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Decision Modeling for Analyzing Fire Action Outcomes

Donald G. MacGregor and Armando González-Cabán

Authors

Donald G. MacGregor is President, MacGregor-Bates, Inc., 1010 Villard Ave., Cottage Grove, OR 97424. **Armando González-Cabán** is a research economist, U.S. Department of Agriculture, Forest Service, Pacific Southwest Research Station, 4955 Canyon Crest Drive, Riverside, CA 92507.

Cover photos

Top photo: El Dorado Hot Shots crew preparing for burnout on the Pot Peak fire, Chelan Ranger District, Washington, July 2004.
Bottom photo: Crew members plan strategy for the day. Pot Peak fire, Chelan Ranger District, Washington, July 2004.

Other photos: Mike Ferris Public Information Officer, National Incident Management Information (NIMO), State Forestry (WO), Fire and Aviation Management, NIFC.

Abstract

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A methodology for incident decomposition and reconstruction is developed based on the concept of an "event-frame model." The event-frame model characterizes a fire incident in terms of (a) environmental events that pertain to the fire and the fire context (e.g., fire behavior, weather, fuels) and (b) management events that represent responses to the fire environment. The model defines a sequential set of event-frames according to temporal and contextual factors (e.g., management processes) that yield a visual representation of an incident decomposition. The set of event-frames decomposes an incident into discrete units of analysis that can incorporate other models or processes (e.g., decision analysis) to describe decision elements of a fire incident. Based on the reconstructions reported here, we find that decision processes differ according to the incident and its events. From the reconstruction of the Old Fire, we identified how some incident decisions are actually legacy decisions. These are for anticipated incidents–ones for which even extreme occurrences have been envisioned and action contingencies established. From the reconstruction of the Fork Fire, decision modeling revealed that local knowledge plays a key role in early management stages as well as in management decisionmaking several days into an incident. Our analysis reaffirms that although fire is a continuous, exponential process that changes seamlessly, if abruptly at times, management is a discrete process that changes linearly and in discontinuous stages with the intention of avoiding a purely reactionary management response. However, this fundamental incompatibility between fire as a nonlinear, continuous process and management as a linear and discontinuous one means that discontinuities in management processes may impede management performance.

Keywords: Event-frame model, Old Fire, Fork Fire, wildfire decisionmaking, fire management.

Summary

Although the vast majority of wildland fires are suppressed effectively in initial or extended attack, on relatively rare occasions fires become exceptionally large, resulting in unusual resource damages, significant financial impacts, and even loss of life. Understanding how to better manage large fires and to improve methods for

controlling their costs and impacts requires a detailed knowledge of the decisionmaking processes that were ongoing at the time of the incident. Fire reviews undertaken post hoc tend to focus predominantly on incident characteristics and not on the broader decisionmaking context within which incident management occurs. The intent of the research reported here is to use the theories, concepts, and language of decisionmaking to develop models for decomposing and reconstructing large-fire decision processes. A theory of incident decomposition is developed based on a hierarchical set of influences that include (a) incident-specific factors, (b) pre-incident factors, and (c) legacy influences that reflect historical factors such as land use policies. The hierarchical set of influences is organized in terms of "meta decisions" that result in conditions that subsequently influence the decision process and outcomes of specific fire incidents.

A methodology for incident decomposition and reconstruction is developed based on the concept of an "event-frame model." The event-frame model characterizes a fire incident in terms of (a) environmental events that pertain to the fire and the fire context (e.g., fire behavior, weather, fuels, resources at risk) and (b) management events that represent responses to the fire environment. The model defines a sequential set of event-frames according to temporal and contextual factors (e.g., management processes) that yield a visual representation of an incident decomposition. The set of event-frames decomposes an incident into discrete units of analysis that can incorporate other models or processes (e.g., decision analysis) to describe decision elements of a fire incident.

As a basis for this approach, a set of relevant theoretical models of decisionmaking are discussed in terms of their essential concepts and language. Decision models serve as a basis for the development of a knowledge acquisition approach that is used to reconstruct key decision processes on actual fire incidents. The reconstruction process uses a combination of incident documentation and a decision process tracing protocol (DPTP) to guide interviews with key incident personnel. Incident documentation (e.g., Incident Command System [ICS-209], Wildland Fire Situation Analysis [WFSA]) provides a basis for the development of an initial event-frame model. The DPTP is a framework of decision concepts and language that identifies a set of knowledge probes to which interviewees respond. Each of the knowledge probes is linked to a theoretical model. Responses to the knowledge probes are then used to identify the relevant theoretical models to include in the reconstruction. The results of the reconstruction are represented graphically as influence diagrams and process models.

To illustrate how the reconstruction process is applied, two case studies are examined. One case study is based on the Fork Fire, which occurred on the Mendocino National Forest (NF) in August of 1996. A second case study is the Old Fire, which occurred on the San Bernardino NF in October of 2003. The case studies are illustrative, but are not intended to be fire reviews. They were chosen to provide a realistic basis for demonstrating the approach and types of outputs it produces. No attempt is made to evaluate the quality of decisionmaking on the case incidents.

Although decisionmaking can be conceptualized as a process of evaluating alternatives represented in terms of a decision tree, there are other decision models and languages that describe in greater detail and with more fidelity the realism of dynamic, time-pressured decisionmaking where multiple influences interact to form an impression on the decisionmaker that guides their actions. Based on the reconstructions reported here, we find that decision processes differ according to the incident and its events. From the reconstruction of the Old Fire, we identified how some incident decisions are actually legacy decisions. These are anticipated incidents–ones for which even extreme occurrences have been envisioned and action contingencies established. Although no large fire can be thought of as a normal occurrence, it is within reason to think of events like the Old Fire as "normal catastrophes," similar to the concept of "normal accidents" that has been used to characterize some major technological accidents (Perrow 1984).

Within ongoing incidents, decision processes can differ considerably depending on the stage of the incident and on how management processes are structured and executed. From the reconstruction of the Fork Fire, we observed fundamental differences in decision processes between initial/extended attack and ongoing incident management team (IMT) management. Decision modeling revealed that local knowledge plays a key role in early management stages as well as in management decisionmaking several days into an incident. We note that fundamental and important discontinuities may exist in these different management decisionmaking stages. Our analysis reaffirms that although fire is a continuous, exponential process that changes seamlessly, if abruptly at times, management is a discrete process that changes linearly and in discontinuous stages. This fundamental incompatibility between fire as a nonlinear, continuous process and management as a linear and discontinuous one means that discontinuities in management processes may impede management performance. A definition and operationalization of these concepts may be found in the notion of decision-process discontinuities.

The results of this project identified the following directions for further research.

Apply Methods to a Larger Base of Incident Cases

This project provides potentially powerful insights into how decision processes can be revealed through the application of decision science theories and concepts to fire incidents. Additional cases need to be examined for further validation of this approach to understanding large-fire decisionmaking.

Identify Approaches for Incorporating Decision Modeling Into Fire Reviews and Accident Analysis

Field-related research could see to identify how the methods developed in this project could be incorporated into management review activities. Possible methods include workshops and seminars on the approaches in the present study and how they can be directly applied in the field, as well as the development of a set of in-depth protocols directed toward understanding key decision stages of fire incidents, such as initial attack (IA) and extended attack (EA) and management transitions.

Improving the Worst-Case Scenario Process

Our research identified dramatic effects a worst-case analysis can have on downstream decision processes associated with large-fire management. At present, the process for constructing a worst-case analysis or scenario is not standardized within the fire management community. Given the importance of a worst-case analysis in developing an appropriate basis for comparing strategic alternatives and for communicating to line management the potential scope and impact of an emerging incident, better standards and procedures could be developed and communicated concerning how a worst-case scenario should be constructed and represented. Current methods from the decision and risk sciences that offer guidance on worst-case analyses need to be translated and applied in the context of fire management decisionmaking.

Improving Accessibility and Usability of Local Knowledge

Local knowledge was shown to be of significant importance in the decision processes associated with IA and EA as well as ongoing IMT management. However, significant management discontinuities can exist that inhibit or prevent local knowledge from entering into decision processes. Effort should be placed on understanding in greater detail how local knowledge of all aspects of the fire situation can be made more accessible and usable to incoming IMT members.

Effects of Individual Differences in Initial and Extended Attack Decisionmaking

The application of control theory to the decision processes associated with IA and EA identified a set of trigger conditions that determine when and how the decision to transition to a higher level of incident management occurs. These trigger conditions relied on an affective assessment of the relationship between current capabilities, resources required, and the fire situation. Effort should be directed toward understanding how individuals differ with respect to risk assessment in ongoing IA and EA operations, and how they differ with respect to the conditions under which they decide that an upward transition is needed.

Characterizing Discontinuities in Decision Processes

Ideally, shifts from one management mode to another would be continuous and well-articulated. In reality, the continuity between management modalities may be disrupted or impeded. This project identified a number of potential discontinuities in decision process that arise from management events and activities on large fires. These discontinuities pose potential challenges to effective and continuous decisionmaking. Research could further examine decision-process discontinuities and how they can influence incident decision processes and outcomes.

Contents

Introduction

Each year, thousands of fires occur on public lands. The vast majority of these fires are effectively suppressed in initial attack (IA) at a relatively small size, usually an acre or two, or less. Of fires that exceed IA, most are suppressed in extended attack (EA) and rarely exceed 100 acres or more. However, for a small proportion of all fires, generally less than 1 percent, unusual environmental, fuel, or resource capability conditions can result in particularly large or uncharacteristic fires that have as outcomes high monetary costs, loss of high-valued public or private resources, and (in the extreme case) loss of human life. Although large fires are relatively rare, they tend to lead to a high level of postincident analysis to determine (a) the possible causes and attributions of the catastrophic outcomes, and (b) actions or steps that can be taken to help prevent or mitigate similar occurrences in the future. An accounting of the incident is required in terms of decisions and decision factors that influenced the outcome.

This paper reports on the development of a process for analyzing fire incidents to help improve fire management practices. The focus of the research is a method for analyzing fire incidents in terms of decisionmaking principles, using the language of decision and risk analysis as a basis for representing the relationship between fire management decisionmaking and incident outcomes. The essential spirit of the approach is embodied in one of the central concepts from decision analysis, that of decomposition. The essence of decomposition is that large, complex problems can be understood better by breaking them down or "decomposing" them into smaller, more tractable problems that can be solved or characterized in some detail. The individual components of the decomposition are then reconstructed or assembled into a whole. Decomposition is the fundamental principle on which decision and risk analysis are based (Frohwein and Lambert 2000, Haimes 1998, Keeney and Raiffa 1976, Raiffa 1968) and has been applied in numerous other contexts including judgmental forecasting (e.g., Armstrong 2001, MacGregor 2001).

Different models give us concepts to work with, and no one model or theory tells the whole story. Multiple models are needed to describe complex decisionmaking. We can only capture the richness and complexity of fire management decisionmaking on large incidents by examining incidents through the lenses of multiple models and theories. Each theory provides different concepts and frameworks that give insights into how decisionmaking is done, the factors that influence decisionmaking, and the relationship of a stream of incident-related decisions to the ultimate outcome of the incident.

Large-fire decisionmaking is a multilayered phenomenon. It has properties of organizational decisionmaking as well as individuals' decisionmaking. In this project, we first develop the general concept of an incident decomposition and identify a tiered layering of social, organizational, and incident factors that influence incident-specific decisions and decision outcomes. We then review a set of relevant theories and models relating to dynamic decisionmaking as a basis for identifying concepts and principles that have value in explaining or characterizing incident decision. We then apply this theoretical development to the decomposition of an incident in terms of an event-frame model, by which key events relating to the incident are set out in a temporal sequence and represented according to a set of concepts and principles identified in the overview of models. The structure of an incident is populated with two general sources of information: the documentation generated as part of the incident, and a protocol approach for key incident personnel. The protocol is based on a framework of concepts from the overview of decision theories and models. The overall approach is then illustrated in the context of two case studies. The purpose of the case studies is to show how the language of decisionmaking and the structure of the event-frame process can be used to characterize and represent decisionmaking on an actual incident.

It is not the purpose of this study to serve as an incident review of the cases chosen as examples. Neither the time nor the resources were available to conduct such an exercise. The purpose of the project is to demonstrate how decision science principles can be transferred from a set of theories of models and applied to key decisions on a fire incident. This demonstration may be useful for improving the processes by which fire reviews are conducted, as well as identifying training opportunities in decision-support cases where more effort and resources can be applied to understanding an incident in greater detail.

The Language of Constructed Decisionmaking

Over the past several decades, a number of theories have been advanced to describe how people do or should make decisions, including economic decision theory, subjective expected utility theory, Bayesian decision theory, behavioral decision theory, cybernetic control theory, and naturalistic decisionmaking. These theories constitute explanations for observable behavior based on concepts and constructs that are not directly observable, but that become available or are inferred based on observed behaviors, verbal descriptions of mental processes or events, and deductions based on controlled laboratory experiments. When these explanations pertain to what people purportedly do, they constitute a descriptive theory; when they pertain to what people should do, they constitute a prescriptive theory, by which it is meant that the theory represents a normatively appropriate or optimal scheme that if followed by the decisionmaker will lead to the best course of action. Traditional theories of decisionmaking based on economic theory relied upon the logic of mathematics for their prescription. More recent theories rely on a combination of process and logic (e.g., decision analysis; cybernetic theory) or on the notion of an expert decisionmaker (e.g., naturalistic decisionmaking) as a benchmark by which to gauge the quality of decision performance.

In both cases, however, explanations for behavior in terms of decisionmaking concepts constitute a language-based description. As such, they are an emergent phenomenon, a reflective construction based on the mental activities people experience (e.g., images, thoughts, intentions, expectations) and the physical actions people take (e.g., behaviors) expressed in terms of a decisionmaking language derived from one or more decisionmaking theories. We refer to these as decisionmaking languages because they have properties in common with languages in general: (a) a semantic structure that gives meaning to the terms of the theory and therefore the language, (b) a grammar that defines the system of rules for generating meaningful statements in the theory or language, and (c) a syntax that defines the way in which statements in the language are formed.

We refer to the construction as reflective for two reasons. First, the term reflective refers to the tendency of decisions to be manifest in one's actions. Second, reflectiveness also captures the seriousness of intent and consideration that is characteristic of those actions and circumstances important enough to represent in terms of a decisionmaking language.

Like natural human languages, decisionmaking languages each provide a unique perspective on decisionmaking according to their particular variations of the basic language properties of semantics, grammar, and syntax. Each language provides a unique perspective on decisionmaking and leads to a different construction of a decision.

We characterize decisionmaking as an emergent phenomenon because it comes into being as a result of our descriptions of human behavior. Decisionmaking is not an intrinsic property of human consciousness and action, but rather is an emergent property of mental activities and physical events in the same sense that liquidity is an emergent property of the movement of H_2O molecules. Emergent decisions are computational interpretations that arise from information flows, attitudes, perceptions, beliefs, behaviors, and collaborative (or social) interactions that are represented according to the language and terminology of a particular theory of decisionmaking.

In general, it is difficult if not impossible to construct an explanation of human actions in decisionmaking terms without recourse to language. Indeed, it is arguable that we cannot think with any degree of coherence without recourse to language of some type, even if the language is simply metaphorical. Languages serve as the basis for all communication, and an understanding of different decisionmaking languages improves our ability to represent and understand human actions and their outcomes from a more complete set of perspectives, as each language will provide a richer characterization of some aspect of decisionmaking than will others. Thus, there is no single “right” or correct language by which explanations of decisionmaking can be constructed. Therefore, the best way to understand a set of circumstances as a decision problem is to characterize it in terms of several languages or theories.

A General Model for Incident Decomposition

Decomposing a fire incident requires a guiding structure that identifies the factors influencing incident decisions and outcomes. A framework for this decomposition represents incident decisions and outcomes as the result of factors specific to an incident as well as factors and influences present at higher organizational and social contextual levels (fig. 1).

The framework comprises multiple levels of influence beginning at a broad social level that includes laws, statutes, and cultural values (S_i’s in the model). These general influences are exterior to the organization but influence organizational meta decisions (O_i’s in the model) that include policies, plans, and procedures that set an organizational contextual frame for how decisions specific to an incident are structured and evaluated. These incident-specific decisions are shown in the model as a set of alternatives ($A_{i,j}$’s) associated with decision problems that are linked to a temporal dimension associated with the incident. In the course of a given incident, a number of such decision situations arise and can be given a temporal location. Likewise, decision outcomes and effects (E_i’s) resulting from incident decisions can be given a temporal location as well. In an actual incident analysis, decision outcomes and effects are linked to subsequent decisions.

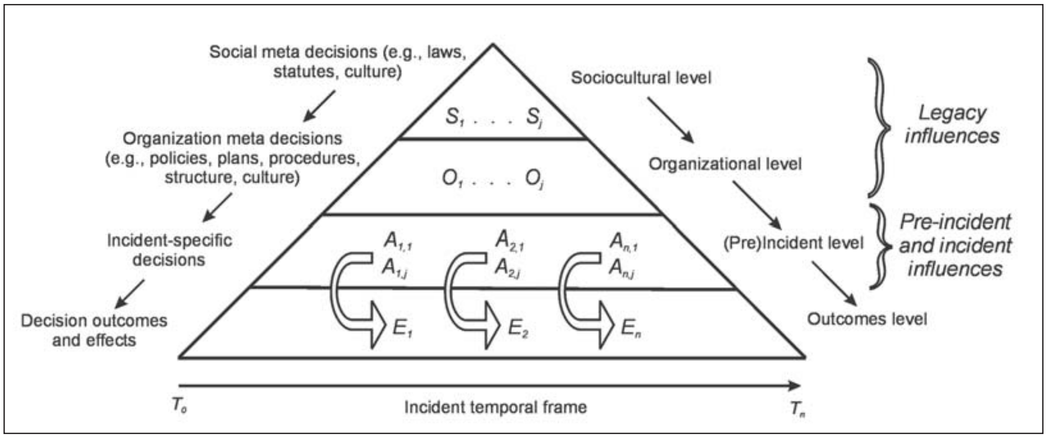

Figure 1—General model of incident decomposition. Adapted from Paté-Cornell 1993.

An Influence Diagram Representation

The essential elements of the model can be represented as an influence diagram depicting the relationship between components at each of the levels. Influence diagrams are a form of visual representation that depicts relationships between components of a decision problem (e.g., Oliver and Smith 1990). Arrows between components denote an influence, where an influence expresses knowledge about relevance. A causal relationship is not necessarily implied, but an influence exerts a force such that knowing more about A directly affects our belief or expectation about B.

For an actual case, an influence diagram would be complex and would show not only the relationships between levels, but also the relationships between concepts at each level as well as the relationships between incident outcomes and the societal and organizational levels. A relatively simple model serves to illustrate how the relationships might be portrayed in terms of influences using some general elements at each level (fig. 2). Starting at the bottom of the model is a sequence of major incident events starting at time T_0 and continuing through to the end of the incident at time T_n, where *n* can represent a range of days, weeks, or even months depending on the length of the incident. At the top level of the representation is the societal level, comprising three components: political and public values, statutory law, and civil law. In the middle is the organizational level, represented by three components: organizational culture, formal policy, and plans and strategies.

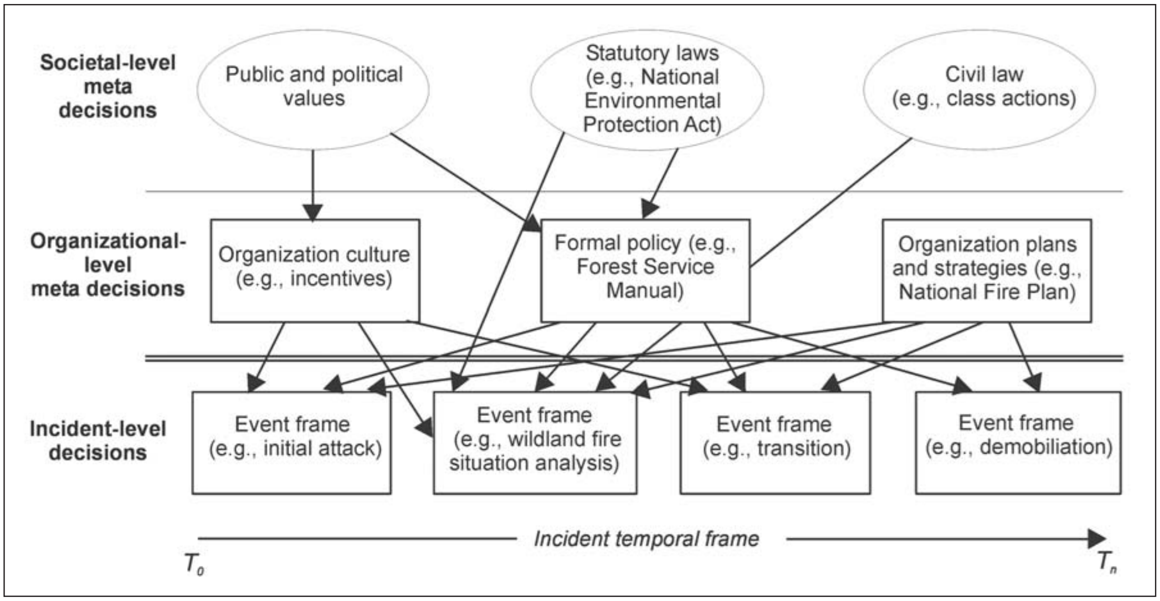

Figure 2—Influence diagram representation of a simplified fire incident.

