# Proceedings of 11th International Wildland Fire Safety Summit

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## MISCELLANEOUS

# Introduction to the Proceedings of the Eleventh International Wildland Fire Safety Summit

Martin E. Alexander[A,B]

[A]Deputy Program Committee Chair, Eleventh International Wildland Fire Safety Summit, International Association of Wildland Fire.
[B]University of Alberta, Department of Renewable Resources and Alberta School of Forest Science and Management, Edmonton, AB, T6G 2H1, Canada. Email: mea2@telus.net

**Abstract.** The eleventh installment in the International Association of Wildland Fire's International Wildland Fire Safety Summit series was held in Missoula, Montana, April 4-8, 2011. The conference theme was 'Promoting the Story of Wildland Fire Safety … From the Local to the Global'. The summit proceedings contain a total of 35 written contributions resulting from the various oral and poster presentations.

**Additional keywords:** accidents, aviation safety, fatalities, fire behavior, fire management, fire suppression, firefighter safety.

The International Association of Wildland Fire (IAWF) is a non-profit, professional organization (http://www.iawfonline.org/proceedings.php) founded to promote a better understanding of wildfire, built on the belief that an understanding of this dynamic natural force is vital for natural resource management, for firefighter safety, and for harmonious interaction between people and their environment. The association is dedicated to facilitating communication within the entire wildland fire community and providing a global linkage for people with shared interest in wildland fire and comprehensive fire management. IAWF publications such as *Wildfire* magazine and the *International Journal of Wildland Fire* (Alexander 2011*a*) contribute towards this communication objective as does the proceedings from the various conferences sponsored by the association. These include the Human Dimensions of Wildland Fire Conference, Fire Behavior and Fuels Conference (Alexander 2011*b*), and Wildland Fire Safety Summit (Alexander and Butler 2008) series as well as other special conference events (e.g. Masters *et al.* 2009).

In 1997, the IAWF sponsored the first international wildland fire safety summit in Rossland, British Columbia, Canada, from September 29 to October 2. Nine additional summits have been held since that time:

- Winthrop, Washington, USA, October 26-29, 1998
- Sydney, New South Wales, Australia, November 2-5, 1999
- Edmonton, Alberta, Canada, October 8-10, 2000
- Missoula, Montana, USA, November 6-8, 2001
- Luso, Portugal, November 18-23, 2002
- Toronto, Ontario, Canada, November 18-20, 2003
- Missoula, Montana, USA, April 25-28, 2005
- Pasadena, California, USA, April 25-27, 2006
- Phoenix, Arizona, USA, April 28-30, 2009

Proceedings have been produced in one form or another from all of the summits with the exception of the second one in Winthrop which were unfortunately not completed (Greenlee

1998; IAWF and NSW Rural Fire Service; 1999; Butler and Shannon 2000; Butler and Mangan 2001; Viegas 2002; IAWF and OMNR 2003; Butler and Alexander 2005; IAWF 2006, 2009). In keeping with the precedent set with the wildland fire safety summit in 2005 (Alexander and Butler 2008), the proceedings from the ten previous events are included on the present summit proceedings CD.

The general goal of the IAWF wildland fire safety summits has been to bring together wildland firefighters and managers from different countries, agencies, and levels to discuss common problems and determine a variety of approaches to solving them. This year's summit is a continuation of IAWF's efforts in aiding communication concerning wildland fire safety issues since the first summit was held in Rossland, British Columbia, Canada, back in 1997. The theme of this year's summit, 'Promoting the Story of Wildland Fire Safety' highlights the importance of stories and storytelling in safety training, operations, research, and organizational learning. 'From the local to the global' calls forth the story of safety from the entire spectrum of the global wildland fire community: from the individual, the crew, the incident, the local community, the agency, the region, the state, the nation, the continent, to the entire hemisphere. Ziegler (2011) provides a fuller account of the background that led to deciding on the conference theme.

Over 150 participants from several countries were in attendance at the conference in Missoula. A total of 35 presentations covering nearly the full spectrum of wildland fire safety were delivered over the course of the 3.5 days of presentations. This involved opening and closing presentations by David Turner and Robert Palmer, respectively, a keynote presentation by Gordon Graham, and a plenary session presentation by Dave Thomas. Gordon Graham also conducted two workshops: *Why Things Go Right, Why Things Go Wrong* and *Non Punitive Close Call Reporting*. A total of 24 oral presentations were delivered within seven subject matter sessions along with 7 poster presentations.

The summit presenters were given the opportunity to decide whether they wished to contribute an abstract, an extended summary or a full paper for the summit proceedings. Some presenters have elected to publish fuller accounts of their presentations in peer-review journals such as the *International Journal of Wildland Fire* or in other mediums such as *Wildfire* magazine.

The conference also included seven pre-conference workshops and training sessions attended by more than 40 people coupled with exhibitor and vendor displays as well as post-summit tours. A special screening of the classic 1952 movie *Red Skies of Montana* was held at the Wilma Theatre in downtown Missoula, with the proceeds going towards the Museum of Mountain Flying and the International Fire Relief Mission. For the first time at a wildland fire safety summit, a 'hotstove session' featuring stories of close calls and near misses involving four guests and members of the audience was held. Finally, a firefighter memorabilia auction was held to benefit the Wildland Firefighter Foundation. A description of all these activities are given in Robinson *et al.* (2010) which is also included on the summit proceedings CD along with photos taken of various conference activities and a list of registered conference participants.

Many folks contributed to the success of the IAWF's Eleventh International Wildland Fire Safety Summit, including the registered summit participants. Thank you, one and all, for a job well done. The Robinson *et al.* (2011) document contains a list of the members of the summit steering and program committees, the session moderators, and summit sponsors and exhibitors. It also includes biographical sketches of all the summit presenters.

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# The Thirteenth Fire: Ranger Jansson's story of Mann Gulch

David L. Turner[A]

[A]US Forest Service, retired, kzanddaveturner@mt.net

**Abstract:**
This presentation, given by keynote speaker David Tuner, discusses the 1949 Mann Gulch fire, focusing on the experiences of the District Ranger/Fire Boss, Robert Jansson, and fire researcher Harry Gisborne.

On the afternoon of August 5th, 1949 a Forest Service firefighting crew conducting initial attack on the Mann Gulch fire on the Helena National Forest in southwest Montana was over-run by the fire resulting in the deaths of 13 men of the 16-man crew. Three members of the crew, including the crew foreman, escape unharmed.

When the 6-8 acre lightning-caused fire was detected in the rugged Gates of the Mountains Wild Area just east of the Missouri River and 25 miles north of Helena, forest officials initially assigned a 20-person hand crew and 15 smokejumpers from the Missoula, Montana smokejumper base. The blaze was under the command of Canyon Ferry District Ranger John Robert Jansson. A seasonal fire guard stationed at a nearby F.S. campground would also join up with the smokejumper crew.

However, before the ground crew or the smokejumper crew, which had parachuted into Mann Gulch by mid-afternoon, could reach the fire, it blew up. Ranger Jansson's ground crew was able to escape unharmed, but the smokejumpers and the fire guard were over-run by the fire. Three smokejumpers were able to escape the blow-up, two by running into a nearby rock field and the crew foreman by burning out an escape fire. Two smokejumpers initially survived being burned over, but later died in a Helena hospital from their burns.

The Thirteenth Fire tells the story of the disaster from Ranger Jansson's perspective, including the rescue effort, the investigation of the incident, subsequent death in Mann Gulch of fire researcher Harry Gisborne, and the toll the fire had upon Jansson and his family. The Mann Gulch Fire's 62-year legacy to wildfire suppression is also highlighted.

## International Association of Wildland Fire
### Continued Professional Training

April 5, 2011

Speaker: Gordon Graham

# AMERICAN PUBLIC SAFETY 2010:

## "Seven Rules of Admiral Rickover"

Thanks for inviting me here to your Wildland Fire Conference. I have met some of you in prior presentations, and you know my focus in life is in the Management of Risk. Today I have been asked to give you some thoughts on the importance of "real risk management" and how this discipline applies to the high-risk world of wildland fire service operations.

My goal is over the next hour or so is to give you some ideas, strategies, tactics and thoughts on what you can do to better protect yourself, your Department, our forests and the noble profession of public safety.

One of the great icons of the 20th Century was Admiral Hyman Rickover. He is known as the "father" of our nuclear navy and his efforts have made America safer. Born in Warsaw in 1900, Rickover rose to rank of Admiral and directed the development of our nuclear navy, which has a tremendous safety record. He recognized he was dealing with a highly risky, highly complex issue, and he developed rules for success.

How can these rules help you in your highly complex, highly risky world of wildland fire operations? How did his focus on quality control reach the "line employee", the "supervisor" and "command staff" in the nuclear navy? Let's take a look at each of these rules and explore the possibilities.

### Rule 1. You must have a rising standard of quality over time, and well beyond what is required by any minimum standard.

We have to get better and better at what we do. Our public deserves it. Our personnel deserve it. We must be constantly looking for a better way to do things. Status Quo – we have always done it this way – is not longer acceptable.

On an Organizational level, there are better ways to get and keep good people. There are better ways to build your policy manual. There are better ways to train. There are better ways to supervise. There are better ways to discipline errant employees.

On an operational level, we must improve our performance in response times, quality and timeliness of written reports, training, candor in performance evaluations, eliminating harassment, bias and discrimination, equipment and apparatus maintenance, physical conditioning, and anything else that we can measure.

## Rule 2. People running systems should be highly capable.

Wildland fire operations require people who know how to think. Fifty years ago, you did not need to be all that sharp to be a firefighter (or a cop for that matter). Then, the job required just strength and bravery. Things have changed.

Technology, equipment, strategies and tactics involved in providing services have all changed. This is an extremely complex job, and if you hire people who can't think things through, you are in route to disaster. We need highly competent people.

And remember, that those you hire will ultimately become part of the promotional process. For those of you who are the Chief Officers here today, if you promote idiots into the ranks of supervision, they will not disappoint you – they will always be idiots. In view of the consequences that can occur when things do not go right in your complex, high-risk job – this may end being the cause of a future tragedy.

## Rule 3. Supervisors have to face bad news when it comes, and take problems to a level high enough to fix those problems.

When you take an honest look at tragedies in your profession, from the lawsuits to the injuries, deaths, embarrassments, internal investigations and even the rare criminal filing against your personnel, so many of them get down to supervisors not behaving like supervisors.

The primary mission of a supervisor is "systems implementation". If you promote people who either can't or won't enforce policy, you are in route to tragedy.

To be sure, the transition from firefighter to supervisor is a difficult one, but supervisors have to like their people so much, that they will enforce the policy to protect each of them from harm. Rules without enforcement are just nice words.

## Rule 4. You must have a healthy respect for the dangers and risks of your particular job.

Your job is still extremely high risk in nature, and the consequences for not doing things right can be dramatic. Remember the basic rules of Risk Management. RPM – Recognize, Prioritize, Mobilize.

You must do a risk assessment on each job in your organization and identify the tasks that have the highest probability of causing you grief. Then you must prioritize these tasks in terms of potential frequency, severity and available time to think prior to acting. Finally, you must mobilize (act) to address the recognized risks appropriately and prevent consequences.

## Rule 5. Training must be constant and rigorous.

Every day must be a training day! We must focus the training on the tasks in every job description that have the highest probability of causing us grief. These are the High Risk, Low Frequency, Non Discretionary time events – and this is why "Six Minutes for Safety" was developed.

We must assure that all personnel are fully and adequately trained to address the tasks that give them no time to think, and that they understand the value of thinking things through when time allows.

Also it is important to remember that most of the things you do in your profession do not require split second decisions. Most things you do give you time to think! If you have time to think – please use it.

## Rule 6. All the functions of repair, quality control and technical support must fit together.

Audits and inspections are an important part of the job of the Chief officers in your department. You cannot assume that all is going well. You must have control measures in place to assure things are being done right. This is not micro-management – It is called doing your job.

If you do not have the audits in place, you will not know about problems until they become consequences, and then you are in the domain of lawyers. That is too late for action, as all you can do then is address the consequences.

## Rule 7. The organization and members thereof must have the ability and willingness to learn from mistakes of the past.

Analysis of past data is the foundation for all of risk management. We (public safety operations) keep on making the same mistakes over and over again. You must learn from the past mistakes in your department – and you must take advantage of the mistakes made in "similarly situated organizations".

To wrap it up today, allow me to give you the three basic rules of risk management. I have use these for four decades, and when you keep these in mind you can help yourself, your peers and your Department stay out of trouble.

Here are the three basic rules of Risk Management.

**There are no new ways to get in trouble.**

**There is always a better way to stay out of trouble.**

**Things that go wrong in life are predictable and predictable is preventable.**

**Thanks for coming to this brief program and I look forward to seeing you again soon.**

**Gordon Graham**
**714.374.9326**
**gordongraham@earthlink.net**
**www.firefighterclosecalls.com**
**www.firefighternearmiss.com**

# *Wildland Firefighter Health and Safety – A Discussion of Emerging Issues and Topics for Study: MTDC and University of Montana

Joseph.W. Domitrovich M.S.[AC], Brian J. Sharkey PhD[A] , Charles G. Palmer EdD [B], Steven E. Gaskill PhD.[B], Brent C. Ruby PhD[B], John S. Cuddy M.S.[B]

[A] Missoula Technology and Development Center, USFS, 5785 Hwy 10 West, Missoula, Montana, 59808, USA, joseph.domitrovich@umontana.edu, bsharkey@fs.fed.us
[B] The University of Montana, 32 Campus Drive, Missoula, Montana, 59812, USA, charles.palmer@umontana.edu, steven.gaskill@umontana.edu, brent.ruby@umontana.edu, john.cuddy@umontana.edu
[c]Corresponding Author

## Abstract:

Since the 1960’s the Missoula Technology and Development Center (MTDC) and the University of Montana have worked under a memorandum of understanding investigating wildland firefighter health and safety. Work has included studies on energy expenditure, nutritional strategies, hydration, fitness requirements, and health hazards associated with wildfire suppression. New areas of interest have included psychological performance, stress, and the health of Incident Management Teams. This seminar included a review of studies conducted by MTDC and the University of Montana, and concluded with a discussion of emerging issues related to wildland firefighter health and safety. Conference participants were asked to bring ideas and be ready to discuss these issues and to develop recommendations for future studies.

*Abstract appears as it was originally submitted.

# *NWCG Risk Management Committee Incident Emergency Medical Subcommittee Update

Janette Peterson[A]

[A]Bureau of Land Management, 1387 S. Vinnell Way, Boise, Idaho, 83709, USA, jpeterson@blm.gov

## Abstract:

Incident Emergency Medical Subcommittee
Wildland firefighting requires a unique array of support services due to remoteness, terrain, and multiple agencies involved in major responses. Medical support is essential because of the inherent risks found at these events. The issues of standards of care and legal licensure or certification of emergency medical service (EMS) providers come into play when EMS providers from other jurisdictions cross state lines or other geopolitical boundaries to provide medical care. These situations are further complicated in areas where medical control is sometimes nonexistent, or the capabilities of nearby medical facilities may be limited, including the variability of local emergency medical services agency capacities. The National Wildfire Coordination Group (NWCG) Risk Management Committee (RMC) has formed and chartered the Incident Emergency Medical Subcommittee (IEMS) formerly known as the Incident Emergency Medical Task Group (IEMTG) and Emergency Medical Standards Group (EMSG) to address these issues.

The tactical mission statement of the IEMS is to develop national emergency medical and occupational health standards, procedures and guidelines. The mission purpose is to ensure the health and safety of workers on wildland fire incidents in an efficient and cost effective manner. The focus will be to provide information, updates, and guidance as necessary in the development and ongoing effort for a successful outcome.

Our hope is to provide an overview of the IEMS efforts and discuss the issues surrounding EMS in the wildland fire arena.

*Abstract appears as it was originally submitted.

# What are the safety implications of crown fires?

Martin E. Alexander[A,C] and Miguel G. Cruz[B]

[A] University of Alberta, Department of Renewable Resources and Alberta School of Forest Science and Management, Edmonton, AB, T6G 2H1, Canada.
[B] CSIRO Ecosystem Sciences and CSIRO Climate Adaptation Flagship - Bushfire Dynamics and Applications, GPO Box 284, Canberra, ACT 2601, Australia. Email: miguel.cruz@csiro.au
[C] Corresponding author. Email: mea2@telus.net

**Abstract.** In his pioneering work on the common denominators of fire behavior associated with fatal and near-fatal wildland fires published in 1977, Carl Wilson pointed out that many firefighters were surprised to learn that tragedy and near-miss incidents occurred in fairly light fuels, on small fires or isolated sectors of large fires, and that fire behavior was relatively quiet just before the incident. This is certainly a valid conclusion as the general belief had been that high-intensity crown fires in timber were responsible for entrapping and burning-over firefighters. The focus of this paper is on contrasting several fire behavior characteristics (e.g. forward or head fire rate of spread, fireline intensity, flame depth) between fully-cured grass and conifer forest in relation to wind speed for a fixed set of burning conditions. The results of this comparison coupled with the new knowledge gained from research studies undertaken since the late 1970s, indicate that there is a general need for a readjustment in the emphasis placed on certain aspects of fire behavior in current firefighter safety awareness training.

**Additional keywords:** crowning, fire behavior, fire environment, firefighter fatalities, fireline intensity, flame depth, flame front residence time, flame height, flame length, rate of fire spread.

## Introduction

With respect to the title of this paper and after looking at Fig. 1, is it not obvious that crown fires pose a serious risk to the safety of wildland firefighters? As author Norman Maclean (1992) so eloquently stated in his seminal book 'Young Men & Fire':

> As for big fires in the early history of the Forest Service, a young ranger made himself famous by answering the big question on an exam, "What would you do to control a crown fire?" with the one-liner, "Get out of the way and pray like hell for rain."

In discussing the various types of free-burning wildland fires, Brown and Davis (1973) had this to say about crown fires:

> This is the most spectacular kind of forest fire. Since it is over the heads of ground forces it is uncontrollable until it again drops to the ground, and since it is usually fast-moving it poses grave danger to fire fighters and wildlife in its path. It is the most common cause of fire fighters becoming trapped and burned.

The purpose of this paper is explore the specific aspects of crown fire behavior that should be a cause of concern for wildland firefighters as well as members of the general public with regard to their personal safety. This is discussed in light of Carl Wilson's (1977) ground-breaking research into the common denominators of fire behavior on fatal and near-fatal fires.

The International System (SI) of units is used throughout this paper. A list of SI-to-English unit conversion factors is given in the Appendix.

**Fig. 1.** Crown fire advancing through a radiata pine (*Pinus radiata*) plantation (~15 m tall) towards a grazed pasture consisting of fully-cured grasses with scattered eucalypt trees, located near Wandong in central Victoria, Australia. Photo by Alan Sewell, Country Fire Authority, 14 January 1998.

**Wilson's common denominators of fire behavior on fatal fires**

Based on his analysis of 67 fatal fires involving 222 wildland firefighter deaths in the US over a 61-year period (1926-1976), Wilson (1977) identified some common features connecting these incidents. The five common denominators of fire behavior associated with these fatal fires were:

1. Most of the incidents occurred on relatively small fires or isolated sectors of larger fires.
2. Most of the fires were innocent in appearance prior to the "flare-ups" or "blow-ups". In some cases, the fatalities occurred in the mop-up stage.
3. Flare-ups occurred in deceptively light fuels.
4. Fires ran uphill in chimneys, gullies, or on steep slopes.
5. Suppression tools, such as helicopters or air tankers can adversely modify fire behavior. (Helicopter and air tanker vortices have been known to cause flare-ups.)

