agreement with the University of Maryland.

The objectives of this task are as follows:

- Evaluate the ability of various methodologies to assess model uncertainty to the same level as parameter uncertainties, and formulate a framework under which their combined uncertainties can be assessed.

- Demonstrate how the formulated framework can be applied to address real issues involving combined parameter and model uncertainties.

3.10 Frequency of Challenging Fires

One of the key issues in fire frequency analysis for FRA is the reduction of fire frequencies performed in most detailed FRAs to accommodate the fact that not all fires are risk significant, i.e., that a fire must have the proper location and severity characteristics to be an important contributor to critical equipment damage. Current reduction factors used to address location and severity considerations can reduce the compartment fire frequencies (the λ_j) by one or more orders of magnitude. However, the basis for these reduction factors is not strong. Early studies (e.g., Ref. 28) relied heavily on analyst judgment. Attempts to reduce the influence of judgment have led to: a) the component-based approach to fire frequency, employed in the FIVE methodology [14], and b) event-based estimation of severity fractions (e.g., [10]). The concerns with the event-based treatment of the severity issue include: ambiguity in the data (qualitative event narratives are used to determine if a given fire was severe); possible double-counting of the impact of suppression in the data (effective suppression may be the reason why a particular fire was not reported as being severe, but fire suppression is modeled separately in the FRA); neglect of possibly significant differences between conditions (e.g., fuel bed geometry) of the event and those of the situation being analyzed in the FRA which can affect the severity of the fire; and scarcity of data for the large, transient-fueled fires that have been predicted to dominate fire risk in a number of studies.

The preceding issues deal with the problem of quantifying the likelihood of fire occurrence. A related issue concerns the establishment of conditions for the next stage of the FRA, the estimation of the likelihood of equipment damage. Current methods for performing this next stage generally rely upon fire environment simulation models which require the specification of the initial scenario conditions. The problem is that current fire frequency analyses provide, at most, the frequency of "small" and "large" fires in a specified compartment or involving a specified component. They do not provide the physical characteristics associated with these "small" and "large" fires needed by the simulation models. This ambiguous interface between the fire frequency and equipment damage analyses allows significant analyst discretion. For example, Ref. 28 assumes that "large" fires have a severity equivalent to a 2-foot diameter oil fire, while Ref. 29 assumes that this is the equivalent severity of "small" fires.

The objectives of this task are to:

- Determine the feasibility of developing a practical, improved methodology for defining, characterizing, and quantifying the frequency of challenging nuclear power plant fire scenarios.

- Develop and demonstrate the methodology.

3.11 Fire Model Limitations and Application Guidance

In FRA, characterization of the fire-induced hazardous environment requires the estimation of the time-dependent temperature and heat fluxes in the neighborhood of the safety equipment of interest (i.e., the "targets"). This requires the treatment of a variety of phenomena as the fire grows in size and severity, including the spread of fire over the initiating component (or fuel bed), the characteristics of the fire plume and ceiling jet, the spread of the fire to non-contiguous components, the development of a hot gas layer, and the propagation of the hot gas layer or fire to neighboring compartments. It also requires an appropriate treatment of uncertainties in the structure and parameters of the models used to perform the analysis.

To date, U.S. nuclear power plant FRAs have used quite simple zone model-based tools, e.g., the correlations provided as part of the FIVE methodology [14] and the COMPBRN IIIe computer code [30], to predict the thermal environment due to a variety of fire sources. However, it is not always recognized in FRAs that these tools have been developed to address specific classes of fire problems and are not applicable to all situations. For example, the inherent modeling assumptions in both FIVE and COMPBRN do not address many practical complexities (e.g., obstructions in the fire plume, complex compartment geometry, complexities in forced ventilation flow, physical movement of fuel, room flashover) which can be important in some analyses. Further, the correlations employed implicitly or explicitly by these models are not appropriate for all situations. Some scenarios of potential concern include very small fires (e.g., single wire electrical insulation fires), very large fires (e.g., very large oil spill fires), or elevated fires. Unfortunately, the limitations of these simple models have not been succinctly characterized to inform FRA analysts, many of whom may not have strong background in fire science, when they should be wary of the model predictions.

The objectives of this task are:

- To identify the areas of uncertainty and limitations associated with fire models which are either: a) currently used in FRAs, or b) might be used in future FRAs.

- To develop improved guidance for using these fire models in FRAs.

3.12 Risk Significance of Turbine Building Fires

Historical turbine building fires (e.g., Narora [21]) and a number of IPEEEs show that severe turbine building fires can be important contributors to risk. Potential sources of uncertainty in the evaluation include the lack of knowledge concerning the frequency-magnitude relationship for turbine building fires and the adequacy of current FRA tools for predicting the environment induced by a severe turbine building fire.

The objectives of this task are to:

- Improve the technical basis for fire risk assessments of turbine building fires.

- Assess the risk significance of turbine building fires.

- Develop recommendations for FRA improvements and areas for further investigation.

3.13. Penetration Seals

Between 1994 and 1998, the NRC staff performed a number of technical assessments of fire penetration seals to address reports of potential problems, to determine if there were any problems of safety significance, and to determine if NRC requirements, review guidance, and inspection procedures were adequate [31]. During the resolution process of this issue, questions were raised regarding the risk significance of the issues and problems, and whether risk-informed approaches to issue resolution were available [32].

The objectives of this task are to:

- Determine the extent to which current fire risk assessment methods and data can be confidently used to support prioritization of penetration seals for inspection.