Social and Organizational Influences on Decision Outcomes

The process of analyzing fire incidents based on their outcomes is generally one of working backwards or upstream to determine the proximal causes of the outcomes. Most generally this is done in terms of one of three general categories of causal factors: environmental conditions (e.g., weather, fire behavior, fuels), technological conditions (e.g., equipment), or human actions. As relatively clear causal influences emerge, the analysis becomes bounded and the pattern of causation becomes fixed. This approach contains key assumptions about the relationship between incident factors and incident outcomes. First, it assumes that the diagnostic or causative weight of an incident factor is greater the closer it is in time and space to the outcome. Second, it assumes that a "bottom up" approach will capture the majority of influences that are present in an incident management situation and that account for incident outcomes. Third, it assumes that the links between incident factors and incident outcomes is deterministic or strictly causal, rather than probabilistic.

The root influences on incident decisions and decision outcomes can come from factors far removed in space and time from the incident itself. As has been shown in other contexts, such as technological failure, accidents and events that result in monetary and material losses (including loss of human life) may evolve from "normal" operations, and the antecedents of decision outcomes can only be understood by examining factors that are part of the social and organizational context within which events occur (Perrow 1984). As an example, Paté-Cornell (1990, 1993) used a combination of influence diagramming and decision analysis to model the failure of an offshore drilling platform (Piper Alpha) in the North Sea oil field. She found that the original failure analysis of the drilling platform accident was heavily driven by technical and engineering factors, which tended to focus the inquiry in such a way as to produce technical solutions to the problem. However, a more careful and extended analysis of the roots of engineering failure identified a number of organizational decisions that influenced failure probabilities in ways that were not readily identifiable by examining details of the incident alone. As a result of the analysis, a general model was developed that decomposed incident outcomes into a combination of social, organizational, and incident-specific factors.

Societal Metadecisions

These are decisions made at a broad societal level and reflect general cultural views and values. The decisions themselves are embodied in laws and statutes that govern and guide what organizations can do. Cultural values relevant to these laws can range from the general to the specific with respect to fire and its management. For example, broad sociopolitical values about the appropriate role of government in regulating organizations and the lives of individuals captures, perhaps, the broadest sense of this concept. More specific to fire and its management, social values about the environment, environmental protection, the role of fire in ecosystems and the like also impact societal metadecisions. As an example, the various federal statutes and laws that provide for protection of environmental amenities (e.g., threatened and endangered species, air quality, water quality) are the result of scientific and political processes that operate at the highest levels in society and that reflect a determination that overarching goals and objectives (many of them protective) be met as part of any actions that impact the environment (e.g., National Environmental Protection Act).

These influences can be thought of as upstream factors that exert their effects in a number of ways. They may take the form of specific standards and guides that organizations are required by law to abide by as part of their operations. Air quality standards, for example, fall into this category as do water quality, species protection laws, and occupational safety standards. In some cases, these standards and guides will be directly passed through to the organizational level, and in other cases they may be interpreted and incorporated into an organization's culture. Also, they may have an impact by sociopolitical pressures they exert on organizational decisionmaking. For example, an imperative to reduce large-fire costs may be reflective of a relatively nonspecific sociopolitical goal of cost reduction but without a specific rule or guide to identify either the means to use to achieve cost reduction or the specific cost-reduction end to achieve.

Another category of influence at the societal level results from broad public views about factors relating to fire management decisionmaking. Public attitudes about fire and fire management, including activities that have an impact on fire management such as the use of prescribed fire for fuels management, can exert powerful effects on how organizations frame problems and set priorities for fire management actions. For example, the precautionary principle as applied to risk management decisionmaking is generally reflective of a broad public attitude that favors a conservative interpretation of risk and that corresponds to a generally risk-averse public attitude with respect to outcomes that are perceived as severe or catastrophic (e.g., Graham 2001, MacGregor et al. 1999, Sandin 1999, Slovic 2000). In essence, the precautionary principle is a "better safe than sorry" view that prescribes protective action even when no harm is certain to occur. One consequence of this principle is a conservative interpretation of science by organizations charged with risk management: in the absence of science confirming the presence of harm, protective action should be taken until such time as science confirms the opposite.

Organizational Metadecisions

Decisions at this level are reflected in a number of influences. Three general categories include formal policies of the organization, organization culture, and organization plans and strategies (fig. 2). Organization culture comprises many components not shown here, such as the history of the organization and its values, as well as the incentive structure (both explicit and implicit) that exists within the organization and that influences individual preferences and decisions. Formal policies include specific policies and manuals (e.g., Forest Service Manual, Interagency Standards for Fire and Fire Aviation Operations) that provide the general standards and guides that serve as the business framework for day-to-day activities and operations. Included here as well are periodic directives that may highlight, modify, or expand on a particular element of policy. Finally, there is a relatively large body of organization plans and strategies (e.g., National Fire Plan, Cohesive Strategy) that serve to provide general management direction and strategy.

Incident-Specific Decisions

At the incident level are decisions specific to the particular fire management action on the ground, depicted as a series of events, each of which could be further decomposed to reveal underlying decisions specific to the event (fig. 2). The term "event" is used in this context to refer to the components of a fire incident that include elements of judgment and decisionmaking. To express events having multidimensional or multiattribute characteristics, we use the concept of an "event frame" (discussed below). For example, an event frame containing a WFSA (Wildland Fire Situation Analysis) can be decomposed into a number of specific WFSA elements, each of which may be influenced by higher level societal and organizational metadecisions, such as air quality standards (social level, statutory law), public values (social level), and organization culture.

Dynamic Decisionmaking Influences on Decision Outcomes

Cue-Based Models

One approach for modeling how a human decisionmaker operates in the context of dynamic environment is based on the notion of cues or pieces of information, their relationship to one another in the environment, and the way in which they are processed by the decisionmaker. A general model of expert judgment based on multiple cues is the lens model (e.g., Cooksey 1996, Cooksey and Freebody 1985). A schematic representation of the lens model is shown in figure 3.

The lens model draws a distinction between a decision environment that is represented by a collection of cues, and the psychological representation of that object in terms of a decision or judgment based on those cues. Like an optical lens, the environment is portrayed in terms of a set of information components whose importance is expressed in terms of ecological validity coefficients (the left side of fig. 3). The information cues impinge on the individual, who uses them to form an impression of the environment. The degrees to which cues are weighted or used by the decisionmaker are expressed in terms of cue utilization coefficients (the right side of fig. 3). The policy or process by which these cues are weighted and an impression or decision is formed can be modeled in terms of a regression equation. The equation predicts the individual's assessment of the environment from a combination of cues and cue weights, derived empirically by varying the environmental conditions and observing the judgmental or decision response. The degree to which the individual has achieved an accurate impression of the environment is expressed

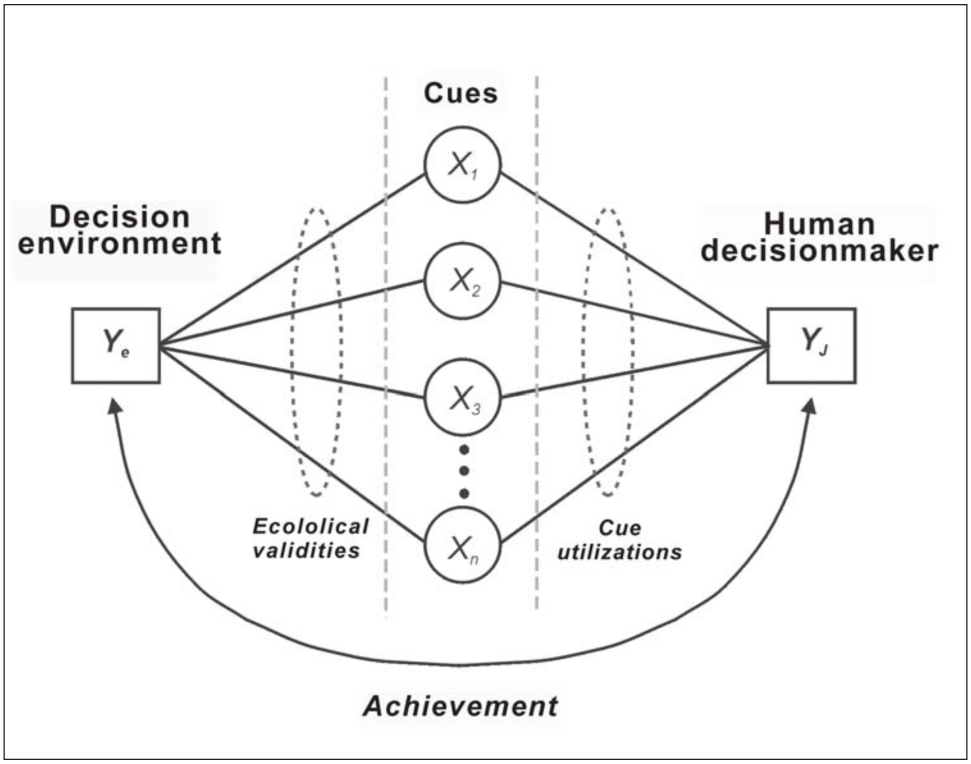

Figure 3—Lens model representation of cue-based decisionmaking.

by the correlation between the true value of the object and its judged value. Other related theories also conceptualize decisionmaking in terms of the relationship between the decisionmaker and the environment, sometimes accounting for decision performance in terms of critical cues that stimulate the recognition of situations that call for specific behaviors or actions (e.g., Klein et al. 1989).

The importance of cue-based approaches to decision modeling is their emphasis on discrete information elements in the decision environment and on the recognitional processes that the decisionmaker uses to select and weight information in forming a response. These processes rely heavily on the ability to focus on the most relevant information in a dynamically changing environment, as well as to reject or filter out irrelevant, redundant, or unreliable information. An important aspect of cue-based decisionmaking is the ability of the decisionmaker to recognize information that is not present in the environment but that should be.

Control Theory Models

A class of decision models that is important in dynamic environments is the control theory model (e.g., Sheridan and Ferrell 1981, Wickens and Hollands 2000, Wiener

1948). Control theory models conceptualize the human decisionmaker as an element of a closed-loop system that exercises control through a set of output processes that impact the environment. The environmental effects of the output processes are returned to the human decisionmaker through a feedback loop where they are compared with one or more reference points. The results of the comparison yields an error signal that is interpreted by the human decisionmaker in terms of available options to effect an environmental change in the appropriate direction.

Figure 4 shows the essential elements of a control theory model of decisionmaking. A key concept that derives from models of this type is that of a reference point. Reference points are conditions that serve as a gauge by which system effects on the environment are compared. Reference points can be established by a number of means, including directives, policies, elements from training scenarios, cues in the environment (e.g., fire behavior), and affective or emotional conditions of the decisionmaker.

A second key concept is that of a comparator mechanism by which the human decisionmaker evaluates the effect of system outputs under their control in terms of the magnitude and meaning of differences from a reference point. How departures from reference points are evaluated in the comparator process with respect to gains versus losses can have dramatic impacts on decision behavior. Consider figure 5, which shows an asymmetrical psychological response to a decision alternative that offers economically equivalent gains or losses.

The psychological loss experienced from an economic loss is greater than the gain experienced from an equivalent economic gain. Thus, human decisionmakers are susceptible to “framing effects” by which the definition or framing of a decision problem in terms of gains versus losses influences how a decision alternative will be evaluated in light of its potential outcomes.

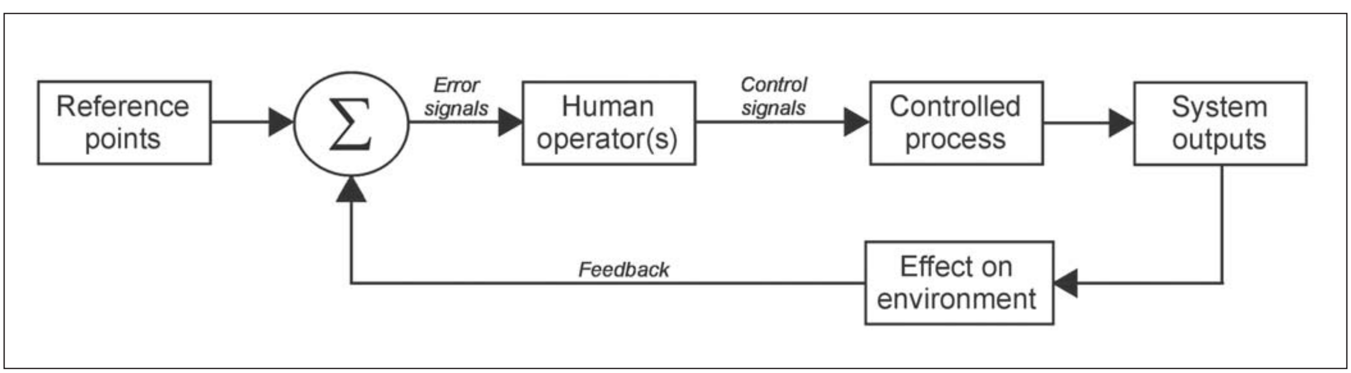

Figure 4—Control theory model of dynamic decisionmaking.

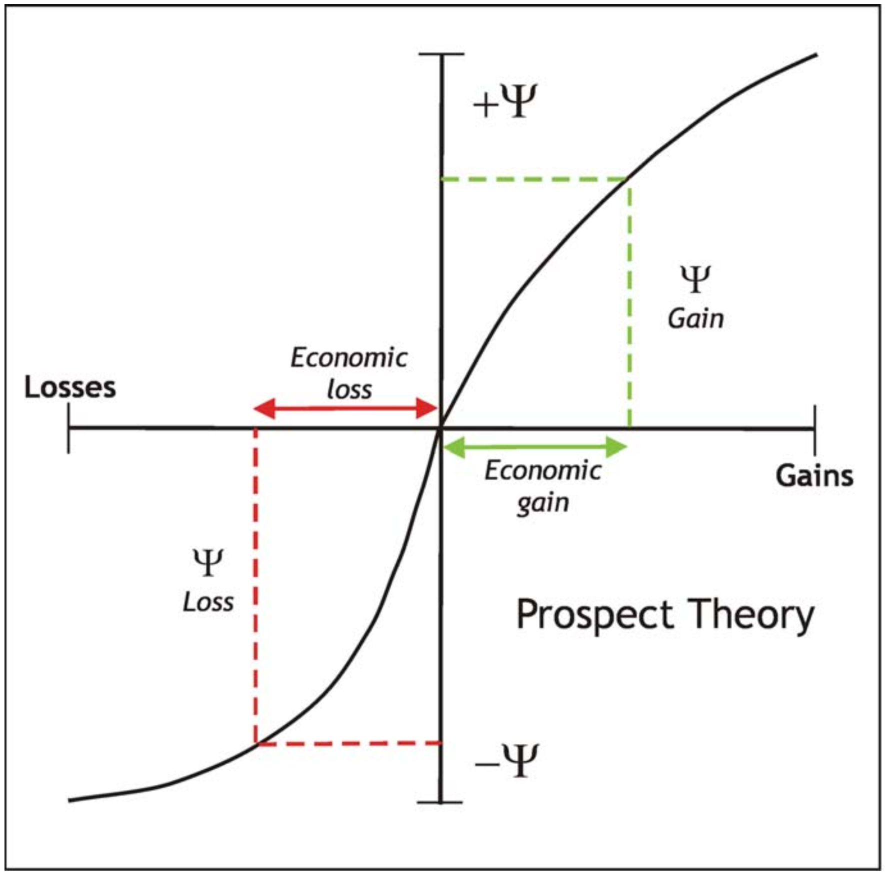

Figure 5—Prospect theory representation of the psychological impacts of gains vs. losses.

The implications of the asymmetry shown in figure 5 extend to how risks are evaluated and acted upon. In the domain of gains, decisionmakers tend to be risk averse, choosing to maintain their status quo rather than "gamble" for an additional gain at the risk of losing. In the domain of losses, decisionmakers tend to be risk seeking, choosing to accept (excessively) risky alternatives in the hope of recouping previous loss or avoiding further loss.

Production Models

An important class of model that relates to control theory is the production model. Production models represent the human decisionmaker in the context of a process or product environment that is goal or objective oriented. The analogy to fire management is direct. Figure 6 shows a prototypical production system.

In this generic representation, inputs are shown on the left as scheduled and expected events that serve as triggers to system processes. The various system

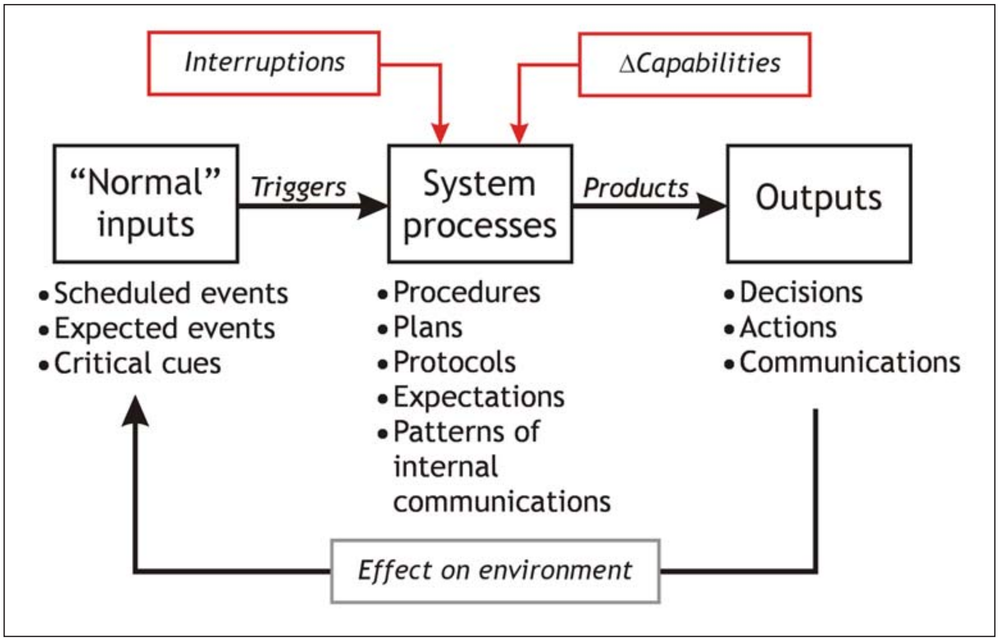

Figure 6—Basic production model.

processes (e.g., procedures, plans, internal communications) result in products that are outputs of the production system. These outputs include decisions, actions, and communications that are intended to have an effect on the environment within which the system operates (e.g., a fire incident). The impact of the production system on the environment acts as a closed-loop feedback to the input of the system, thereby controlling its actions (e.g., Powers 2005). Essentially, production systems such as that shown in figure 6 are a form of cybernetic control system for which output from the system serves as a basis for the evaluation of how well system processes (e.g., fire management decisions) are meeting the goals and objectives of the system (e.g., perimeter control).

System processes can be perturbed or altered by a number of means. One type of alteration can occur because of human factors, such as physical or mental fatigue and stress. More generally, system processes are influenced by on-going changes in capabilities; changes (Δ) in capabilities can alter how the system responds to inputs and how the various processes are implemented with a resulting effect on system outputs. Changes in human resource capabilities can also influence how critical decision cues are recognized and processed.

A second type of alteration can occur because of interruptions; these are unanticipated events or situations external to the system that prevent the completion of organized actions or sequences of decisions. Understanding how interruptions influence the dynamics of production systems is critical to improving their functioning and making them more resilient against degradation and collapse (Rudolph and Repenning 2002).

This can be conceptualized as a two-factor model of how interruptions and disturbances can influence decisionmaking in a dynamic environment (fig. 7). Two dimensions of interruptions are shown: the number of interruptions and the novelty of interruptions. Novel interruptions are those for which human decisionmaker(s) have less experience or that occur relatively rarely and for which training is either incomplete or inadequate. Essentially, novel interruptions burden the system with the need to solve a new problem for which existing protocols and procedures are either incomplete or nonexistent.

The center of the figure constitutes a zone or envelope of normal operations. Within this sphere are situations for which decisionmaking is relatively routine. Interruptions to decisionmaking cycles are consistent with a normal pace or tempo of operations. Situations in the right half of the figure constitute those for which the number of interruptions is relatively high compared with normal operations. Here, the system experiences a higher level of arousal and an increase in stress. Situations in the left half of the figure are those for which interruptions are unusually low compared to normal, and here there may be problems with vigilance (lack of), boredom, or distraction.