Although not explicitly noted in the above list, surely it is a given that dead and(or) live fuel moistures are at critically dry levels. Furthermore, 'worst-case' fuel conditions must also apply. For example, grasslands would have been in a fully-cured state as was the situation on the Mann Gulch Fire in northwestern Montana in August 1949 (Maclean 1992) or when hardwood forests are in a leafless stage, as was the case on the Pepper Hill Fire in north-central Pennsylvania in the fall of 1938 (Schultz 2001).

Wilson's (1977) findings were subsequently reprinted in several popular, pocket-sized booklets over the years (Wilson and Sorensen 1978, 1992, 1996) and included within many other publications (e.g. Goodson and Adams 1998; Alexander *et al.* 2011). Quite often only the first four common denominators are given and presented in slightly altered forms from Wilson's (1977) original concept. For example, 'the four major common denominators of fire behavior on tragedy fires' are (from Wilson and Sorensen (1996):

1. Most incidents happen on small fires or on isolated sections of large fires.
2. Flare-ups generally occur in deceptively light fuels, such as grass and light brush.
3. Most fires are innocent in appearance before unexpected shifts in wind direction and/or speed result in flare-ups. Sometimes tragedies occur in the mop-up stage.
4. Fires respond to large- and small-scale topographic conditions, running uphill Surprisingly fast in chimneys, gullies, and on steep slopes.

Note in the latest edition of the *Incident Response Pocket Guide* (NWCG 2010) or IRPG, as it is frequently called, that the indication is that firefighter fatalities often occur:

1. On relatively small fires or deceptively quiet areas of large fires.
2. In relatively light fuels, such as grass, herbs, and light brush.
3. With unexpected shifts in wind direction or wind speed.
4. When fire responds to topographic conditions and runs uphill.

As Wilson (1977) so perceptively pointed out, many firefighters were surprised to learn that tragedy and near-miss incidents occurred in fairly light fuels, on small fires or on isolated sectors of large fires, and that the fire behavior was relatively quiet just before the incident, even in the cases involving aircraft (Countryman *et al.* 1969). Many have been lead to believe that it is the conflagration or large, high-intensity crown fire in timber or heavy brush that traps and kills firefighters. Some of the fatality fires involving crown fire runs in conifer forests that come to mind, two of which were part of Wilson's (1977) study, include for example:

- 1937 Blackwater Fire – Wyoming: 15 fatalities (Brown 1937)
- 1958 Wandilo Fire – South Australia: 8 fatalities (McArthur *et al.* 1966)
- 1967 Sundance Fire – Idaho: 2 fatalities (Anderson 1968)
- 1977 Bass River Fire – New Jersey: 4 fatalities (Brotak 1979)
- 1980 Mack Lake Fire – Michigan: 1 fatality (Simard *et al.* 1983)
- 1990 Dude Fire – Arizona: 6 fatalities (Goens and Andrews 1998)
- 1994 Sabie – South Africa: 10 fatalities (de Ronde 2002)
- 2001 Thirtymile Fire – Washington: 4 fatalities (Maclean 2007)

Yet, with some rare exceptions, Wilson (1977) claims that most fatal fires that he examined were innocent appearing just before the fatal moment.

Wilson's (1977) common denominators have been the accepted doctrine with respect to wildland firefighter safety and fire behavior for some 35 years now. It is our belief that we should reexamine these established beliefs in the light of new fire behavior research and operational experiences accumulated since 1977.

**Defining and characterizing fire behavior**

One wildland fire management glossary defines fire behavior as 'the manner in which fuel ignites, flame develops, fire spreads and exhibits other related phenomena as determined by the fire environment' (Merrill and Alexander 1987). The more important fire behavior characteristics from the practical standpoint of fire suppression are considered to be (Alexander 2000):

- Forward or head fire rate of spread
- Fireline intensity
- Flame front dimensions
- Spotting pattern (densities & distances)
- Fire size and shape
- Rate of perimeter increase
- Burn-out or smoulder time

The thermal environment of a wildland fire is perhaps best characterized by the record or signature it leaves in the form of a time-temperature trace as the moving flame front passes by a given point (Fig. 2). Photography from within the fire itself offers yet another perspective. See for example the still photographic images presented in Taylor *et al.* (2004) and the 'Inside the Fire' video at http://www.youtube.com/watch?v=zvPa_yEEd4E, both from the International Crown Fire Modelling Experiment, Northwest Territories, Canada (Stocks *et al.* 2004).

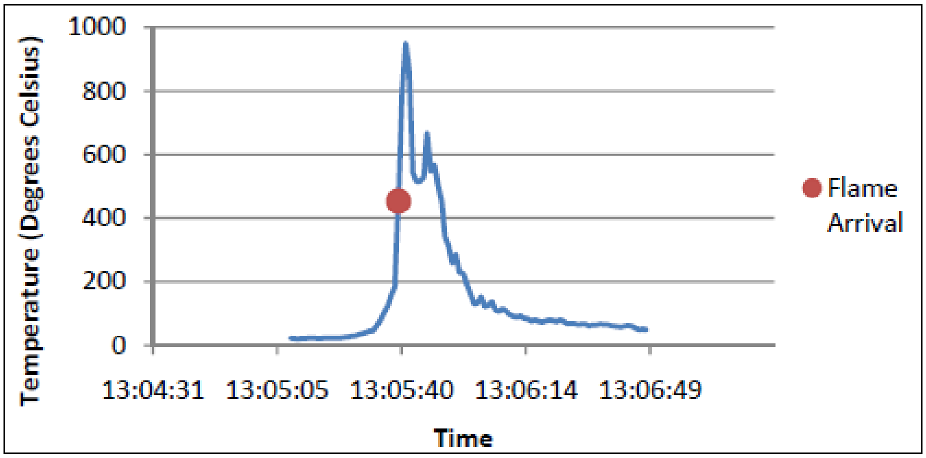


**Fig. 2.** Example of a time-temperature trace obtained from a thermocouple and an electronic datalogger (i.e. a 'thermo-logger') for a single height above the ground surface just prior to, during, and immediately following passage of the flame front. In this case, the thermal signature is for a grass fire in southern Ontario, Canada (from Kidnie 2009).

**Simulation of fire behavior characteristics**

Our initial intent was to contrast fire behavior potential in three broad fuel complexes, namely grass, shrubland, and conifer forest, each exhibiting relatively simple structural characteristics, both vertical and horizontally. Furthermore, it was our desire to use models for predicting fire behavior derived from empirical datasets covering a wide range of burning conditions (Cruz and Gould 2009), as opposed to theoretical or physical based models that have undergone limited evaluation. In this respect, the empirical based models for predicting rate of fire spread described by Cheney *et al.* (1993, 1998) for the natural or ungrazed pasture grass fuel type and by Cruz *et* *al.* (2008) for the conifer forest using the litter fuel model of Cruz and Fernandes (2008) were considered most suitable. A similar, compatible model or modeling system for chaparral could not be found, although qualitative comparisons against the other two fuel complexes were considered possible (Table 1) on the basis of empirical field studies of fire behavior, wildfire observations, and model simulations of fire behavior (Chandler *et al.* 1963; Green and Schimke 1971; Rothermel and Philpot 1973; Countryman 1974; Stephens *et al.* 2008). The fire behavior simulations focused on forward or head fire rate of spread, fireline intensity, and flame dimensions (Fig. 3).

**Table 1. Relative rankings of simulated fire behavior characteristics presented in Figs. 4-6 as well as nominal numerical values for other fire behavior characteristics amongst three broad fuel complexes**

| Fire behavior characteristic | Grass | Chaparral[A] | Conifer forest |
|---|---|---|---|
| Forward or head fire rate of spread | Highest | Intermediate | Lowest |
| Fireline intensity | Lowest | Intermediate | Highest |
| Flame length/height | Lowest | Intermediate | Highest |
| Flame depth | Lowest | Intermediate | Highest |
| Flame front residence time (sec) | 5-10 | 10-20 | 30-60 |
| Maximum spotting distance (km) | <0.1 | ~6.5 | ~16 |
| Burn-out or smoulder time (min) | 1 | 1-3 | 10-20 |
| Maximum firewhirl size potential | Small | Moderate | Large |

[A]Assuming a live moisture content of 75%.

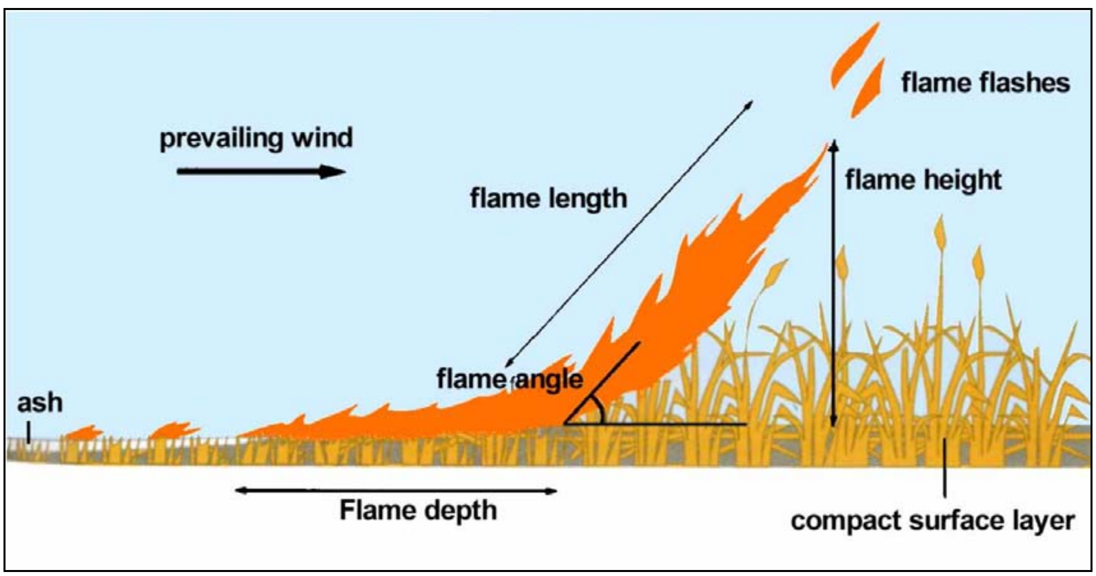


**Fig. 3.** Idealized cross-section of a surface head fire in grass fuels on level terrain (from Cheney and Sullivan 2008).

Nominal fuel characteristics were selected for the simulations of fire behavior. For grass, this involved a fuel load and height of 0.35 kg/m$^2$ and 35 cm, respectively (representing roughly the average values the model is based on), and a 100% degree of curing. The conifer forest was viewed to be 14 m tall with a canopy base height of 6 m, canopy bulk density of 0.23 kg/m$^3$, and available surface fuel load of 1.3 kg/m$^2$; this is similar to the red pine plantation fuel complex described by Van Wagner (1968, 1977). The best way to contrast differences in fire behavior potential between the two fuel complexes was to vary the wind speed. For the purposes of the fire behavior simulations the following environmental conditions, viewed as being reasonably ‘severe’, were held constant: slope steepness – 0% (i.e. flat to gently undulating topography); air temperature – 30 °C; relative humidity – 20%. This equates to 4.8% moisture content in fully-cured grass (Cheney and Sullivan 2008) and 6.0% fine dead surface fuel moisture content in the conifer forest (Rothermel 1983).

What distinguishes wildland fires from structural or urban fires is their horizontal spread potential. The forward or head fire rate of spread versus wind speed simulation for the two fuel complexes presented in Fig. 4 clearly shows that grass has a higher potential spread rate than the conifer forest. However, it is worth noting the sudden increase in spread rate with the onset of crowning in the conifer forest evident in Fig. 4.

Fireline intensity ($I$, kW/m) represents the energy output rate per unit length of fire front and is directly related to flame size (Byram 1959). Numerically, it is equal to the product of the net low heat of combustion ($H$, kJ/kg), amount of fuel consumed in the active flaming front ($w$, kg/m$^2$), and a spreading fire's linear rate of advance ($R$, m/min):

$$I = (H \times w \times R) \div 60 \tag{1}$$

A nominal value of 18 000 kJ/kg is commonly assigned to $H$ for the purposes of calculating fireline intensity (Stocks *et al.* 2004).

It is quite evident from the simulation of fireline intensity versus wind speed for the two fuel complexes (Fig. 5), that varying combination of spread rates and fuel consumption levels can lead to a more complicated pattern than was the case with rate of fire spread. Again, the effect of the onset of crowning is evident both in terms of the increased spread and the additional fuel consumed from within the canopy layer or strata. Below this crown fire threshold, grass fires yield higher fireline intensities than surface fires in conifer forests.

The average flame height of fully-developed crown fires is generally regarded as being at least two times the stand height (Cruz and Alexander 2010). Empirical relationships have been established between forward or head fire rate of fire spread and flame height for grazed and ungrazed pastures Cheney and Sullivan (2008, p. 38, Fig. 4.6) based on experimental fires carried out in grass as described by Cheney et al. (1993).

The flame depth ($D$, m) of a spreading wildland fire is a product of $R$ and the flame front residence time ($t_r$, min) which represents the duration that a moving band or zone of continuous flaming combustion persists at or resides over a given location (Fons *et al.* 1963):

$$D = R \times t_r \tag{2}$$

Flame front residence times for conifer forest fuel types at the ground surface are commonly 30 sec to 1 min compared to 5 to 10 sec in fully-cured grass fuels (Table 1). The simulations of fire behavior shown in Fig. 6 are based on a flame front residence time of 0.75 min (i.e. 45 sec) for conifer forest at the ground surface and 0.125 min (i.e. 7.5 sec) for grass. Free-burning fires in conifer forests are capable of producing very deep flame fronts compared to grass fires, once crowning commences (Fig. 6).

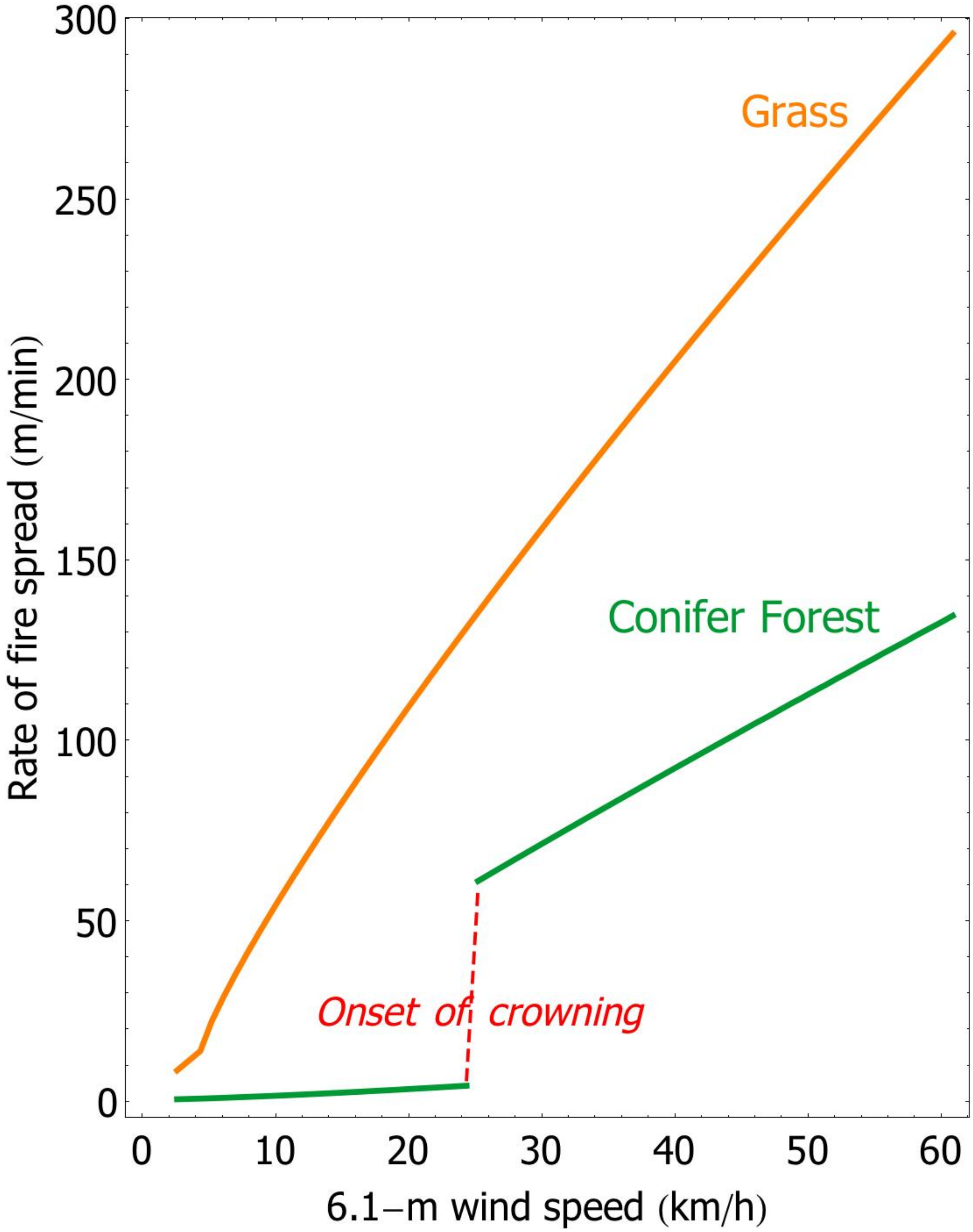


**Fig. 4.** Comparison of simulated rate of fire spread on level to gently undulating terrain as a function of wind speed for two broad fuel complexes. Refer to the text for specific details on fuel characteristics and other environmental conditions.

