Injury Analysis during Nighttime Operations in Wildland Firefighting

Executive Leadership

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ABSTRACT

Many agencies and fire managers have limited nighttime operations on wildland fires in an attempt to minimize injuries and fatalities, theorizing that night shifts were more dangerous than day operations. The problem was that data for this rationale were either not reported or not available. Accident trends have not been fully evaluated to determine if minimizing night operations minimizes accidents.

The purpose of this research is to determine if statistics exist that show that nighttime operations are inherently more hazardous than day operations. To reach a conclusion, a combination of the descriptive and historical research methods were used to answer the following questions:

1. What kinds of fatalities have historically occurred during night operations?
2. What kinds of accidents and injuries have historically occurred during night operations?
3. What is the likelihood of wildland fire entrapments occurring at night?

Fatality investigation reports, accident and injury listings, and entrapment reports were examined to determine what incidents were occurring at night. Additional information was researched regarding nighttime atmospheric conditions to determine the likelihood of blow-up conditions occurring at night.

It was found that 43 incidents resulting in 101 deaths were determined to have occurred during day shifts, and eight incidents involving 13 fatalities were found to have occurred at night. Burnovers and snags were important killers of firefighters. Footing injuries and respiratory problems from smoke were key categories of injuries from three different datasets. Atmospheric conditions that could result in blow-up conditions were found to exist at night.

Although no ultimate answers were uncovered, certain trends resulted in recommendations for (1) operational decision making, (2) procedural changes and (3) further research.

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INTRODUCTION

Wildland firefighting, by nature is a hazardous activity. The unpredictability of the fire creates an environment that poses a variety of possibilities that are not always predictable. Even the National Fire Protection Association is doubtful about preventing all injuries, "Firefighting is hazardous work undertaken in a hazardous environment, so it's unlikely that firefighter injuries can be eliminated altogether. However, a good risk management system and the application of existing technology can reduce injury levels and bring about corresponding reductions in lost time and medical costs" (Karter and LeBlanc, 1998).

Additionally, the external forces acting on fire can change quickly and frequently making the risk to firefighters a constant challenge. Fire managers are constantly training crews how to conduct their operations in a safe manner and to be prepared for rapid change. As accident trends are analyzed, new safety equipment, policies, and procedures are developed to mitigate potential risks.

One such procedural change which has occurred among some agencies and some fire managers is the attempt to minimize nighttime operations on wildland fires with the hope of reducing accidents. The theory is that nighttime operations carry a higher potential hazard and those operations are unneeded exposure hours. The problem with this rationale is that accident trends have not been fully evaluated to determine if minimizing night operations minimizes total accidents.

The purpose of this research is to determine if statistics exist that show that nighttime operations are inherently more hazardous than day operations. To reach a conclusion, a combination of the descriptive and historical research methods was used to answer the following questions:

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BACKGROUND AND SIGNIFICANCE

The Oregon Department of Forestry has several objectives in their Protection From Fire Program to provide the most efficient firefighting system to the citizens of Oregon. Within those objectives is the policy, "to furnish, establish and maintain clean, safe and healthful working places, conditions and practices for all employees. The Department will maintain a comprehensive accident prevention program designed to prevent loss of human resources, property and facilities." (*Directive 0-3-6-100 Safety Policy – Personnel*, 1980, p. 3).

"In 1997, public fire departments attended 1,795,000 fires in the United States, of which… 719,000 occurred in outside properties". (*Facts About Fire*, 1999, p. 1). Wolf reported, (1998, p. 72) "'Firefighters have suffered the most unfair occupational discrimination in the United States, as it relates to health and safety,' says Alan Brunacini, chief of the Phoenix Fire Department. 'For 200 years, we never really had much of a discussion about it. But during the last decade or so, we started to focus on the welfare of the people doing the work."

Some fire managers have suggested that there is a greater risk of injury during wildland operations at night. Leschak (1989) reflected,

> It's astonishing that more firefighters aren't hurt or killed at night, scrambling over rugged, unfamiliar terrain and laboring with sharp tools in the meager light provided by four D-cell batteries and a flashlight bulb. Maybe we automatically take greater care at night, or maybe we're just lucky as hell (p. 13).

Much analysis has been done on firefighter accident and fatalities. The National Fire Protection Association and the United States Fire Administration annually provide yearly reports on firefighter injures and fatalities that include structural and wildland activities. Wildland agencies such as the Bureau of Land Management and the Forest Service as well as the various state agencies analyze information for their perspective organizations. The National Wildfire Coordinating Group made up of federal agencies with state representation, routinely commission studies with respect to wildland firefighter safety.

Considering how much information that is collected and analyzed through these organizations, there is very little information relating to the time accidents and fatalities occur. Specifically, there is no data with respect to nighttime injuries compared with those during the day. However, policy decisions and operational judgments are being made based on intuition and anecdotal evidence. These decisions have the potential to be inefficient in one direction, or disastrous in the other. Fire managers might be giving up potentially innocuous opportunities to use night shift operations to safely control fires sooner and thereby minimize exposure hours. On the other hand, fire managers could unknowingly be submitting their crews to heightened risk at night when not properly evaluating the potential hazards.

Wildland firefighter safety awareness study (1998) found,

> There does not yet exist reliable, comprehensive data on wildland firefighter injuries, near-misses, entrapments and shelter deployments. The number of fatalities is accurately reported, but investigations of them are not done consistently, nor are the underlying factors for safety incidents always identified (p. xxiii).