The vertical axis of the figure represents the novelty of interruptions. At the high end, these can lead to distractions and confusion as individuals or teams attempt to recognize the novelty in terms of preexisting or standard procedures that can be applied. At the low end, lack of novelty can lead to inattention. This is a problem sometimes encountered in supervisory control environments where most of the activity is related to monitoring and only rarely do events occur that are out of the ordinary. A level of fatigue can be brought on by lack of novelty, and research has shown that in such situations people may change standard protocols for action and decisionmaking simply to introduce novelty as a relief from boredom.

The upper right quadrant of the figure can be thought of as a critical zone in that it contains situations that have a high number of interruptions that are highly novel. These circumstances can pose excessive demands on individuals and organizations, resulting in high error rates and very high levels of stress as well as disintegration of team or organization functioning.

Of particular concern in dynamic decisionmaking environments is the pace or tempo of operations. By tempo we mean the periodicity of action-decision-outcome cycles and the expectations that individuals and teams form about how events will

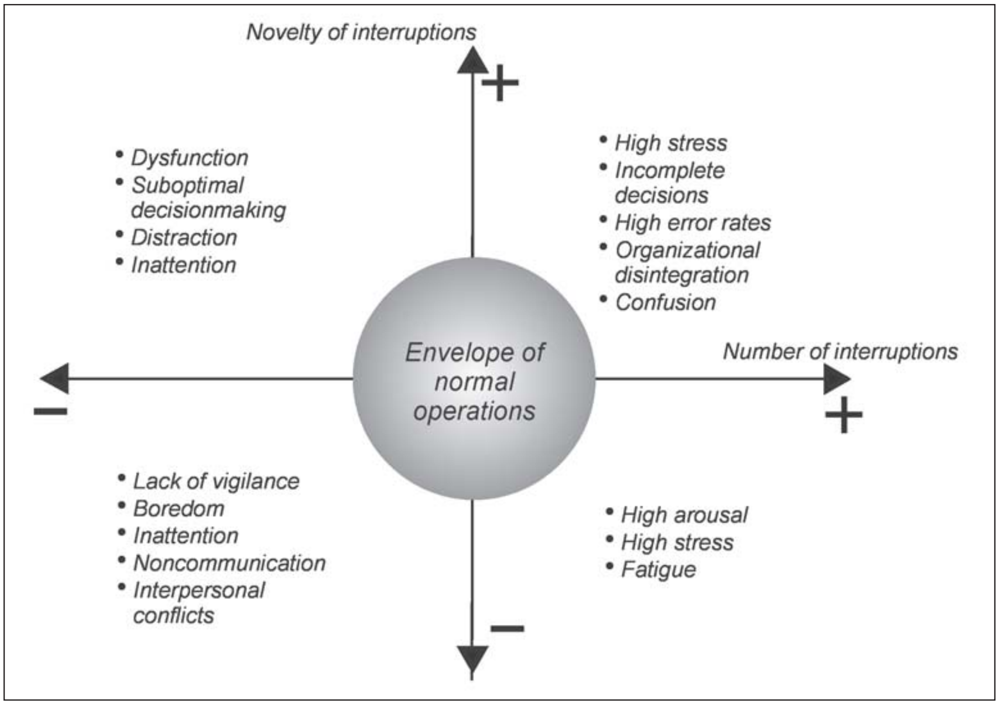

Figure 7—Effects of the interruptions on the envelope of normal operations for production models.

be sequenced in time. For example, in fire-line organizations such as 20-person fire crews, a cycle of activity (e.g., work/rest) may exist that constitutes normal operations. If the tempo is accelerated, fatigue-related problems may result such as lowered productivity or impaired judgment that could compromise safety. If the tempo is decelerated, boredom and interpersonal conflicts may result.

A particular type of problem occurs when individuals or teams must quickly increase their decision tempo in response to a changing decision environment. These "tempo transitions" impose demands to make a shift or change to a new level of operations or to a new strategy (MacGregor 1993).

During the tempo transition, task or decision performance may decrease while adaptation takes place, and may remain low for some period of time before performance resumes at a high level (fig. 8). This is an adaptation period during which low performance may result in errors, inattention, and confusion.

Affective and Emotional Factors

Although emotional factors play a large role in decisionmaking, they have only recently begun to receive much attention in formal models of decisionmaking processes. The various models discussed above have included emotional components,

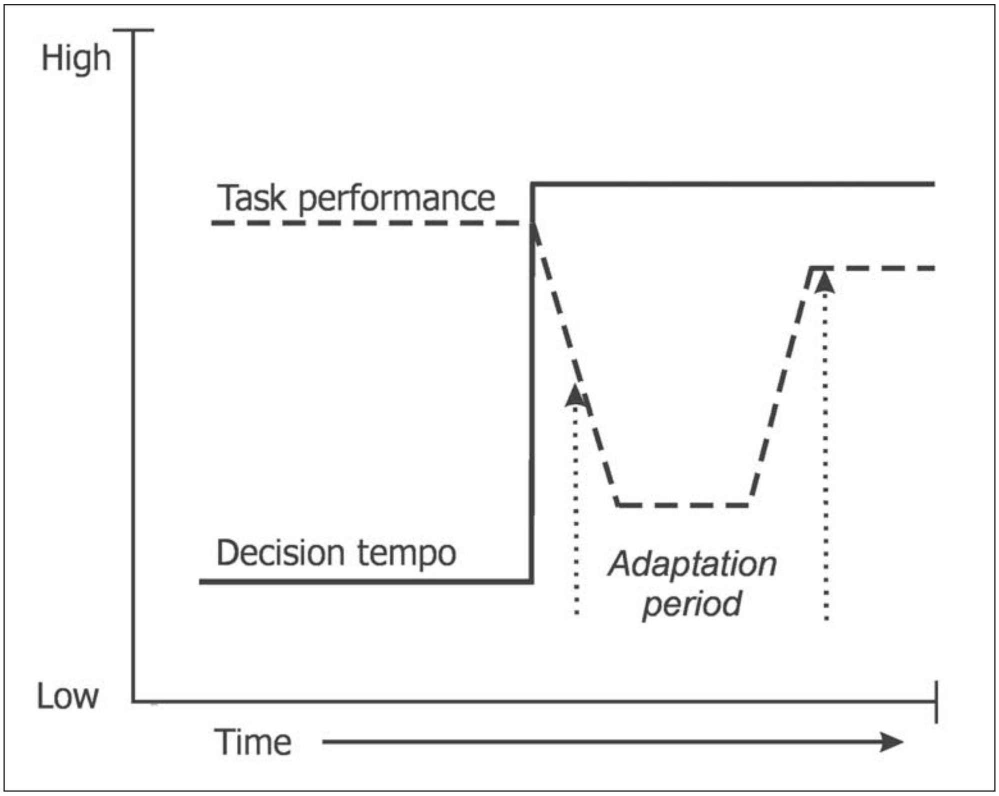

Figure 8—Decision tempo transition effect on decision task performance.

such as stress, but as a process element, emotion has generally been regarded as a factor that pollutes or disrupts reasoning and thought. Recent research in the decision and cognitive sciences has identified the positive role that emotion and affect play in the judgments and decisions people make in routine circumstances (e.g., Schwartz and Chlore 1988). For example, reactions to risk may be based largely on affective reactions to situations rather than on thought processes that involve mental calculations (e.g., Lowenstein et al. 2001).

Emotion enters into decisionmaking in a number of ways. One is through the experiential system by which past instances or experiences are revived and used to guide decisions (Epstein 1994). Sometimes decisionmakers will experience this effect in terms of intuition–a spontaneous and often unprovoked sense of the right or appropriate thing to do in a complex, dynamic, and time-pressured decision situation. Often decisionmakers will rely on images of previous experiences, and research has shown that images are affectively or emotionally encoded such that their recall provides an emotional context or reference point by which a current situation can be evaluated (e.g., Tulving 1972). Decisionmaking in these kinds of situations can be thought of in terms of a set of feeling or emotional states that are evoked by a combination of (a) cues that trigger the recall of previous image-based experiences, and (b) the emotional conditions that are a part of those experiences. Thus, a decision situation may “feel bad” or “feel good” because it bears an emotional resemblance to previous situations or experience for which outcomes or circumstances leading up to outcomes bear a similarity. The processes by which these experiences and their related emotional content become available to the decisionmaker may not require thought. Indeed, it is the automaticity of these processes that give rise to the experience of intuition that can accompany dynamic, real-time decisionmaking and the feeling of knowing a “correct” course of action with relatively little deliberative or conscious effort.

Structure of an Incident Analysis

The process of structuring an incident analysis begins by constructing a series of event-frames along an incident temporal dimension (fig. 9). The initial set of event-frames is based on incident documentation. Large-fire incidents are generally documented in part through the WFSA and other procedural documents (e.g., Delegation of Authority, Incident Command System (ICS) 209s) that provide a convenient and authoritative basis for collecting a set of initializing information, including the fire situation early in the incident, preliminary information about values at risk, strategic alternatives for fire management, and other land management issues that reflect decision priorities.

The general framework takes the form of a set of schematic event-frames located along a temporal dimension that ranges from the beginning of an incident (t_0) to the end of an incident (t_n), where t_0 correspond to the date and time of fire ignition and t_n corresponds to the date and time the fire is determined to be contained. In principle, the number of discrete event-frames is unlimited. In practice, however, the number of event-frames is determined by the desired granularity of the analysis and by pragmatic factors such as (a) characteristics of the incident, with longer or more complex incidents requiring a greater number of event-frames, and (b) availability of information.

Event-frames are of two types: environmental event-frames (shown on the top of the figure), and management event-frames (shown in the interior of the figure). The term “environmental” is used here in the same way it is used in cue-based decision models (fig. 3) to denote events that occur in the decision environment, such as (a) the fire ignition, and (b) weather and fire-related events (e.g., fire behavior).

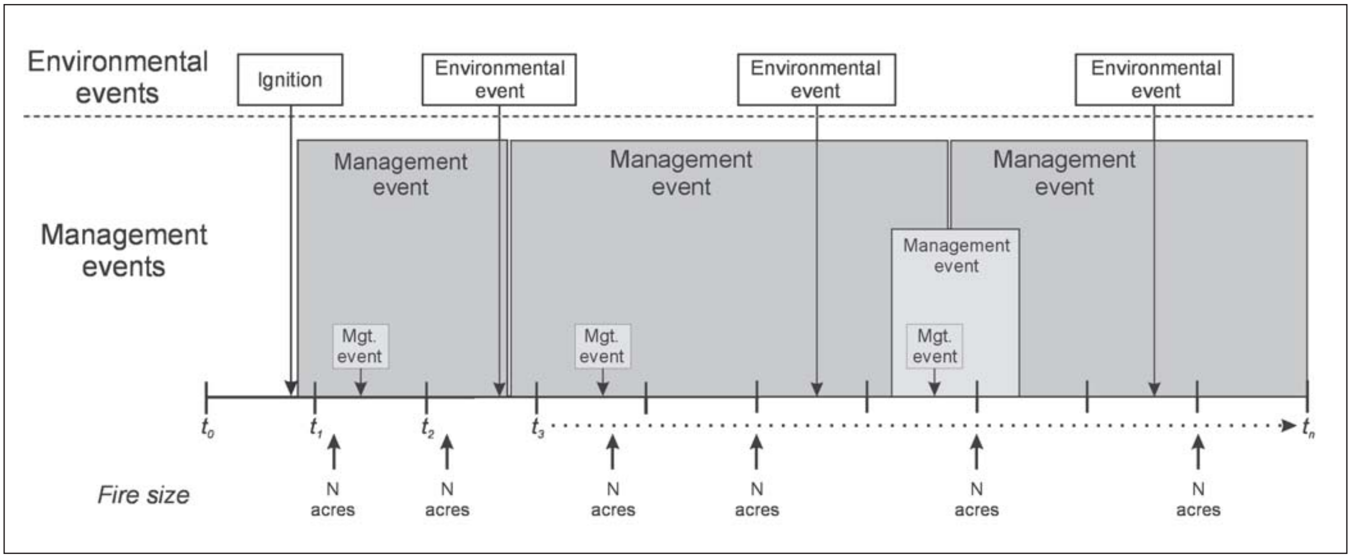

Figure 9—General structure of the event-frame model.

Environmental events can be thought of as events that are significant to management and to which management can (or must) respond. Management events are those decisions and actions that managers take in response to events in the decision environment. Some management events can span a significant period of time, such as an ongoing Incident Management Team (IMT) response. Other management events can be points in time, such as the ordering of an evacuation or the preparation of incident documentation (e.g., WFSA).

Each event-frame is characterized by a set of possible event-frame elements that can include (a) values, goals, and objectives; (b) decision alternatives; (c) expected outcomes associated with each alternative; (d) sources of uncertainty; (e) tradeoffs; (f) sources of risk; and (g) costs. Methods for representing these elements include multiattribute value trees and decision trees. Risks associated with each event tree can be represented in terms of a basic risk assessment model that characterizes risk in terms of (a) events or scenarios that can happen, (b) the likelihood that each would happen, and (c) the consequences associated with their occurrence (e.g., Haimes 1998, Kaplan and Garrick 1981). In practice, the extent to which more sophisticated methods for analyzing each event-frame can be used are dictated somewhat by the value of greater analytic detail and rigor and by the availability of information.

Information Sources: Incident Documentation

Primary information for incident analysis comes from documents that are produced during the course of an incident. Incident documentation provides the basis for initial construction of an event-frame model. Among the various federal wildland fire agencies in the United States, typical documentation for large fires includes:

Fire situation analysis (FSA)
Briefing documents
Wildland fire situation analysis (WFSA)
Incident complexity analysis (ICA)
Delegation of authority
Shift plans
Transition plans
Final fire report (e.g., FS 5100-29)

For example, the WFSA is developed early in a fire incident and is continually updated (and in some cases redone) as part of incident management. The WFSA provides primary information about land management objectives and values at risk, strategic alternatives for fire management, and preliminary estimates of fire suppression costs and monetary losses to the resource base. Monetary cost elements are periodically reviewed and updated, and provide the basis for a set of periodic event-frames that directly relate incident costs to values at risk.

Information also comes from periodic plans and documents developed as part of incident management, including shift plans and transition plans. Shift plans can be used to structure a protocol process whereby incident decisions are reconstructed on the basis of (a) tactical alternatives and a chosen alternative, (b) control objectives for the incident, (c) critical resource concerns and values at risk, (d) resource allocations, and (e) personnel assignments. Shift plans indicate the chosen tactical direction, but do not indicate other tactical alternatives that may have been considered, nor do they indicate the outcomes that are expected or the basis on which outcomes are evaluated. The decision problem structure that is (partially) implied by the tactical direction in shift plans must be supplemented with interviews to obtain a more complete representation of the structure.

Information Sources: Knowledge Elicitation Using a Decision Process Tracing Protocol

Incident documentation provides an efficient means for identifying key parameters of incident decisions, including the sequence of key events and how decision problems were structured. Knowledge elicitation pertaining to how decisions are actually made can only be gained by direct involvement with fire management personnel. This requires the development of a structured process that can be used to guide interviews with individuals who had key roles in incident decisionmaking.

As a knowledge elicitation tool, we have developed a decision process tracing protocol (DPTP). Process tracing is a form of knowledge elicitation that uses a sequenced set of questions and responses to guide an individual through a decision-making process in which they were involved. The essence of process tracing is a reconstruction of key incident decisionmaking as it was experienced by the decisionmaker.

The content for the DPTP comes from concepts associated with the theories and models of decisionmaking outlined in the previous sections. The concepts are organized into a set of probes or questions that direct the interviewee to different aspects of a decision. Subprobes are used for deeper levels of knowledge elicitation. The overall protocol is divided into two main sections: (a) process elements, and (b) probes and questions within each process element.

The structure and content of the DPTP is shown in table 1. Note that in the course of applying the DPTP not all of the process elements are appropriate or needed for every decision point. The purpose of the DPDT is to provide a road map or guide for the knowledge elicitation process that is, of necessity, tailored to the circumstances of the fire incident and the role of the individual fire management expert in that incident. Without a structured process, important points could be overlooked or probed inconsistently.

Case Studies

In this section, we apply the general framework discussed above to examining two case studies. Our purpose in the examination is to illustrate how the concepts, principles, and language of decision science can be applied to the analysis of decisionmaking in the context of an actual fire incident. The objective here is to demonstrate the operation of a knowledge elicitation theory and approach, not a post hoc review of fire management decisionmaking on an incident. The incidents used as case studies serve as a context only; to conduct a proper postincident review

Table 1—Decision Process Tracing Protocol

Process element	Process content
Key decision points and judgmental assessments	Where in the incident timeline were the key decision points? • Timing • Events • Basic description • Judgmental assessments
Actors	With regard to a particular decision point or event-frame: • Who was involved in the decision? • What role did they play in the decision? • Was this a collaborative decision? • How were responsibilities distributed?
Situation assessment: cues and cue utilization	What were you seeing, hearing, noticing, attending to with regard to environmental factors? • Fire behavior • Fuel conditions • Terrain or topography • Weather factors • Other What were you seeing, hearing, noticing, attending to with regard to managerial factors? • Suppression resources: availability, timeliness, effectiveness • Incident documentation: 202s, 209s, WFSAs • Personnel workload, fatigue, and morale • Safety factors: firefighter safety, public safety, aviation safety • Cost factors: cost efficiency of suppression actions, cost apportionment, cost negotiations • Fire camp disruptions • Communications and collaborations: line officer involvement, local fire staff involvement, incident command team interactions • Other What conflicts did you experience with regard to cues or information? • Number of conflicts • Difficulty of resolution • Ambiguities in information
Knowledge and information	With regard to a particular decision point or event-frame: • What key pieces of knowledge did you rely on? • What information did you have available? • What information did you need that was not available? • Why was the information you needed not available? • What could have been done to improve its availability or timeliness?

Table 1—Decision Process Tracing Protocol (continued)

Process element	Process content
Goals and objectives	What were the specific goals and objectives you were working toward at this point in the incident timeline? • Short term (near term) • Mid-term (next burning period) • Long-term (beyond next burning period, demobilization, beyond containment/control)
Alternatives and options (“decision space”)	What decision alternatives or options did you have at this point and what influenced the alternative set (decision space)? • Number • Range • Constraints on options • Difficulty generating options • Organization rules and directives • Organizational biases and orthodoxies • Structure and content of social interactions • Rules of engagement • Resource constraints • Feasibility
Sources of uncertainty	What were the sources of uncertainty in the decision? • Objectives/goals • Information • Environmental factors (e.g., fire behavior) • Situation assessment
Time pressure	How would you characterize the time pressures and their effects on decisionmaking? • Influences on decisions • Normal tempo of action-decision-outcome cycles • Changes in decision tempo • Adaptation strategies • Changes in decision performance during the adaptation period
Reference points	What reference points were guiding your decision? • Gains vs. losses • Decision frames • Perceptual references • Emotional reference points
Tradeoffs	What tradeoffs were involved in the decision? • Objective tradeoffs • Risks vs. benefits • Risk vs. risk • Cost vs. benefits • Cost vs. risk

Table 1—Decision Process Tracing Protocol (continued)

Process element	**Process content**
Images	What images or recollections were you using to guide your decisions? • Information or experiences from past fire incidents • Incident familiarity
Interruptions and disruptions	What interruptions or disruptions occurred in the "normal" way that decisions were made? • Unusually high number of interruptions • Effect(s) of the interruptions/disruptions • Novel interruptions • Characterization
Communication patterns	How did communication take place as part of the decision process? • Critical issues in communication • Timing • Constraints or bandwidth problems
Collaborations	How did people interact as part of the decisionmaking process? • Patterns of collaboration and cooperation • Negotiation and resolution • Reconciling conflicts of interest
Hypotheticals	What would have changed your decision(s)? • Key feature of the situation • Different information • Change in uncertainties • Change in resource constraints
Managerial discontinuities	What discontinuities were present that influenced your decision(s)? • Communication disruptions • Transition discontinuities • Process discontinuities (e.g., WFSA)
Actions	What action(s) did you take as the result of the decision?
Outcomes and effects	What were the outcomes and effects of your decisions? • On the environment (e.g., fire behavior) • On managerial factors (e.g., safety, cost)
Decision complexity	
Risk factors	

would require time and resources beyond that available for this project. Our ultimate goal is to demonstrate and illustrate an approach that, with continued development and refinement, could lead to improvements in how fire reviews are done and how the information obtained from them could potentially be applied to, for example, revising policies and directives or upgrading training and certification procedures.

As those who manage large fires will attest, no two fires are alike. In the world of large-fire management there is no normal or routine incident. To say that the two incidents we have chosen for case studies are in some way typical of large fires is to say little more than that they covered a large number of acres, spanned multiple burning periods, involved multiple management jurisdictions, resulted in the significant loss of natural resources, and cost multimillions of dollars to manage. At such a molar level, all larges fires that enter Class G (5,000+ acres) appear the same–a perspective that belies the unique management challenges that each one creates and that fire management personnel experience.