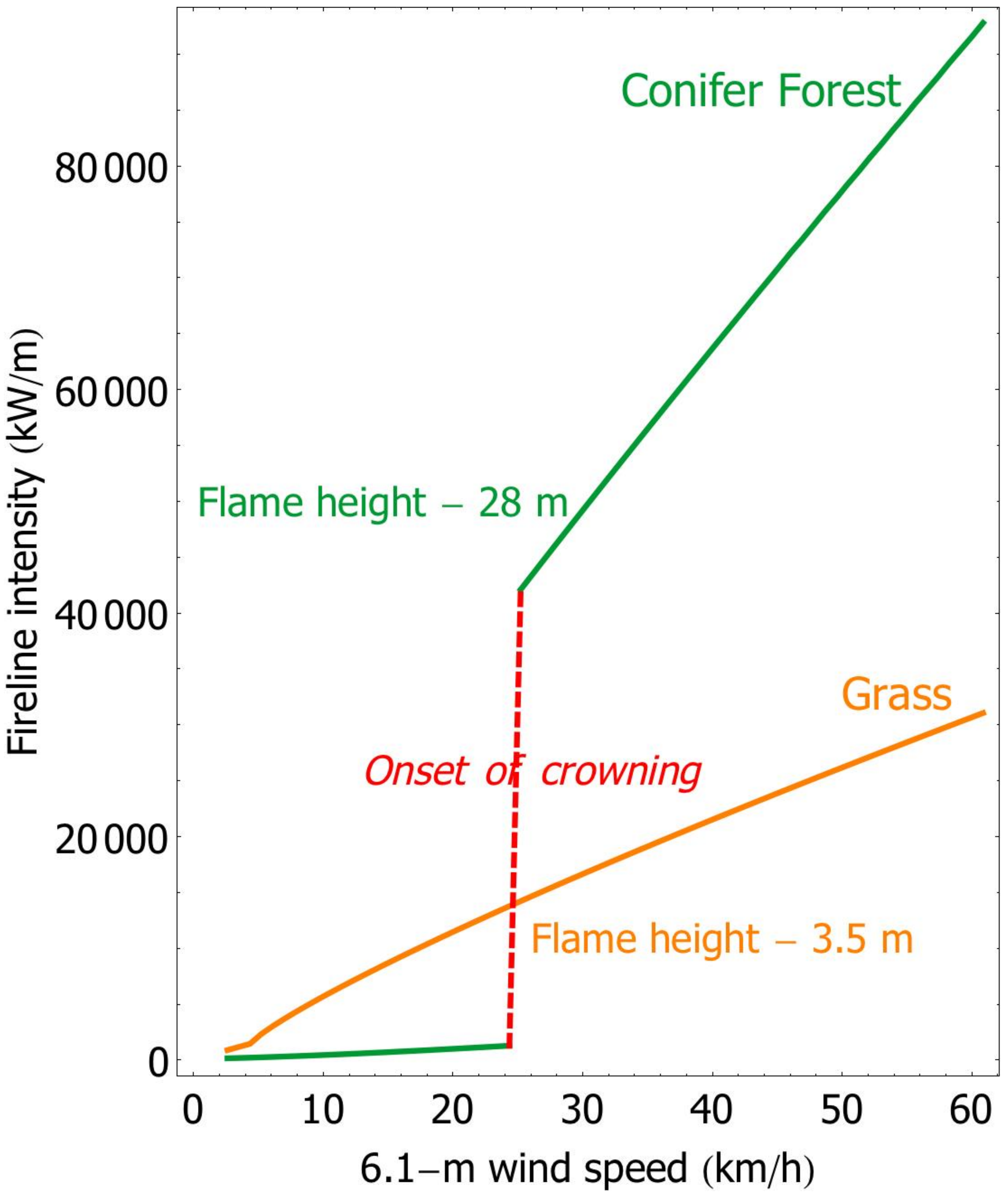


**Fig. 5.** Comparison of simulated fireline intensity and associated flame heights (at the onset of crowning) on level to gently undulating terrain as a function of wind speed for two broad fuel complexes. Refer to the text for specific details on fuel characteristics and other environmental conditions.

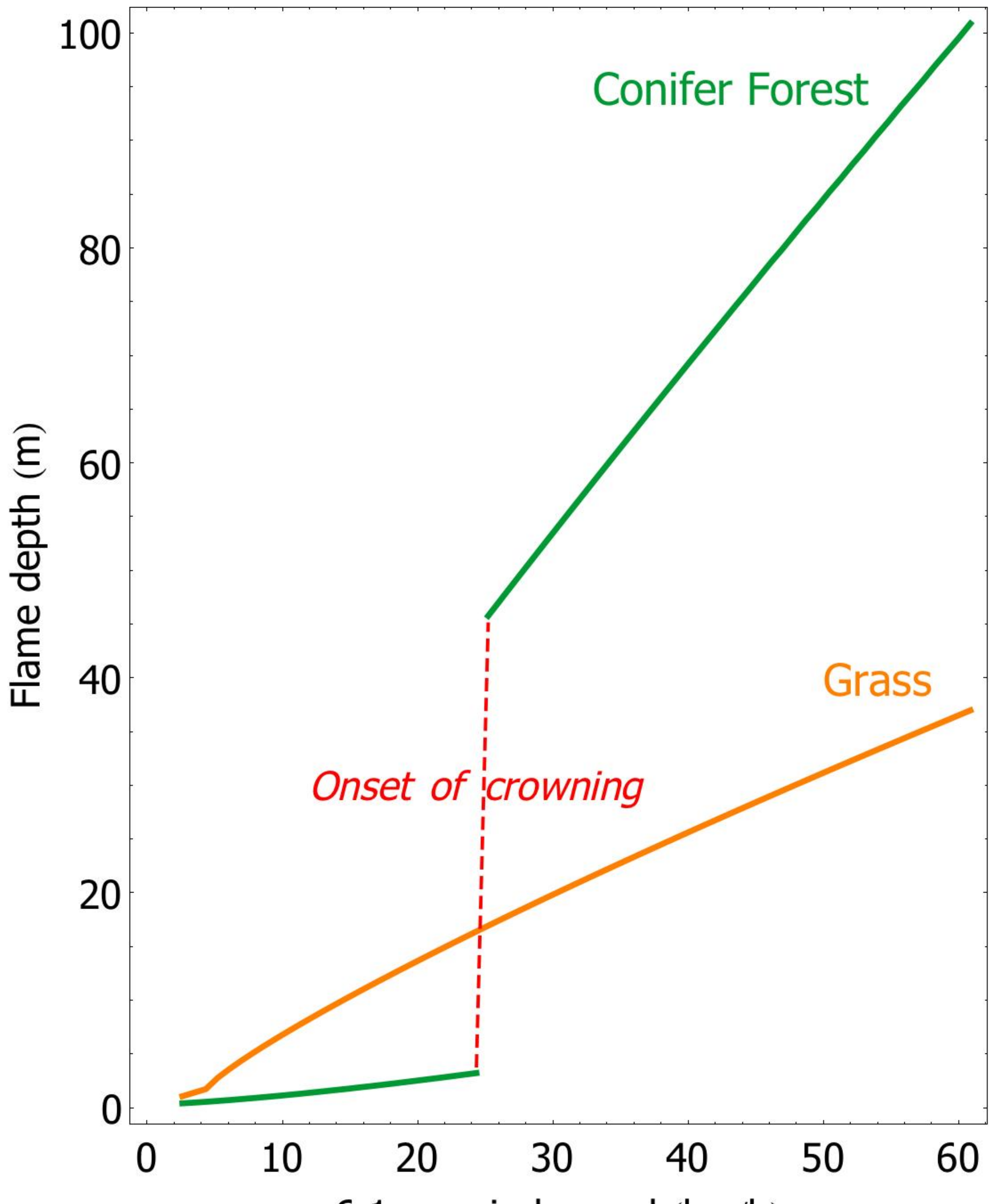


**Fig. 6.** Comparison of simulated flame depth on level to gently undulating terrain as a function of wind speed for two broad fuel complexes. Refer to the text for specific details on fuel characteristics and other environmental conditions.

## Discussion of fire behavior simulations in light of firefighter safety

A summary of the relative rankings in simulated fire behavior for grass, shrubland and conifer forest fuel complexes is given in Table 1 along with nominal values for other characteristics of fire behavior. There are other elements that one might wish to consider adding to the list, including direct implications for fire suppression such as firefighter travel rates for escape routes (Alexander 2011*b*) and fireline production rates (Broyles 2011).

The implications for fire safety between grass and conifer forest as a result of differences in fire behavior are clear. Grass fires are certainly far more responsive to the influence of wind than surface and crown fires in conifer forests which can easily lead to very sudden changes in the rate of spread and the direction of fire spread as a result of the natural variability in winds (Cheney *et al.* 2001). However, the heavy fuel loads associated with conifer forests easily lead to far more intense flame fronts than grass fires are capable of producing (Alexander *et al.* 2009*a*), thereby requiring larger safety and survival zones for firefighters (Sullivan *et al.* 2003; Alexander *et al.* 2009), especially for the case of crown fires (Alexander *et al.* 2009b). Furthermore, the burn-out or smoulder times associated with conifer forests are considerably greater than those experienced in grass fuelbeds (Table 1) (Sullivan *et al.* 2002; Cheney and Sullivan 2008). Both of these factors effectively eliminate at two of the four survival options available to a person during a wildland fire entrapment or burnover (Alexander *et al.* 2011), namely numbers 2 and 4:

1. Retreat from the fire and reach a safe haven.
2. Burn out a safety area.
3. Hunker in place.
4. Pass through the fire edge into the burned-out area.

A word on the significance of the surface fire-to-crown fire transition phenomena found in conifer forests is in order. This has been described in laymen's terms as the fire 'shifting gears' (R. Arthur, Alberta Sustainable Resource Development, pers. comm., 2011). If a conifer forest stand is capable of active crown fire propagation, the most obvious thing that occurs with the onset of crowning is the dramatic increase in flame height (and in turn the radiant heat flux) -- from perhaps nearly 3 m to almost 30 m in a span of a few seconds. It is worth noting that this abrupt change in fire behavior is not presently featured in fire modeling systems like NEXUS (Scott and Reinhardt 2001), FFE-FVS (Reindhardt and Crookston 2003), FARSITE (Finney 2004), FlamMap (Finney 2006) and FMAPlus (Carlton 2005), but rather a gradual increase in potential crown fire behavior. Warnings regarding this deficiency have been issued (Alexander 2010, 2011*a*). Recent fire research in Australia has identified wind speed thresholds in shrubland fuel complexes similar to those displayed in Figs. 4-6 (Cruz and Gould 2010; Cruz *et al.* 2010).

## Concluding remarks

The results obtained from the simulations of fire behavior suggest that one needs to be wary of the tendency to generalize too much when it comes to describing the safety implications of wildland fires amongst firefighters as well as members of the general public. The following are the key 'take-home' messages emanating from the analyses reported on in this paper:

- Wildland fires are complex and varied, dependent on numerous combinations of fuels, topography and weather. We must be very careful not to think, when dealing with this complexity, that a single set of fire safety guidelines will always fit every situation. Examination of the firefighter fatalities due to entrapments and burnovers, including near-fatal fires (e.g. Pearce *et al.* 2004), that have occurred since 1976 would be in order (Morse 1990), especially in light of changes in fuel conditions and climate change.

- There is a general need to emphasize that there are many aspects or characteristics of wildland fire behavior and we need to strive to relate fire behavior more directly to fire suppression (e.g. fireline production rates, firefighter travel rates for escape routes, safety and survival zone sizes) -- in other words, a more holistic approach to the overall wildland fire environment, including the human dimension (Sutton 2011).
- Provide scientific explanation for Wilson's (1977) common denominators in light of fire behavior research completed since that time (e.g. Sneeuwjagt and Frandsen 1977; Clark 1983; Cheney and Gould 1995, 1997; Cheney and Sullivan 2008; Alexander and Cruz 2009; Cruz 2010), including 'lessons relearned' (e.g. Butler *et al.* 1998), and incorporate this information into fire behavior and fire safety training.
- Look to incorporate the latest insights into the dynamics of wildland fire behavior into training and operations. For example, rather than viewing fire spread rate as gradually increasing with increasing wind speed (see, for example, Rothermel 1972, p. 38, Fig. 25), emphasize the "step" pattern that occurs in many fuel types once wind speed thresholds are exceeded (McArthur 1967; Lindenmuth and Davis 1973; Davis and Dieterich 1976; Bruner and Klebenow 1979; Burrows *et al.* 1991; Cruz *et al.* 2005).

We believe these updates, integrated with Wilson's (1977) original five common denominators of fatal fires, would constitute a major step towards improving the forecasting of probable fire behavior with respect to ensuring the safety of firefighters and members of the general public.

## Dedication

One of us (MEA) met Carl Wilson for the first time in 1980 and subsequently maintained contact with him over the years up until his death at the age of 94 on August 21, 2009[1]. Carl was one of the globe's true pioneering wildland fire researchers. This paper is affectionately dedicated to his memory.

## Acknowledgments

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[1] http://www.berkeleydailyplanet.com/issue/2009-09-03/article/33676?headline=Carl-C.-Wilson-1915-2009 [Verified 12 July 2011]

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## Appendix

**Table A1. International System (SI)-to-English unit conversion factors**

| SI unit | | Multiplication factor | | English unit | Inverse factor |
|---|---|---|---|---|---|
| Degree Celsius (°C) | × | 5/9 (°F -32) | = | Degree Fahrenheit (°F) | (9/5 °C) +32 |
| Kilogram per cubic meter ($kg/m^3$) | × | 0.624 | = | Pound per cubic foot ($lb/ft^3$) | 16.0 |
| Kilogram per square meter ($kg/m^2$) | × | 0.205 | = | Pound per square foot ($lb/ft^2$) | 4.88 |
| Kilojoule per kilogram (kJ/kg) | × | 0.430 | = | Btu per pound (Btu/lb) | 2.32 |
| Kilometer | × | 0.621 | = | Mile (mi) | 1.61 |
| Kilometer per hour (km/h) | × | 0.621 | = | Mile per hour (mi/h) | 1.61 |
| Kilowatt per meter (kW/m) | × | 0.289 | = | Btu per second per foot (Btu/s-ft) | 3.46 |
| Meter (m) | × | 3.28 | = | Feet (ft) | 0.305 |
| Meter per minute (m/min) | × | 3.28 | = | Feet per minute (ft/min) | 0.305 |
| Meter per minute (m/min) | × | 2.98 | = | Chain per hour (ch/h) | 0.335 |
| Square meter per hectare ($m^2$/ha) | × | 4.36 | = | Square feet per acre ($ft^2$/ac) | 0.230 |
| Number per hectare (no. /ha) | × | 0.405 | = | Number per acre (no./ac) | 2.47 |

Note: factors are given to three significant digits. To convert a English unit to a SI unit, multiply by the inverse factor given in the right-hand column. A “Btu” is a British thermal unit.

[2] http://www.wildlandfire.com/docs/2003_n_before/carl-wilson(1977).pdf [Verified 12 July 2011]

# Fire behavior observations in beetle killed trees in Lewis & Clark, Jefferson, Broadwater, and the southwest portion of Cascade county

Everett M. "Sonny" Stiger[AC]
Chief Rocky Infanger[B]

[A]Fire Behavior Analyst, Local Incident Support Team, sonnystiger@gmail.com
[B]Wolf Creek/Craig, Fire Service Area, Rocky@3riversdbs.net
[C]Corresponding Author

## Abstract:

This presentation addresses the controversy over the effect the Mountain Pine Beetle epidemic is expected to have on fire behavior. It summarizes observations by experienced firefighters and fire managers on recent fires in the Tri-County area of Lewis & Clark, Broadwater, Jefferson, and the SW portion of Cascade Counties in Oregon. The presentation provides safety "Watch Out" scenarios by comparing fuel and expected fire behavior differences between Lodgepole pine and Ponderosa pine in the Tri-County area, and advocates the more extensive use of the Probability of Ignition. The measures initiated in the Tri-County area to address the problem are also presented.

**Additional Keywords:** fire behavior, wildland firefighting safety, Mountain Pine Beetle

## Introduction

This presentation addresses the controversy over the effect the current Mountain Pine Beetle epidemic is expected to have on fire behavior. It summarizes observations by experienced firefighters and fire managers on recent fires in the Tri-County area of Lewis & Clark, Broadwater, Jefferson, and the SW portion of Cascade Counties. The presentation provides safety "Watch Out" scenarios derived by comparing fuel and expected fire behavior differences between Lodgepole pine and Ponderosa pine in the Tri-County area, and advocates the more extensive use of the Probability of Ignition. The measures initiated in the Tri-County area to address the problem are also presented.

Experienced firefighters were interviewed over a three-year period (see Appendix A of the full report at http://www.iawfonline.org/missoula2011**)** to record their observations of fire behavior in beetle infested timber stands. The following is a summary of those observations.

Even though wildland fire weather has been rather mild since 2008 we have been experiencing intense wildland fires in the mountain pine beetle infested stands within the Tri-County Area. The forested portions of these counties have been hit hard by the beetles, and several hundreds of thousands of acres are red and dead or green and dying This latter category of green and dying has been more of a problem than the red/dead. Our firefighters on the front lines have noticed that the green trees that have just recently been attacked by the beetle, are burning with more intensity and carrying a crown fire more readily than the trees that have been dead for some time, but still retain their red needles. Jolly *et al* (2011) at the fire lab in Missoula have found that the green trees that are just recently hit by the beetle have lost as much as 50 % of their foliar moisture. These trees, still possessing their resins and terpenes, have been transitioning from a surface fire to a crown fire faster, and with more intensity and speed than we have experienced in the green healthy trees in previous years, even under drought conditions. A recent example is the Davis fire near Helena, Montana (August, 2010) that burned in a mixture of Lodgepole pine and Alpine fir with a 50 to 70 % red/dead component. The percentage of green, freshly attacked trees is unknown, but would have been substantial. This fire exploded from a small spot fire to three acres in two minutes, 10 to 15 acres in the next eight minutes, and to over 100 acres in the first hour, with rather mundane weather. The air temperature at the time was 78 degrees F., with a relative humidity of 28% and light winds (pers. comm., District FMO, August, 27th, 2010).

This kind of fire behavior has been witnessed over the last several years in the beetle infested Ponderosa pine stands as well. These stands of Ponderosa pine are particularly vulnerable to spot fires, due to a heavy buildup of their long needles (4 to 5 inches) on the forest floor, and hanging up in the lower tree branches and underbrush. The North Fork fire in this Ponderosa pine type near Wolf Creek, Montana, grew quickly from a 10 to 15 acre running crown fire to 70 acres of spot fires. Hundreds of embers created hundreds of spot fires that could coalesce and create a mass ignition. It has become obvious that our firefighters must be cognizant of the Probability of Ignition when in initial attack. A Probability of Ignition of over 60 in beetle-infested stands of Ponderosa pine should be a Red Flag for the possibility of a mass ignition.

Not only are we witnessing increased spotting potential, increased rates of surface fire spread, increased fireline intensities, and increased crown fire potential, all a concern for the safety of our firefighters and civilians, but we also have a serious potential for 'widow–makers.' Trees attacked by mountain pine beetles are breaking off at mid-tree and uprooting more easily than other dead trees that have not been attacked.

In short, fires in the mountain pine beetle infested stands will require a higher level of vigilance and fire behavior evaluation for firefighter and civilian safety, than previously recognized. These silent killers can come down with no notice to the unsuspecting fire fighter or civilian.

**Lessons learned**:

- More intense surface fires to crown fires faster.
- Red/green mix of beetle infested trees supports intense, rapid spreading crown fire.
- Profuse short- and long-range spotting can be expected.
- Does not necessarily have to be severe fire weather.
- Subalpine fir provides the impetus to initiate a crown fire in Lodgepole pine stands, and dense thickets of Ponderosa pine reproduction provide the ladder fuels to initiate a crown fire in Ponderosa pine stands, particularly with needle drape.
- A probability of Ignition of 60 or greater is cause for potentially profuse and DANGEROUS SPOTTING.

**Pre-fire readiness measures**
The following pre-fire readiness measures have been initiated to address the problem in the Tri-County area.