This chasm in the available information is even less available or reliable for nighttime events of this nature

This analysis relates to the Executive Leadership course of the Executive Fire Officer Program by providing key information to fulfill roles as a decision maker or policy maker, and documents information to be able to influence others in the role of an expert.

LITERATURE REIVEW

A literature review was done to determine any conclusions reached from previous studies and to determine the extent of available research. Little research was available that compared day time versus nighttime accidents for any type of firefighting; no research was found comparing day versus night injuries for wildland fatalities. *Wildland firefighter safety awareness study* (1998) found, "At present, the agencies are struggling to obtain thorough accident information. There is no central reporting system, aside from the OWCP (worker's compensation) form, despite several efforts to create a system" (p. 3-8).

However, certain conclusions determined by some research were found to have significant implications. For instance, if many accidents or fatalities are the result of heart attacks (as they are), perhaps there would be little difference between day and night operations. Much of the information was taken from data in tabular form rather than text. Certain publications below also provided the datasets for closer evaluation later in the paper.

Wildland deaths as a component of all firefighter deaths

The National Fire Protection Association has tracked firefighting fatalities and injuries for many years. Their studies report a continued trend toward fewer total firefighter fatalities. Each of the annual studies between 1991 and 1998 except 1994 relate this declining trend. "1998 was the fourth consecutive year in which the total number of firefighter deaths in the United States fell below 100" (Washburn, LeBlanc and Fahy, 1999, p. 55). Wildland operations

continue to be an important segment of total firefighting fatalities. A study from 1981 to 1990 found, "the number of [wildland] deaths was generally between 15 and 22 per year…. Over the period, 20 percent of all fire ground deaths occurred at wildland fires" (1993, p. 30). These fatalities were divided fairly evenly between wildland agencies and municipal departments. *Analysis report on firefighter fatalities in the United States in 1994* found that 1990 and 1987, "are the only years since at least 1978 in which more firefighters died fighting wildland fires than died fighting residential structure fires" (1995, p. 34).

The conclusion from *Fire fighter safety in wildland/urban interface fires* (1990), quoting from the NFPA report "*Wildland fire fatalities 1978-1987*" agreed with the later study. "Approximately 17 percent of all fire ground deaths occurred in wildland fires…. Three-quarters of the deaths occurred during fire suppression activities" (p. 15). These data found 11.5 percent of total firefighting deaths to be a result of wildland fires. Wildland fire fatalities make up a significant portion of the total firefighter deaths and are worthy of separate analysis as a category in and of themselves.

Causes of wildland firefighting deaths

In the 1993 NFPA study of 162 wildland fire fatalities between 1981 and 1990 (*Selected special analyses of U.S. fire fighter fatalities*, 1993) found, "Almost 75 percent of all wildland fire deaths (117) occurred during fire suppression activities. The remaining 45 deaths occurred when fire fighters were responding to or returning from such fires" (p. 34).

Historical wildland firefighter fatalities 1910-1996 (1997) evaluated 699 deaths and also found 24 percent of the deaths were attributable to vehicle and aircraft accidents. Fifty-eight percent were a result of entrapments, and the remainder fell into a variety of miscellaneous categories. Wolf (1998 p. 72) quoting Alan Brunacini "Safety is local. A firefighter typically

gets hurt where the work occurs, on the task level of operations. We have to be certain that the system focuses on that." As such, a thorough analysis of the hazards for any shift operation needs to be considered and mitigated; some may be greater at night. Clearly, it is important to evaluate what is causing these fireground deaths and when they are occurring.

Causes of wildland deaths on the fireground

This paper will concentrate on the causes of injuries and fatalities on the fireground and the operational implications at the fire scene. Therefore, issues such as heart attacks and accidents while traveling to and from an incident will not be discussed here in a thorough manner; these topics are important issues and deserve individual attention. Mangan (1999) in his study from 1990 to 1998 of wildland fatalities found four major categories of causes of wildland firefighter deaths: burnovers (29 percent), aircraft accidents (23 percent), heart attacks (21 percent), and vehicle accidents (19 percent). The remaining eight percent are made up from snags (4 percent) and miscellaneous (4 percent).

In the 1993 NFPA study of 162 wildland fire fatalities between 1981 and 1990 (*Selected special analyses of U.S. fire fighter fatalities,* 1993) found nearly one third of the wildland fire ground deaths were a result of heart attacks. *If A Tree Falls* (video recording, 1995) stated that snags "are the second leading cause of wildland injuries or fatalities".

Fire fighter safety in the wildland/urban interface fires (1990), quoting from the NFPA report "*Wildland fire fatalities 1978-1987*" found stress (heart attacks) resulted in 27 percent of the deaths, and 12 percent from being caught or trapped (entrapments).

Preliminary report of task force on study of fatal/near-fatal wildland fire accidents (1980, p. 20) found a much lower category of heart attacks. "An analysis of 125 wild fires which include 236 fatalities and 66 near miss situations" included heart attacks into a miscellaneous

category and found less than 10 percent of the accidents were heart attacks. Since only percentages are given, it is unclear whether heart attacks were 10 percent of the 125 fires or the 236 fatalities, or how the 66 near miss situations were handled in the percentages.

The video *International crown fire modeling experiments, Northwest Territories 1997* found that the, "Radiant flux significantly higher than what has ever been measured before…The results imply that previous assumptions about the thermal environment within crown fires need to be scaled upward" (1998, video recording). A conclusion could be that crown fires and resultant burnovers, are a high potential for fireground tragedies.