We have chosen incidents that occurred over 8 years apart: the Fork Fire on the Mendocino National Forest (NF) in 1996, and the Old Fire on the San Bernardino NF in 2003. A significant factor in choosing these incidents was the ready availability of incident documentation and convenient access to agency personnel who were involved. No attempt was made in selecting incidents to define a sample space or to obtain a representative set of incidents based on a set of selection criteria. Certainly, this could be done and should be done in future research along the lines of the research initiated here. The Fork Fire provides an opportunity to illustrate decision modeling on an incident that burned over a large number of acres and spanned more than 2 weeks. The Old Fire, on the other hand, occurred very quickly as part of a complex of catastrophic fires that burned in southern California in October and November of 2003, destroying many homes and private resources just in a few days.

Case Study: Fork Fire

Incident Synopsis

The Fork Incident occurred on the Mendocino NF in August 1996 in northern California (USDA Forest Service Region 5). The incident was first reported on the evening of August 11, 1996, at 2130 hrs (9:30 p.m. PDT) on the southern portion of the forest on the Upper Lake Ranger District. Owing to rugged terrain and accessibility problems, initial attack personnel did not reach the fire location for over an hour after the initial incident report, at 2245 hrs. (10:45 p.m.). By that time, the fire was approximately 2 acres. Within a half hour, at 2315 hrs, the fire had grown to 3 to 5 acres. The fire continued to grow, moving up an adjacent slope to the ridgetop. By 0100 hrs on the following day (August 12), the fire had reached approximately 20 acres with spotting up to 200 feet. At 0300 hrs a type II incident management team was ordered. A cumulus cell weather event at approximately 0400 hrs dramatically increased the fire to over 100 acres, moving in a direction toward the community of Upper Lake. At 0507 hrs, a type I IMT was ordered and a unified command established. By now, the fire was moving rapidly to the south, toward private structures, and people in the fire's path were notified of the threat. The type I IMT arrived at approximately 1700 hrs on August 12. A map of the incident shows the major changes in the fire perimeter from ignition to the final fire size of 82,980 acres (fig. 10).

By midnight (2400 hrs) of the second day (August 13), the fire had grown to 1,500 acres, with a rapid expansion to 7,000 acres by 1300 hrs of the following afternoon. The fire would make two additional rapid expansions, going to 21,000 acres by the afternoon of August 16, and then to 69,000 acres by the evening of August 18. The fire would continue for several more burning periods before being contained at over 82,000 acres on August 28. Ultimately it was determined that the fire was human caused; most likely a hunter or hiker who stopped by a stream near the Middle Creek Campground and failed to extinguish a discarded cigarette.

Event-Frame Representation

We begin the analysis and reconstruction process by developing an event-frame description of the incident. The event-frame description decomposes the incident into a sequence of occurrences that describe the major parts of the incident. Figure 11 shows an overview of the major aspects of the incident.

The event-frame model draws a distinction between environmental events that are related to aspects of the fire, including ignition, fire behavior, and weather events, and management events that are related to management decisions, actions, and outcomes. The use of the term environmental in this context reflects the conceptual relationship discussed earlier with regard to cue-based models such as the Lens Model that distinguishes the human decisionmaker from the decision environment.

In the figure, three major management events are represented: initial and extended attack, type I IMT operations, and IMT management in two zones. These

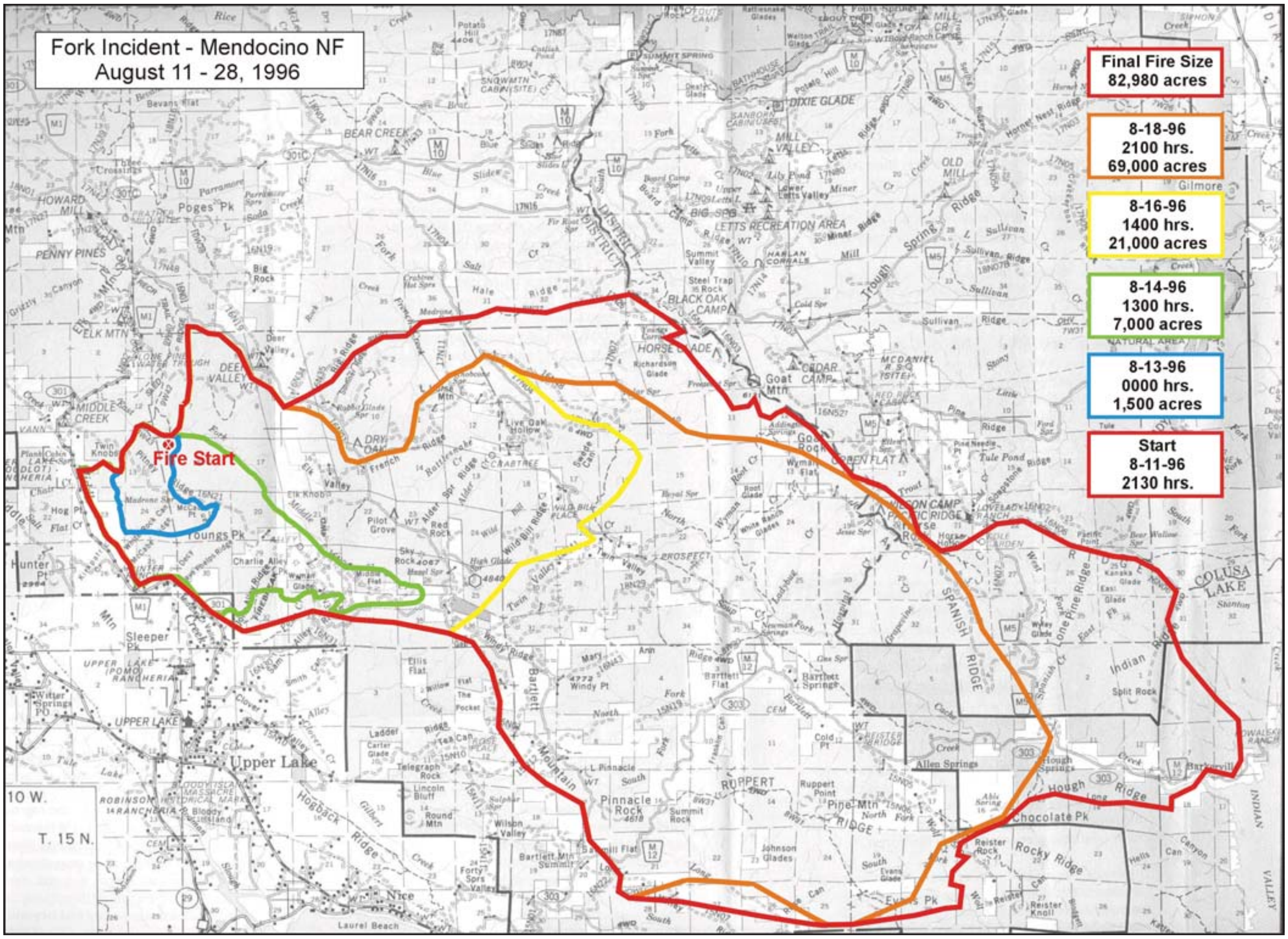

Figure 10—Incident map of the Fork Fire (Mendocino National Forest, August 1996).

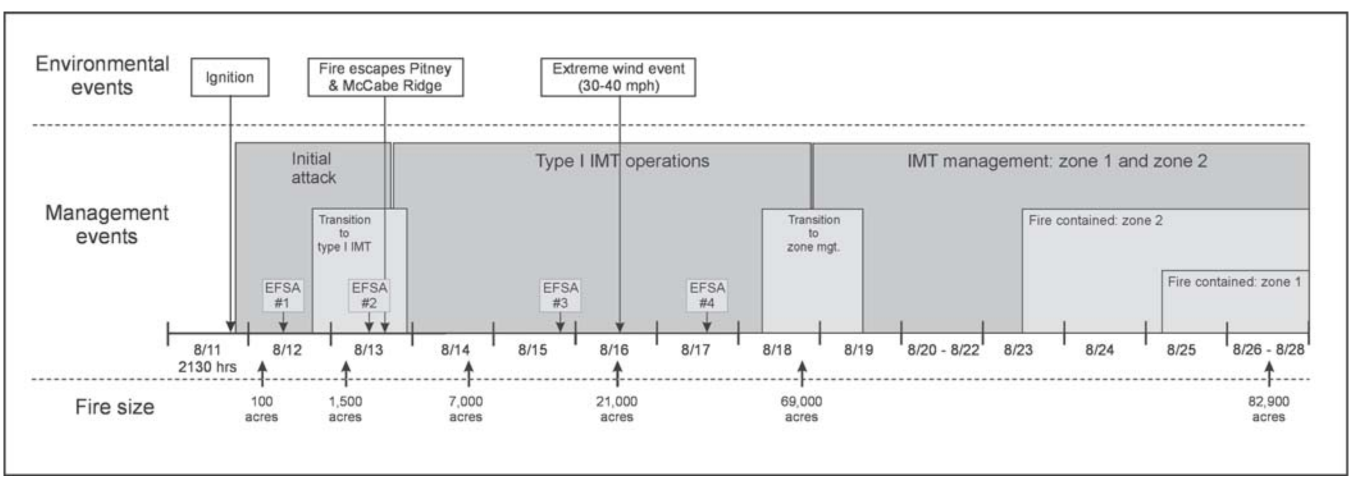

Figure 11—Event-frame representation of major events on the Fork Fire. EFSA = escaped fire situation analysis, IMT = incident management team.

are plotted against a timeline running from ignition to the end of delegated operations, at which time the incident was returned to local management authority. The IA/EA extended from shortly after ignition for a period of approximately 6 hours, at which time a type II IMT was ordered. Within approximately 2 hours, the order for a type II IMT was canceled and a type I IMT was ordered.

Two transition events are shown in the model: a transition from local management to the type I IMT and a transition from management by a single type I IMT to two management zones with the addition of a second type I IMT.

The incident was managed under four escaped fire situation analyses (EFSAs).[1] The complete structure of the ICS documentation for the incident is shown in appendix A. During the IMT portion of the incident (from initial transition to an IMT and for several burning periods after the transition to zone management), both daylight and night operations were conducted, resulting in two incident action plans (IAP) per 24-hour period. Again, the ICS documentation timeline in appendix A shows the complete structure of this aspect of the incident.

From the standpoint of environmental events, two key events had a dramatic influence on the incident. The first was the loss of significant fireline early in the incident that had the potential to keep the fire relatively small at about 3,000 to 5,000 acres. The second was a major wind event that resulted in extreme fire behavior and spread, and that expanded the size of the fire from approximately 21,000 acres to over 60,000 acres in a matter of a few hours. Each of these events necessitated management actions that included establishment of new strategic and tactical objectives

In the next section, we expand upon two elements of the above model, the IA/EA event and the IMT operations event, to show in greater detail the decision processes associated with these two key aspects of the incident.

Reconstruction and Representation of Key Incident Decision Processes

A large fire such as the Fork incident involves many decisions, judgments, and assessments. Some of them are small and of relatively little consequence in light of the scope of the incident. Others are critical, not only because they are associated with significant outcomes, such as risks to life and property, but also because they define the nature and character of the event itself. Exploring the details of

[1] At the time of the incident, the agency was changing over from the escaped fire situation analysis to the wildland fire situation analysis terminology that is currently in use.

such decisions reveals the processes by which they are made and provides insight into the dynamic relationship between events in the environment and the processes that human decisionmakers use to interpret and respond to these events. The two key events we explore in this section are (a) the decisionmaking associated with initial and extended attack, and (b) the decisionmaking associated with ongoing IMT operations.

Initial and Extended Attack

Two fundamental processes characterize the decisionmaking in IA/EA: an assessment of the fire situation (FSA), an assessment of the resources required to manage the situation (RRA) and an assessment of the capabilities of local fire management resources that are available. These three assessments are combined to form an overall assessment of the situation in terms of a plan of action. Figure 12 shows in graphic form a very general model of how this process might operate.

Note that these assessments are not formal and they do not have any associated documentation, at least of the kind that is present in longer term operations on large fires where the wildland fire situation analysis (WFSA) and IAP processes are in place. Indeed, in IA and EA there is virtually no direct documentation, and a modeling of the decision processes associated with these events is modeled based on a combination of dispatch reports and interviews with key incident personnel using the DPTP discussed above.

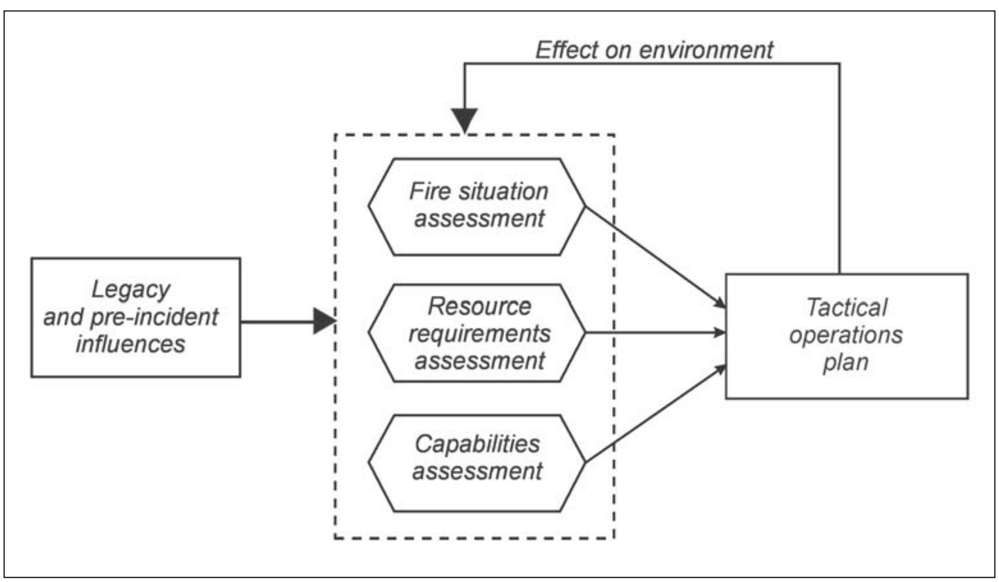

Figure 12—Influence diagram of basic decision elements in initial and extended attack.

We begin by developing an event-frame model for the IA/EA phase of the incident. The complete event-frame model is shown in appendix A. This model decomposes the IA/EA event into a set of discrete subevents each with a time signature, an event code, an event name, fire size, fire behavior, knowledge and cues, goals and objectives, and decision-related actions. The sequence and content of the events are used to reconstruct a decision-process model.

Initial Fire Situation Assessment

An influence diagram representation of the initial FSA is shown in figure 13. In keeping with the general model of incident decomposition discussed in previous sections, the initial FSA is driven by three categories of influences: (a) legacy influences that have their source well in advance of the incident, (b) pre-incident influences that occur closer in time to the incident, and (c) incident-specific influences that are immediately present after ignition occurs.

The initial FSA itself is dependent, in this model, on four precursor assessments that deal with threat, the fire pattern, estimated fire growth rate, and accessibility. Accessibility was particularly critical in this incident because the location was such that it was difficult for suppression personnel to reach the fire perimeter and to work in the area. In addition, there was considerable uncertainty about the fire's growth rate, and therefore the safety of personnel. Fire pattern and rate of growth are both influenced by pre-incident factors relating to terrain knowledge and ignition location. Rate of growth was additionally influenced by fuel conditions and weather conditions. Fire pattern was additionally influenced by existing fuel breaks and preexisting fire line. The legacy influence of the local fuels program influenced both fuel conditions and existing fuels breaks. The legacy influence of fire history influenced both existing fuel breaks and preexisting fire line. The threat assessment component of the initial FSA was largely associated with threats to private structure and to public safety. This was driven by property at risk, which was driven by a legacy of land use decisions.

Several features characterize this model. First, a great deal of local knowledge is embedded in the precursor influences and their linkages that contribute to the initial FSA. This knowledge is drawn from a number of sources, including the (a) local fuels program and its geographic-specific outcomes, and (b) fire history knowledge that provides background on fuel conditions resulting from prior incidents, the existence and condition of preexisting fire lines, and the nature of fire behavior in the local area of the incident.

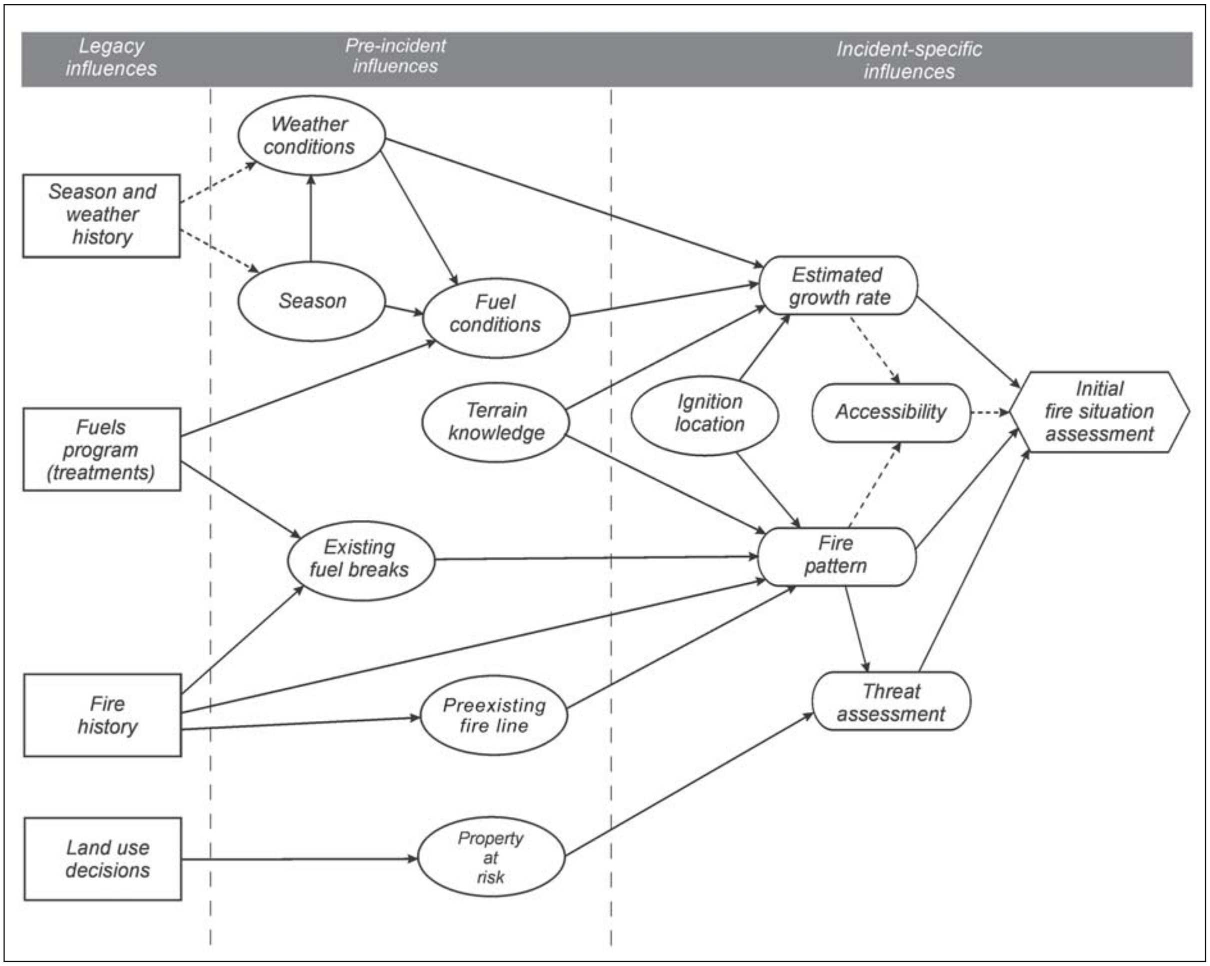

Figure 13—Influence diagram for initial fire situation assessment.

Second, some of the elements that contribute to the initial FSA are related to (or are components of) the National Fire Danger Rating System (NFDRS) for which fire management personnel are trained. A key intermediate influence on the initial FSA is an assessment of the expected fire pattern, which is a spatial representation of the fire and is influenced by other geospatial parameters associated with local fire and fuels history, terrain, and location-specific weather factors. It appears that the initial FSA is driven by a combination of generalized knowledge about fire and its related elements, modified and enhanced by local knowledge of geographic, weather, terrain, and fuels factors that can significantly alter generalized fire knowledge.