- LOCAL INCIDENT SUPPORT TEAM. The LIST team is a rapid deployment team established to provide management support to a Tri-County incident until an Incident Management Team arrives. It is made up of a cross-section of trained individuals from local Volunteer Fire Departments and Agencies.
- POPULATION PROTECTION PLANS. These pre-incident plans have been completed by 20 Volunteer Fire Departments in the Tri-County area under the auspices of the TRI-COUNTY FIRESAFE WORKING GROUP.
- MITIGATION. Over 1,000 home sites have been treated for defensible/survivable space. The mitigation work has recently been expanded to include removal of beetle-killed trees that could compromise the use of evacuation routes identified in the Population Protection Plans.
- TRAINING. Emphasis has been placed on including volunteer firefighters in Interagency training. Twenty-three volunteer firefighters have recently completed on-line S-290, Intermediate Fire Behavior.

**References**

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# Facts and fictions: Firefighters and their stories

David Thomas[A]

[A]Renoveling, Ogden, Utah, Address, **renoveling@msn.com**

**Abstract:**
The following is a brief synopsis of a one-hour keynote talk given by David Thomas on Wednesday morning, April 6, 2011, at the IAWF Safety Summit in Missoula, Montana. The talk was given extemporaneously and the PowerPoint slides used as talking points are available at the IAWF's conference proceedings website.

**Additional Keywords:** Firefighting, storytelling,

## Introduction

The basic premise and take-away point for this talk was that all stories are linked, that stories build upon one another, and that if we can see ourselves within the great chain of stories, if we can muster the courage to tell our own stories using our own words, in our own voice, then we will see that we all have important stories to tell each other. This is particularly true of the stories formed from our diverse firefighting experiences. When individual perspectives, captured while working on wildland fires, whether they are moods or emotions, thoughts or feelings, are told as stories, we will have discovered a better way to learn. Stories, told to us and by us, will help us become better firefighters.

Using my own life as a student of literature (I mentioned, in my introduction to the talk, how Montana poet Richard Hugo's poem, "Degrees of Gray in Philipsburg," and Norman Maclean's early story, "USFS 1919: The Ranger, the Cook, and a Hole in the Sky," found in "A River Runs Through It and Other Stories," affected me and became profoundly linked in my life as a fire management officer at Powell Ranger Station) and my thirty seven year career as a Forest Service firefighter in the Western U. S., I made a case that hopefully proved some of these suppositions to be true.

Throughout the talk, I demonstrated how storytelling, used within an organizational context, is an exceptionally strong and vibrant method to pass on organizational knowledge. I buttressed this point by showing a ten-minute podcast production, with National Park Service Fire Management Officer, Kelly Martin. In the video, Ms. Martin, who is now stationed at Yosemite National Park, described a process she used for personal learning after a near-miss wildfire incident near Carson City, Nevada. I suggested to the audience that the proper way to use the Martin videotape was to tell their own stories of their own near misses, and that their stories of near misses layered over Kelly Martin's story would then become an even richer, more complex and robust story, a story worth telling and learning from

To deepen my points about the power of storytelling, I related stories from other firefighting perspectives told to me by Yellowstone National Park employees, Dan Sholly and Bob Barbee, NBC Nightly News national correspondent Roger O'Neill, and former Secretary of the Interior under the Reagan Administration, Don Hodel, all of whom shared their experiences (their stories) reporting or managing, at both the local and national scales, the Yellowstone Park Fires of 1988.

In closing my presentation, I paid homage to two recently deceased federal wildland fire mangers, Len Dems and Rick Gale, both of whom were National Park Service employees who were interviewed as part of the 'Learning from the Experts' series hosted at the Wildland Fire Lessons Learned Center,Tucson, Arizona (http://wildfirelessons.net/Additional.aspx?Page=153). I used the following quotation from page 104 of Norman MaClean's book, "A River Runs Through It and Other Stories," to introduce my closing comments on stories

> Now nearly all those I loved and did not understand when I was young are dead, but I still reach out to them.
> Of course, now I am too old to be much of a fisherman, and now of course I usually fish the big waters alone, although some friends think I shouldn't. Like many fly fishermen in western Montana where the summer days are almost Arctic in length, I often do not start fishing until the cool of the evening. Then in the Arctic half-light of the canyon, all existence fades to a being with my soul and memories and the sounds of the Big Blackfoot River and a four-count rhythm and the hope that a fish will rise.
> Eventually, all things merge into one, and a river runs through it. The river was cut by the world's great flood and runs over rocks from the basement of time. On some of the rocks are timeless raindrops. Under the rocks are the words, and some of the words are theirs.
> I am haunted by waters

I ended this speech by gently admonishing the audience to begin telling their own fire-stories. I paraphrased a sentence from MaClean—"On some of the rocks are timeless raindrops. Under the rocks are the words, and some of the words are yours."—Yes, some of the words are yours!

# 2005-2006 Oklahoma and Texas grass fires: 25 lives lost, lessons learned—and re-learned

Robert W. Mutch[A]

[A]Fire Management Applications, 9752 W Fork Rd, Darby MT 59829, bobmutch@montana.com

**Additional Keywords:** Oklahoma and Texas grass fires, lessons learned

## Introduction

Strong winds, prolonged drought, and extreme fire danger produced wildfires that ravaged the grasslands of Oklahoma and Texas in 2005 and 2006, killing 25 people, destroying numerous homes, and killing thousands of livestock (Mutch and Keller 2010). Disasters of this magnitude are reminiscent of the outcomes of the Fire Siege of October 2003 in southern California where 14 major fires burned 750,043 acres, destroyed 3,710 homes, and killed 23 people (Mutch 2007). Because the fires in Oklahoma and Texas burned in short grass, mixed grass, and tall grass prairies, the Lessons Learned Center in Tucson, Arizona, sponsored an in-depth review of the grass-fueled wildfires to achieve the following objectives:

- To explain the circumstances of the victims and survivors at the time of their entrapment.
- To use the victims' and survivors' stories as a catalyst to motivate firefighters and interface residents to modify their behaviors to become more fire safe.
- To derive wildland-urban interface lessons learned insights.

The disturbing part of this wildfire assessment was the finding that some very basic fire safety tenets, like several of those listed in Figure 1, must be re-learned and applied to prevent future injuries and deaths. These include the wearing of personal protective equipment, briefings, 10 Standard Orders, 18 Watchouts, wearing a seat belt in a moving vehicle, and not fighting fire while drinking alcohol. When we have to re-learn safety principles, it often means that these principles were not learned well the first time. Firefighters died in 2005 and 2006 in Oklahoma and Texas when they did not observe the most basic of safety principles; and it happened again in the Texas wildfires of 2011.

At the 2005 Safety Summit in Missoula a vision, or goal, was presented in my Keynote paper to develop and apply a template for Systematic Wildland Fire Safety to support policies and practices for no injuries or fatalities. Pursuing the goal of no injuries or fatalities during the conduct of our fire use, prescribed fire, and wildfire business makes sense, because it leads us away from the mindless position that firefighting is dangerous, people will make mistakes, and bad things will sometimes happen. With a commitment to an injury-free fire environment, when an injury or fatality occurs, we are alerted that an intolerable action has occurred that must be corrected immediately.

Let's examine the fire safety template mentioned earlier:

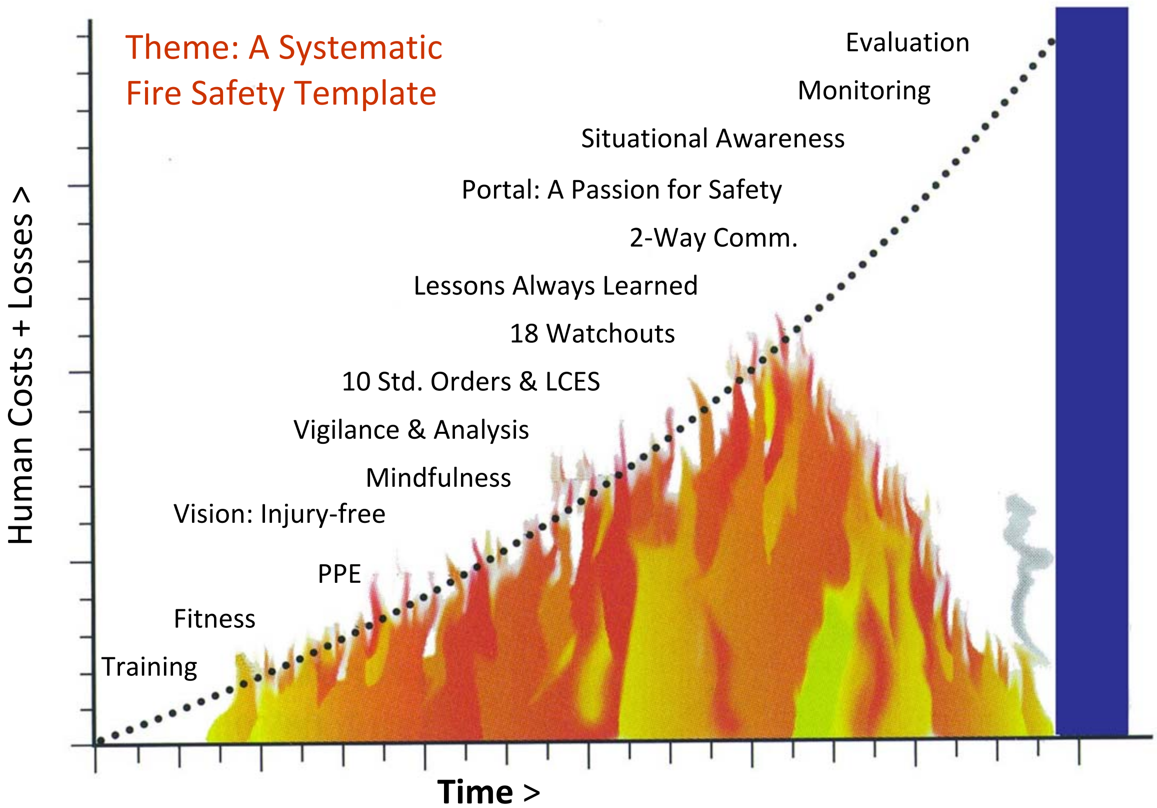


**Figure 1. A Systematic Wildland Fire Safety Template. The longer it takes to carry out the fire safety elements represented along the curve, the greater the costs to human well being represented along the vertical axis. If some of these elements are omitted during fire training or fire response, it is a given that unwanted outcomes will occur.**

Some firefighters have objected to a fire safety goal that calls for an injury-free fire environment, saying that it sets the safety standard at too high a level. But Gordon Graham's summary remarks of Admiral Rickover's seven principles of risk management at the 2011 Safety Summit in Missoula provided a note of optimism. Graham closed his keynote address by saying that:

- There are no new ways to get in trouble.
- There is always a better way to stay out of trouble.
- Things that go wrong in life are predictable and predictable is preventable.

**"Things that are predictable are preventable,"** if we are in tune with our fire environment and activate appropriate safeguards to mitigate unwanted events before they spin out of control.

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# Learning by doing: Wildland firefighters' stories about their pivotal fireline learning experiences

Jody L. S. Jahn [A]

[A]University of California
4415 SS&MS,
Santa Barbara, CA 93107
jodyjahn@umail.ucsb.edu

**Abstract:**
This paper explores how wildland firefighters' pivotal fireline experiences help them develop a sense of confidence in their engagement of fireline situations. Previous studies have identified ways that the social environment discourages members from voicing concerns, pointing to ways that social constraints cause organization members to *question their own assessments*. The next logical question, which previous research on wildland firefighters has not explored is: How do firefighters' experiences help them to *trust* their own assessments? This paper explores that question, unpacking how firefighters' previous experiences help them to develop as firefighters, coming to trust their abilities to make sense of ambiguous fireline circumstances, to manage conflicting objectives, and to negotiate the social environment. Findings reveal four story themes that address the research question: 1) Developing a technique for organizing details, 2) Developing a technique for trusting others, 3) Recognizing one's readiness for more responsibility, and 4) Perfecting a reasoning process.

**Additional Keywords:** High reliability organization, sensemaking

## Sensemaking and Stories

This paper explores how wildland firefighters' pivotal fireline experiences help them develop a sense of agency, or confidence, in their engagement of fireline situations. Stories are the verbalized interpretations of the complex and ambiguous environments that organization members face, and they represent how an individual has imposed a system of order onto a situation that was otherwise complex and confusing (Weick, 1995; Weick and Browning, 1986). Stories about pivotal learning experiences are explanations (Labov, 2001; Squire, 2005) that the individual uses as a basis for managing various organizational objectives, navigating through challenging social situations, and identifying hazards in the environment. Stories illustrate the "sense" an individual has already made about circumstances they have encountered. Stories often indicate how the individual plans to draw from their experience when they encounter such opportunities for *sensemaking* in the future.

*Sensemaking* (Weick, 1995; Weick, Sutcliffe and Obstfeld, 2005) is a process of "ongoing, retrospective development of plausible images that rationalize what people are doing (Weick et al., 2005, p. 409). Sensemaking involves, at the individual level, a scanning of the environment to look for the most meaningful information among numerous cues. A cue is a piece of information the individual recognizes as important, either because they were trained to look for that information (e.g., changes in weather or fire behavior), or because they discovered its importance in the course of doing the job (Weick, 1995). Individuals *notice* cues from the environment and *bracket* them as potentially important. They *label* the cues according to what they might indicate, and *presume* an explanation of what could be going on. Then they act on the presumption and retrospectively assess the extent to which their presumptions and action fit with the circumstances they encountered. Retrospective assessments guide them to change future assessments and actions if initial responses turned out to disconfirm what they thought.

There are several key ways sensemaking has been explored with regard to wildland firefighting, two of these areas include noticing and bracketing information from the environment, and exploring ways that sensemaking plays out as a social process. First, according to Weick (1995) sensemaking is about noticing and bracketing cues from the environment. This means that individuals are constantly assessing their surroundings for information that helps them decide what to do next. This involves looking for ways their environment gives them a tactical advantage in addition to scanning for things that are or could become problematic. Bracketing refers to grouping related cues together. For example, a change in weather often also means changes in fire behavior. In Weick's (1993) analysis of sensemaking during the Mann Gulch incident, based on Norman McLean's (1992) “Young Men and Fire,” he contends that the firefighters had the impression that they were going to be fighting a relatively easy blaze. The firefighters referred to the incident as a "10:00 fire, [which is] one that can be surrounded completely and isolated by 10:00 the next morning" (Weick, 1993, p. 635). This initial impression remained unchanged throughout the day, preventing them from taking the time to notice reasonable escape routes, and inhibiting their ability to see that fire and weather conditions in the environment around them were changing in serious ways.

Second, noticing and bracketing cues may begin as an individual cognition process, but as individuals notice changes in the environment, sensemaking often becomes a social process as individuals talk about changes with co-workers. Through their communication, they construct an explanation for what they are noticing. For example, Barton and Sutcliffe (2009) explored the social sensemaking process among wildland firefighters by exploring their narratives about speaking up in problematic situations. They found that voicing concerns serves to interrupt chains of errors; it slows down the momentum of problematic events. However, they found that lower status firefighters often stayed quiet even when they felt strongly that they should take a different course of action. Exploring the ways that lower status inhibits people from voicing concerns, Blatt, *et al.* (2006) explored communication in the hospital environment. There are two important reasons why their findings from the hospital context are relevant to firefighters. The first reason is that a regular part of the job for both doctors and wildland firefighters involves creating order from chaos. Much of their attention is focused on constructing an explanation for the situation based on the information in front of them. Doctors observe a variety of the patient’s symptoms and must figure out which ones are most important in pointing to the nature of the problem. Once they determine the likely problem, they can develop a course of action to deal with it. In a similar way, wildland firefighters observe the physical environment looking for information that tells them what the fire is likely to do, which areas may be safe or unsafe, and which factors they should monitor on an ongoing basis. Once they have sized-up the situation, they can decide what to do next. A second reason that hospital and firefighting contexts are similar is because their hierarchical pecking orders involve less-experienced organization members learning from more-experienced members. Barton and Sutcliffe found that the difference in experience level tended to cause the less-experienced, lower-status firefighters to question themselves. This is the dynamic that Blatt et al. explored between medical Interns and their Attending Physician supervisors in the hospital context. They found that speaking up was not just constrained by status, as Barton and Sutcliffe's findings indicated, their study pointed to several other factors including lower ranking members' beliefs that there is something they can do to mitigate or correct the situation, whether they were confident in voicing a concern, and whether they anticipated that there would be a negative social outcome if they were to say something.

The studies discussed above have primarily identified ways that the social environment discourages members from voicing concerns. These studies point to ways that status differences cause members to resist questioning another member's evaluation of a situation, and they unpack the ways that social constraints cause organization members to *question their own assessments*. This is an important safety concern because firefighting requires that firefighters have an awareness of what is going on around them, the ability to paint a sensible picture of how various factors influence one another (e.g., fire behavior, weather, terrain, etc.), and the confidence to act decisively. Doubting the importance of what one sees can be deadly. Previous studies have revealed important findings addressing reasons why--and circumstances under which--organization members may doubt themselves or choose not to voice a concern. However, the opposite question is equally compelling because it points to ways that firefighters overcome social constraints. This is more than just a sense of self-confidence. Rather, it points to a person's deep belief in the importance of what he or she sees in the social and material environments, and how that is tied to personal experience. So to offer a new perspective, this study focuses on an issue overlooked in previous research on wildland firefighters: How do firefighters' experiences help them to *trust* their own assessments? Exploring this question may help us uncover ways that wildland firefighters' confidence is rooted in their lived fireline experiences. The following research question is proposed:

RQ: How do wildland firefighters' narratives about their fireline experiences reflect how they have developed trust in their own abilities to make sense of fireline circumstances?

**Methods**

This study involves individual in-depth interviews following a semi-structured interview protocol. I asked wildland firefighters to talk about pivotal fire experiences. Pivotal experiences are those that are particularly memorable because they contain at least one important take-away lesson. I asked them to tell me about pivotal experience that they felt had meaningfully contributed to their knowledge base as firefighters. I told them that a pivotal experience could involve any kind of situation they have encountered as a firefighter, whether it be about engaging with flames, being surprised by something, taking on leadership roles, performing helitack, managing social situations, etc. The most important thing was that they felt the lesson learned from the experience was of critical importance to them. The specific interview question was, "Are there experiences you've had on the fireline, working with helicopters or with other firefighters that you consider to have been pivotal learning experiences for you?" If interviewees had a difficult time pinpointing a story to tell, I asked a more pointed version of the question designed to probe for specific experiences that firefighters associated with specific lessons, "Are there experiences you relive in your mind, situations where you wish you had done something differently, spoken up, or made a different decision?"

**Participants.** Participants included 27 heli-rappel/helitack wildland firefighters from two geographically distant crews. There were 15 participants (12 male, 3 female) from the West Fork[1] crew located in Region 4, and 12 participants (11 male, 1 female) from the Manzanita crew located in Region 5. The majority of the interviews lasted between 45 to 90 minutes, depending on participant's levels of elaboration. Four of the interviews were approximately 30 minutes. Of those, two were cut short due to the crew being called to respond to fires,[2] and the other two were shorter due to participants' narrative styles. Many firefighters talked about more than one experience, resulting in a total of 58 narratives about pivotal fireline experiences.

**Data analysis.** Firefighter's narratives were analyzed using a narrative analysis approach (Labov and Waletsky, 1967; Labov & Fanshel, 1977; Labov, 1997, 2001; Squire, 2005). According to Labov and Waletsky, there are six basic narrative elements: An *abstract* indicates what the story is about. The individual sets up the scene with *orientation* details. *Complicating actions* describe 'what happens next' and are the events that drive the story forward. *Evaluative clauses* refer to what the storyteller sees as the human consequences of an event. The *resolution* is how the story ended. And the *coda* links the story to the present by indicating what the narrator learned from the event, how the event has influenced his or her later actions.