Time of injury or fatality for firefighters (wildland included with all firefighters)

The U.S. Fire Administration's annual reports evaluated time of death for 1995, 1996 and 1997 for fatality reports which listed the time of the accidents. Using 9 p.m. until 6 a.m. (2100-0600) as an arbitrary measure of nighttime operations, 1995 had 17 of 51 (33%) fatalities, 1996 found 19 of 45 (42%), and 1997 had 22 of 48 (46%) fatalities. There was no evaluation of number of alarms or exposure hours day versus night. (*Firefighter fatalities in the United States in 1995, 1996* and *1997*).

Karter (1996) found a high number of injuries occurring at night although he assigned a greater number of hours to night rather than the normal hours of darkness. Nonetheless, he discovered the 12-hour night period had approximately 45 percent of the fires yet 52 percent of the injuries.

> The highest injury rates occurred in the midnight to 6:00 a.m. time frame when 5.0 to 5.9 injuries per 100 fires attended [sic]. Among the factors that may contribute to the high injury rates during the night time hours are lack of visibility, cold temperatures, and lower alertness of fire fighters during this time period. (p. 23).

In a similar study in 1998 Karter similarly found midnight to 6:00 a.m. as the highest injuries per 100 fires. Nighttime, therefore, has a slightly higher rate of injuries for all types of firefighters.

Phase of the fire for wildland fatalities

> Although time of day is not mentioned, Mangan (1999) reported,
>
> Most of the burnover events occurred during the initial attack or extended initial-attack phase…. The other dangerous phase of a wildfire is the 'transition phase,' when the fire has escaped initial attack efforts and higher level incident management teams are being brought in (p. 8).

He did not include the data for this conclusion, yet when asked, he stated that his conclusion was obvious when reading the reports (personal communication, 7/20/99). In another study, "The Bureau of Indian Affairs (BIA) has found that 80 percent of injuries occur during the third week in the field" (*Wildland firefighter safety awareness study*, 1998, p. xx). These data suggest that day and night may not be as important as the phase of the fire or the duration of the assignment.

Injuries

"In 1997, 85,400 firefighters were injured in the line of duty. Of those, 40,920 occurred on the fireground" *Facts about fire* (1999, p.1). "Of these, an estimated 4,750 had to be hospitalized." (Karter and LeBlanc, 1998, p. 1). Karter and LeBlanc (1998) also report that approximately one-half of all firefighter injuries occurred on the fireground. "The major types of injuries firefighters sustained during fireground operations were strains, sprains, and muscle pain, which accounted for 38.1 percent" (Karter and LeBlanc, 1998, p. 1). Karter (1996) analyzed fireground injuries from 1989 to 1993 and found about three percent of the injuries were severe or life threatening where "immediate medical care is necessary" (p. 1). The other 97 percent were characterized as moderate which he defined as minor or medical care being advisable.

Atmospheric influence on fire growth

In addition to evaluating what others have written on accident and fatality statistics, information was researched on fire behavior, specifically the role of the atmosphere in creating dangerous conditions. Recent research has found a link between large fire development and the condition or the atmosphere, particularly the instability and dryness of the parcel of air over the fire. This has recently been developed in an guide referred to as the Haines Index.

> Land management agencies and fire weather meteorologists have used the Haines Index operationally since the early 1990s as an indicator of the potential for extreme fire behavior, e.g. high rates of spread, extensive spotting, prolific "crowning", or the development of large convection columns. Research by Werth and Ochoa found correlation between a Haines Index of 5 or 6 and large wildfire growth in central Idaho. Other fire weather meteorologists and fire managers in the western United States have also associated a Haines Index of 5 or 6 with extreme fire behavior (Werth and Werth, 1997, p. 2).

Saltenberger further refined this statement by reporting,

> The Haines Index tends not to 'cry wolf' too often. A 1990 study at the Boise Fire Weather Office found that a Haines Index value of 6 occurred on only 6% of the days during the fire season. However, it was on these days that 75% of the season's total acreage was burned! On the other hand, days with a Haines Index of 2, 3, or 4 [sic] occurred much more often but only 7% of the total acreage was consumed. (un-dated, p. 1).

Comparison between firefighting and military campaigns

Finally, it is interesting to compare military philosophies with that of firefighting. A large wildland fire is often compared to going to war. However, there is an important difference; casualties are an expectation from military battles whereas no injuries or fatalities are anticipated from engaging in a wildfire when lives of the public are not threatened. However, aggressive nighttime firefighting operations may actually reduce injuries by controlling a fire much sooner resulting in far less firefighters exposed to risks.

Wolf (1998) quoting Stephen N. Foley, NFPA's senior fire service specialist,

> 'If we've done our jobs,' continues Foley, 'our decision and actions will reflect good judgment and result in taking only calculated risks with an acceptable benefit attached to them. NFPA 1500 tries to capture this concept succinctly by saying, 'we will risk a lot to save a lot, and risk nothing to save nothing'" (p. 73).

The *Preliminary report of task force on study of fatal/near-fatal wildland fire accidents* (1980) reported,

> It is apparent from the review of past fatal and non-fatal incidents that there is substantial risk-taking which is not commensurate with the values threatened. In no incident were non-firefighter lives immediately threatened, and in almost every incident the fire was controlled shortly thereafter or the sector involved was secured. There is no justification for risking firefighter lives in a wildland situation dealing with renewable resources. Firefighting is a paramilitary operation. However, the parallel stops at the point where casualties are acceptable to the action strategy (p. 9).

Quoting Dennis Compton, Fire Chief Mesa, Arizona, Wolf (1998) reported, "Balancing the risk/gain scale is often not popular, but it's always important" (p. 74).