Initial Capabilities Assessment

An influence diagram representation of the initial capability assessment (initial CA) is shown in figure 14. In this model, the initial CA is driven by two primary, incident-specific influences: an extended attack CA (EA-CA) and an initial attack CA (IA-CA). The former considers the ability of the local organization to be successful in a period beyond the next 24 hours. The IA-CA considers capability for a period less than 24 hours. Both assessments are driven by an assessment of local production capability. Additionally, the EA-CA is driven by the assessment of local logistical capability. Both local logistical capability and local production capability are influenced by fire duty participation, which is in turn subject to the legacy influence of unit staffing. Local production capability is influenced by pre-incident drawdown, which is influenced by the national fire situation and the geographic area situation.

On the Fork incident, extended attack was very limited and it appears that a type III response was never fielded. We use the concept of extended attack to reflect a larger scope of consideration than the initial CA, and the model represents how the initial CA would come about were the IA/EA event of longer duration (fig. 14).

Overall, this is a less complex model than that for the FSA, but the small number of influences is counteracted by their strength. Legacy influences appear to exert a large effect on the initial CA. The lack of logistical capability is a strong

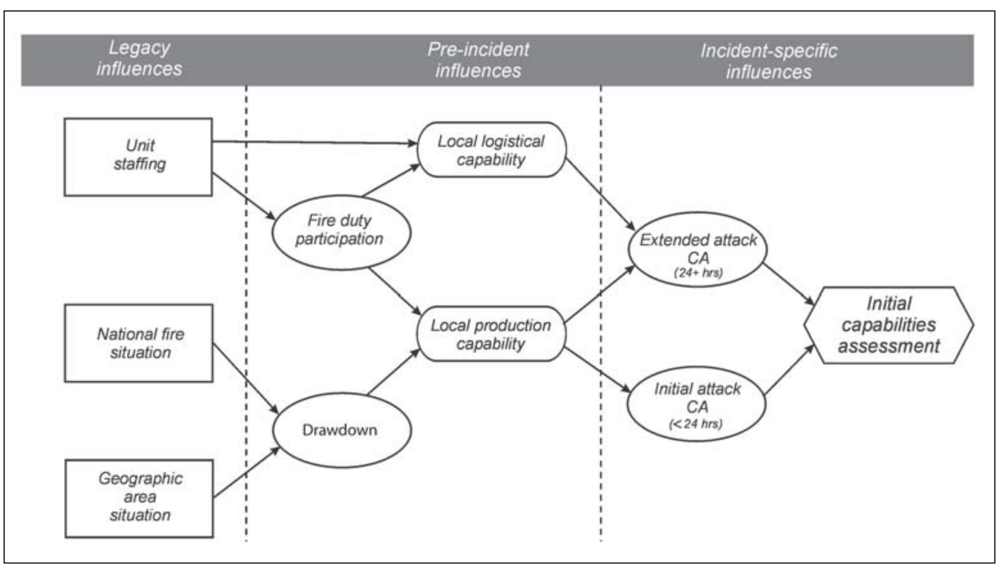

Figure 14—Influence diagram for initial capabilities assessment (CA).

influence on the initial CA, and the absence of local capability (logistical and suppression action) quickly diminish the capability assessed. We hypothesize that the process of capability assessment evolves continuously within fire management organizations and that relatively few incident-specific influences can modify or change the impression of an organization's capabilities that is already formed prior to an incident.

Initial Attack and Extended Attack Dynamic Decisionmaking

Up to now we have been examining decisionmaking in terms of a set of influences that interact as part of an initial assessment process that contributes to IA and EA decisionmaking. We view these two initial assessments as primary initiators of a dynamic decisionmaking process that is ongoing during IA and EA. The dynamic process is modeled on control theory principles and ultimately leads to one of two outcomes: either the incident is effectively controlled and contained by the process, or the process leads to a decision to transition to a higher level of incident management (e.g., type II or type I). The model is shown in figure 15.

The model comprises a dynamic feedback loop that involves a comparator (Σ). The comparator is embedded inside a larger tactical situation assessment (TSA) that includes an RRA and a CA. These two assessments take their starting conditions from the initial FSA and initial CA discussed in the previous section.

The RRA serves as a reference point input to a comparator against which the CA is evaluated. The comparator is affective in character and produces a generalized impression of the tactical situation. The emotional valence of the comparison (positive or negative) is evaluated; a positive evaluation results in continued implementation of the current tactical plan and, with an appropriate time lag, produces an effect on the fire environment. This effect acts as in input to the FSA and then to the RRA, closing the loop.

If the emotional valence of the comparator output is negative, but not greater than a triggering threshold, α, capabilities are increased, the tactical plan revised, and then implemented with the results fed back to the beginning of the loop. The triggering threshold, α, is a control variable that is associated with the level of confidence a decisionmaker has in the ability of the current state of the fire management process to continue to be effective. Levels of α•will vary from one decisionmaker to another, and with a single decisionmaker from one time to another, depending on factors such as experience, familiarity with the situation, and fatigue. When the negative valence of the comparator output exceeds the level

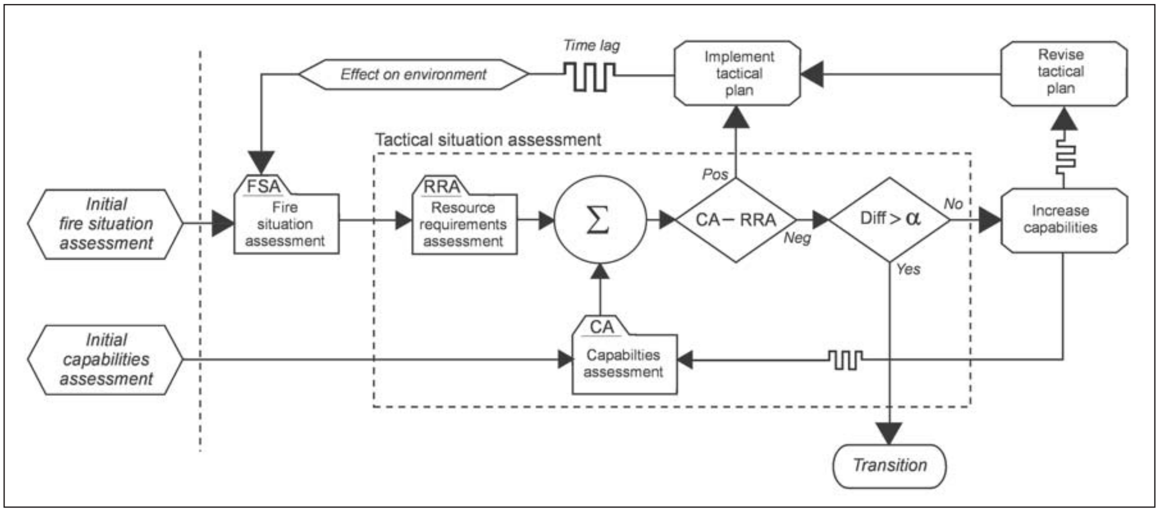

Figure 15—Control theory representation of initial and extended attack dynamic decisionmaking.

of α, a decision is made to transition to a higher level of incident management capability. Below α, operations continue, although they may be near to exceeding the threshold for some time.

The model includes a number of points where time lags or delays occur that influence the tempo of the model and the values that the model components take on. Notice that increasing capabilities (e.g., through resource ordering procedures) is followed by a time lag because, for example, requesting additional resources is not equivalent to having them available, and significant time may pass before requested resources can appropriately be included in a CA and a revised tactical plan.

The model requires significant attention capabilities to operate effectively. That is, decisionmakers must be capable of highly focused attention under time pressures and under fatigue. Instabilities in the model may result from excessive levels of stress that can influence the comparator process. Ideally this process would rely mainly on cognitive resources and would reflect a deliberative or reasoned response to resource requirements (RAA) and capabilities (CA). However, it is more reasonable to hypothesize that in rapid-tempo, high-stress environments, a quick impression is formed that yields an emotional response either positive or negative in valence, and it is the sign of the valence that affects decision behavior.

From a performance perspective, the human decisionmaker may or may not execute the various operations shown in the model in the exact sequence depicted in the figure. What is critical is that the decisionmaker adopt a dynamic perspective on the various subprocesses and systematically shift the focus of attention from one element to another such that all aspects of the model are attended to and no element is overweighted by placing undue attention on it at the expense of others. This can be a problem in high time-pressure environments where the tendency is to focus strongly on a primary task resulting in a reduction in the quality of performance on secondary tasks. A tendency toward task-shedding and information filtering that often accompanies time-pressured decisionmaking can also lead to decrements in decision performance in this model.

To achieve optimal performance, the human decisionmaker is encouraged to learn to develop a scanning strategy, similar to that of aircraft pilots who systematically review all aspects of aircraft performance, attitude, and instrumentation while in flight. Ideally, these scanning techniques are imparted in the form of a visual metaphor that portrays that specific sequence in which task elements are attended to.

Incident Management Team Operations

The second major event-frame that we discuss is that associated with IMT operations. This event-frame has some of the same characteristics as the IA/EA frame, in that a dynamic model can be applied, based on the production model concept discussed previously. However, there are some significant and important differences. These have to do largely with the lower level of time pressures as well as a more deliberative and reasoned approach to planning and execution. At this junction in the incident, a transition has been made from local incident management to an outside IMT. The fire has grown to over 1,000 acres and has gone beyond local logistical and line-producing capabilities. A second difference is the increasing reliance on documentation processes that serve as both a basis for management (e.g., EFSA/WFSA) or as a communication method for management (e.g., IAP).

Although many decisions that go into establishing the operational basis for an IMT (e.g., location of command post, interjurisdictional communications), the IMT organization, once established, can be conceptualized as a decisionmaking body that implements a core management process, the central goal of which is to produce fire line in sufficient quantity and at a sufficient rate to complete a perimeter around the fire, thus containing it. As such, a production model approach is an appropriate set of modeling principles on which to represent its processes.

A reconstruction of ongoing IMT management processes is shown in figure 16. Embedded in the model are a subset of key processes that respond to changes in the operational environment, particularly production results, expected fire behavior, and the presence of disturbance events (e.g., significant weather events). The model

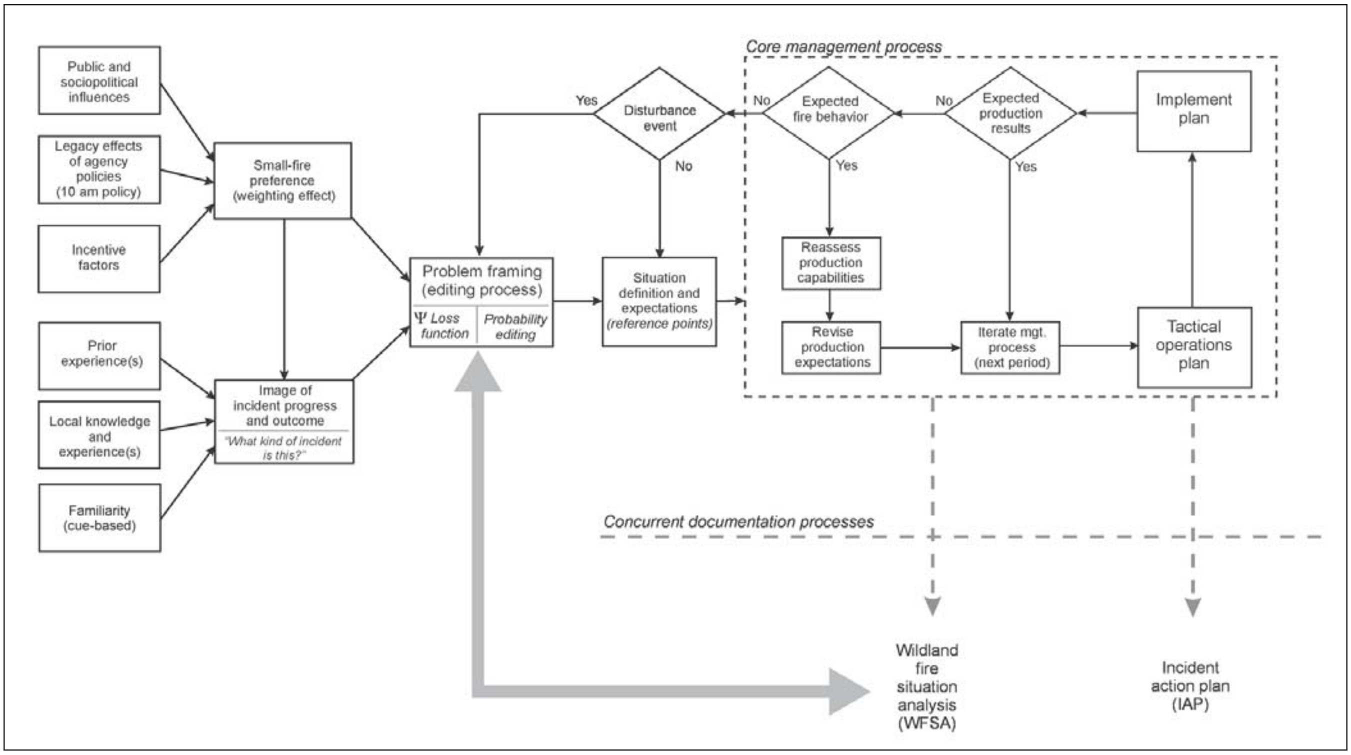

Figure 16—Production system modeling of ongoing incident management team operations.

is initiated by a problem-framing process that is influenced by two principal factors: a small-fire preference model that gives a strongly favorable weight to a small-fire outcome, and an imaging process that represents the situation in terms of an image of the incident progress and outcome.

The small-fire preference process is influenced by a number of legacy influences, particularly public and sociopolitical influences, the legacy effects of agency policies (e.g., 10 a.m. policy) and incentives such as perceptions of what constitutes a "job well done" in agency terms. The incident image process is influenced by prior experiences of key management personnel, local knowledge and experience with fires on the unit, and a familiarity influence that is established from a cue-based relationship between the current incident and other known incidents. These factors combine to yield an impression that may have visual properties and that categorize the incident in terms of a personalized typology; in essence, what kind of an incident this is.

The problem-framing process is essentially an editing stage in which the image of the incident and preferences for particular outcomes combine to define a problem frame and set of reference points by which the process of managing the incident can be gauged or measured. In the editing process, probability editing may occur such that very unlikely events are recoded as having no chance of occurrence, and highly likely events are recorded as occurring with certainty. In addition, a psychological loss function is applied according to the general principles of prospect theory.

The result of the problem-framing process is then used to support a model of situation definition and expectations. In this stage, concrete reference points are defined in terms of management constructs such as amount of line to construct, days to contain/control, segmentation of the fire perimeter, and resources required. These substantive variables are direct inputs to the core management process and lead to the development of a tactical operations plan (TOP). The TOP is evaluated in terms of its production goals and its effect on expected fire behavior. A favorable evaluation recycles the process for another operational period. Provided that expectancies are met, production continues until the incident is contained.

If fire behavior expectations are not met and no other significant disturbance events have occurred, the process revisits the situation definition and expectations. Depending upon the form that unmet expectations take, the values of management reference points may be reestablished (e.g., a larger amount of line). On the other hand, if a significant disturbance event occurs, such as a major weather event, the problem frame aspect of the process may be reengaged. In the case of the Fork Incident, the weather event of August 16 was such an occurrence, leading to a redefinition of the problem frame and recognition that the fire had a much larger potential size than was previously believed.

In our discussion up to now we have not considered the role of incident documentation on this process. Incident documentation in this model is part of a concurrent documentation process. That is, the documentation is generated as part of the incident progress, but does not directly drive the incident. It is concurrent in that it is produced as part of ongoing management activity and coherence is maintained between the content of the documentation and the management model. Incident documentation does play a role in problem framing by the manner in which it structures or represents key framing elements. Thus, the WFSA (EFSA in the case of the Fork Incident) provides a specific structure for representing the strategic management of the incident. This structure includes values at risk, potential losses, strategic alternatives, uncertainty assessments and expected economic and noneconomic outcomes. Codifying the incident in these terms has a framing effect that can influence management definitions of the incident through the problem-framing processes. Again, the relationship between management process and incident documentation is one of coherence, which tends to force a correspondence between the way an incident is concretely framed in the documentation and the way it is framed psychologically in terms of decision processes.

Lessons Learned

Local knowledge is a critical element in IA/EA decisionmaking as well as in ongoing IMT operations. Our modeling approach identified a number of places where local knowledge of fuel conditions, weather, and terrain were critical factors in adjusting the management approach to the incident conditions.

Ideally, continuity should exist between the various decision processes that surround an incident, both at the level of legacy decisions (e.g., land use planning), pre-incident decisions (e.g., preparedness planning), and incident-specific decisions (e.g., IA/EA, ongoing IMT operations). The models of decisionmaking we have examined here suggest that significant discontinuities can exist between these decision stages for various reasons. First, discontinuities may come about because of fundamental differences in the processes applied to different stages of an incident. For example, the focal decision during IA/EA can be on continuing engagement (e.g., direct attack) vs. a holding action, whereas ongoing IMT operations may focus more heavily on line production factors (e.g., efficiency). These shifts in focus represent changes in the reference points by which decisions are structured, evaluated, and made.

Second, discontinuities can come about owing to differences in the tempo or pace of decisionmaking. Altering the tempo of a decision process influences the amount of time for deliberation and conscious recognition of decision alternatives. In fast-paced operations, attentional resources may be limited and stress effects may be high.

Third, discontinuities can arise from differences in the structure of the influences that combine to effect decision processes. In the case of IA/EA, an incident may not have established itself sufficiently for a determination of the best longer term strategic approach to its management. Once the opportunity for strategic consideration of the incident is available, decision processes may shift to concerns that derive from broader organizational goals and objectives (e.g., cost containment).

Finally, discontinuities can exist because the shift from one management stage (e.g., IA/EA) to another (e.g., outside IMT) involves not only a shift in process but also a shift of individuals. If local individuals are also the carriers of local knowledge, the way that they interact with incoming management personnel will influence how (and how well) local knowledge becomes part of a larger, ongoing IMT management response to the incident.

We note that, at least for this case study, formalized local land management planning appeared to have little direct influence on incident decisionmaking except (perhaps) as an indirect influence through fuels management activities.

Case Study: Old Fire

Incident Synopsis

The incident began on a Saturday morning, October 25, 2003, at approximately 9:00 a.m. in Waterman Canyon, above the city of San Bernardino. The fire quickly spread down-canyon threatening private resources near the southern boundary of the San Bernardino NF. Gusting winds spread the fire into the neighborhoods east and west of Waterman Canyon (Highway 18), consuming some residences (fig. 17).

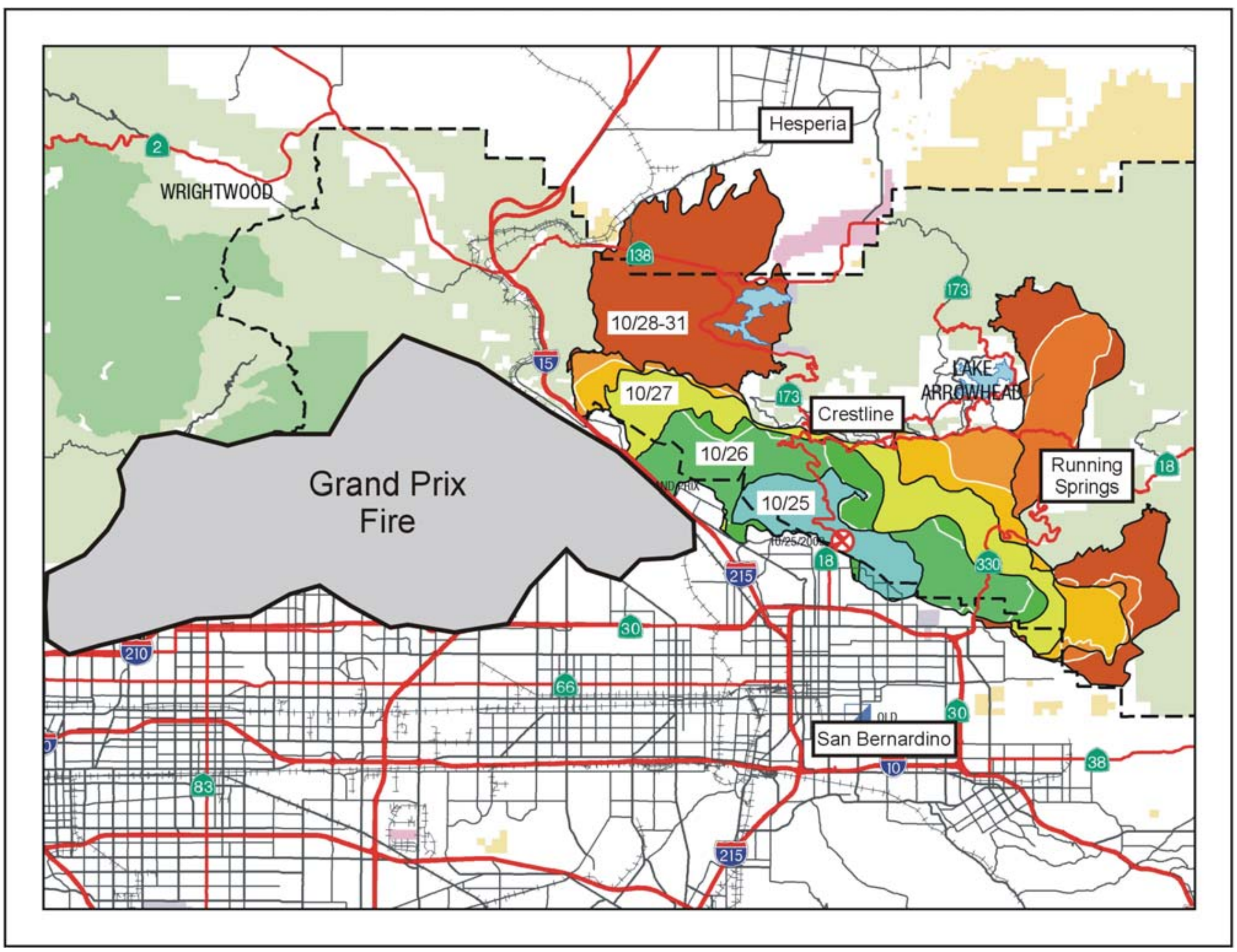

Figure 17—Incident map of the Old Fire (San Bernardino National Forest, Oct/Nov 2003). Old Fire is shown in color and labeled with dates.