First, I coded each narrative for the six narrative elements. This first step was necessary so that I could then "dissect" and compare the narrative elements of one firefighter's narratives to another's. Second, I sorted the narratives into groups based on the prominent narrative elements present in them. For example, I grouped together narratives in which participants gave extensive accounts of *orientation* information such as detailed accounts of the terrain, weather, fire behavior, etc. Another grouping of stories included those that seemed to be driven by *complicating events* in which the participant was surprised by a decision or mistake made by a supervisor or co-worker, or the participant did not agree with the the group's actions in response to something. Third, I read through the stories within each of the groupings, looking for the ways that the *codas*--or takeaway lessons from the event--related back to the other narrative elements in the stories. From this I further classified the stories into numerous categories of themes. I selected the four themes that most strongly answered the research question. The themes include: 1) Developing a technique for organizing details, 2) Developing a technique for trusting others, 3) Recognizing one's readiness for more responsibility, and 4) Perfecting a reasoning process.

## Findings and Discussion

The goal of this paper is to uncover how firefighters' previous experiences help them to develop as firefighters, coming to trust their abilities to make sense of ambiguous fireline circumstances, to manage conflicting objectives, and to negotiate the social environment. The interviews reveal that the majority of the participant's stories about coming to trust themselves followed one of four themes. In order to illustrate the themes and lessons to the fullest possible extent, I have selected one exemplary narrative to discuss in detail for each theme.

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[1] Pseudonyms have been used instead of the actual names of crews and participants.
[2] I was unable to follow-up with these two participants because their crew's season ended shortly after my initial interviews with them.

**Theme #1: Developing a technique for organizing details**

Stories related to developing a technique for organizing details involve situations in which the firefighter takes part in a new task or operation (e.g., learning to rappel, entering a new specialty, figuring out various gear, etc.). They discuss the events by which they encountered the complexities in the environment or task, observed the potential for mistakes with undesirable and possibly major consequences, and described how they devised a way to manage those details.

Ryan (West Fork) talked about his transition from being a "spotter" for helicopter rappelling on a light helicopter to spotting on a medium helicopter. He described how the set-up of the gear is different between the two kinds of helicopters and he explained that the procedures for the rappel operations are completely different too. In order to manage all of the details, Ryan said he came up with his own "system" or technique that made sense to him and that he could remember.

"When I came from [being a rappel spotter] on a light to the medium helicopter, the spotting was a whole lot different, and everything's different in the aircrafts. I started immediately, like when I got here, they started putting me through their spotter training here. And just watching the spotters, how they loaded the machine, checked how their folks' loaded machine, which side they started on, which side they finished on. And I basically watched all those guys and then I built my own way of how I do it. So that helped me become a better spotter and then figure out my system, which works for me when I'm checking them, loading them in the aircraft, and then checking everything in the aircraft. So yeah, I learned a lot by just watching."

Ryan's technique helped him remember the numerous details associated with the rappel configuration and procedures. His system allowed him to observe other spotters and model specific behaviors. Modeling their behaviors helped him to remember the numerous details associated with the rappel configuration and procedures. Also, because he was familiar with the specific techniques and steps that other spotters used, he felt his system of carefully watching others functioned as a check on the system.

"If I'm in the back and somebody else is spotting, one of the other spotters, I know my system, and then I'll watch theirs, and it is so close. It is very close. There are tiny little differences between all of us. Knowing my system and then watching theirs, it helps me see if maybe they forgot something. Or vice versa, if I forgot something, they can catch it…I do everything my way, in a way that works for me. Because then I don't second-guess myself. If I deviate from the way I do things, then I'll start second-guessing myself, and then I start thinking I may have missed something. And then it just starts snowballing in my head, and it just throws me out of whack in a hurry."

For a highly complex and tightly-ordered procedure like heli-rappelling, it is important for spotters not only to know what they are doing, but also to know that they can *trust* what they are doing. Ryan's technique for managing the complexities and procedure of spotting for rappels is rooted in his own logic—a logic that makes sense to him. While other spotters may approach the activity differently than he does, Ryan knows that he can trust his own technique in addition to potentially catching errors that other spotters make.

**Theme #2: Developing a technique for trusting others**

Stories related to *developing a technique for trusting others* involve situations in which a member describes a situation in which they took for granted their trust in another firefighter (usually a supervisor) who surprises them by making a "stupid" mistake. From this type of incident, the individual devises a set of criteria to use in the future when evaluating the trustworthiness of others.

Carly (Manzanita) described an experience from her first fire season working on an engine. In it, she observed her foreman making an elementary mistake.

"The first fire I ever responded to on the engine was on [an island] and we rode out there on a hovercraft. But we were told in briefing, in order to get on these hovercrafts, everything [on the engine] had to be closed down: doors, windows, *all* the doors. Everything had to be zip tied down because these props on the back of these things are so strong they can literally suck the doors off of Humvees."

Carly described how the instructions for safely loading the engine onto the hovercraft were very clear and explicit, and the dangers associated with not following the instructions were also very clearly stated. Because of this, she was surprised when her engine captain made a mistake that endangered the operation of the hovercraft.

"And so it was about 4:00 in the morning. We're going out, and all of a sudden my captain grabs his door. And it won't stop, it won't stop shaking. He's like, 'oh my God. We're going to lose the door.' And so he has us turn on the lights and sirens. And [military hovercraft operators] stop, and they come over. And they're like, 'what's wrong?' And he's like 'I didn't have my door closed all the way.' And the [military] guy was like, 'you don't know how to follow directions?' But to me it was like, wow. To me it was weird, because in fire I had never seen my overhead make a mistake that could have been multiple millions of dollars worth of damage. Here we are going out to our very first fire, and now I'm going 'okay, do I trust him?'"

Carly said this was the first time she had seen a supervisor make such a potentially catastrophic mistake. She described her reaction to the mistake as partly about recognizing that the captain is human, and therefore, fallible. But she also said that her reaction to that mistake affected her in a much more far-reaching way because that incident caused her to question her trust in every person with whom she works. As a result, she recognizes that everybody is fallible, but she feels she can mitigate for that fallibility by trying to understand how people think, and whether she can follow their logic in whatever task they may be performing.

"And it's just one of those things that your supervisors are fallible and trust is a fragile, it can be a very fragile thing. But for me, coming into it from a different perspective, I just thought they were all super heroes and I just do whatever they say and it's totally okay. [But after that experience] it's kind of like oh, maybe I need to think about it first." [That experience] helped me to probably develop a method for me to learn to trust people. And it's not just with supervisors. It's also with other new employees, new seasonals. And it's just one of those things where it takes me a little bit longer to figure them out and figure out: do I trust this person's thought process? Do I trust this person's logic? It's the whole process behind our lookouts that we have up on the hill: Who do you want there? Somebody that you trust, that's experienced, that you trust their logic, you trust them to know when it's time to go before it needs to be something that becomes necessary."

Further, Carly goes on to say that being able to size-up the human dynamics of the people she works with was a somewhat surprising component of firefighter safety.

"My entire first year in fire was about working relationships—how crucial those are to functioning efficiently…learning the different mechanics of different people and being able to identify potential issues or preventing unnecessary chains of reaction."

Stories like Carly's that address the human dynamics of firefighting are important because the firefighters who tell these stories often express a sense of surprise at just how important their working relationships--the types of interactions they have with other firefighters--

are to their safety. While there has been an increased focus in recent years on training firefighters to recognize “human factors,” firefighters’ stories still reflect a sense of wonder that sizing-up the people they work with is just as important as sizing-up the conditions they face on a fire.
This story theme, *developing a technique for trusting others*, highlights an additional way the firefighters come to trust themselves in fireline circumstances. By recognizing that human interactions greatly contribute to fireline safety, firefighters are able to devise ways to mitigate for potential hazards that result from their working relationships. Carly’s story demonstrates the specific way she goes about evaluating her relationships: She observes others to see whether she can trust their “thought processes” and prevent “unnecessary chains of reaction.”

**Theme #3: Recognizing one’s readiness for more responsibility**

Stories related to this pattern involve a transformation in how individuals see their responsibility or role in a situation. These stories tend to involve members seeing themselves as more experienced than they previously thought, or they realize they are ready to assume a higher level of authority or responsibility under similar future circumstances.

Stuart (West Fork) described a fire experience in which he was working with a module of members from his own crew on a particularly active fire. He observed the conditions and decided on a plan that seemed to make the most sense. He was one of the least experienced firefighters on his crew and encountered resistance from another more experienced crewmember. Through this story, he started to see himself less as a newcomer and more as a firefighter who has valuable experience and ideas. Stuart began his account by describing the terrain, fuel, fire behavior, and his "instinct reaction" to the situation.

"We got to this section of brushy, thick stuff. The fire had kind of stalled out in there--there’s probably leaf litter in there; it’s going to punk around for a while. And there was a 50-foot swathe, 100-foot swathe of grass on the other side of it. And that didn’t really connect to a whole lot, but you never know. As the three of us got to that area, my instinct reaction was, we need to burn that [swathe of grass] out. There’s about a 100-foot long section of brush, and it’s pretty thick. So there’s no reason for the three of us to get in there and try to handle it. We should just cut it off [by burning the grass] and be done with it and have this big nice black buffer between [the brush] and the line."

Stuart was excited about his plan to burn the swathe of grass because it meant that the three-person module would not have to lose time by becoming entangled in a patch of brush. His plan made the most logical sense to him. However, it was a bold plan, one that is typically suggested by firefighters higher in the chain-of-command or with more fire experience than he had at that time.

"And we debated about it in our little module. I don’t have any hotshot experience, so I don’t have a whole lot of experience with big fire, a little bit, but not a lot, not certainly, as much as them. But I have been in roles where I’ve been making those kinds of decisions more, being right next to the engine boss or the squad boss or whatever or the manager when they’re discussing their options and thinking about their decision. And so I feel like there was one guy [with hotshot experience] that was kind of resistant to that. He was like, ‘you just want to burn stuff.’ I’m like, ‘well, yeah, kind of, but it’s also the easiest way to deal with it.’"

Stuart explained that even though he encountered some resistance from a more experienced crewmember, he was adamant that his idea to burn out the swathe of grass made the most sense under the circumstances and sought a second opinion from a respected crewmember who was working adjacent to them on the fire.

"I ended up talking to [a more experienced crewmember in a higher level of command] and kind of mentioned it, painted the situation for him. He's like, 'well, if you guys need to burn it off to get it done, do it.' I was like, 'yes, thank you.' Because it verified what my initial reaction was and was the easiest option."

Stuart goes on to say that this experience showed him that he has reached a point in his fire career where he sees himself and his fire background as being more valuable than he previously had thought. He says that even though he's relatively new to fire and has not worked on a hotshot crew (like many of his fellow crewmembers have) where he would see more "big fire," he is beginning to see that he does have quality experience and valuable insights to offer.

"The lesson I took home was that I need to forget sometimes that I haven't been on a hotshot crew. That weighs on me a lot of times. I let that shape my confidence in myself and my decision-making and also just the fact that I've only been in fire for four years, and most people I've worked with have been in for more than that, typically, and with special crew experience, most of them. So anyways, it helped me understand that I need to be the stronger voice--to say: I know this is what we need to do. This is the right way to do it--not cram it down their throats--but be a little bit more strong, less passive."

Stuart's account illustrates an important transition in how he sees himself. Through this experience he realizes that he no longer sees the fire environment through the eyes of a newcomer. Rather, he is beginning to assess situations from the perspective of a knowledgeable firefighter. This is an important transition to examine because wildland firefighters' career paths vary greatly from one person to the next. Even though all firefighters ultimately manage the same fireline hazards, they must first become acquainted with the realities of those hazards--what they look like, how they play out. They must see the strategies and tactics enacted to deal with fireline conditions and situations, which are managed in different ways depending on the crew's specialty and that specialty's capabilities (e.g., engine, hotshot, helitack, etc.).

Also important is that Stuart indicates his impression that experience in some specialties is considered to be more valuable than others. Stuart's primary background had been working on an engine, and in his story, he indicates that his lack of hotshot experience has made him question himself. Specifically, he sees his assessment of a fire situation--as someone with primarily engine experience--as less valuable than assessments by those with any amount of hotshot experience. Stuart's story illustrates an experience in which he overcame that perception and saw that he did not need to question himself. This is because, from that particular experience, he was able to devise a strategy, test it, and see that it worked well with the fireline conditions.

**Theme #4: Perfecting a reasoning process**

Stories related to *perfecting a reasoning process* involve situations in which firefighters describe the environmental conditions in detail, including fire behavior, weather, terrain, and tactical moves. They explain their initial assessment, and describe how their resulting plan made the most sense given the circumstances. Through the course of the narrative, one or a few key events occur, which require a change in plans, and cause them to reconsider the importance of some of the initial conditions they encountered. Nearly every story in this theme related to escape routes and safety zones that turned out to be inadequate. Since most of the stories were about identifying escape routes and safety zones, the focus is on how the individual assesses the fire environment. The role of the social environment also is present but it is less obvious. Instead of referring to specific social interactions, the participants talked about their use of standard procedures (e.g., 10 Standard Firefighting Orders, 18 Situations that Shout “Watchout,” etc.). What makes these standard procedures social is that firefighters talk about the typical ways their crews go about implementing these safety precautions. These narratives are particularly memorable for firefighters because they are instances in which they felt they took all of the precautions typically accepted as their crews’ normal ways of implementing safety, but they still ended up in unsafe situations.

Paul (West Fork) described a situation in which the primary objective was to cut a helispot for a large helicopter. He has identified ‘Lookouts, Communications, Escape Routes, and Safety Zones’ (LCES), and an increase in fire behavior later in the day causes them to retreat to their safety zone via their escape route. Through this process, Paul recognized that helitack sometimes involves managing both firefighting and helicopter safety, the objectives of which sometimes conflict. In recognizing this, he hones his reasoning process in order to account for the decisions he has made and anticipates how he would manage competing priorities in the future.

"[We were] cutting out a helispot for a Type 1 aircraft. Going into it, flying over the fire, we saw that there’s not a lot of activity on the fire and [were] thinking that, oh, this is a fine spot. We’re not in the black, but the black is ten minutes distance away, so if something is to happen, we can hike out of it, hopefully, fast enough to get to a safety zone, and having a lookout also readily available. So I guess with that situation, I mean, everything seemed normal."

In addition to establishing an escape route and safety zone, Paul described that he also had a lookout and communication in place, completing the LCES requirements for safe fireline operations. He indicated that the situation they encountered and their plan to mitigate hazards was similar to what they usually do—it was a “normal” situation.

"So as we were cutting out the helispot, we had one person that was on the radio, which is pivotal. So while two chainsaws are running, obviously, you can’t be listening to your radio as you’re running your chainsaw. So there was somebody there that was managing the radio, and they got a call, not from our lookout, but from a hotshot crew. They were saying activity was picking up, and the fire was coming our way, and we should look at getting out of there."

Paul goes on to say that the safety precautions they put in place were based on their view of a relatively inactive fire earlier in the day. Even though they had LCES in place, their plan did not account for the severity of conditions they were to experience later in the afternoon, conditions they may have known about had they had the opportunity to observe the fire behavior during previous burn cycles over the previous days.

“It was our first few days actually going out on the fireline. We hadn’t been out, I don’t think, the day before, so we hadn’t seen what the activity is like at certain hours of the day, and perhaps, if we had known what it’s like, say, at 1300. I think the fire had been doing that continuously every day at a certain hour, really picking up. Because from our perspective, when you looked over the fire as we flew to where we were going, everything was dead, and there were just little bits of smoke. [We didn't expect it to] immediately turn into a huge, giant column coming towards us. So I guess that’s the big thing to learn is just always be ready, have your safety zone prepared and your routes to getting there, and make sure that you can make it within the time, based on what you think could come your way, and always have lookouts.”

Paul’s takeaway lesson from this experience was to make sure that escape routes and safety zones were not only in place, but also useable. This may seem obvious, however, Paul’s account highlights his routine way of providing for LCES, and the lesson from his story points to an important assumption underlying this routine. The assumption is that having an escape route and safety zone *in mind* is enough. The lesson he took from the experience is that it is not enough to simply identify an escape route and safety zone; firefighters must do so with the expectation that they may have to use them. Further, Paul's account points to the added complexity of managing helitack objectives in addition to firefighting objectives.

"The idea was to have the helispot outside of the black, because it was a flatter area, and with a Type 1 aircraft, they’re usually wheeled, and they need quite a large area to land in. And the slope was an issue with most of the spots in the black. And so in this instance, it was probably better just to stick with [standard procedure], have it in the black, and that way you wouldn’t run into the risks that we obviously ran into."

Paul's objective, first and foremost, was to cut a helispot that would be safe for landing a very large helicopter. However, the safest landing zone was in an area of unburned fuel, which compromised his safety. Knowing that this was the case, Paul mitigated for the added hazard of working in unburned fuel by ensuring he had deliberately accounted for LCES. His reasoning reflects that he managed both helitack and fireline objectives, but privileged the helitack objectives because they were of the most immediate concern when initially devising the plan.

Paul's example is a useful illustration of the conflicting objectives that firefighters often encounter. While the fire environment poses any number of dangers, working with helicopters poses an entirely different, and added, set of dangers that are just as potentially lethal. Paul's story highlights his reasoning process--how he defends, justifies and critiques the reasons why his decisions did (and did not) work in this circumstance. Paul's story of how he reasoned through his decisions enables us to see the ways that one compelling set of objectives (e.g., building the safest possible helispot) sometimes conflicts with other equally compelling objectives (e.g., maintaining a safe proximity to the black). His story allows us to see how he observed the conditions, and chose one line of logic to follow, a logic that put helitack safety concerns in the forefront. He then developed a plan, mitigated for safety, encountered unexpected fire intensity, and was then forced to prioritize fireline safety guidelines. From this event, he ultimately developed a wider understanding of potential dangers he must consider in his reasoning process in the future as he balances helitack and fireline safety.

## Conclusion

These stories illustrate types of ‘slides,’ a term wildland firefighters often use to refer to memorable experiences of enacting the tasks of firefighting. As a result of their ‘slides,’ firefighters talk about coming to deeper understandings of fireline situations and reflect on ways to act knowledgeably and decisively in the future. Their ‘slides’ become the foundation on which they build a sense of trust in their enacted experiences. The four story themes identified above illustrate key dimensions for the ways that wildland firefighters come to trust themselves by developing techniques for managing details, evaluating other firefighters’ logic and thought processes, recognizing the value of their previous experiences, and perfecting the ways that they have made sense of fireline experiences through reflection on the ways they fulfilled various objectives. Firefighting is ultimately a social process that plays out in an ambiguous and complex environment. As Barton and Sutcliffe (2009) note, one mechanism for maintaining reliably safe operations includes firefighters voicing their concerns. This interrupts chains of errors and forces firefighters to re-evaluate their observations and decisions. However, this process is inhibited when firefighters are not able to trust the importance of their experience—when they doubt their assessments. The story themes presented in this study extend Barton and Sutcliffe's work by highlighting the kinds of experiences that have helped firefighters to trust themselves as knowledgeable contributors to firefighting processes.