Common denominators of fire behavior on tragedy and near-miss wildland fires (1996)

> Fighting large wildland fires is often compared to a military operation. Each involves such things as: an organization with a general at the head, massive movements of personnel and equipment; tactical aerial support, and long periods of combat and stress until the enemy is finally conquered. Yet, there is one major difference between a military operation and firefighting strategy: in fighting fires we always figure that no firefighters will die, whereas in a military operation there is a calculated risk of death of soldiers. In spite of this philosophy, many people have lost their lives on wildland fires in the United States (p.1).

The military connection is an interesting comparison. Steven Ambrose in his book on the D-Day Invasion spoke of the differences of philosophy between the British who were known to be cautious and deliberate, while the American forces were more aggressive. "The way to minimize casualties was to take risks, to win the war as soon as possible not exercise caution or avoid offensive action" (1994, sound recording). Perhaps the philosophy of combat in World War II has shaped much of the firefighting forces around the United States. Retired General Colin Powell reiterated this same military doctrine in his autobiography, "Use all the force

necessary and do not apologize for going in big if that is what it takes. Decisive force ends wars quickly and in the long run, saves lives" (1995, sound recording).

The notable nineteenth-century Prussian military strategist, Carl von Clausewitz (1832) was probably responsible for these American philosophies. He developed ideas such as, "Every war ought to end in a complete victory of one side of the other, and also that moderation in war is an absurdity since failure to utilize all the force at one's disposal defeats the purpose of war;" (p. 113-4) and, "The best strategy is always to be very strong…at the decisive point" (p.276). These strategies most certainly were picked up by our post World War II predecessors in the development of strategies we use in the fire service.

Wagner (1997, p. 3) compared this to firefighting making that same argument about minimizing exposure by taking advantage of "many windows of opportunity" which occur at night. The *Wildland firefighter safety awareness study* (1998) sanctioned this concept when they formulated their Goal 41. "Develop and use criteria for determining when night operations would be safe and effective. Acknowledge that, depending on circumstances, night operations are a tool that may enhance safety or may increase risk" (p. 4-24). Again, von Clausewitz (1832, p. 129) recognized that increased exposure and wear and tear can ultimately result in the loss of the campaign, "…then the duration of the contest will suffice gradually to bring the loss of force on the part of the adversary to a point at which, therefore, he must give up the contest."

Two other military examples bear comparison. One of the most debated decisions of this century has been to drop the atomic bombs on Japan. One argument which has always carried a tremendous amount of logic was that ending the war immediately eliminated the continued hours of exposure to combat which allied forces would have encountered. The more recent example is the huge build up of the military machine in the Persian Gulf whereby the Gulf War was

ultimately won in a short duration with only 100 exposure hours of actual ground combat. A smaller force would have taken much longer to be successful and therefore exposed to more of the hazards of war.

PROCEDURES

Research Methodology

The desired outcome of the research was to determine the answers to the questions to provide input to fire managers to make wildland operations safer. Proper application of the conclusions could result in mitigating some of the risks on wildland operations both during the day and night.

In order to make these conclusions, a combination of the descriptive and historical research methods were undertaken. Different procedures were used to answer the various questions. To answer Question 1, "What kinds of fatalities have historically occurred during night operations?" a review of all available investigation reports from wildland fire fatalities were studied. The size of data from just Oregon Department of Forestry would be too small a sample to be meaningful, so all documented wildland fatalities were considered. A library of many reports is available at the USDA Forest Service Missoula Technology and Development Center (MTDC) in Missoula, Montana. These were compared to the database of wildland fatalities to determine which were day incidents and which were at night and then evaluated to look for trends occurring at night.

Research Question 2, "What kinds of accidents and injuries have historically occurred during night operations?" entailed review of three different datasets from wildland fire agencies. Data from multiple organizations provided the opportunity to look at the bigger picture rather

than just one agency. Additionally, it is very common for crews and individual from one agency to work on fires in other jurisdictions. Therefore, datasets were gathered from the Oregon Department of Forestry, the California Department of Forestry and Fire Protection, and the USDI Bureau of Land Management. Exhaustive attempts were made to obtain data from largest wildland agency, the USDA Forest Service; unfortunately their database does not capture the time of the incident or accident. (Time of the incident is noted on the accident forms, however it is not a field that is input into the database.) Due to differences in reporting styles and compatibility between data fields, it was not possible to directly compare data from the three organizations; trends, however, were examined.

To answer Question 3, "What is the likelihood of wildland fire entrapments occurring at night" a fourth dataset of wildland fire entrapments was analyzed. The USDA Forest Service Missoula Technology and Development Center (MTDC) is in the process of researching entrapments. Although time of day is not a field in their analysis, many of the reports were available for study. Each report was reviewed to evaluate if the time of day was readily apparent.

Next, study was done on the role of the upper atmosphere in nighttime entrapments. Research on the fire weather forecasting tool, the Haines Index was evaluated and National Weather Service weather researchers were interviewed to determine the potential of the atmosphere played in contributing to nighttime blow-up conditions. This information would help determine the likelihood of entrapments occurring at night.

Project limitations:

(1) The Forest Service data for injuries were unavailable. Although the time of injuries is documented in individual accident reports, it was not included in any database field for the agency or their worker's compensation listings.

(2) A pure statistical analysis comparing day time accidents and fatalities with night time accidents and fatalities was not possible since the data did not show total exposure hours on any given incident. There was no way of determining the number of either accidents or fatalities as a function of exposure hours during day or night operations.