The Old Fire was almost immediately adjacent to the Grand Prix Fire, and co-occurred along with a number of other major incidents in southern California. Weather conditions were a combination of high temperatures, low relative humidity, and Santa Ana winds coming off of the desert interior. These extreme weather conditions caused the fire to spread quickly up both sides of Waterman Canyon and toward the mountainous areas of the forest to the north and toward numerous mountain communities and residential areas. Ultimately, 940 residences were destroyed along with 30 commercial properties. Six individuals lost their lives, two in the first few hours of the incident. The cause of the fire was determined to be arson. A number of arson-caused incidents had already occurred in other forested areas in southern California.

The Old Fire along with the numerous other catastrophic fire incidents that occurred in southern California in the fall of 2003, drew extensive national attention not only for the obvious conflagration that viewers across the Nation witnessed on their television screens, but also for the disruptions that it caused to local communities and cities as well as to airline services and interstate highways, and the dangers other parts of the country faced from wildland fire because of the extreme drawdown on national-level fire suppression resources.

Event-Frame Representation

An event-frame representation of the Old Fire is shown in figure 18. The event-frame model shows three management phases: I/A/EA event, a type II management event, and a type I management event. However, management of the incident escalated almost immediately to a type II and then a type I response. The sequencing of the type II and type I management events on the timeline reflects the time required for these management resources to be in place on the incident and readiness to accept transition to their authority. Structure losses began to occur quickly, with additional structures lost on a daily basis through October 29. Community evacuations began within a matter of hours of the start of the incident. These evacuations were a major management event and were influenced a great deal by pre-incident preparations.

As can be seen in the sequence of events near the beginning of the incident, the response to the Old Fire was immediate and extreme from a management perspective. Very little time passed before national-level management was ordered and community evacuations begun. This was largely due to two factors: (a) pre-incident planning that anticipated the need for a quick management response under the kinds

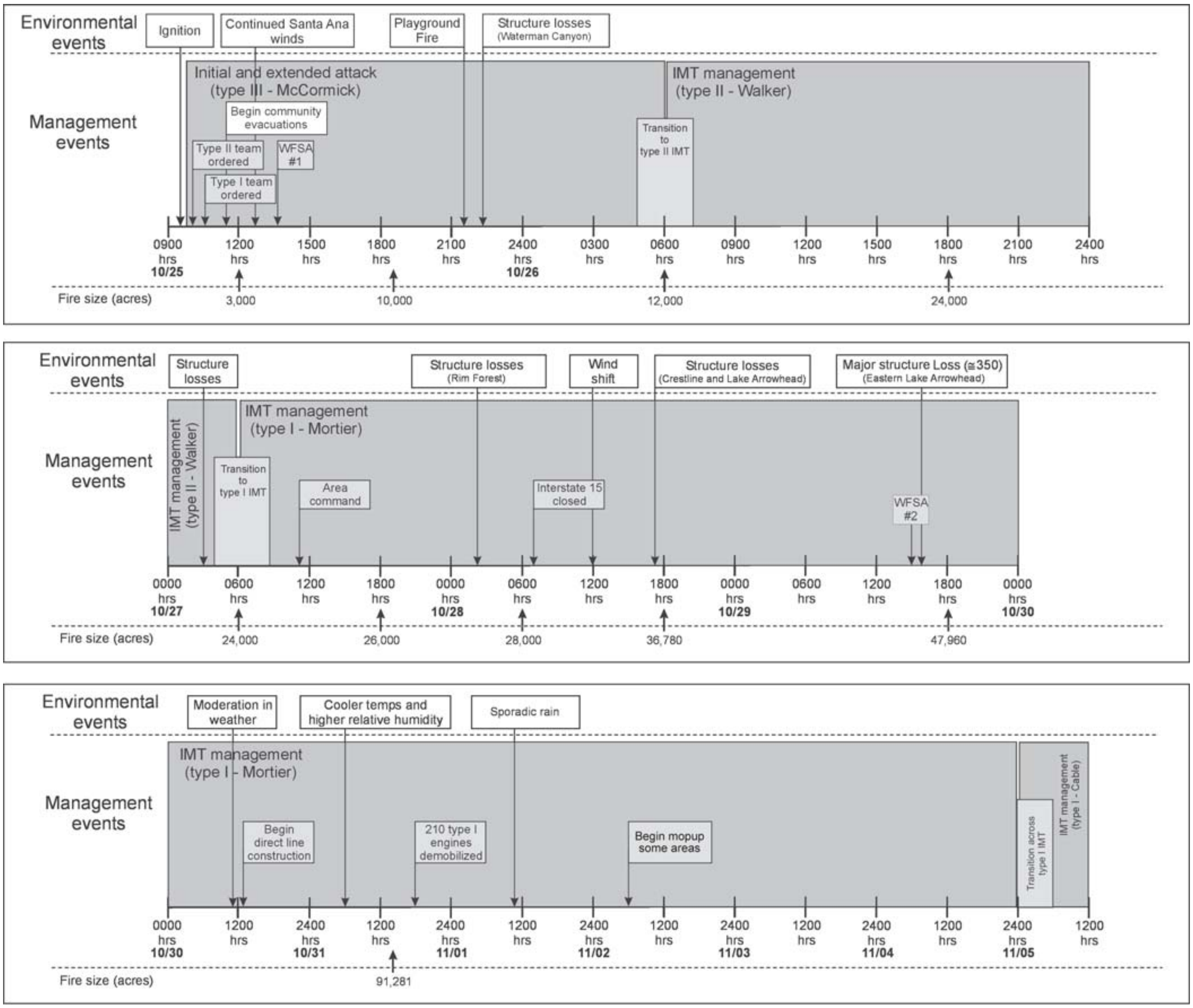

Figure 18—Event-frame representation of major events on the Old Fire. WFSA = wildland fire situation analysis.

of weather and fuel conditions present on the forest, and (b) a worst-case scenario that reflected the diversity or variance in fuel conditions and fire history. This diversity created a high-risk scenario with extreme variability in outcomes and, therefore, a very large worst-case scenario from the perspective of (a) the potential size of the area burned, and (b) the potential length of time the incident could continue.

Reconstruction and Representation of Key Incident Decisions

As with most large, complex incidents, there are many decisions on which focus can be placed. A feature that distinguishes the Old Fire is the nature and timing of what we call here the "initial management response" (fig. 19). By this, we mean the events shown on the event-frame timeline between the initial incident report and a period approximately 3 hours into the incident. Within this period, four key management events occurred: (a) IA, (b) type II IMT ordered, (c) type I IMT ordered, and (d) community evacuations initiated. This sequence of decisions was initiated or "triggered" by the incident but reflected other decision factors that occurred prior to the incident, some of them months or years before the incident took place.

In this representation, the incident management response is a combination of three categories of factors: (a) the specific conditions present at the time of incident ignition, (b) a worst-case analysis, and (c) multijurisdictional planning and coordination. In the Old Incident, the worst-case analysis appears to have been one of the major drivers of the initial management response. The worst-case scenario was influenced largely by the diversity of fire history and fuel conditions. This diversity was expressed as high uncertainty about the geographic size and temporal duration of the incident. The worst-case model, therefore, had extremely large upper bounds on the possible extensiveness of the incident, prompting a rapid escalation of the incident management.

The uncertainties inherent in the worst-case analysis were due largely to the range of fire history experienced in the local region as well as a high level of uncertainty about how to gauge a fire-return interval for a forest in which stand conditions and proper development interacted to produce the potential for a fire situation that had no historical referent. In addition, some parts of the forest had experienced recent fire activity that made it relatively low risk with regard to a new incident, whereas other parts of the forest had not experienced fire in almost 80 years. A high rate of tree mortality owing to insect and disease had produced very adverse fuel conditions in some areas, and fuel treatments produced the opposite effect in others. Given the weather conditions and the potential for the fire to spread in numerous directions, high uncertainty existed about the potential pattern of the fire, thereby creating a very large worst-case potential. The size of the worst-case outcome prompted a management decision on October 27 to initiate structure protection in the Big Bear area, well east of the fire perimeter at that time, but well within the worst-case boundary.

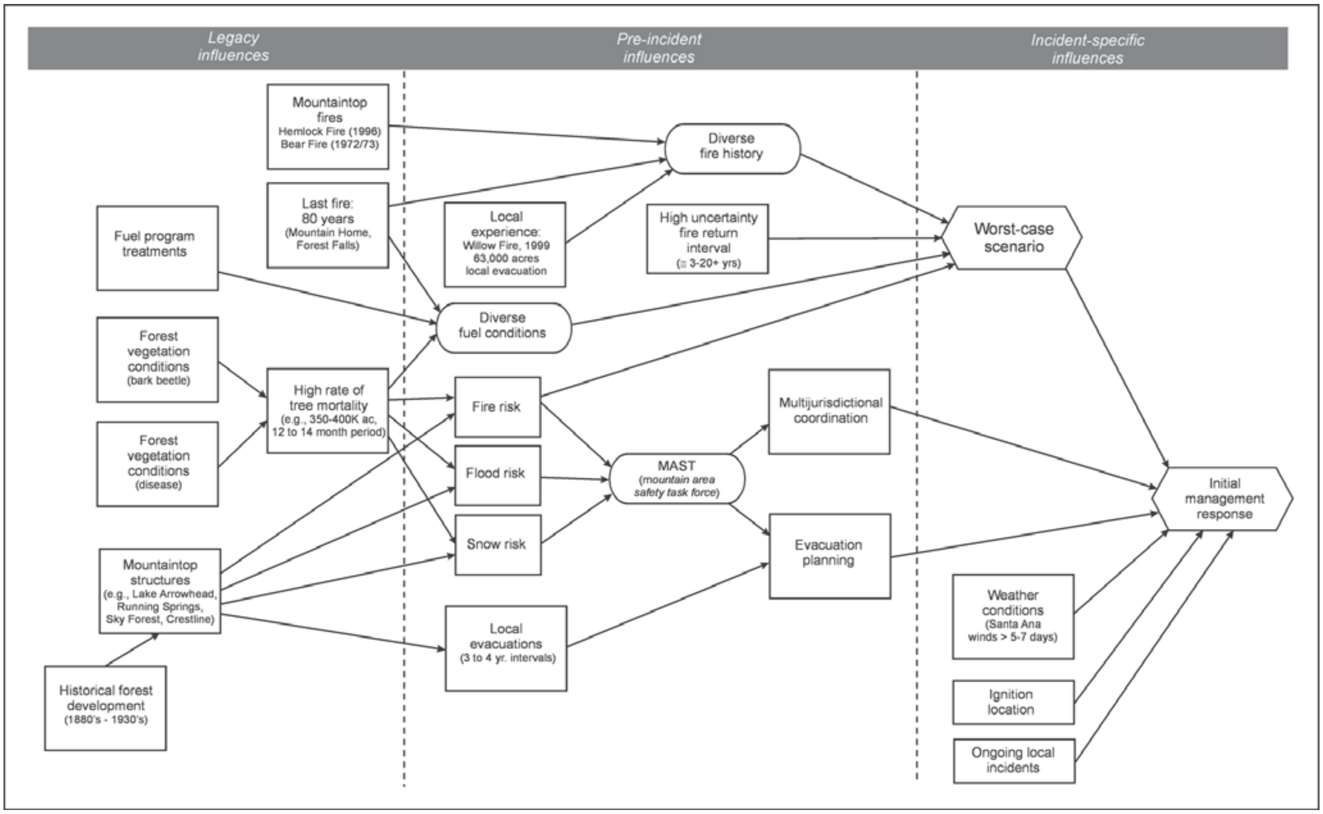

Figure 19—Influence diagram representation of initial management response.

The initial management response was influenced strongly by pre-incident planning and coordination that reflected risks relating to fire, flood, and snow that were the result of the high rate of tree mortality caused by insects and disease. These risk influences combined to yield a multijurisdictional task force response (Mountain Area Safety Task Force) that provided coordination as well as evacuation planning to cover a range of risk-related events, some associated with fire but others owing to dangerous trees, snow, and floods. Historical forest development patterns combined with the location of mountaintop structures had in the past prompted local evacuations on a 3- to 4-year interval. These trends influenced as well the need for evacuation planning. As a result, a management decision to evacuate residents very near the beginning of the incident was a response well within the envelope of decisions for which preparations had already been made.

Lessons Learned

The Old Fire is an example of an incident for which the major decisions that influenced incident outcomes occurred well in advance of the incident itself. In a real sense, the particular incident that came to be called the Old Fire could have been any one of a number of possible incidents occurring near that location. The specifics of the incident were essentially embodied in a set of decisions concerning preparedness and multijurisdictional coordination. The outcomes of the incident with respect to property losses and forested acres burned were in large part the result of weather and fuel conditions present at the time of ignition. The extremely small loss of life given the catastrophic nature of the event on other dimensions appears to be the result of an early determination of the potential magnitude of the outcomes and a management response that gave considerable weight to the worst-case outcome.

A telling feature of this incident is the strong influence that pre-incident and legacy factors have on the nature of the initial management response. This is evident in the Old Fire when we look at the role that the worst-case analysis played in prompting not only a rapid escalation to a type II and type I IMT response, but also in the decision to go well beyond the current fire perimeter to begin structure protection in areas nearer the boundary of the worst-case scenario.

Conclusions

The objective of this project was to develop a basis for using the concepts, models, and language of decisionmaking to characterize the decision processes on large fires. In pursuit of this objective, we have described a range of decision concepts and models and applied their associated modeling languages to decisions made on two case studies that serve as examples for how we can better represent the basis on which fire management personnel make the decisions that they do.

There is, perhaps, a tendency when we think of decisionmaking to conceptualize the process as one of evaluating alternatives represented in terms of a decision tree. Indeed, the decision tree is a convenient metaphor for how decisions can be structured, but as this report has shown, there are other models and languages that describe perhaps in more detail and with more fidelity the realism of dynamic, time-pressured decisionmaking where multiple influences interact to form an impression on the decisionmaker that guides their actions.

As we have explored the application of decision modeling to different aspects of decisionmaking on large fires, we have seen that decision processes differ according to the incident and its events. As the reconstruction of the Old Fire has shown, some incident decisions are actually legacy decisions, and the incident itself is an event for which decisionmaking has already occurred but the actions have not been yet executed. These are anticipated incidents–ones for which even extreme occurrences have been envisioned and action contingencies established. Although no large fire can be thought of as a normal occurrence, it is within reason to think of events like the Old Fire as "normal catastrophes," to paraphrase Perrow's description of some major technological failures as "normal accidents" (Perrow 1984). Given the precursor combination of forest conditions, weather and climate, and private inholdings, the trigger conditions necessary to produce highly impactful events may be just a matter of time. And, like technological failures, decision-making about their management is part of a larger cycle that involves preparation and analysis well in advance of their occurrence.

Even within ongoing incidents, decision processes can differ considerably depending on the stage of the incident and on how management processes are structured and executed. From our analysis of the Fork Fire, we observed fundamental differences in decision processes between IA/EA and ongoing IMT management. That analysis revealed that local knowledge plays a key role in early management stages as well as in management decisionmaking several days into an incident. We note as well that fundamental and important discontinuities may exist in these different management decisionmaking stages. Our analysis reaffirms that although fire is a continuous, exponential process that changes seamlessly although abruptly at times, management is a discrete process that changes linearly and in sometimes discontinuous stages. This fundamental incompatibility means that discontinuities in management processes may have the effect of retarding management performance. As fire management professionals sometimes note, it is important to get out in front of the fire, and to avoid getting behind the "power curve." One definition and operationalization of these concepts maybe found in decision process discontinuities. A better understanding of how mismatches occur between decision processes at different management stages of fire incidents may help identify how decision processes and fire management training can be improved.

Directions for Future Research

Apply Methods to a Larger Base of Incident Cases

The results of this project provide some potentially powerful insights into how decision processes can be revealed through the application of decision science theories and concepts to fire incidents. As a step toward further validation of this approach to understanding large-fire decisionmaking, additional cases need to be examined. This examination would take advantage of the methods and tools developed by this project, and efficiency could be obtained by extending the results demonstrated here to a large set of cases. A sampling frame should be developed to identify the structural dimensions that define how additional cases should be selected.

Identify Approaches for Incorporating Decision Modeling Into Fire Reviews and Accident Analysis

The goal of this project was to use the concepts, models, and language of decision science to characterize and represent the decision processes on large fires. One application would be a set of procedures and guidelines for using the DPTP approach in the context of field reviews, such as fire reviews and accident investigations. Field-related research should be done to identify how the methods developed in this project could be incorporated into management review activities. Possible methods include workshops and seminars on the approaches in the present study and how they can be directly applied in the field. Another possible method is the development of a set of indepth protocols directed toward understanding key decision stages of fire incidents, such as IA/EA and management transitions.

Improving the Worst-Case Analysis and Scenario-Generation Process

Our research here has shown the dramatic effects a worst-case analysis can have on downstream decision processes associated with large-fire management (Old Fire). By implication, the lack of a carefully constructed worst-case analysis can lead to an excessive small-fire bias that influences the development and implementation of tactical plans such that they may be overly optimistic about what is achievable given local conditions. At present, the process for constructing a worst-case analysis or scenario is not standardized within the fire management community. Although it is integrated as a concept into the wildland fire situation analysis process, the process that should be used to construct such a scenario is left up to the background and experience of the individual analyst or fire management professional. Given the importance of a worst-case analysis in developing an appropriate basis for comparing strategic alternatives and for communicating to line management the potential scope and impact of an emerging incident, better standards and procedures could be developed and communicated concerning how a worst-case scenario is constructed and represented. Methods currently exist in the decision and risk sciences that offer guidance for worst-case analyses. These methods could be translated and applied in the context of fire management decisionmaking.

Improving Accessibility and Usability of Local Fire Management Knowledge

Local knowledge was shown to be of significant importance in the decision processes associated with IA/EA as well as ongoing IMT management. We speculate that some of the difficulties incorporating local knowledge into ongoing fire management decision processes may stem from differences in how local units are staffed and managed. These differences in management style may leave the process of bringing local knowledge into the management picture subject to variability. A systematic study of how local knowledge is accessed, communicated, and used as part of the transition from IA/EA (local management) to incoming IMT management would help reveal where and how the process could be improved and (perhaps) standardized. Although line officer briefings are intended to serve this purpose (in part), it may also be the case that ongoing IA/EA operations may leave those who have the best local knowledge (e.g., fire management officers) not available at the time and place they are needed. Some form of decision support may be required to insure that key local knowledge is not overlooked during the transition from local incident management to IMT management. Alternatively, local knowledge could be structured and encoded in a form that is relevant for use by incoming IMTs and that is retrievable through automated or semiautomated means. The current process of insuring knowledge continuity across incident management levels relies heavily on the availability of local unit personnel who may be involved in incident activities and not (fully) available to interact closely with incoming IMT members.

Effects of Individual Differences in Initial and Extended Attack Decisionmaking

Our application of control theory to the decision processes associated with IA/EA identified a set of trigger conditions that determine when and how the decision to transition to a higher level of incident management occurs. These trigger conditions relied on an affective assessment of the relationship between current capabilities, resources required, and the fire situation. Research in contexts other than wildland fire suggests that this assessment can be expressed as a risk assessment, in which case the thresholds that fire management personnel use will be a matter of individual differences in risk attitudes. Ideally, these thresholds and the trigger conditions that produce them would be known in advance, thereby lending reliability and consistency to how an incident situation (e.g., fire situation, capabilities, resources) would relate to the decision to call for an outside IMT. Effort should be directed to identifying methods for understanding how individuals differ with respect to risk assessment in ongoing IA/EA operations, and how they differ with respect to the conditions under which they decide that an upward transition is needed. The results of such an investigation would help identify inconsistencies in training and experience that could be remediated, thereby improving the process by which personnel gain qualification.