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# *Lessons Learned Mapping System and Facilitated Learning Analysis-Google (FLAG)

Matt Gibson[AB], Bill Phillips[A], Ben Murphy[A]

[A]US Forest Service, Building 24A, Fort Missoula Road, Missoula, Montana, 59804, USA, mbgibson@fs.fed.us
[B]Corresponding Author

**Abstract:**

The Geospatial Equipment and Technology Application Group (GETA) would like to present The Lessons Learned Mapping System, a map-based display of common information regarding an event in the wildland fire community. We are currently working with the fire fatality database to display locations of each incident in Google Earth. Simple geo-referencing can be done to achieve this map, so "theme" based maps can be created to identify trends and characteristics that also allows the viewer to see the terrain where the accident happened. Other datasets will be incorporated into the system in the future.

Each incident can then be explored further with a Facilitated Learning Analysis-Google or FLAG that takes the official review and converts it to a companion file in Google Earth. The FLAG can then be used as a standalone version of the report, or viewed simultaneously to enhance the viewer's understanding of the event. We are also recreating accident scenes with 3D models for smaller-scale events.

FLAGs, movies, news articles, 3 dimensional models, and most other digital formats housed on the internet can then be linked into the Lessons Learned Mapping System which automatically updates on the end-user's file within Google Earth.

*Abstract appears as it was originally submitted.

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# Beyond the AAR: The Action Review Cycle (ARC)

Michael T. DeGrosky[A]
Charles S. Parry[B]

[A]Guidance Group, Inc., 613 Bryden Ave. Ste. C #331, Lewiston, ID 83501 USA, guidancegroup@cableone.net
[B]Signet Research & Consulting LLC, 198 Bryant Road, Jaffrey NH 03452 USA, cparry@signetconsulting.com

## Abstract:

The authors describe the Action Review Cycle (ARC) as a logical next step from the current use of After Action Reviews (AAR) in the wildland fire service. The change described offers significant positive implications for wildland firefighter safety, builds on the solid foundation provided by the current approach, and extends existing practices into more robust ones. A shift to the ARC would place the AAR into an integrated cycle, magnify its contribution, and focus its conduct. In everyday practice the ARC strengthens the integration of multi-unit efforts and infuses learning into the conduct of work. Accomplishing a shift to ARC involves introducing Before Action Reviews (BAR), and interlinking leader's intent, planning, preparing, acting and reviewing as a cycle–a cycle that wildland fire personnel already intuitively understand. ARC makes the integration explicit, and keeps learning through AARs worthwhile to those taking the time to do it. The authors suggest that a shift to ARC might not be difficult for wildland fire agencies as most of the elements are already in place, and that by making this strategic shift the agencies will create valuable benefits that AARs alone will not produce.

**Additional Keywords:** After-Action Review (AAR), Action Review Cycle (ARC), Before-Action Review (BAR), Leader's Intent, firefighter safety, organizational learning

## Introduction

A learning organization is "…skilled at creating, acquiring, interpreting, transferring, and retaining knowledge, and at purposefully modifying its behavior to reflect new knowledge and insights" (Garvin 2000 p. 11). As a tool supporting organizational learning, the After-Action Review (AAR) has drawn much interest because it provides a simple structure enabling teams to learn from their daily experiences and improve the results they achieve. Yet, beyond being a field-level technique for performance improvement, AAR processes also hold the potential to move organizations toward greater agility in facing dynamic situations, by building a learning culture that continually strengthens the organization's ability to achieve its mission. Peter Senge, a prominent figure in formulating the learning organization as a concept, said "The Army's After Action Review (AAR) is arguably one of the most successful organizational learning methods yet devised" (Senge, pers. comm.. with Darling and Parry, December 2000).

*Origins of the AAR*

The story of AARs as an organizational learning tool, now in its 4th decade, begins with its origin at the U.S. Army's National Training Center (NTC) in the 1970's. The NTC was created to transform the way the Army built unit readiness and developed its leaders–by engaging them in intense, extremely realistic battles against a highly capable enemy force convincingly played by another Army unit (referred to as OPFOR). During these battles, the opposing units interspersed frequent reviews throughout the action. The approach proved highly effective, and After-Action Reviews became a well-established part of both Army culture and standard procedure in both training and operations. As generations of soldiers rotated through the NTC, the methodology evolved, and AARs eventually escaped the bounds of the NTC.

*AARs in the Wildland Fire Service*

Successful fire management organizations share many of the dynamics the military faces on the battlefield. For example, both confront fast changing, complex situations in which lives are at risk, and for both, inter-unit coordination and communication prove critical. So it seems quite reasonable to expect that methods that the military find effective in improving performance would translate quite well to the world of fire management.

The impetus to adopt the AAR from the military first came to U.S. wildland fire agencies in the late 1990s within the context of a grassroots effort. That effort came both in the wake of the South Canyon Fire and in response to exposure to ideas advanced at the first Human Factors Workshop. Much of that effort grew out of the initiative of (recent International Association of Wildland Fire Safety Award recipient) Jim Cook, Training Projects Coordinator for the U.S. Forest Service's Fire and Aviation Management program. According to Cook, he and his collaborators were acquiring potential solutions with promise from many sources, rapidly prototyping them, and seeing what worked. At the time, their intent was to quickly find solutions to pressing organizational needs through trial and error, not necessarily to achieve optimal design and performance. A group of Interagency Hotshot Crew (IHC) Superintendents gained exposure to the AAR through this budding human factors and leadership training effort, then modeled and pioneered the concept in their agencies. This body of practices would later become the training curriculum of the National Wildfire Coordinating Group (NWCG) Wildland Fire Leadership Development Program (WFLDP) (Cook, pers. comm. with DeGrosky, October 25 & 26, 2004).

As the NWCG leadership training initiative evolved and eventually gained full management support, what is now the WFLDP introduced thousands of emerging leaders to the AAR process. AAR implementation in NWCG agencies accelerated rapidly in 2002 when guidance for the conduct of AARs appeared in the NWCG Incident Response Pocket Guide (IRPG) and the Wildland Fire Lessons Learned Center conducted a series of AAR train-the-trainer workshops.
Owing to the success of these initiatives, a significant part of the wildland fire workforce now knows the purpose and intent of the AAR, and many crews, modules, teams, and organizations conduct some type of AAR process.

Research into current AAR practices in wildland fire agencies is limited. However, while little hard data exists, available data collected both anecdotally and through a single quasi-experimental study, suggest that, as a tool of organizational learning, AARs may not be influencing wildland fire operations as thoroughly as might be hoped (DeGrosky 2005). That is not to suggest that the agencies have underachieved in their effort to adopt the AAR as a technique for reviewing experience with the intent of improving performance. Indeed, the AAR concept also evolved slowly (over 20 years) in the U.S. Army, who created the process. (Garvin, 2000; Parry and Darling 2001). The research that has been done suggests that perceptions exist that an AAR represents an administrative requirement, something to be endured, or a one-off, stand-alone event (DeGrosky 2005).

Darling and Parry (2000) found that many organizations that had attempted to import the AAR to use it within their operations as a path to becoming learning organizations had fallen short, and few had succeeded in making AARs part of their culture. Though Darling and Parry's study did not include wildland fire agencies, their findings provide some insights about causes and solutions that may apply, so an excerpt of those findings follows.

*The Struggle to Transport AARs to Civilian Organizations*
Darling and Parry (2000) found that most early AAR adopters simply did not transport enough of the way the Army used AARs to make it a living practice. The most common error was holding AARs infrequently as ad-hoc responses to an event or problem–often a post-mortem of a failure. This removed AARs from the normal context of, and mechanisms for, planning and taking action. According to Darling and Parry, AARs conducted outside of a regular context very rarely enhance future performance. In workplaces where AARs were not a regular part of how leaders lead, AARs happened infrequently or (if they were mandated) people often treated them as a check-the-box exercise. By way of contrast, the Army considers leading AARs a critical part of leadership behavior (Shinseki and Hesselbein 2004, p. 138).

Parry and Darling (2001) also found that a knowledge-management mindset led some organizations to introduce AARs to generate comprehensive understanding about a past event or to capture knowledge–rather than to generate actionable insights. Though initially successful, in some cases, over time this practice diminished the level of candor and the willingness to take the time to do AARs. In some settings AAR participants were expected to produce a set of recommendations for unspecified others to implement. When this happened, no one was accountable for action, so recommendations gathered dust. By contrast, Army AARs are strongly focused on producing action items that the team itself will take. In the course of Darling and Parry's (2000) research, several Army leaders underlined this point by saying that, in practice, the AAR meeting represents only the middle third of a successful AAR, with the first third being preparation, and the all-important last third being active follow through. Failing to generate actionable improvements for AAR participants becomes a critical point of AAR failure, because the energy that fuels the sustained use of any tool comes when people see better outcomes from the time they invested in using that tool.

According to Parry, Darling and Robbins (1997), well-intended efforts to transfer best practices to a different context often fail, and such disappointments typically begin when practitioners miss interdependencies between the practice and other tools, structures and norms in the original setting. Every practice has what can be called an "inside" (the process steps, skills and behaviors) and an "outside" (the connecting points into its context - the critical elements of its ecosystem). The outside can often prove fairly invisible, complex, and difficult to untangle, yet is part and parcel of the success of the practice. So for propagation of a practice to succeed, one must discover which of these outside connecting points were critical to its success in the original setting, and then find or build equivalents of these connections in the new setting.

In their efforts to transplant AARs from their Army context, most early adopter organizations took the inside–the AAR meeting (the four questions, ground rules, etc.) out of the Army's rich web of interlaced practices (the AAR's outside) and tried to grow the AAR in their own settings– as a stand-alone practice. Consequently, they failed to bring along critical elements of context that AARs need to thrive (Parry and Darling 2000). Peter Senge broke it down this way, " . . . most every corporate effort to graft this truly innovative practice into their culture has failed because, again and again, people reduce the living practice to a sterile technique . . . the crucial difference lies in the synergy between culture and method" (Senge, pers. comm.. with Darling and Parry, December, 2000)

**Beyond the AAR: The Action Review Cycle (ARC)**

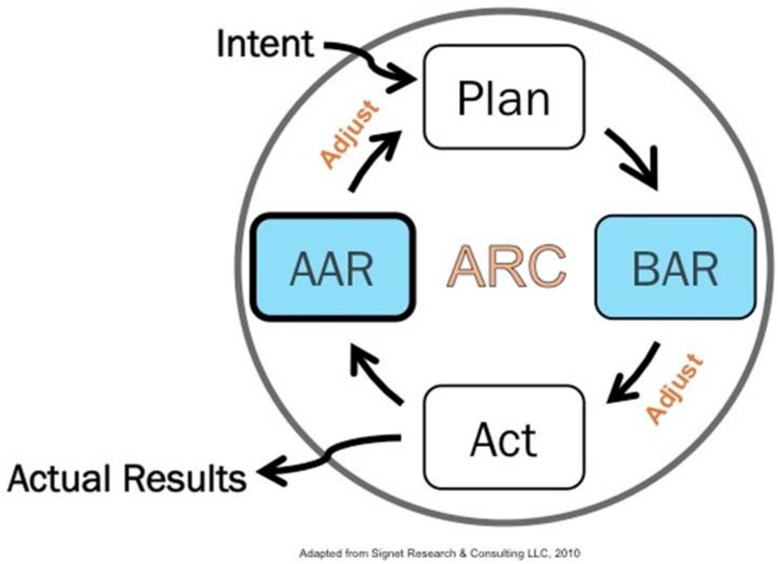
In looking at examples of strong success in applying AARs outside the Army context, Parry and Darling (2001) found that the most successful adopters had used AARs as an iterative, forward-focused regular practice that became part of how the team's own work was accomplished. This orientation worked because it paved the way for the team to make improvements through the team's own local action. This in turn fueled participation because people saw the time they had spent in AARs producing a tangible impact. Darling and Parry (2000) posited that over time, local success with improving results, through AARs, increases the interest in seeking out applicable improvements developed by other teams, which sets a positive cycle in motion serving as a key ingredient in shaping a culture of learning in the overall organization.

Subsequent research by Darling, Parry and Moore (2005), led them to a gold-standard AAR practitioner that strongly shaped their thinking about how to upgrade the concept and practice of AARs. That gold standard practitioner was the OPFOR at the U.S. Army's NTC. OPFOR's purpose is to be a worthy adversary on the battlefield so that every brigade deployed to the NTC for training improves its performance. That means that the OPFOR must be capable of humbling any unit that comes up against them throughout ever-changing scenarios. Consequently, the OPFOR must learn and adapt very quickly as a unit, during mission execution, and every day. In addressing why they were publishing an in-depth article about a military organization in a premier business publication, Harvard Business Review's Executive Editor described the NTC's OPFOR as very likely the world's premier learning organization – quite an accolade (personal communication with Darling and Parry, 2004).

Darling and Parry were drawn to studying OPFOR for two pragmatic reasons; demonstrated strategic impact and the sustainability of its use of AARs. This organization had taken the AAR out of its original application as a training technique and applied it to shape an agile learning organization – with impressive results. Second, by building an AAR cycle into their everyday work without the benefit of extra specialized staffing (such as observers or facilitators), OPFOR had demonstrated that an mid-sized organization without a lot of supplemental resources could make AARs a sustainable practice, and make it an every-day part of the way the organization operated (Darling, Parry and Moore 2005).

Finally, Darling, Parry and Moore (2005) established that, at its origins and at the hands of its best practitioners, the AAR was only one element in a complete organizational learning cycle, and that this fact proved essential to its potency and efficiency. This cycle included communicating intent, planning, preparation, action, review, and follow-through that informed future intent and planning, and so on.

In 2006, Parry, Pires and Sparkes-Guber (2007) presented a concept that would return the AAR to its proper function as a part of an integrated cycle, prove portable to other contexts, and re-establish the AAR as a potential toolset for building a culture of organizational learning. They chose the name Action Review Cycle (ARC) to differentiate the integrated cycle from its well-known element (the AAR meeting) and to escape the problematic bias created by the term "after-action." Note that, while an AAR meeting does occur after a unit of action, as used by its most successful practitioners, it is used regularly and iteratively enough that it could be as accurately described as occurring *between* units of action. By 2008, Parry et al. had applied the ARC model in a wide range of settings, refining it along the way. Through application in the energy, consumer products, manufacturing, mining, finance, philanthropy, IT, education, and insurance sectors, the ARC cycle had proven itself a useful upgrade to AAR-only approaches.




ARC consists of three elements (Leader's Intent, BAR, and AAR) that fit into the flow of existing work processes (such as planning and action). The three ARC elements all reference one another and, over time, reinforce one another in team processes. When embedded in existing cycles of work, they also act to keep a clear shared picture of intent in the front of everyone's mind, and over time refine the quality of thinking and accountability that goes into formulating intent, plans, preparation and communication.

**Applying ARC in wildland fire agencies**

Learning about the AAR technique outside of the context of a complete cycle of intent, planning, preparation, action, review and follow-through appears to limit its utility in wildland fire agencies, just as it has in other civilian settings. While wildland fire personnel intuitively understand the complete cycle of leader's intent, BAR, and AAR within the flow of planning and action; they typically have not learned about the AAR in this context.

ARC repositions AARs as one of the elements of the complete cycle. The current WFLDP curriculum incorporates concepts that align well with the ARC. The WFLDP already includes leader's intent and planning as key concepts, strives to prepare participants with effective briefing skills, and teaches developing leaders to conduct AARs as standard procedure. Consequently, wildland fire agencies could adopt the ARC concept with relative ease. It is the authors' contention that a few steps would achieve this:

1. Enhance the existing approach to leader's intent, focused on building and verifying a more robust, shared understanding of the intent;
2. Modify and expand existing briefing approaches to include the four elements of a Before Action Review (BAR);
3. Present the concepts of leader's intent, planning, BAR and AAR as a holistic cycle that integrates leading, learning and execution.
4. Consider whether the cycle is being practiced in the places where it will provide greatest value in improved performance and in the shaping of a learning organization;
5. Strive to make it a norm that part of leading is leading learning, and that this is done by participation in learning both before and after firefighting engagements.

*The first element of ARC: Leader's Intent*
Wildland fire personnel currently learn a conventional, military inspired approach to leader's intent in which task, purpose, and end-state form its three essential parts. Shattuck (2000) made a clear case for the importance of clarity and communication of intent in the military, while also documenting a widespread lack of consistency in its formulation and in its practice. Parry had observed this inconsistency as widespread in the civilian world as well–clarity was often assumed to exist even when in fact it did not, and, when intent was unclear (or had changed over the course of an extended piece of work), confusing, unfocused and unproductive AARs resulted.

The authors suggest that improvements can and should be made to the way that agencies in the wildland fire services develop and communicate intent. For example, historical perspectives on Commander's Intent (the military origin of leader's intent), and a contemporary perspective on leadership both suggest that leader's intent should develop interactively and collaboratively between leaders and their constituents. In Army operations the standard follow-up to a leader stating their Commander's Intent is subordinates reporting back their understanding of the intent along with a sketch of how they plan to operationalize it. This interaction has the effect of providing feedback to the leader on the clarity of their own and the team's communication and thinking, and provides an opportunity for revision, clarification and collaborative thinking. As each of the units involved in the mission brief back their understanding it becomes apparent whether an overall plan is emerging that makes sense.

Similarly, in their exploration of leader's intent in the wildland fire service, Ziegler and DeGrosky (2008) recommended that the NWCG cultivate a discussion of leader's intent that takes the concept beyond the conduit model of communication and traditional leader-centric approaches to leadership that privilege an appointed leader's meanings without acknowledging the important role followers play in constructing intent by interacting with the leader. Plans in complex situations (such as battle with an enemy unit or a wildland fire) succeed or fail in execution in large part by how the parts fit together–and by how well the constituent units can adapt to emerging changes and make sound decisions that keep efforts integrated. Without a strong, shared understanding of well-articulated intent, units within any large operation default to optimizing their decisions locally, and that can be a disaster to the overall effort.

*The second element of ARC: Before Action Review (BAR)*
The BAR is a short disciplined conversation that efficiently provides a foundation for rigorous, meaningful learning by the same people engaged in the action. It is about being prepared before launching into action; preparing to achieve the desired results together, and preparing to learn together effectively.

A BAR consists of a team addressing four items together:
What is our intent (situation, task, purpose, end state, guidance) and high-level plan?
What specific challenges do we predict that we may face?
What lessons have we (or others) identified that we should apply in this situation?
What do we think will be our key to success THIS time? (This is to focus the team effort and articulate the key hypothesis behind the plan).

By assuring a shared understanding of intent, BARs also set the stage for a rigorous and focused AAR. BARs leverage past AARs by providing a trigger by which participants remember to apply insights gained from previous AARs to upcoming actions. The AAR question about causality provides an opportunity for the team to check its thinking against what they said in the BAR. This feedback loop in turn improves the care and precision that go into subsequent BARs.

As shared understanding of intent plays a foundational role in both effective, efficient AARs and in successful operations–the first step in any BAR is to verify (and often further refine) a shared understanding of leader's intent. The BAR also provides a final opportunity to clarify any fuzziness in plans, situational awareness, assumptions, or choice-points before jumping into action.