(3) A certain amount of interpretation was required of each accident reviewed. For instance, the data fields frequently gave only very brief phrases describing the injury. In was not always possible to determine if the injury occurred on the fire line or on some other job task. Additionally, some reports indicated time when the injury became apparent rather than when it occurred. For instance, a tick bite reported while sleeping at night most likely resulted from a day shift operation. These cases were screened out when apparent.

(4) Aircraft accidents were not considered. Although some jurisdictions continue to use aircraft resources at night, this activity is beyond the scope of the research and is better addressed as a specific problem.

(5) Vehicle accidents and heart attacks were not considered. Although significant causes of deaths and injuries, these two arenas have specific problems and measures to be dealt with. These causes are important enough that research could be targeted specifically at each source.

(6) The analysis involved data from the United States only. Other countries have major wildland organizations and may provide additional findings.

Definitions:

BIA	Bureau of Indian Affairs (land management agency within the USDI)
BLM	Bureau of Land Management (land management agency within the USDI)
Entrapment was	An incident where a firefighter was caught by the fire and either succumbed or forced to survive through the use of a fire shelter or other means.
CDF	California Department of Forestry and Fire Protection
Haines Index	Weather index measuring large fire potential using lapse rates and dryness
MTDC	Missoula Technology and Development Center (research facility)
NFPA	National Fire Protection Association (non-profit organization providing codes, standards, research, training, and education.
NWCG	National Wildfire Coordinating Group (federal wildland agencies with state representation)
ODF	Oregon Department of Forestry
Snags	Dead trees or live trees weakened by fire that pose a falling hazard
USFA	United States Fire Administration (federal agency within the Federal Emergency Management Agency)
USDA	United States Department of Agriculture
USDI	United States Department of Interior
USFA	United States Fire Administration (agency within FEMA that works to reduce life and economic losses due to fire and related emergencies)
USFS	United States Forest Service (land management agency within the USDA)
Wildland	Includes fires in grass, brush, and forests

RESULTS

1. What kinds of fatalities have historically occurred during night operations?

Historical wildland firefighter fatalities 1910-1996 and the unpublished data for 1997 and 1998 (obtained from Ms. Pam Ensley, Project Coordinator) were evaluated. The author evaluated which incidents occurred with certainty at night versus day. Additionally, some contacts were made for events where potential connections were known. The publication lists 362 wildland incidents which resulted in 699 fatalities, and the 1997 and 1998 data add an additional nine incidents for 10 fatalities and 12 incidents for 14 fatalities respectively. This totals 383 incidents involving 723 fatalities.

	Incidents	Fatalities
1910-1996	362	699
1997	9	10
1998	12	14
TOTAL	383	723

After the aircraft accidents and training fatalities were removed, it was found that 43 incidents resulting in 101 deaths were determined to have occurred during day shifts, and eight incidents involving 13 fatalities were found to have occurred at nighttime. (It is important to remember that the ratio of eight night fatalities to 43 day fatalities has no real meaning since exposure hours during the day and night was impossible to determine; historically, night shifts are staffed at a lower levels.)

	Day	Night

	Incidents (Fatalities)	Incidents (Fatalities)
Burnovers	34 (91)	5 (10)
Snags	2 (2)	2 (2)
Vehicles	3 (4)	1 (1)
Miscellaneous*	4 (4)	0 (0)
TOTAL	43 (101)	8 (13)

*Miscellaneous includes powerline, heart attack, parachute, heat stress

2. What kinds of accidents and injuries have historically occurred during night operations?

Bureau of Land Management

Bureau of Land Management (BLM) data were obtained through their Safety Management Information System (SMIS) available on-line through their web site at http://www.smis.doi.gov. It was necessary to obtain a password from BLM to log on through this system. The data evaluated were from January 1975 through May 1999. Two separate evaluations were completed, one on government employees and a second, smaller one, on non-government employees. Further categorization was difficult since sometimes the incident was reported by the injured body part (e.g. back) while in other cases it was listed as a lifting accident. Each of 336 night injuries were reviewed individually. No attempt was made to compare the percentage of accidents types to those during the day since the database was not organized to be able to compare totals, and each report had to be evaluated separately.

BLM reported 1802 injuries to government employees of which 336 were identified as occurring at night (19 percent). However, a large number of the 336 included events that did not include classic fireline activities such as gastritis, ear infections, boils, broken teeth (while eating

in fire camp). Also, several categories could not be attributed directly to night activities since they were more of a chronic problem or the incident was only discovered at night. Examples included poison oak, tick bites, bronchitis (from smoke inhalation), and fatigue. Therefore, the figure of 19 percent is misleading. Still, important trends are readily identifiable:

Type	Incidents
Slips/fall resulting in bruises, fractures, back problems, etc.	80
Respiratory problems from smoke	39
Insect stings (bees, etc.)	23
Eye injuries from ash, sticks, dust, wood chips	20
Lacerations	13
Hit by rolling rocks and snags	6
Burns	6
Heat Exhaustion/dehydration	3

The use of non-governmental employees showed similar trends, but with a much smaller database. Of these 68 firefighting accidents, 13 incidents occurred at night (19 percent). More than 50 percent (seven) of these 13 accidents were caused by poor footing on the fireline and an additional footing problem occurred in fire camp after dark. The remaining five accidents were each different categories and unremarkable.

California Department of Forestry and Fire Protection

California Department of Forestry and Fire Protection (CDF) is the largest state fire protection organization in the United States. The staff of their Occupational Safety and Health Program provided the author with an Access database of nighttime injuries between 1996

through August 1999 between May 1 and November 1 (approximate fire season) of each year. The year 1999 was not complete so it was dismissed.