Characterizing Discontinuities in Fire Management Decision Processes

Virtually all land management involves shifts from one mode of management to another. For example, in the case of fire management, the increasing severity of an incident may signal a shift to move from local management to an outside management team. This project identified a number of potential discontinuities in decision process that arise from management events and activities on large fires. These discontinuities pose potential challenges to effective and continuous decision-making. Research could further examine decision process discontinuities and how they can influence incident decision processes and outcomes. Along these lines, it maybe valuable to explore merging the important elements from the models presented in this paper into a single model that is unique to the context of real-time fire management.

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Metric Equivalents

1 foot = 0.305 meters

1 acre = .405 hectares

1 mile per hour = 1.609 kilometers per hour

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Appendix A: Summary of Incident Documentation—Fork Fire

WFSA Summaries – Fork Fire

WFSA/EFSA:	EFSA #1	EFSA #2
Date/Time Signed:	8/12/96 1020 hrs.	8/13/96 1130 hrs.
Objectives		
Economic	None	None
Environmental	None	None
Social	None	None
Other	None	None
Alternatives		
Alternative A:	Direct Attack: Direct attack on all flanks of fire.	***Combination Direct/Indirect 1: Combination of direct and indirect attack. Current strategy being used.***
Alternative B:	Indirect Attack: Construct line on major ridges and backfire as needed.	Combination Direct/Indirect 2: Combination of direct and indirect attack. Current strategy, with southern flank backed off to Sam Alley ridge.
Alternative C:	***Combination Direct/Indirect: Combination of direct and indirect attack.***	Combination Direct/Indirect 3: Combination of direct and indirect attack. Utilize Deer Valley road as eastern flank and Sam Alley Ridge as southern flank.
Alternative D:		Combination Direct/Indirect 4: Combination of direct and indirect attack. Same as Alternative 3, only using Ladder Ridge as southern flank.
Alternative E:		
Alternative F:		
Alternative G:		
Alternative H:		

WFSA/EFSA:	EFSA #1	EFSA #2
Date/Time Signed:	8/12/96 1020 hrs.	8/13/96 1130 hrs.
P(Success chosen alt.)		
Target Outcome:	100%	80%
Fallback:	0%	20%
Worst Case:	0%	0%
Outcomes		
Final Fire Size (Target):	1000 acres	5200 acres
Time to Contain (Target):	4 Days	5 Days
Time to Control (Target):	6 Days	9 Days
Expected Suppression Cost	$1,270,000	$19,600,000
Target Outcome Supp. Cost	$1,268,000	$18,400,000

WFSA Summaries – Fork Fire

WFSA/EFSA:	EFSA#3	EFSA#4
Date/Time Signed:	8/15/96 2000 hrs.	8/17/96 1700 hrs.
Objectives		
Economic	Use local contracts and vendors	**Improvements:** Minimize loss of structures in urban interface. **Wildlife:** Riparian areas. **Water:** Stream crossings
Environmental	*Utilize combination of direct/indirect attack, utilizing existing roads and ridgetops where possible. *Minimize use of equipment and retardant in riparian area. *Cross streams perpendicular to stream. *Minimize impacts to archeological sites - no incidental collecting.	**T&E:** Spotted owl habitat and species.
Social	*Minimize losses of structures in urban interface. *Firefighter and public safety is primary; use LCES.	**Employment:** Use local contracts and vendors. **Public Concern:** Local communities - evacuations. **Cultural:** Minmize damage to sites. No collecting.
Other	*Save the nest sites in late successional reserves (LSR). *Keep north of Long Ridge. *Keep south of Snow Mtn. Wilderness and Letts Lake. *Keep west of Love Lady and Indian Ridge.	
Alternatives		
Alternative A:	***Combination of direct/indirect: Goat Mtn. To Middle Creek. Ladder Ridge to Hale Ridge***	***Direct/Indirect Combination: Goat Mt. To Middle Creek. Ladder Ridge to Hale Ridge***
Alternative B:	Combination of direct/indirect: Letts Ridge to Pacific Ridge. Lovelylady Ridge to Goat Mtn.	Direct/Indirect Combination: Adds Letts Ridge to Pacific Ridge. Love Lady Ridge to Goat Mtn.
Alternative C:	Combination of direct/indirect: Pacific Ridge to Rupert Ridge. Bartlett Flat to Indian Ridge.	Direct/Indirect Combination: Adds Pacific Ridge to Rupert Ridge. Bartlett Flat to Indian Ridge.
Alternative D:		Direct/Indirect Combination: Adds Rupert Ridge to Long Valley. Clover Valley/Hogwood Ridge to Roclay Ridge/Wilson Glade
Alternative E:		Direct/Indirect Combination: Adds Long Valley Ridge to High Valley. East of Lucerne to North Fork Cache Creek.
Alternative F:		Direct/Indirect Combination: Adds Pacific Ridge to North Fork of Cache Creek. Roday Ridge/Wilson Glade to Stanton Creek/Indian Valley Reservoir.
Alternative G:		Direct/Indirect Combination: Adds High Valley Ridge to ridge north of Paradise Valley/Glenhaven/Clear Lake Oaks.
Alternative H:		Direct/Indirect Combination: Adds ridge north of Paradise/Glenhaven/Clear Lake Oaks to north of twin communities. Pure Mtn. To North of Cache Creek.

WFSA/EFSA:	EFSA#3	EFSA#4
Date/Time Signed:	8/15/96 2000 hrs.	8/17/96 1700 hrs.
P(Success chosen alt.)		
Target Outcome:	80%	80%
Fallback:	Not Given Explicitly	18%
Worst Case:	Not Given Explicitly	2%
Outcomes		
Final Fire Size (Target):	42,000 acres	42000 acres
Time to Contain (Target):	15 Days	Not Given
Time to Control (Target):	Not Given	13 Days
Expected Suppression Cost	Not Given	Not Given
Target Outcome Supp. Cost:	Not Given	$26,628,000

ICS-209 Summaries – Fork Fire

WFSA/EFSA:	**EFSA #1**	**EFSA #1**	**EFSA #2**	**EFSA #2**
Date/Time Signed:	**8/12/96 1020 hrs.**		**8/13/96 1130 hrs.**	
ICS 202 Code:	**ICS202-Z1-01**	**ICS202-Z1-02**	**ICS202-Z1-03**	**ICS202-Z1-04**
Date Prepared:	August 12, 1996	August 12, 1996	August 13, 1996	August 13, 1996
Time Prepared:	1400 hrs.	2354 hrs.	1500 hrs.	1500 hrs.
Operational Period:	8/12-8/13 1800-0600	8/13 0600-1800	8/13-8/14 1800-0600	8/14 0600-1800

General Control Objectives

	Provide for firefighter safety through utilizing LCES analysis process	Provide for firefighter safety through utilizing LCES analysis process	Provide for firefighter safety through utilizing LCES analysis area	Provide for firefighter safety through utilizing LCES analysis area
		Utilize combination direct/indirect attack, utilizing existing roads and ridgetops where possible	Utilize combination direct/indirect attack, utilizing existing roads and ridgetops where possible	Utilize combination direct/indirect attack, utilizing existing roads and ridgetops where possible
		Keep fire northeast of the town of ***Upper Lake***	Keep fire northeast of the town of ***Upper Lake***	Keep fire northeast of the town of ***Upper Lake***
		Hold southern flank of fire northwest of ***Bartlett Mountain***	Hold southern flank of fire northwest of ***Bartlett Mountain***	Hold southern flank of fire northwest of ***Bartlett Mountain***
	Keep fire northwest of ***McCabe Ridge*** and east of ***Middle Creek***	Hold east flank of fire west of ***East Fork Middle Creek***	Hold east flank of fire west of ***East Fork Middle Creek***	Hold east flank of fire west of ***Deer Valley Road***
		Hold north flank of fire southwest of ***Elk Mountain***	Hold north flank of fire southwest of ***Elk Mountain***	Hold north flank of fire southwest of ***Elk Mountain***
	Keep fire southeast of ***Middle Creek***	Keep west flank of fire east of ***Middle Creek***	Keep west flank of fire east of ***Middle Creek***	Keep west flank of fire east of ***Middle Creek***
	Provide for structure protection in and around ***White Rock Road***	Provide for structure protection.	Provide for structure protection.	Provide for structure protection.
	Provide for timely and orderly evacuation in and around ***White Rock Road***	Provide for timely and orderly evacuation	Provide for timely and orderly evacuation	Provide for timely and orderly evacuation

District Resource Concerns

	None	Minimize the use of equipment and retardant in riparian areas	Minimize the use of equipment and retardant in riparian areas	Minimize the use of equipment and retardant in riparian areas
		Cross streams perpendicular to the stream	Cross streams perpendicular to the stream	Cross streams perpendicular to the stream
		Minimize impacts to archeological sites. No incidental collecting. No digging out of spring areas.	Minimize impacts to archeological sites. No incidental collecting. No digging out of spring areas.	Minimize impacts to archeological sites. No incidental collecting. No digging out of spring areas.

ICS-209 Summaries – Fork Fire

EFSA #2	EFSA #2	EFSA #2	EFSA#3 8/15/96 2000 hrs.	EFSA#3
ICS202-Z1-05 August 14, 1996 1500 hrs. 8/14-8/15 1800-0600	ICS202-Z1-06 August 14, 1996 2320 hrs. 8/15 0800-1800	ICS202-Z1-07 August 15, 1996 1430 hrs. 8/15-8/16 1800-0600	ICS202-Z1-08 August 15, 1996 2300 hrs. 8/16 0600-1800	ICS202-Z1-09 August 16, 1996 1500 hrs. 8/16-8/17 1800-0600
Provide for firefighter safety through utilizing LCES analysis area	Provide for firefighter safety through utilizing LCES analysis area	Provide for firefighter safety through utilizing LCES analysis area	Provide for firefighter safety through utilizing LCES analysis area	Provide for firefighter safety through utilizing LCES analysis area
Utilize combination direct/indirect attack, utilizing existing roads and ridgetops where possible	Utilize combination direct/indirect attack, utilizing existing roads and ridgetops where possible	Utilize combination direct/indirect attack, utilizing existing roads and ridgetops where possible	Utilize combination direct/indirect attack, utilizing existing roads and ridgetops where possible	Utilize combination direct/indirect attack, utilizing existing roads and ridgetops where possible
Keep fire northeast of the town of ***Upper Lake***	Keep fire northeast of the town of ***Upper Lake***	Keep fire northeast of the town of ***Upper Lake***	Keep fire northeast of the town of ***Upper Lake***	Keep fire northeast of the town of ***Upper Lake***
Hold southern flank of fire north of ***Ladder Ridge***	Hold southern flank of fire north of ***Ladder Ridge***	Hold southern flank of fire north of ***Ladder Ridge*** and ***Wild Bill Ridge***	Hold southern flank of fire north of ***Ladder Ridge*** and ***Wild Bill Ridge***	Hold southern flank of fire north of ***Ladder Ridge*** and ***Wild Bill Ridge***
Hold east flank of fire west of a ***Red Rock*** to ***Deer Valley Campground*** line	Hold east flank of fire west of ***Rice Fork***	Hold east flank of the fire west of the ***Stonyford District boundary***	Hold east flank of the fire west of the ***Stonyford District boundary***	Hold east flank of the fire west of the ***Stonyford District boundary***
Hold north flank of fire south of ***Elk Mountain***	Hold north flank of fire south of ***Elk Mountain***	Hold north flank of fire south of ***Elk Mountain***	Hold north flank of fire south of ***Elk Mountain***	Hold north flank of fire south of ***Elk Mountain***
Keep west flank of fire east of ***Middle Creek***	Keep west flank of fire east of ***Middle Creek***	Keep west flank of fire east of ***Middle Creek***	Keep west flank of fire east of ***Middle Creek***	Keep west flank of fire east of ***Middle Creek***
Provide for structure protection.	Provide for structure protection.	Provide for structure protection.	Provide for structure protection.	Provide for structure protection.
Provide for timely and orderly evacuation	Provide for timely and orderly evacuation	Provide for public safety with timely and orderly evacuation and restricted access	Provide for public safety with timely and orderly evacuation and restricted access	Provide for public safety with timely and orderly evacuation and restricted access

Minimize the use of equipment and retardant in riparian areas	Minimize the use of equipment and retardant in riparian areas	Minimize the use of equipment and retardant in riparian areas	Minimize the use of equipment and retardant in riparian areas	Minimize the use of equipment and retardant in riparian areas
Cross streams perpendicular to the stream	Cross streams perpendicular to the stream	Cross streams perpendicular to the stream	Cross streams perpendicular to the stream	Cross streams perpendicular to the stream
Minimize impacts to archeological sites. No incidental collecting. No digging out of spring areas.	Minimize impacts to archeological sites. No incidental collecting. No digging out in spring areas.	Minimize impacts to archeological sites. No incidental collecting. No digging out in spring areas.	Minimize impacts to archeological sites. No incidental collecting. No digging out in spring areas.	Minimize impacts to archeological sites. No incidental collecting. No digging out in spring areas.

ICS-209 Summaries – Fork Fire

EFSA#3	EFSA#4 8/17/96 1700 hrs.	EFSA#4	EFSA#4	EFSA#4
ICS202-Z1-10 August 17, 1996 0200 hrs. 8/17 0600-2000	ICS202-Z1-11 August 17, 1996 1500 hrs. 8/17-8/18 1800-0800	ICS202-Z1-12 August 18, 1996 0200 hrs. 8/18-8/19 0800-0600	ICS202-Z1-13 August 18, 1996 1800 hrs. 8/19-8/20 0600-0600	ICS202-Z1-14 August 19, 1996 2300 hrs. 8/20-8/21 0600-0600
Provide for firefighter safety through utilizing LCES analysis area	Provide for firefighter safety through utilizing LCES analysis area	Provide for firefighter safety through utilizing LCES analysis area	Provide for firefighter safety through utilizing LCES analysis area	Provide for firefighter safety through utilizing LCES analysis area
Utilize combination direct/indirect attack, utilizing existing roads and ridgetops where possible	Utilize combination direct/indirect attack, utilizing existing roads and ridgetops where possible	Utilize combination direct/indirect attack, utilizing existing roads and ridgetops where possible (Keep fire east of ***Bartlett Ridge*** and ***High Valley Road*** and North)	Utilize combination direct/indirect attack, utilizing existing roads and ridgetops where possible (Keep fire east of ***Bartlett Ridge*** and ***High Valley Road*** and North)	Utilize combination direct/indirect attack, utilizing existing roads and ridgetops where possible (Keep fire east of ***Bartlett Ridge*** and ***High Valley Road*** and North)
Keep fire northeast of the town of ***Upper Lake***	Keep fire northeast of the town of ***Upper Lake***	Keep fire northeast of the town of ***Upper Lake, (Nice and Lucerne).***	Keep fire northeast of the town of ***Upper Lake, (Nice and Lucerne).***	Keep fire northeast of the town of ***Upper Lake, (Nice and Lucerne).***
Hold southern flank of fire north of ***Ladder Ridge*** and ***Wild Bill Ridge***	Hold southern flank of fire north of ***Ladder Ridge*** and ***Mary Ann Ridge***	Hold southern flank of fire north of ***40 Spring Valley*** and ***Hog Back Ridge***	Hold southern flank of fire north of ***40 Spring Valley*** and ***Hog Back Ridge***	Hold southern flank north of ***40 Spring Valley*** and ***Hog Back Ridge***
Hold east flank of the fire west of the ***Stonyford District boundary***	Hold east flank of the fire west of the ***Stonyford District boundary*** and ***Lady Bug Creek***	Hold east flank of the fire west of the ***Stonyford District boundary*** and ***Lady Bug Creek***	Hold east flank of the fire west of the ***Stonyford District boundary*** and ***Lady Bug Creek***	Hold east flank of the fire west of the ***Stonyford District boundary*** and ***Lady Bug Creek***
Hold north flank of fire south of ***Elk Mountain***	Hold north flank of fire south of ***Elk Mountain***	Hold north flank of fire south of ***Elk Mountain***	Hold north flank of fire south of ***Elk Mountain***	Hold north flank of fire south of ***Elk Mountain***
Keep west flank of fire east of ***Middle Creek***	Keep west flank of fire east of ***Middle Creek***	Keep west flank of fire east of ***Middle Creek***	Keep west flank of fire east of ***Middle Creek***	Keep west flank of fire east of ***Middle Creek***
Provide for structure protection.	Provide for structure protection.	Protect structures in ***High*** , ***Long*** and ***Spring Valley*** and all structures in or near the perimeter.	Protect structures in ***High*** , ***Long*** and ***Spring Valley*** and all structures in or near the perimeter.	Protect structures in ***High*** , ***Long*** and ***Spring Valley*** and all structures in or near the perimeter.
Provide for public safety with timely and orderly evacuation and restricted access	Provide for public safety with timely and orderly evacuation and restricted access	Provide for public safety with timely and orderly evacuation and restricted access	Provide for public safety with timely and orderly evacuation and restricted access	Provide for public safety with timely and orderly evacuation and restricted access

Minimize the use of equipment and retardant in riparian areas	Minimize the use of equipment and retardant in riparian areas	Minimize the use of equipment and retardant in riparian areas	Minimize the use of equipment and retardant in riparian areas	Minimize the use of equipment and retardan in riparian areas
Cross streams perpendicular to the stream	Cross streams perpendicular to the stream	Cross streams perpendicular to the stream	Cross streams perpendicular to the stream	Cross streams perpendicular to the stream
Minimize impacts to archeological sites. No incidental collecting. No digging out in spring areas.	Minimize impacts to archeological sites. No incidental collecting. No digging out in spring areas.	Minimize impacts to archeological sites. No incidental collecting. No digging out in spring areas.	Minimize impacts to archeological sites. No incidental collecting. Avoid known cultural sites.	Minimize impacts to archeological sites. No incidental collecting. Avoid known cultural sites.

ICS-209 Summaries – Fork Fire

EFSA#4	EFSA#4	EFSA#4	EFSA#4	EFSA#4
ICS202-Z1-15	ICS202-Z1-16	ICS202-Z1-17	ICS202-Z1-18	ICS202-Z1-19
August 20, 1996	August 21, 1996	August 22, 1996	August 23, 1996	August 24, 1996
2300 hrs.	2300 hrs.	2300 hrs.	2300 hrs.	1000 hrs.
8/21-8/22 0600-0600	8/22-8/23 0600-0600	8/23-8/24 0600-0600	8/24 0600-1800	8/24-8/25 1800-0600
Provide for firefighter safety through utilizing LCES analysis area	Provide for firefighter safety through utilizing LCES analysis area	Provide for firefighter safety through utilizing LCES analysis area	Provide for firefighter safety through utilizing LCES analysis area	Provide for firefighter safety through utilizing LCES analysis area
Utilize combination direct/indirect attack, utilizing existing roads and ridgetops where possible (Keep fire east of ***Bartlett Ridge*** and ***High Valley Road*** and North)	Utilize combination direct/indirect attack, utilizing existing roads and ridgetops where possible (Keep fire east of ***Bartlett Ridge*** and ***High Valley Road*** and North)	Utilize combination direct/indirect attack, utilizing existing roads and ridgetops where possible	Utilize combination direct/indirect attack, utilizing existing roads and ridgetops where possible	Utilize combination direct/indirect attack, utilizing existing roads and ridgetops where possible
Keep fire northeast of the town of ***Upper Lake, (Nice and Lucerne).***	Keep fire northeast of the town of ***Upper Lake, (Nice and Lucerne).***	Keep fire northeast of the town of ***Upper Lake, (Nice and Lucerne).***	Keep fire northeast of the town of ***Upper Lake, (Nice and Lucerne).***	Keep fire northeast of the town of ***Upper Lake, (Nice and Lucerne).***
Hold southern flank north of ***40 Spring Valley*** and ***Hog Back Ridge***	Hold southern flank north of ***40 Spring Valley*** and ***Hog Back Ridge***	Hold southern flank north of ***40 Spring Valley*** and ***Hog Back Ridge***	Hold southern flank north of ***40 Spring Valley*** and ***Hog Back Ridge***	Hold southern flank north of ***Spring Valley Subdivision*** and ***Hog Back Ridge***
Hold east flank of the fire west of top of ***Pacific Ridge***	Hold east flank of the fire west of top of ***Pacific Ridge***	Hold east flank of the fire west of top of ***Pacific Ridge***	Hold east flank of the fire west of top of ***Pacific Ridge***	Hold east flank of the fire west of top of the ***Colusa County Line***
Hold north flank of fire south of ***Elk Mountain***	Hold north flank of fire south of ***Elk Mountain***	Hold north flank of fire south of ***Elk Mountain***	Hold north flank of fire south of ***Elk Mountain***	Hold north flank of fire south of ***Elk Mountain***
Keep west flank of fire east of ***Middle Creek***	Keep west flank of fire east of ***Middle Creek***	Keep west flank of fire east of ***Middle Creek***	Keep west flank of fire east of ***Middle Creek***	Keep west flank of fire east of ***Middle Creek***
Protect structures in ***High***, ***Long*** and ***Spring Valley*** and all structures in or near the perimeter.	Protect structures in ***High***, ***Long*** and ***Spring Valley*** and all structures in or near the perimeter.	Protect structures in ***High***, ***Long*** and ***Spring Valley*** and all structures in or near the perimeter.	Protect structures in ***High***, ***Long*** and ***Spring Valley*** and all structures in or near the perimeter.	Protect structures in ***High***, ***Long*** and ***Spring Valley*** and all structures in or near the perimeter.
Provide for public safety with timely and orderly evacuation and restricted access	Provide for public safety with timely and orderly evacuation and restricted access	Provide for public safety with timely and orderly evacuation and restricted access	Provide for public safety with timely and orderly evacuation and restricted access	Provide for public safety with timely and orderly evacuation and restricted access

Minimize the use of equipment and retardant in riparian areas	Minimize the use of equipment and retardant in riparian areas	Minimize the use of equipment and retardant in riparian areas	Minimize the use of equipment and retardant in riparian areas	Minimize the use of equipment and retardant in riparian areas
Cross streams perpendicular to the stream	Cross streams perpendicular to the stream	Cross streams perpendicular to the stream	Cross streams perpendicular to the stream	Cross streams perpendicular to the stream
Minimize impacts to archeological sites. No incidental collecting. Avoid known cultural sites.	Minimize impacts to archeological sites. No incidental collecting. Avoid known cultural sites.	Minimize impacts to archeological sites. No incidental collecting. Avoid known cultural sites.	Minimize impacts to archeological sites. No incidental collecting. Avoid known cultural sites.	Minimize impacts to archeological sites. No incidental collecting. Avoid known cultural sites.