Wildland fire personnel currently learn and practice briefing techniques and protocols, and using them represents an accepted part of the wildland fire culture. To implement the ARC, wildland fire agencies could incorporate their existing briefing concept into the more robust BAR practice. Also, when the level of complexity and/or critical interdependencies justified it, and time and resources allowed, the organization could conduct a more elaborate BAR using a walkthrough or rehearsal of the planned action on either maps or terrain models, applying BAR questions to the individual elements of the plan in order to take readiness, alignment, coordination and situational awareness to a higher level.

An effective BAR improves situational awareness and helps build humility as a strength. By asking one's team to anticipate challenges and articulate their keys to success, leaders acknowledge uncertainty and establish up-front that no plan has a 100% probability of success, which creates an opening for teams to talk about that uncertainty and prepare to handle it as best they can.

*The third element of ARC: After Action Review (AAR)*
An AAR consists of a team having a disciplined conversation, framed in the comparison of intended vs. actual results; a process that uses reflection on the past unit of shared work to shape the team members' future actions.

**Conclusion: A Strategic Shift**
The AAR has proven itself as an effective innovation for U.S. wildland fire agencies and their personnel. Yet in optimal practice the AAR represents just one part of a complete cycle–a cycle of intent, planning, preparation, action, and review. While wildland fire personnel intuitively understand this cycle, they typically have not learned about the AAR in this context, and that is limiting the AAR's utility. The authors suggest the Action Review Cycle (ARC) as a logical next step to build on the solid foundation provided by the current AAR approach in U.S. wildland fire agencies. Shifting to the ARC model offers a practical pathway to extend an existing practice widely adopted by the wildland fire service into an even more robust tool, with significant implications for improved wildland fire safety.

To move to this critical next step, the authors recommend that wildland fire agencies:

- Move quickly, firmly, and comprehensively from the AAR meeting as a stand-alone process to the ARC. The key early action is to add the BAR as a standard part of preparation for important actions.

- Engage in an intense effort to integrate ARC into operations as a fundamental and continuous organizational learning process that becomes routine, consistent, rigorous and important.

- Systematically prepare people to facilitate BARs and AARs, both as an element of the WFLDP and by employing a systematic train-the-trainer strategy.

- Consider shifting the AAR to a new set of questions, somewhat different than the four questions most wildland fire personnel have been taught.

    1. Look Forward and Focus: What situations are on the horizon where we are most likely to want or need lessons from this fire? What is our focus for this AAR (a key issue or framing question)
    2. Intent: What was our leader's intent – and what were the important gaps (plus and minus) in the intended vs. actual results?
    3. Causes: What happened that is relevant to how we got those results, what are the root causes, and did we anticipate and prepare for the challenges we faced?
    4. Lessons: What hypotheses do we have about what to take forward – what to sustain or improve and how– individually and as a team?
    5. Actions: What will each of us do as a result of this AAR conversation?

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# The Sawtooth Mountain prescribed fire burnover fatality

Richard C. McCrea[A]

[A]LarchFire LLC, 1490 Shenandoah Drive, Boise, ID, 83712, Rich.Cam.McCrea@Gmail.com

**Abstract:**

On May 14th, 2003, a firefighter was entrapped during a prescribed burn operation, on the Fort Apache Indian Reservation, in the White Mountains, in the State of Arizona, United States. This area is heavily forested and very rugged. The prescribed burn operation began on May 12 and continued on May 13 during which time 1,200 acres were ignited. On May 14th, 40 firefighters and two burn bosses were assigned to hold and patrol control lines. At approximately 2:30 pm, a lookout reported an increase in fire behavior activity. One of the burn bosses assigned to the prescribed fire indicated he would hike into the area where the fire activity had been observed. The burn boss arrived at that location, and was suddenly trapped in a fire blowup, and sustained fatal injuries. There are several management factors that contributed to this entrapment. A prescribed fire plan for this burn was completed in April of 2001 but was later rescinded. The prescribed fire was also out of prescription on the day of ignition and subsequent days. Additional contributing factors included failing to establish anchor points, and failing to identify escape routes and safety zones.

**Additional Keywords:** prescribed fire, entrapment, fire behavior

## Introduction

On May 14, 2003, a Bureau of Indian Affairs (BIA) firefighter was entrapped during a prescribed burn operation, on the Fort Apache Indian Reservation, in the White Mountains, in the State of Arizona, United States. The firefighter was assigned as a burn boss and he was fatally injured. The area where the entrapment occurred is heavily forested with pinyon pine (Pinus edulis), juniper (various species) and ponderosa pine (Pinus ponderosa). The general fuel types are timber and brush.

The brush type consists of pinyon and juniper trees, 10-15 feet tall with scattered oak and Manzanita. There is a general lack of fine fuels in this fuel type and fire spreads mainly in the crowns of the shrubs, but only with higher wind speeds. The fuel model that best depicts pinyon/juniper is shrub model SH7 (Scott and Burgen) or National Forest Fire Laboratory (NFFL) Fuel Model 4.

Timber fuels consisted of ponderosa pine, which is generally found along the canyon bottoms, north slopes and at higher elevations. Fire spread is through the pine litter, best depicted by timber/litter model TL8 (Scott and Burgen) or NFFL model 9. Fuel model 9 generally has moderate spread rates with low flame length low but extreme fire behavior can occur with crown fire. In areas of ponderosa pine, fire spread can sometimes accelerate rapidly and ignite adjacent stands of pinyon/juniper that might not burn under normal conditions.

The topography in the incident area is very rugged with a complex series of winding canyons, flat mesas, and generally rolling terrain, with some steeper slopes, up to 60%. Elevation ranges from 5200 feet to 6500 feet. The incident occurred at three intersecting drainages. The pattern of aspects and canyons is quite complicated in the incident area. The main canyon runs from the southeast to the northwest. At the entrapment area there are three small canyons that branch out from the main drainage and run to the northwest, north and northeast.

The Palmer Drought Index, issued May 10th, 2003 showed that much of the White Mountains were in moderate to severe drought. Rainfall was very sparse in April and May with many stations receiving no moisture for 30 days. The weather forecast, issued by the National Weather Service (NWS), for May 14th called for temperatures of 75-80 degrees, minimum relative humidity (RH) 12-15%, Haines Index of 5 (moderate), and south winds (20 foot) 10-20 miles per hour (mph) increasing to 15-20 mph in the late afternoon, with a chance of thunderstorms.

The fire danger indices for the Heber remote automated weather station (RAWS) exceeded the 90th percentile for energy release component (ERC), fuel model G, beginning on May 1st 2003 and by May 14th, 2003 had reached the 97th percentile. The Heber RAWS station provides the most complete and accurate data for this area. Fuel moistures for that station were calculated as 10 Hour Fuels: 2%, 100 Hour Fuels: 4%, 1000 Hour Fuels: 7%.

The prescribed burn operation began on May 12th 2003 and 1,200 acres were ignited. Actual weather observations on those two days showed temperatures up to 83 degrees, RH as low as 7%, winds southwest, mostly light up to 7-10 mph. Fire behavior observations noted flame lengths to 20 feet and higher with fire spread rates up to one mile per hour for short distances, which was heavily influenced by the ignition patterns.

The plan on May 14th was to hold and patrol control lines, and about 40 personnel and two burn bosses were assigned to support the operation along with a type three helicopter (H-355) with bucket. None of the fire perimeter was contained except by natural barriers in some places. There were two areas of concern on the east side of the burn where the fire was backing in pine litter. There were spot fires in several areas as well. The objective was to keep fire from moving south.

At 1000 to 1100 hours the fire crews and the burn boss hiked up the canyon on the east side of the burn and started building fire line and patrolling the perimeter. At approximately 1430 hours, a lookout reported an increase in fire behavior activity and noted a large smoke plume on the southeast side of the burn. The burn boss indicated he would hike into the area to check it out. A short time later the burn boss was suddenly trapped in a fire blowup, and managed to partially deploy his fire shelter, but was critically injured. The burn boss walked to the helispot at 1500 hours with assistance and was flown by H-355 to the hospital then flown to burn center in Phoenix, AZ, but his injuries proved to be fatal.

A Serious Accident Investigation Team (SAIT) was ordered on May 15th, 2003 by the BIA. The SAIT interviewed witnesses, gathered evidence in the field and completed a report on the incident. The report indicated that there were several management factors that contributed to this entrapment. A prescribed fire plan for the Sawtooth Mountain prescribed fire was completed in April of 2001 but was later rescinded by the BIA Regional Office. Hence there was *no* approved prescribed fire burn plan when operations were undertaken in 2003. The prescribed fire was also out of prescription on the day of ignition and subsequent days. Additional factors that contributed to this incident included failing to establish anchor points, failure to identify escape routes and safety zones, and failure to designate proper lookouts.

Other major findings by the SAIT included:

- The entrapped firefighter was observed to have no gloves. All the other personal protective equipment (PPE) was located but the gloves weren't with them. A fire shelter was deployed and was badly damaged in the fire
- Small pieces of aluminum foil and glass cloth from the fire shelter were found over a distance of approximately 200 feet, from where the burned fire tool and vinyl bag were found.
- No medical plan or job hazard analysis was completed for the burn plan
- Two Burn Bosses were assigned on May 14th, and the organization outlined in the burn plan was not followed. No safety officer was assigned.
- The Go-No-Go List was not appropriately completed.

The extreme fire behavior event that occurred between 1400 to 1600 hours on May 14th, 2003 can be characterized as a "blowup". A blowup is defined as a sudden increase in fireline intensity sufficient to preclude immediate control or to upset existing suppression plans, often accompanied by violent convection (National Wildfire Coordinating Group, Glossary of Wildland Fire Terminology). The backing fire that was observed on the morning of May 14th in the canyon bottom transformed from a low intensity surface fire with a few individual torching trees to a rapidly moving surface and crown fire with erratic fire behavior. Factors contributing to extreme fire behavior included: low afternoon relative humidities with values less than 10%, low dead and live fuel moistures, multiyear drought, heavy fuel loading, ladder fuels, and narrow and converging canyons causing erratic winds (deployment site).

The importance of following prescribed fire planning protocols and requirements is essential. Establishing lookouts, anchor points, escape routes and safety zones in advance cannot be overlooked in any fire situation. Fire weather and fuels monitoring is critical on prescribed fires (RxFire) for a period of time before the project is initiated, and during operations. During major holding actions on an RxFire a simple written plan with a map may have to be completed. Chain of command always needs to be clearly articulated and PPE is a must!

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# *Psychological Safety: The Key to High Performance in High Stress, Potentially Traumatic Environments

James Saveland[A]

[A]US Forest Service, Rocky Mountain Research Station, 240 W. Prospect Rd, Fort Collins, CO 80526, USA, jsaveland@fs.fed.us

## Abstract:

Safety is typically talked about in a context of the absence of injury. The field of resilience engineering has been advocating that we think about safety differently, by taking a systems view and begin to see how people create safety in unsafe systems by managing risk. There is growing recognition that safety is an emergent behavior of our complex system of human performance. A model of human performance focused on resilience and adaptation will be presented. The ability to learn and adapt is at the heart of individual and organizational high performance. Kurt Lewin is often recognized as “the founder of modern social psychology.” Over 60 years ago Lewin, in his classic model of how people make significant change, pointed out the importance of providing psychological safety. In his model, psychological safety is essential to reduce learning anxiety. In short, psychological safety is necessary for learning to take place. Related to this conference theme, storytelling only takes place within a container of psychological safety. Without psychological safety, there is no story telling. This paper explores the crucial but often ignored ingredient to making profound change (individual and organizational) – the concept and application of psychological safety: what it is, why it’s important, and how to cultivate it.

*Abstract appears as it was originally submitted.

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# *Large Airtanker Use Trends and Implications for Fire Safety

Matthew Thompson[AC], Dave Calkin[A], Jason Herynk[B], Karen Short[B], Chuck McHugh[B]

[A]US Forest Service, 200 E. Broadway, PO Box 7669, Missoula, Montana, 59807, USA, mpthompson02@fs.fed.us, decalkin@fs.fed.us
[B]US Forest Service, Rocky Mountain Research Station, Fire Sciences Lab, 5775 US Hwy 10 West, Missoula, Montana, 59808, USA, jherynk@fs.fed.us, kcshort@fs.fed.us, cmchugh@fs.fed.us
[C]Corresponding Author

**Abstract:**

Fatalities and an aging fleet of leased fixed-wing airtankers have prompted the US Forest Service to investigate purchasing new large airtankers (LATs). As a baseline to inform future cost-benefit analyses, we mined data from U.S. Forest Service aviation, finance, and fire incident records to categorize and understand large airtanker use. In the wake of the fleet reduction the average number of flights per aircraft per year and flight hours per aircraft both increased. Recent aviation and incident records indicate that the primary use of these aircraft are on fires greater than 300 acres, which are generally considered to be in the extended response phase, and a significant number of flights were associated with very large fires (> 10,000 acres). Our results highlight and may call into question the use of LATs on very large fires that are known in many circumstances to be driven primarily by weather and not suppression efforts, and which comprise a large share of suppression costs. Questions of firefighter safety must also be considered in the context of calls for additional use of LATs.

*Abstract appears as it was originally submitted.

# *Exploring the use of Unmanned Aircraft Systems to Facilitate Wildfire Management and Increase Firefighter Safety

Lindsay Voss[A]

[A]Association for Unmanned Vehicle Systems International (AUVSI), 24 Dunthorte Lane, San Antonio, Texas, 78250, USA, voss@auvsi.org

**Abstract:**

The purpose of this presentation was to present the potential benefits of incorporating unmanned aircraft systems (UAS) into wildland fire response, management, suppression, containment and prevention. Since 2009, the Association for Unmanned Vehicle Systems International (AUVSI) has conducted a series of Table Top Exercises and unmanned systems demonstrations in conjunction with the U.S. Naval Postgraduate School (NPS) and the U.S. Forest Service to explore how UAS could assist firefighters and incident managers during wildfire events. These live demonstrations incorporated a number of unmanned aircraft platforms and associated equipment into the monitoring and assessment of real world fire scenarios. The presentation described findings from experts in the firefighting and UAS communities who collectively investigated the employment of UAS live fire scenarios with the end goal of identifying the strengths and shortcomings of the demonstrated technologies. Technical, regulatory, political and organizational obstacles are discussed as well as potential opportunities for unmanned aircraft to improve wildland fire management and increase firefighter safety.

*Abstract appears as it was originally submitted.

# Identifying airspace congestion in aerial firefighting: How do additional resources impact attack times and operational effectiveness?

Kat Sonia Thomson[AB]

[A]Teachers College, Columbia University, 285 South 2nd St. Apt.2, Brooklyn, NY 11211
Email: kst2106@columbia.edu
[B] Contract Air Attack Officer, Aviation Operations, Provincial Forest Fire Center, Alberta Sustainable Resource Development

**Abstract:** In aerial firefighting, it is common to send several aircraft to the scene based on the hazard rating and values at risk as estimated by the responding agency. However, once aircraft arrive, there is not much known about the trade-off between efficiency and safety that may take place over incidents with multiple resources assigned. One commonly known challenge facing line-pilots is the issue of airspace organization and congestion associated with increased fire loads. In the literature concerning air tanker management and performance, there is no formal process for identifying airspace congestion nor is there any analysis of its possible effects. This study proposes a theoretical definition of congestion, followed by a space-time permutation cluster analysis to identify high-density air traffic cases using initial attack data. An empirical assessment of the impact of heavy air traffic on operational efficiency is attempted using a multiple linear regression model framework. This paper is a call to the Operations Research (OR) field to study the issue of airspace organization when multiple aircraft are assigned.

**Additional Keywords:** Air Operations Management, aviation safety, clusters, airspace congestion modeling]

## Introduction

This paper seeks to introduce a formal means to identify and quantify a potentially crucial airspace operations issue- airspace congestion-in a manner that is both simple and helpful. Beginning with a theoretical conceptualization of airspace congestion, potential occurrences of congestion are identified using recent large-scale incident data. Empirical analysis tests the impact of congestion on efficiency and infers some implications for safety. The ideas and findings reported here should be considered preliminary and comments are encouraged.

## Motivation

Operations research (OR) regarding air tanker deployment and management, is typically from a service delivery perspective, where queues of fires are serviced by air tankers and the goal is to minimize fire size and suppression cost through efficiencies in spatial deployment (Islam et al, 2009; Greulich, 2008; Haight and Fried, 2007; Martell, 2007; Fried et al, 2006; Greulich, 2005; Martell, 1997; Martell et al, 1984; Martell, 1982; Bookbinder & Martell, 1979). Generated to assist agencies in optimal acquisition, allocation and fleet management decisions, OR papers focus on reducing congestion in service queues. Other research in air operations focuses on equipment performance (USDA Forest Service, 2009; McCulloch & Mooney, 2008; Schroeder, 2008; McCullough, 2006; Iannidinardo, 2005).

As stated simply in the 2005 Wildland Fire and Aviation Program Management Operations Guide, Chapter 8: Aviation Operations, "(a)ll aviation missions have some inherent risk," (8-4). Helicopter and air tanker companies address flight safety issues with their own internal initiatives and directives regarding operational flight. In the United States, the BIA and its interagency partners have shifted their emphasis from the 'traditional approach' to the 'contemporary approach' with the Safety Management Systems (SMS) as their aviation safety program core (U.S. Department of the Interior, BIA, 2011, p. 8-4). At the national level, Canada's CIFFC (Canadian Interagency Forest Fire Center) operates an Aviation Working Group, dedicated to "a national, consistent approach to aviation safety," and whose goal is to and to "develop and maintain a consistent aviation incident/accident reporting system" ("Goals," 2007). As efficiency and safety continue to be upheld at the regulations and management-level, analysis of actual operations data will provide additional ways of detecting problems and solving them.

## Conceptualizing Air Space

**Locational Congestion** is conceptualized as the build-up of multiple resources over multiple events, hypothetically under multiple modes of operational control. **Resource Congestion** refers to the build-up of multiple resources over a single event, under a single mode of operational control. Both forms of congestion must occur in a *shared airspace*- where flight corridors have some positive probability of intersecting. The above forms of congestion could coexist as **Locational/resource Congestion**- where an established escaped fire is burning in close proximity to new smaller fires, with both modes of control operating in a single geographic area. Finally, **Communication Congestion** is hypothesized as the occurrence of heavy traffic over the necessary mode of communication (radio frequencies) in an operational area. Each additional resource arriving on scene must make a pre-determined set of protocol transmissions (at minimum) in order to operate (both en route and over the target). Radio silence is a finite resource, where the maximum amount available for use exists with zero aircraft, and the minimum amount (zero radio silence) occurs at some resource threshold.

## Modeling Airspace Congestion

I model airspace congestion using 5 years of agency data on air tanker load deliveries in initial attack (N= 986 fires and 1,548 drops). 399 aircraft "clusters" in space and time were identified by utilizing *SaTScan Software* and the Space-Time Permutation Model (Kulldorff *et. al*, 2005). Each individual aircraft was coded with the total number of aircraft (fixed-wing and rotor-wing) present *simultaneously*, and a multiple linear regression model was used to estimate a statistical relationship between congestion and measures of efficiency. Controls for fire, administrative, and Crew Resource Management (CRM) (Sexton et al, 2000) characteristics enter the equation.