CDF reports approximately 1500 claims per year according to Rob Perret (email, August 2, 1999). During the three years from 1996 to 1998, the organization experienced an average of 73.5 accidents that were at night and during the fire season. Due to the nature of their mission, it is likely that most (but not all) of these were related to firefighting. That represents five percent of their total injuries. As with the BLM data, many were not classified for the purpose of tracking trends due to insufficient information in the database or the nature of the injury implied a chronic problem. During the three-year period, the claims were classified in the following distribution.

Type	Incidents
Slips/fall resulting in bruises, fractures, back problems, etc.	37
Respiratory problems from smoke	32
Insect stings (bees, etc.)	15
Eye injuries from ash, sticks, dust, wood chips	20
Lacerations	21
Burns	17
Struck by falling/flying object	4
Pushing/pulling/lifting	10

Oregon Department of Forestry

Oregon Department of Forestry (ODF) is the third largest state forestry organization. Data printouts were obtained from SAIF Corporation, Oregon's worker's compensation insurer through ODF's Safety Section staff. Accidents from 1975 through February of 1999 were evaluated. Injuries were highlighted which occurred at night and appeared to have occurred on fires. Most injuries at night should have been from firefighting since the Department's mission has very limited other reasons to be working during the night.

Of the approximate 3500 injuries during the almost 25 year period, about 215 were injuries that appeared to have occurred on fires during night operations. This relates to about six percent of all injuries. The breakdown of types is as follows:

Type	Incidents

Slips/trips/falls resulting in strains/sprains, etc.	57
Lacerations/abrasions/punctures	19
Poison oak/dermatitis	33
Respiratory problems from smoke, etc.	10
Struck by falling/rolling objects	12
Bee stings/animal bites	10
Vehicle Accidents	9
Fatigue/Heat Problems	5
Burns	4
Undetermined or non-fireline	47

3. What is the likelihood of wildland fire entrapments occurring at night?

Historical Entrapments

Entrapment investigation reports were reviewed to ascertain if the time of day was documented when the event occurred. Most of the reports involved incidents since 1980, but five were found between 1956 and 1979. Of more than one hundred reports reviewed, 63 burnover/entrapments clearly indicated at least the approximate time of the incident to the point of being able to classify it as night or day. The 63 burnovers represented more than 611 entrapped persons. (Five of the reports did not document the number of people involved.)

Four entrapments were found to have occurred at night which in turn, affected 84 persons. This represented six percent of the burnover events, but 14 percent of the persons involved.

	Day (%)	Night (%)	Total
Burnovers	59 (94)	4 (6)	63
Persons Involved	527 (86)	84 (14)	611

Role of the Atmosphere

The Haines Index is a tool becoming popular to determine the likelihood for plume-dominated fires. The Haines Index measures the dryness and instability of a given parcel of air on a regional basis. It has been set to a scale of one to six with 5 and 6 indicating a likelihood that a fire will be affected by the atmosphere greater than the influence of the wind. These fires can be known as "firestorms", "blow-ups" or by the technical term "plume-dominated'.

The key issue is, "Can there be a high (5 or 6) Haines Index at night?" According to John Saltenberger, Fire Weather Forecaster in Portland, Oregon, "Since the Haines Index samples the upper altitudes and the upper atmosphere is not 'contaminated' by the normal diurnal changes, and is independent of surface heating, you can still have a 6 at night." (personal communication, 10/29/99). He went on to say, "This could still represent a potentially dangerous condition, although other weather conditions could keep [the Haines Index] from ever actually reaching [6]." In other words, the measurements and calculations may indicate a Haines Index 6, but the fire may not be influenced by the upper atmosphere if the conditions close to the ground outweigh the conditions higher up.

Paul Werth, Boise, Idaho Fire Weather Forecaster concurred, saying, "It would depend on the elevation of the fire and whether it was above the inversion or below the inversion." (personal communication, 11/4/99). (Both forecasters have published research on the Haines Index.)

DISCUSSION

Fatalities:

It may be significant that multiple fatalities in burnover situations is greater during day shifts. The average number of fatalities per burnover during the day is 3 to one, yet only 2 to one at night implying that entrapments during the day occur with larger groups of people.

Investigation reports from nighttime burnovers show an important trend. These events frequently occurred in Southern California and are associated with wind. More specifically, the cause was found to be with a sudden wind shift connected with a Santa Ana wind or an anticipated Santa Ana wind that did not materialize which resulted in unexpected topographic winds. Of the Santa Anna wind incidents analyzed, none were more recent than the 1970s. It is possible that this has become well understood by fire managers and forecasters in Southern California, yet not all recent fatalities were analyzed since the time of the incident was undetermined.

Of the incidents of fatalities being caused by snags, it is important that of the accidents analyzed, the same number have occurred at night as day (two). This is significant in that it can be assumed that there are far fewer fire fighters being deployed at night. Therefore, it can be assumed that there is a higher incidence rate from this category. It is also expected that night would offer a greater hazard to snags due to visibility.

Injuries:

Much of the data on injuries show similar trends, despite the differences in formatting and time periods covered.

BLM data

At least one quarter of the problems at night were related to footing problems, and this percentage would be much higher if chronic problems were not considered in the total of nighttime injuries. Snags hit two individuals and rolling rocks hit four others. Smoke problems resulting in respiratory distress, carbon monoxide exposure, bronchitis, pneumonia, and smoke inhalation may be a significant problem resulting from night time firefighting due to environmental conditions such as inversions and lighter winds.