- Identify issues (if any) requiring research to improve risk-informed prioritization and/or confidence in such a prioritization.

3.14 Risk Significance of Multiple Unit Interactions

The results of a number of IPEEE reviews show that the risk implications of scenarios where a single fire can induce simultaneous transients in multiple units may be significant. Although the frequencies of such scenarios are expected to be low, their potential consequences are significantly greater than those of scenarios affecting only one unit. A concern is that IPEEEs using scenario screening frequencies of 10^{-6}/yr may have screened out these scenarios without considering their potential effect.

The objectives of this task are to:

- Identify plants where a single, severe fire may simultaneously affect multiple units and assess the risk implications of such fires.

- Develop recommendations for additional research.

3.15 Use of Advanced Fire Models in Fire Risk Assessment

As discussed in Section 3.11, the modeling assumptions inherent in the fire models currently used in FRAs do not address many practical issues which can be important in some analyses. A number of these issues, e.g., obstructions in the fire plume, complex compartment geometry, complexities in forced ventilation flow, are addressed by state of the art “field models” (e.g., the National Institute of Standards and Technology’s Large Eddy Simulation code [33]) which explicitly address the computational fluid dynamics aspects of fire. Although these models are currently too resource intensive (including analyst time as well as computation time) for routine use in FRAs, it appears that they should be useful tools for evaluating, and even modifying, the simpler FRA models.

The objectives of this task are to:

- Identify specific FRA areas where field models could be used to improve confidence in FRA results.

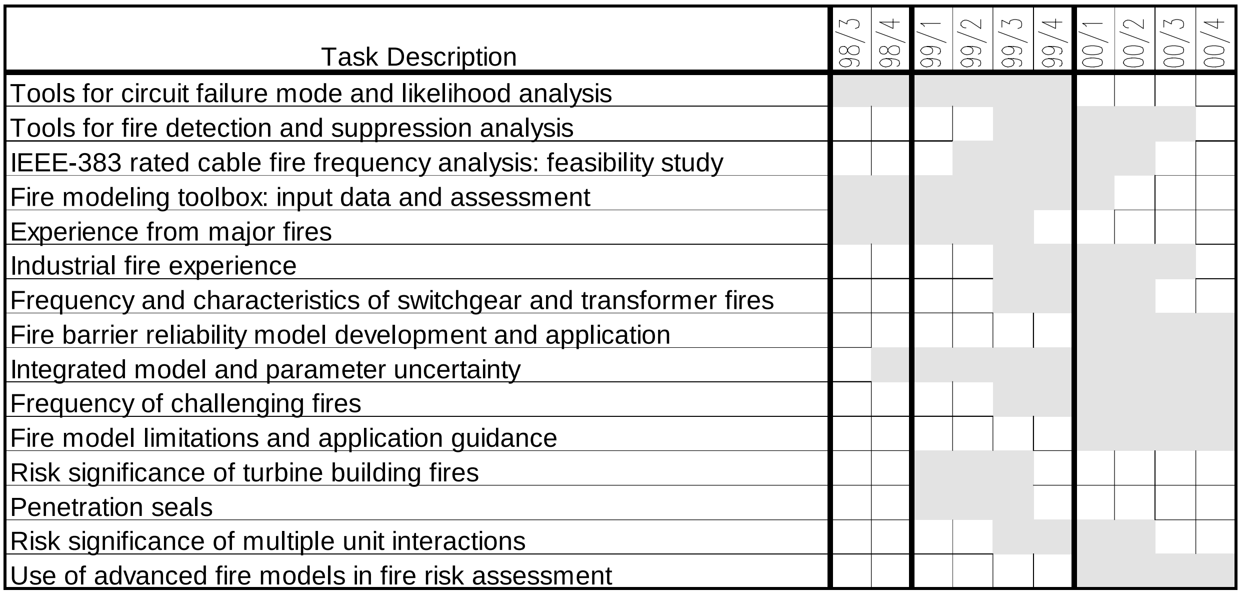
- Use a selected field model to model fire experiments of interest to FRA (including the SNL base line validation tests [19]).

- Develop recommendations concerning the appropriate role of current field models in FRA and what work needs to be done to allow such use.

4. PROGRAM SCHEDULE

Figure 1 shows the overall schedule for the fire risk research program tasks.

Figure 1. Overall Task Schedule



5. POTENTIAL FUTURE ACTIVITIES

It is anticipated that, by the end of FY 2000, the NRC fire risk research program will yield a set of FRA improvements and insights that will be useful in addressing specific fire protection issues. However, the program as currently defined does not provide a summary statement of the overall impact of the FRA improvements, nor does it provide a summary set of guidance for performing improved FRA. Furthermore, it does not complete the integration of advanced fire models (or their results) into FRA. These are important activities for supporting the increased use of risk-informed, performance-based methods in fire protection. The following tasks may therefore be defined and initiated after FY 2000.

! Fire risk requantification. This task will apply the results of the fire risk research program in a requantification of the fire risk for a selected plant. The objectives of the requantification will be to determine the risk impact associated with the FRA improvements and to develop insights concerning the application of the improved FRA methods and tools.

- FRA guidance development. This task will use the results of the fire risk research program to develop an improved guidance document for performing FRA. This document will support the standardization of FRA at a level of description more detailed than that currently envisioned for the NFPA 805 standard.

- Integration of advanced fire models into FRA. This task will use the results of the task "Use of Advanced Fire Models in Fire Risk Assessment" (see Section 3.15) to incorporate advanced fire models (or their results) into FRA.

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