ICS-209 Summaries – Fork Fire

EFSA#4	EFSA#4	EFSA#4	EFSA#4	EFSA#4
ICS202-Z1-20 August 25, 1996 1000 hrs. 8/25-8/26 1800-0600	ICS202-Z1-21 August 25, 1996 1800 hrs. 8/26 0600-1800	ICS202-Z1-22 August 26, 1996 1000 hrs. 8/26-8/27 1800-0600	ICS202-Z1-23 August 26, 1996 1800 hrs. 8/27 0600-1800	ICS202-Z1-24 August 27, 1996 1800 hrs. 8/28 0600-1800
Provide for firefighter safety through utilizing LCES analysis area	Provide for firefighter safety through utilizing LCES analysis area	Provide for firefighter safety through utilizing LCES analysis area	Provide for firefighter safety through utilizing LCES analysis area	Provide for firefighter safety through utilizing LCES analysis area
Complete mop up and fire suppression rehabilitation to Forest standards.	Complete mop up and fire suppression rehabilitation to Forest standards.	Complete mop up and fire suppression rehabilitation to Forest standards.	Complete mop up and fire suppression rehabilitation to Forest standards.	Complete mop up and fire suppression rehabilitation to Forest standards.
Keep fire northeast of the town of ***Upper Lake, (Nice and Lucerne).***	Keep fire northeast of the town of ***Upper Lake, (Nice and Lucerne).***	Keep fire northeast of the town of ***Upper Lake, (Nice and Lucerne).***	Keep fire northeast of the town of ***Upper Lake, (Nice and Lucerne).***	Keep fire northeast of the town of ***Upper Lake, (Nice and Lucerne).***
Hold southern flank north of ***Spring Valley Subdivision*** and ***Hog Back Ridge***	Hold southern flank north of ***Spring Valley Subdivision*** and ***Hog Back Ridge***	Hold southern flank north of ***Spring Valley Subdivision*** and ***Hog Back Ridge***	Hold southern flank north of ***Spring Valley Subdivision*** and ***Hog Back Ridge***	Hold southern flank north of ***Spring Valley Subdivision*** and ***Hog Back Ridge***
Hold east flank of the fire west of top of the ***Colusa County Line***	Hold east flank of the fire west of top of the ***Colusa County Line***	Hold east flank of the fire west of top of the ***Colusa County Line***	Hold east flank of the fire west of top of the ***Colusa County Line***	Hold east flank of the fire west of top of the ***Colusa County Line***
Hold north flank of fire south of ***Elk Mountain***	Hold north flank of fire south of ***Elk Mountain***	Hold north flank of fire south of ***Elk Mountain***	Hold north flank of fire south of ***Elk Mountain***	Hold north flank of fire south of ***Elk Mountain***
Keep west flank of fire east of ***Middle Creek***	Keep west flank of fire east of ***Middle Creek***	Keep west flank of fire east of ***Middle Creek***	Keep west flank of fire east of ***Middle Creek***	Keep west flank of fire east of ***Middle Creek***
Protect structures in ***High***, ***Long*** and ***Spring Valley*** and all structures in or near the perimeter.	Protect structures in ***High***, ***Long*** and ***Spring Valley*** and all structures in or near the perimeter.	Protect structures in ***High***, ***Long*** and ***Spring Valley*** and all structures in or near the perimeter.	Protect structures in ***High***, ***Long*** and ***Spring Valley*** and all structures in or near the perimeter.	Protect structures in ***High***, ***Long*** and ***Spring Valley*** and all structures in or near the perimeter.
Provide for public safety with timely and orderly evacuation and restricted access	Provide for public safety with timely and orderly evacuation and restricted access	Provide for public safety with timely and orderly evacuation and restricted access	Provide for public safety with timely and orderly evacuation and restricted access	Provide for public safety with timely and orderly evacuation and restricted access
Minimize the use of equipment and retardant in riparian areas	Minimize the use of equipment and retardant in riparian areas	Minimize the use of equipment and retardant in riparian areas	Minimize the use of equipment and retardant in riparian areas	Minimize the use of equipment and retardant in riparian areas
Cross streams perpendicular to the stream	Cross streams perpendicular to the stream	Cross streams perpendicular to the stream	Cross streams perpendicular to the stream	Cross streams perpendicular to the stream
Minimize impacts to archeological sites. No incidental collecting. Avoid known cultural sites.	Minimize impacts to archeological sites. No incidental collecting. Avoid known cultural sites.	Minimize impacts to archeological sites. No incidental collecting. Avoid known cultural sites.	Minimize impacts to archeological sites. No incidental collecting. Avoid known cultural sites.	Minimize impacts to archeological sites. No incidental collecting. Avoid known cultural sites.

Appendix B: Summary of Incident Documentation—Old Fire

ICS-209 Summaries – Old Fire

WFSA/EFSA:	WFSA #1	WFSA #1	WFSA #1	WFSA #1
Date/Time Signed:	10/25/2003 1200 hrs			
ICS 209 Code:	ICS209-01	ICS209-02	ICS209-03	ICS209-04
Date Prepared:	October 25, 2003	October 25, 2003	October 26, 2003	October 26, 2003
Time Prepared:	1157 hrs.	1830 hrs.	0600 hrs.	1800 hrs.
Op Period:	10/25 0600-1800	10/25-26 1800-0600	10/26 0600-1800	10/26-27 1800-0600
IC	McCormick	McCormick	Walker	Walker
Incident Type:	3	3	2	2
Fire Size (acres):	3,000	10,000	12,000	24,000
Control Objectives				
	Protect life and property.	Protect life and property.	Protect life and property.	Protect life and property.
	Try and establish anchor point.	Try and establish some perimeter control.	Attempt to establish anchor points.	Attempt to establish anchor points.
	Begin perimeter control.		Stop rate of spread into San Bernardino.	Continue to evcuate mountain communities.
			Continue to evacuate mountain communities.	Walker's T-2 IMT will transition with Mortier's T-1 IMT 10/27 0600
Significant Events				
	Community evacuations.	Community evacuations.	Community evacuations.	Community evacuations.
	October 25		October 26	

ICS-209 Summaries – Old Fire

WFSA #1	WFSA #1	WFSA #1	WFSA #1
ICS209-05 October 27, 2003 0600 hrs. 10/27 0600-1800 Mortier 1 24,000	**ICS209-06** October 27, 2003 1800 hrs. 10/27-28 1800-0600 Mortier 1 26,000	**ICS209-07** October 28, 2003 0600 hrs. 10/28 0600-1800 Mortier 1 28,000	**ICS209-08** October 28, 2003 1800 hrs. 10/28-29 1800-0600 Mortier 1 36,780
Continue structure protection.	Continue structure protection.	Structure protection.	Structure protection continues in a communities.
Assess the resources on the line for 2 to 1 work/rest ratio.	Put in line on the East flank in an attempt to keep the fire out of Running Springs.	Prepare for the possible wind change today.	Line construction on the NW corn around Cajon Mtn.
			Continue to hold fire West of the S Ana drainage.
Structure losses during the night.	Many responses to flareups in areas already burned through. Fire threatened Devore where structure protection resources were able to successfully defend. Air tankers and helicopters kept fire south of the Rim of The World and out of the major pop. Center. Eastward spread threatened the City Creek guard station.	Fire spread into Devore Heights on the west flank and moved into the Plunge Creek drainage to the East. Fire also moved North across Hwy 18 onto Strawberry Peak and burned approx. 20 homes in Rim Forest.	Fire burned into the Crestline and Lak Arrowhead rim causing moderate loss structures. Fire is holding East of the Santa Ana drainage and threatening Running Springs. All aircraft timed out today. Structure protection resources successful in Devore Heights as the fi threatened the area. I-15 closed all da to fire activity.
October 27		**October 28**	

ICS-209 Summaries – Old Fire

WFSA #2 10/29/03 1503 hrs.	WFSA #2	WFSA #2	WFSA #2
ICS209-09 October 29, 2003 0600 hrs. 10/29 0600-1800 Mortier 1 28,204	**ICS209-10** October 29, 2003 1800 hrs. 10/29-30 1800-0600 Mortier 1 47,960	**ICS209-11** October 30, 2003 0600 hrs. 10/30 0600-1800 Mortier 1 49,880	**ICS209-12** October 30, 2003 1800 hrs. 10/30-31 1800-0600 Mortier 1 95,395
Continue structure protection.	Continue structure protection.	Provide structure protection.	Continue to construct direct fireline where able.
Construct primary dozer and handline where able.	Continue line construction.	Construct fire and contingency lines where able.	Use the moderation in weather as an opportunity to improve percentage of containment.
Improve contingency planning, mapping and fire behavior analysis.	Work on contingency lines continues.		Coordinate firefighting activities with Area Command and all involved management teams.
Continue to construct contingency lines.			
Continue to hold fire West of the Santa Ana drainage.			
NOTE: Incident divided East and West of Waterman Canyon. CIIMT2 assumes mgt. of western sector and will include that area in the Grand Prix Incident. All areas East of Waterman Canyon remain with Old Incident.		**NOTE: Area Command met with IC's. Incident divided with CIIMT 2 (Studebaker) taking the western portion, CIIMT 3 (Mortier) the Arrowhead, Running Springs area, and CIIMT 5 (Cable) assuming the Big Bear portion.**	**NOTE: Moderation in weather enabled firefighters to being construction of direct line in the North Lake Arrowhead area. Crews able to secure and mop-up several areas on the mountain top. Fire made short runs and responded well to higher humidity.**
Major road closures remained in effects. Overnight the fire made a significant advance on the northwestern flank reaching the Lake Silverwood/Miller Canyon area.	Fire destroyed 350 residents in the area; 300 of which were in the eastern Lake Arrowhead community.	Additional structures were lost in the North Lake Arrowhead area during the night. Damage will be assessed today. 40,000 remain evacuated.	Began direct fireline construction in the Lake Arrowhead area. Spread has slowed in the area northeast of Lake Arrowhead. No structures were lost today.

October 29		October 30	

ICS-209 Summaries – Old Fire

WFSA #2	WFSA #2	WFSA #2	WFSA #2
ICS209-13 October 31, 2003 0600 hrs. 10/31 0600-1800 Mortier 1 92,395	**ICS209-14** October 31, 2003 1000 hrs. 10/31 0600-1800 Mortier 1 91,281	**ICS209-15** October 31, 2003 1800 hrs. 10/31 - 11/01 1800-0600 Mortier 1 91,281	**ICS209-16** November 1, 2003 1800 hrs. 11/01-02 1800-0600 Mortier 1 91,281
Continue structure protection in all mountain communities	Continue structure protection in all mountain communities.	CIIMT 3 - Continue structure protection.	Construct direct and indirect fireline.
Make aggressive direct attack on fire while favorable weather exists.	Make aggressive direct attack on fire while favorable weather exists.	Utilize direct fire attack where able.	Continue structure protection.
Coordinate firefighting activities with CIIMT 2 on the west and CIIMT 5 on the east.	Coordinate firefighting activities with CIIMT 2 on the west and CIIMT 5 on the east.	Continue to construct fireline and contingencies.	Suppression efforts will be reassessed as the effects of rain and snow are evaluated.
Continue constructing contingency line.	Continue constructing contingency line.	CIIMT 5 - Continue imporiving contingency lines running NW of Big Bear.	CIIMT 5 will continue contingency line construction with a total of 1929 chains to complete.
		NC Team 2 - Continue contingency planning for line construction and structure protection.	
NOTE: Continuing cooler temperatures and higher humidities. Fog anticipated to 4000' elevation.	**NOTE: This 209 appears to be an update of the one earlier the same day. The reason for the update appears to be an error in the fire size from the previous 209 done at 0600 hrs.**	**NOTE: Arson determined to be cause of incident.**	**NOTE: The 209 for the previous period seems to be missing or not done.**
No structures lost overnight. Additional direct and indirect line constructed in all staffed divisions.	No structures lost overnight. Additional direct and indirect line constructed in all staffed divisions.	CIIMT 3 (Mortier) no structure loss. Firefighters able to make direct attack on much of fireline. CIIMT 5 (Cable) and NorCal 2 (Wendt) in position and assuming command of their sectors. CIIMT 5 (Cable) completed dozer lines around towns of Fawnskin and Big Bear City. Completed contingency line to the southeast to Clarks Peak. Contingency lines are being improved to the forest boundary on existing roads. NC Team 2 (Wenst) construction of contingency lines. Contingency planning for structure protection in Angelus Oaks, Mtn. Home Village, Forest Falls, Oak Glen and Barton Flats.	Hwy. 18 restricted for travel due to rock and mud slides. Rain occurred sporadically throughout the day. 210 Type 1 engines were demobilized.
October 31		**November 1**	

ICS-209 Summaries – Old Fire

WFSA #2	WFSA #2	WFSA #2	WFSA #2
ICS209-17 November 2, 2003 0600 hrs. 11/02 0600-1800 Mortier 1 91,281	ICS209-18 November 2, 2003 1800 hrs. 11/02-03 1800-0600 Mortier 1 91,281	ICS209-19 November 3, 2003 0600 hrs. 11/03 0600-1800 Mortier 1 91,281	ICS209-20 November 3, 2003 1800 hrs. 11/03-04 1800-0600 Mortier 1 91,281
Continue structure protection.	CIIMT 3 - Continue direct line construction and mop up.	Continue structure protection.	Complete perimeter line construction.
Construct direct fireline and mop up where able.	Continue damage survey	Continue direct attack.	Continue mop-up and rehab.
	CIIMT 5 - Continue to reduce hazardous fuels around structures and the felling of hazard tress.	Continue perimeter line construction.	Prepare for transition from CIIMT 3 to CIIMT 5 on Wednesday. NorCal 2 to continue demob and deactivation of Oak Glen Zone.
	NC 2 - Continue base camp development.	Mop up.	

Weather allowed crews to construct direct fireline and begin mopup. Hwy. 18 is restricted due to rock and mud slides. Roads are icy. The area has been reopened on a limited basis to some residents in the Waterman Cyn and Big Bear Valley.

November 2	November 3

ICS-209 Summaries – Old Fire

WFSA #2	WFSA #2	WFSA #2	WFSA #2
ICS209-21 November 4, 2003 0600 hrs. 11/04 0600-1800 Mortier 1 91,281	**ICS209-22** November 4, 2003 1800 hrs. 11/04-05 1800-0600 Mortier 1 91,281	**ICS209-23** November 5, 2003 0600 hrs. 11/05 0600-1800 Mortier 1 91,281	**ICS209-24** November 5, 2003 1800 hrs. 11/05-06 1800-0600 Mortier 1 91,281
Complete perimeter line construction.	Complete line construction.	Transition IMT's.	Mop-up and rehab.
Continue mop-up and rehab.	Continue mop-up and damage assessment.	Continue mop-up and rehab.	
Prepare for transition to CIIMT 5.			
Close Big Bear Zone.			
			NOTE: This period transitioned from Mortier to Cable as IC.
November 4		November 5	

ICS-209 Summaries – Old Fire

WFSA #2	WFSA #2	WFSA #2	WFSA #2
ICS209-25 November 6, 2003 0600 hrs. 11/06 0600-1800 Cable 1 91,281	**ICS209-26** November 6, 2003 1800 hrs. 11/06-07 1800-0600 Cable 1 91,281	**ICS209-27** November 7, 2003 0600 hrs. 11/07 0600-1800 Cable 1 91,281	**ICS209-28** November 7, 2003 1800 hrs. 11/07-08 1800-0600 Cable 1 91,281
Rehab.	Continue damage assessment.	Continue rehab, mop-up and patrol.	Continue damage assessment.
Mop-up and patrol.	Mop-up, patrol and rehab.	Damage Assessment Teams working throughout mountain communities.	Rehab, mop-up and patrol.
Continue to work hot spots identified by "Fireball" flights.			
		NOTE: Unified Command terminated this period.	

November 6	November 7

ICS-209 Summaries – Old Fire

WFSA #2	WFSA #2	WFSA #2	WFSA #2
ICS209-29 November 8, 2003 0600 hrs. 11/08 0600-1800 Cable 1 91,281	**ICS209-30** November 8, 2003 1800 hrs. 11/08-09 1800-0600 Cable 1 91,281	**ICS209-31** November 9, 2003 0600 hrs. 11/09 0600-1800 Cable 1 91,281	**ICS209-32** November 9, 2003 1800 hrs. 11/09-10 1800-0600 Cable 1 91,281
Continue damage assessment, rehab, mop-up and patrol.	Mop-up, rehab and patrol.	Continue mop-up, rehab, patrol and BAER assessment.	Continue mop-up, rehab, patrol and BAER assessment.
NOTE: Light rain forecast for this period.	**NOTE: Light rain forecast, but no precipitation has occurred this period.**		

November 8	November 9

ICS-209 Summaries – Old Fire

WFSA #2	WFSA #2	WFSA #2	WFSA #2
ICS209-33 November 10, 2003 0600 hrs. 11/10 0600-1800 Cable 1 91,281	**ICS209-34** November 10, 2003 1800 hrs. 11/10-11 1800-0600 Cable 1 91,281	**ICS209-35** November 11, 2003 0600 hrs. 11/11 0600-1800 Cable 1 91,281	**ICS209-36** November 11, 2003 1800 hrs. 11/11-12 1800-0600 Walker 2 91,281
Continue mop-up, rehab, patrol and BAER assessment.	Continue mop-up, rehab, patrol and BAER assessment.	Continue mop-up, patrol and suppression rehab.	Suppression rehab/damage assessment/mop-up and patrol.
			Back haul excess hose.
		NOTE: Team 1 (Walker) assumes command at 1000 hrs.	

November 10	November 11

ICS-209 Summaries – Old Fire

WFSA #2	WFSA #2	WFSA #2	WFSA #2	WFSA #2
ICS209-37 November 12, 2003 0600 hrs. 11/12 0600-1800 Walker 2 91,281	**ICS209-38** November 12, 2003 1800 hrs. 11/12-13 1800-0600 Walker 2 91,281	**ICS209-39** November 13, 2003 0600 hrs. 11/13 0600-1800 Walker 2 91,281	**ICS209-40** November 13, 2003 1800 hrs. 11/13-14 1800-0600 Walker 2 91,281	**ICS209-41** November 14, 2003 0600 hrs. 11/14 0600-1800 Walker 2 91,281
Patrol & mop-up/rehab	Continue rehab and mop-up.	Rehab and patrol.	Patrol and rehab.	Rehab and patrol.
	Assess potential rain related rehab needs.			
NOTE: Rain falling in fire area this period.	**NOTE: Rain overspread the area of the fire this period with several hours of wetting rain. Accumulations ranged from .59" at the lower elevations and foothills to 1.37" at some mountain locations. Snow fell above 6500 ft.**	**NOTE: Additional rainfall received over the fire area overnight.**	**NOTE: Transition of incident back to a Type 3 organization planned for 0600 tomorrow (11/14).**	**NOTE: Incident transitioned to a Type 3 team (Kelly) this morning at 0600 hrs.**

November 12	November 13	November 14

ICS = incident command system, WFSA = wildland fire situation analysis, EFSA = escaped fire situation analysis, BAER = burned area emergency rehabilitation.

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