CDF data

CDF only reported five percent of their injuries as occurring at night. This is the lowest of the three agencies considered, and considering the scope of their mission, this is admirable. CDF has continued to aggressively staff fires at night. Again, slips, trips and falls were the most prominent cause of injuries with a significant number coming from smoke problems. Objects in the eye were significant in that it is usually preventable by wearing the appropriate safety glasses as part of the compliment of personal protective equipment. Since this data are the most recent (last three years), it would appear that safety glasses may not yet be a requirement. Due to darkness, safety glasses are probably more important at night. Four times injuries were caused by falling or rolling objects which were likely snags or rocks, for an average of more than one per year. Although the severity of the injury was not listed, this classification can be a source of major injuries or fatalities.

ODF data

ODF's data also show a very low percentage of nighttime injuries as a function of total injuries (six percent). The 25 years of data is remarkably similar to that of the BLM and CDF. Injuries resulting from footing problems are one-quarter of the identified nighttime injuries. The 12 injuries resulting from falling and rolling materials accounts for approximately one every two

years. Other problems such as lacerations, burns and fatigue are difficult to drawn any inferences from since the mechanism of injury is not listed. This older database also had more noticeable gaps in the information.

The commonality between footing issues gives an important trend. It also matches what Dr. Michael Schutte said in *Exercises to reduce firefighter injury* (1997), "These [exercise] programs focus on the ankle, knee and back because they are the areas most susceptible to serious injury during firefighting" (video recording).

Entrapments

The night entrapments accounted for only four incidents, but 84 persons or an average of 21 people per incident. One case had 41 shelter deployments, while two others had 18 and 22. This appears contrary to the data of burnovers fatalities where an average of two people per incident were killed. Even the daytime burnover fatality average was less than three people killed per incident, and the non-fatality rate was nine persons per incident.

One possible explanation for this is in the manner the data was collected. The research to obtain the non-fatal entrapments was a request for experiences throughout the wildland fire community and included recently submitted data that was years old. When larger groups of people were entrapped and survive, there is a greater likelihood of it being remembered and reported by at least one of the participants.

Whereas the location of the nighttime burnover fatalities frequently occurred in California, none of the four nighttime non-fatality entrapments occurred there. The states were Texas, New Mexico, Montana, and Idaho. It is uncertain if wind was a common component of these events as it was with the California fatal entrapments.

Dr. Ted Putnam, reported in *Findings from the wildland firefighters human factors workshop*, "We are averaging more than 30 entrapments each year now" (1996, p. 1). Braun and Fouts (1997) observed, "Fire shelter training materials indicate that these devices have been used approximately 700 times since their introduction in 1977. According to Putnam, 500 of these deployments saved lives and prevented serious burns" (p. 1). Although their research suggested that firefighters might be prone to take more of a risk when carrying a fire shelter, the critical implication is that without fire shelters the fire service could have had an additional 500 fatalities or serious injuries in the last 20 years.

Role of the Atmosphere

Although entrapments at night are rare, they are predictable. It is important to know that the Haines Index can be a valuable indicator of nighttime fire conditions, along with wind and topography. Wind is one of the most important forecast items for a fire behavior forecast. Both direction and speed are usually predictable. In fact, when winds are unpredictable, the greatest caution should be used in the development of the strategy, day or night. Additionally, *Common denominators of fire behavior on tragedy fires* (1996) found "Fires respond to large- and small-scale topographic conditions…" (p. 3). "Haines Index data becomes available shortly after weather balloons are released at selected locations across the nation at 5:00 am PDT and 5:00 pm PDT each day during the fire season" (Saltenberger, un-dated, p. 1). This makes the Haines Index readily available for the night shift although probably difficult to have included within the Incident Action Plan for distribution at the Night Shift Briefing to night personnel.

Finally, some have speculated that leadership at night is not as strong. Although not evaluated in this type of analysis, it may be an important consideration. The author

acknowledges that the least senior, least experienced or qualified, or the least influential individual may draw the night shift duty.

RECOMMENDATIONS

Although the data show no definitive answer to whether nighttime firefighting is more hazardous, since the statistics are not available for a complete analysis, there are some areas that the trends suggest potential opportunities for the wildland fire community. It was also noted that many of the recommendations are not exceedingly different from other recommended safety practices; however, it may be that these types of recommendations may be more important at night. In the words of Statesman Henry Clay, (1777-1852) "statistics are no substitute for judgment."

Operational Decision Making

Snags are important killers of firefighters at night. Night work where the fire has had a chance to weaken snags should be avoided. Day operations should be used to make night operations safer by removing snags. Indirect attack followed by burn out operations are a common night strategy. As burnout progresses, trees may become weakened where potential injury from snags rises significantly. Good scouting in the daylight and proper timing and retreat can mitigate this potential to an acceptable level.

Where wildland fuels are more brush and grass-like in the vegetative component (rather that trees), night shift may actually offer a safer environment by minimizing some of the risk of burnover/entrapments. Fire behavior through brush and grass fuel types are influenced by terrain and wind when atmospheric conditions do not present a Haines Index of 5 or 6. These fuel types are quickly influenced by a change in environmental conditions. Although they react quickly,

this change is readily apparent and alert crews can adjust rapidly. Since entrapments can still occur at night, safety zones continue to play a prominent role in firefighter survival and must be stressed to the night crews.

Footing injuries are an important problem during the night shift. However, it is undetermined from the statistics if this is greater than during the day. Intuition suggests that footing problems become more pronounced when lighting conditions are not adequate. Use of experienced crews, scouting during the daylight, and thorough briefing may alleviate some of this potential. Walking on uneven ground, however, will always create some risk, and that risk will be greater when visibility is impaired. The more hazardous the topography, the more consideration should be given to how critical the mission is. It is unlikely that mitigation measures can be developed for this category of injury.

Greater acceptance should be given to the 24-hour shift concept used by CDF. This tool has been successfully used both to minimize injuries and increase production. Within the context of nighttime safety, crews have seen the area they are working during the day shift (Terwilliger and Waggoner, 1999).

Smoke inhalation showed up on all three agency lists of injuries. Although not easy to manage, there are some opportunities that fire managers can use. Dr. Brian Sharkey (1997) summarized recommendations from a conference on the health hazards of smoke. Included within the recommendations are several that can be implemented at night. For instance, "Adjust operational periods on mop-up to avoid periods of inversion" (p. 4). Managers can move personnel during the night and from shift to shift to avoid inversion areas that collect smoke. Also, "Fire behavior forecasts should discuss smoke and inversion potentials." The use of

electronic datalogging dosimeters was also recommended to monitor the levels of carbon monoxide firefighters are being exposed to.

Eye injuries were meaningful in the CDF statistics. Mandatory eye protection at night would effectively mitigate most of these occurrences. In addition to safety glasses and goggles, hard hats have been developed with a variety of shields that swing down to protect eyes. It is important to find a style of eye protection that firefighters will use, particularly at night.

Debriefing of both day and night crews on hazards is important so the next shift can be ready and plan for safety issues. Too often accomplishments and intelligence take priority over the issues of fireline risks.

Wolf (1988) reported an important component in the philosophy of structural fire fighting,

> According to the 1997 edition of NFPA 1500, *Fire department occupational safety and health program*, 'Where there is no potential to save lives, the risk to fire department members must be evaluated in proportion to the ability to save property of value. When there is no ability to save lives or property, there is no justification to expose fire department members to any avoidable risk, and defensive fire suppression operations are the appropriate strategy" (p. 73).

This concept is further amplified in wildland operations by the popular phrase, "There's no tree out there worth getting hurt for". This needs to become a commitment at all levels. Trees will grow back, but an injury to a firefighter may be permanent.

Strong leadership is needed at night. Just as in assigning the most experienced people as crew lookouts, perhaps the most experienced overhead and crews should be used at night when the situation is identified as more than 'routine'.

Procedural Changes

Incident Management Teams should make a conscious effort to include the Haines Index in the night shift forecast as well as the day shift. Fire Behavior Analysts should be waiting for

the output and be prepared to evaluate the fire behavior forecast based on the potential for atmospheric influences. Effort must be made when that information is found to be critical, to have it relayed by radio to all line crews.

The USFS should implement a system similar to BLM's Safety Management Information System making national trends available to field users. This recommendation goes one step beyond that of the recommendation of the *Wildland firefighter safety awareness study* (1998) in that data should be available on-line so that field managers and local safety program coordinators can do their own analysis and not have to rely on standard reports routed by staff.

Time of injury should be an important data field in order to evaluate nighttime injuries and fatalities in the future. A standard query should be developed that includes time of injury to facilitate field level study.

Missoula Technology and Development Center continues to do research on entrapments for the National Wildfire Coordinating Group. Time of incident should be added to Incident/Entrapment Report and/or Field Trial Form NFES 0869, and it should be included as a field in any computer input. This would allow future studies to capture more information on what events are occurring at night.

Accident investigations need to become broader in the scope of their inquiry. Braun, as reported in *Findings from the wildland firefighters human factors workshop*, stated, "Traditional accident investigations tend to be very myopic, focusing only on the circumstance immediately involved in the accident." (1996, p. 29). Future accident investigations need to determine whether the decision to fight fire at night had an effect on the incident. Rather than just evaluating why the causal agent resulted in an injury, the decisions leading to the event's circumstances need to be appraised and reported.

A further recommendation also identified by the *Wildland firefighter safety awareness study* (1998) in its implementations strategies is,

> The agencies, through the NWCG, should develop night operations decision criteria (in the form of a brief job aid) for inclusion in the Fireline Handbook. The job aid should include criteria for when [sic] night operations would be safe and effective. These criteria must acknowledge that, depending on circumstances, night operations are a tool that may enhance safety or may increase risk (p. 4-24).

Research Needs

A study should be implemented to evaluate the effects of aggressive nighttime operations versus limited or no nighttime operations. The objective would be to determine the total of exposure hours in each case to see if and when fires can be controlled at night to save exposure to risks. The project would have to include subjective analysis on whether the night operations would be effective at controlling the fire sooner, but expertise exists among fire behavior analysts and other operations section participants to attempt this. It would make sense to track injuries and near-misses in a examination such as this.

Another project with quicker results would be to use the *Historical wildland firefighter fatalities 1910-1996* database and attempt to further research whether individual incidents occurred during the night shift. Although the information, due to its age would never be completely obtainable, further conclusion would be likely if more of the times were known. This same process could be used with the data fields for entrapments which also already exists. Entrapments can be treated as near-misses and thereby expand the data to show trends. It would make sense to analyze entrapments as well as fatalities in order to have a greater understanding of the potential for entrapments at night and under what sort of conditions.

Final Remarks

It is popular prior to each aircraft mission to evaluate its need and importance. The question should be asked, "What are the alternatives to not flying this mission?" The same should be done with each decision to deploy firefighting resources on the line whether at night or day. What can we expect by not deploying resources there, and what can we accomplish with them there? What are the predictable risks by putting them there?

Washburn, LeBlanc and Fahy (1998) when speaking of firefighting fatalities in general conclude, "There's a limit to how much of the fatality problem can be 'engineered' away. The major concerns that remain are largely due to behaviors that must be changed" (p. 58).

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