## Implications for Congestion on Safety

Identified ‘Aviation Watchout Situations’ established by the BIA Aviation Operations (2005, 2011) risk management platform include other aircraft in the area of operations, as well as potential for confusion and problems with communications. Positive airspace control loss, reduced situational awareness and increased probability of a mid-air collision are among the potential implications of airspace congestion. OR can contribute to interpreting some of the evidence emerging from the field regarding airspace congestion. This paper serves to open the door for both new research into possible issues facing air operations safety and efficiency, as well as to open a discussion into the situation from a problem-solving and growth perspective.

**Acknowledgments**
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***Resilience and High Performance: What the Wildland Fire Community Can Learn from the U.S. Military**

James Saveland[A]

[A]US Forest Service, Rocky Mountain Research Station, 240 W. Prospect Rd, Fort Collins, CO 80526, USA, jsaveland@fs.fed.us

**Abstract:**

Recent advances in the science of psychology are rapidly mending the Cartesian mind-body rift. The U.S. Military has recognized the importance of mental fitness to compliment physical fitness. Health-of-the-Force was a strategic priority of the Chairman of the Joint Chiefs of Staff in 2009-2010. Wellness enhancement and training is one of the four focus areas of a Department of Defense task force report, The Challenge and the Promise: Strengthening the Force, Preventing Suicide, and Saving Lives; issued in August of 2010. This paper will review psychological training in general and resilience training in particular that is being implemented in the military; including the U.S. Army's $120 million initiative on Comprehensive Soldier Fitness (CSF), the U.S. Air Force Total Force Resiliency and Airman Resiliency Program, the Navy's Operational Stress Control program (OSC), the Army Center for Enhanced Performance (ACEP), and the Real Warrior's Campaign. This paper will also examine the work of the Mind Fitness Training Institute (MFTI), a non-profit research and training organization that developed Mindfulness-Based Mind Fitness (MMFT) training for the U.S. Army and Marines to enhance performance and build resilience to stress, change and uncertainty. In addition to examining the content of these programs for applicable lessons for the wildland fire community, methods of implementation will also be discussed.

*Abstract appears as it was originally submitted.

# *The France – USA High Reliability Organizing Project: Enhancing Reliability in Incident Management

David Allan Christenson[A]

[A]Wildfire Lessons Learned Center, 3265 W. Universal Way, Tucson, Arizona, 85706, USA, dchristenson@fs.fed.us

**Abstract:**

This University of California at Berkeley, interagency US Wildland Fire Lessons Learned Center (LLC), and National Advanced Fire & Resources Institute (NAFRI) project collaborated with firefighters from the SDIS13 Bouches du Rhone Regional Fire Service of Southern France and US Forest Service firefighters from 2007 to 2010.

The project takes major research direction for progress in understanding HROs, with direct benefits for practitioners, by analyzing how competing demands (quick versus accurate decisions, ignoring noise versus picking up weak signals …) are successfully managed by highly reliable IMTs.

The central argument of our work is that the successful management of these conflicting requirements is the main source of high reliability in emergency operations. To explore this idea, we observed some of the best Incident Management Teams from France and from the U.S. for three years. This paper presents our findings and contribution to incident management. The first section sets the theoretical framework within which the management of the tension between opposing demands are conceptualized. The second section offers a brief description of the France-U.S. High Reliability Organizing (HRO) project, and the third one presents the contrasted results of French and U.S. Incident Management Teams as well as their interpretation. The final section discusses how firefighters can enhance reliability in incident management, combining stability and change, flexibility and robustness, adaptability and adaptation.

*Abstract appears as it was originally submitted.

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# *Aspiration: The Weak Link in the Safety Chain of Organizational Learning

Jules Leboeuf[A]

[A]Government of Alberta, Alberta Sustainable Resource Development - Forestry Division, Provincial Forest Fire Centre 10th Floor, 9920-108 Street, Great West Life Bldg, Edmonton, Alberta, T5K 2M4, Canada, jules.leboeuf@gov.ab.ca

**Abstract:**
Aspiration can be described as the capacity for individuals, teams and eventually larger organizations to orient themselves toward what they truly care about and to change because they want to, not because they need to.

The success of Wildland fire agencies facing the escalating complexity of wildfire management will hinge on the ability to develop the skills and competencies associated with personal mastery. What is worrisome about this statement is that aspiration is recognized as the most atrophied muscle in organizational learning as it is rarely exercised.

Deep shifts in how we think and interact with each other are in order.

**Personal Mastery**
Personal Mastery can be described as learning to expand personal capacity to:

- Create the results we desire
- Create the organization that encourages people to develop themselves

The pursuit of this involves the ability to expand our capacity to develop the skills and competencies *in action*, required to engage each other in lasting and trustworthy ways. This allows the team to see more of its reality by naming and describing the current experience true to the individuals and whole of the team. The skills of meaningful dialogue cannot be overstated in the pursuit of aspiration.

**Putting Theory into Practice**
Being able to speak to the truth of the situation – everyone's truth – is of vital importance. The concept is simple yet difficult in application. Developmental practices in dialogue must be in place to support the movement of a greater organizational awareness.

Dialogue is an essential foundation to any initiative implemented by a human system. It is a primary building block in transforming an organization in its ability to identify root causes of issues and the follow through that is required to remedy the issues Organizations admit that they do not have a shared understanding on how to consistently engage in this form of dialogue.

Ultimately change is a choice and with it a requirement for a resilient practice of dialogue. Without it, we will continue to create results we no longer desire or afford.

*Abstract appears as it was originally submitted.

## *Enhancing Fire Science Exchange: The Northern Rockies Fire Science Network

Vita Wright[AG], Crystal Kolden[B], Todd Kipfer[C], Kristine Lee[D], Adrian Leighton[E], Jim Riddering[F], Leana Schelvan[F]

[A]US Forest Service/ National Park Service, Branch of Wildland Fire, 650 Wolfpack Way, Kalispell, Montana, 59901, USA, vwright@fs.fed.us
[B]University of Idaho, 2150 Westview Drive, Moscow, Idaho, 83843, USA, ckolden@gmail.com
[C]MSU Big Sky Institute of the Environment
[D]US Forest Service, Rocky Mountain Research Station, Missoula Fire Science Lab, 5775 US Highway 10, Missoula, Montana, 59808, USA, kristinelee@fs.fed.us
[E]Salish Kootenai College Department of Natural Resources
[F]UM National Center for Landscape Fire Analysis, CHCB 441, Missoula, Montana, 59812, USA, leana.schelvan@firecenter.umt.edu
[G]Corresponding Author

**Abstract:**

The Northern Rocky Mountain region is one of the most fire-prone regions in the United States. With a history of large fires that have shaped national policy, including the fires of 1910 and 2000 in Idaho and Montana and the Yellowstone fires of 1988, this region is projected to have many large severe fires in the future. Communication about fire science needs and science products is critical to effective, science-informed management. Despite the concentration of fire scientists and fire research in this region, land managers struggle to sort through available scientific information; find the right tools, models, and applications to make management decisions; and access expertise relevant to management questions. The Northern Rockies Fire Science Network is being developed to assist managers in the Northern Rockies by offering a single place where managers can access the latest knowledge and tools supporting fire and fuels management in this region. The Fire Science Network will also help identify regional research priorities, build and strengthen relationships among managers, scientists, and other science delivery partnerships in the region, and work to overcome barriers associated with the different cultures of science and management. This presentation describes the background, vision, and goal behind the Network and illustrates examples of the types of activities and services the network can provide. It also describes the Fire Science Network's first priority: the conduct of a regional needs assessment to gather feedback on which activities to prioritize.

*Abstract appears as it was originally submitted.

## Learning from escaped prescribed fire reviews

Black, Anne E [AE], Thomas, Dave[B], Saveland, James[C], Ziegler, Jennifer D [D]

[A]Human Factors and Risk Management RD&A, USDA Forest Service, Rocky Mountain Research Station, 1, 800 E Beckwith Ave, Missoula, MT, 59801 E-mail: aeblack@fs.fed.us
[B]Renoveling, 2334N 500W Ogden, UT 84414 E-mail: renoveling@msn.com
[C]Human Factors & Risk Management RD&A, USDA Forest Service, Rocky Mountain Research Station, Fort Collins, CO E-mail: jsaveland@fs.fed.us
[D]Valparaiso University, Department of Communication, 1809 Chapel Dr., Schnabel Hall, Valparaiso IN 46383 Email: jennifer.ziegler@valpo.edu
[E]Corresponding Author

**Abstract:** The U.S. wildland fire community has developed a number of innovative methods for conducting a review following escape of a prescribed fire (expanding on the typical regional or local reviews, to include more of a learning focus – expanded After Action Reviews, reviews that incorporate High Reliability Organizing, Facilitated Learning Analyses, etc). The stated purpose of these reviews has been to identify methods that not only meet policy requirements, but also reduce future escapes. Implicit in this is the assumption that a review leads to learning. Yet, as organizational learning expert David Garvin (2000) notes, learning may be said to have occurred only when individual behaviors change on the ground.

We seek to understand whether and how the escaped prescribed fire review processes as currently designed and implemented by U.S. federal fire agencies promote organizational learning. We are particularly interested in what facilitates individual and organizational learning and how learning may be effectively transferred. We are using structured dialogue sessions as our primary method of inquiry. The two day workshops are guided by three questions: What aspects of the escaped prescribed fire review processes as currently designed and implemented promote organizational learning? How effectively do current reviews transfer the knowledge gained from reviews to other field units? What is needed to strengthen the learning and the knowledge transfer aspects of reviews?

**Additional Keywords:** prescribed fire, organizational learning, reviews

## Introduction

The U.S. wildland fire community has developed a number of innovative methods for conducting a review following escape of a prescribed fire. The stated purpose of these has been to identify methods that not only meet policy requirements, but also reduce future escapes. Implicit in this is the assumption that a review leads to learning.

The sociological and organizational psychology literature is replete with scientific studies concerning the worthiness of organizational learning for error prevention (Senge 1990; Garvin 2000; Kegan and Lahey 2000; Weick and Sutcliffe 2007). Similarly, there are a number of theories about how organizations learn and change, and the conditions and activities necessary to facilitate change (Isaacs *et al.* 2006; Scharmer 2007). However, few scientific studies of fire management operations have attempted to understand the *effectiveness* of accident reviews, particularly how effective reviews collect and analyze information and disseminate lessons learned to those not directly involved in the original event.

We seek to understand whether and how the escaped prescribed fire review processes (such as regional or local reviews, Facilitated Learning Analyses, etc) as currently designed and implemented by U.S. federal fire agencies promote organizational learning. We are particularly interested in what facilitates individual and organizational learning and how learning may be effectively transferred.

We draw our definition of learning from the multiple dimensions of organizational learning previously identified – from who is doing the learning (individual to institutional) to what is being learned (instrumental to fundamental knowledge) (e.g. Shirvastava 1983; Argyris and Schon 1996; Garvin 2000; Argote *et al.* 2000; Fazey *et al.* 2007). To capture the full circuit of learning, we define three phases. Learning involves both a cognitive and a behavioral aspect – the moment of insight and the subsequent change in action or behavior. Framing learning in this way allows us to recognize that changes in behavior often lag behind changes in thinking, and provides the space to explore individual and organizational activities that can facilitate or impair completion of the circuit. Learning may also be phased chronologically. For instance, lessons may occur during the event itself, during or through the process of the review itself, as well as from resulting products or reports and deliberate mechanisms to transfer lessons beyond the local unit. Finally, the entity that learns includes a spectrum from the individual, to burn unit or crew and/or review team, to broader organizational levels such as the Forest/Park/Resource Area/Refuge or the entire organization, such as Forest Service, National Park Service or the inter-agency fire community.

## Workshop Design

Our primary data collection method uses the concept of *dialogue* (Isaacs 1999). Dialogue has been described as "a discipline of collective thinking and inquiry; a process for transforming the quality of conversation, and in particular the thinking that lies beneath it" (Isaacs *et al.* 2006). Ordinary conversation is often focused on informing another about (or convincing another to adopt) one's own perspective. Dialogue differs by emphasizing as its goal the generation of new understanding and insight. This occurs through sharing of individual experience, acknowledgement of multiple – even conflicting - perspectives, and inquiry into the underlying structures (mental models, assumptions) for these perspectives. Dialogue has been shown to be an effective technique to solve and understand knotty, sometimes intractable organizational problems especially if those problems are rooted in the culture of the organization; dialogue has been used successfully by such companies as Monsanto, U. S. Steel and Shell Oil.

We expect to hold five dialogue sessions around the United States –four are complete. Each session has or will include 6 -25 participants drawn from the five federal land management agencies with fire responsibilities (Department of Agriculture - Forest Service, Department of Interior - National Park Service, Fish and Wildlife Service, Bureau of Land Management, Bureau of Indian Affairs). We seek a mix of experiences and responsibilities with respect to prescribed fire escapes, from line officers (Refuge Managers, Park Superintendants, Regional Foresters, etc.) and review team leaders to planning and operational staff (burn plan developers, firing, holding bosses, etc.) and ancillary support (fire weather meteorologists, dispatch, etc). Workshop notifications are electronically circulated through both formal and informal organizational channels.

Sessions are guided by a series of open-ended inquiry questions: What aspects of the escaped prescribed fire review processes as currently designed and implemented promote organizational learning? How effectively do current reviews transfer the knowledge gained from reviews to other field units? What is needed to strengthen the learning and the knowledge transfer aspects of reviews? Sessions are recorded and transcripts prepared to mask identities. Analysis will occur using multiple, concurrent perspectives, including: comparison of processes and procedures with academic definitions of learning organizations such as Garvin (2000) and Dekker (2006); "cognitive task analysis" developed to study complex mental tasks involved with decision-making (Czarniawska 2006; Crandall *et al*. 2006), and communication theory (e.g. Thackaberry 2004).

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# Accidents, accident guides, stories and the truth

Ted Putnam, PhD

Mindful Solutions, 3431 Flicker LN, Missoula, MT 59804, tputnam@bresnan.net

**Abstract:** Here at the 11th Wildland Fire Safety Summit we are students of fire safety, which is our basic reason for gathering to exchange our collective and separate visions. The secondary theme is how stories and narratives aid in this process. Historically accident investigations have provided crucial feedback for maximizing safety. These investigations have usually produced step-by-step factual reports to document the accident. Recently some investigations have recommended relating the accident in a story format to increase readability, interest and learning within firefighter safety cultures. Generally the goal of accident reports is to convey as much of the truth of an event that is discoverable. However time, money, skill level, skill variety, accident guide used and other related factors can either enhance or deter the depth of understanding the accident causal elements. Sometimes investigators deliberately distort or do not report all the causal elements. Such biases lead firefighters to distrust the resulting reports, which can hamper our efforts to stay safe.

**Additional Keywords:** Accident guides, true stories, accident causal factors, mental errors, HROs and accident cover-ups. Historical fire examples: Mann Gulch, South Canyon, Alabaugh Canyon, and the Crandall Ranger Station Chainsaw Accident

## Accidents, accident guides, stories, and the Truth

What follows is an exploration of USA wildland fire accidents, accident guides, stories and the truth. These issues are further detailed to learn how they can produce excellent products, or deteriorate into partial truths and sometime lies. Historical fires are cited to demonstrate the actual processes and reporting involved. Central to this analysis is the need to consider how our own minds tell us stories and make errors, which in turn affect our actions and outcomes. With mindfulness training we can learn the skill of non-attachment, stress reduction and to be mindful in our present environments. Thus reduction of mental errors is a learnable skill. Since the human mind and mental events are common to all people, cultures and organizations the relevancy of cited concerns extends beyond wildland firefighting to safety in other contexts.

## Professional qualifications

Since I will often express my opinions about topics in this presentation, it is relevant to present my professional qualifications. In 1977 I received a PhD from the University of Montana in Experimental Psychology with a learning major and mathematics minor. My master's thesis and doctoral dissertation involved operant conditioning experiments, thus expertise in behaviorism based on rewards, punishments, rules and regulations. Later I began to study Eastern Psychology because it focuses on mental processes and what you can do through meditation to improve your own mental awareness, processes and decision-making. Part of this training has involved four years of supervised study of mindfulness meditation to enhance mental processes. My experience base now offers a blend of Eastern and Western psychology.

My fire accident investigation career began in 1976 with the Battlement Creek Fire and my last accident investigation was the Crandall Ranger Station Tree Felling Accident in 2010; a span of thirty-five years. Prior to my accident investigation experiences I spent 14 seasons fighting wildland fires beginning in 1963. Three years were on Forest Service district fire crews. The next eleven years were with the Missoula, Montana Smokejumpers; the last three years as a supervisor. From 1976 to 1998 I was an Equipment Specialist at the Missoula Technology and Development Center, a detached Washington Office unit located in Missoula. My area of technical expertise was fire and safety equipment; in particular fire clothing and shelters. Part of my job was analyzing how the clothing and shelters performed under actual entrapment conditions and what firefighters could do to avoid entrapments in the first place. I have been involved in the fire arena for roughly forty-eight years.

In the 1980s I began reading and studying wildland fire, other federal Agencies, military and private accident investigation guides. At that time I used the guides and they seemed to account for accident causal elements. Later I began to question those authors and guides because they were mostly externally, physically, rule orientated as opposed to internally, subjective, mental decision orientated. Because such "two quadrant" guides were the best available at the time, the wildland agencies used them as models. Today these same guides have shifted to more emphasis on the cultural causal elements but still fail to seriously consider mental elements. When mentioning mental elements they acknowledge there is something to seeing events as the involved people saw them, but they have few ideas and processes for doing so. By the time I had investigated the Dude Fire in 1990 I no longer put much credibility in these guides unless the accident involved specific physical concerns such as vehicles or the movement of supplies and firefighters (physical organizational problems). None of the models work for dynamic interactions seen in wildland firefighting. When analyzing the South Canyon Fire fatality causal elements I felt as a team we reported at best half of the known fatality causes. When attempting to get several obvious causes into the report the team leaders refused to consider them, not because they weren't potent causes, but because they were not "within the scope of the investigation". Their reasons protected agency images and processes that they were unwilling to consider. This is why I feel the South Canyon was and remains a cover-up. No other members of the South Canyon team would support mental, cultural or organizational causes (per existing guidelines); if it wasn't a physical cause, then it was deemed unimportant. Thus there are often political agendas determining which of the causal factors are acceptable and reported. My analyses often stress individual mental practices and cultural pressures to compliment and soften the endless rules deemed necessary to control firefighter actions.

## Accident Investigation Concerns

Although it seems obvious that accident investigations should strive to uncover the actual causes and conditions that led to the accident, this is seldom attempted let alone advocated in the relevant agency investigation guides used by wildland fire and other organizational (Airlines, NASA, Military, etc.) accident investigators. Failure to look for all discoverable causes and conditions leads to accident reports that are superficial in understanding or missing vital information on what really occurred as well as why it occurred. It is relevant for individuals and organizations to look at what accident guides investigations are focusing on compared to what they could and ought to be focusing on. Specifically, we ignore the impact of the individual's cognitive processing on accident causation.

All phenomena arise in dependency on causes and conditions. Furthermore causes and conditions are constantly changing. Most of our actions are automatic or habitual in nature and occur so rapidly that discrete actions go unnoticed. Most human behavior arises due to unconscious causes and conditions and as such we struggle to know why we do what we do, let alone why others do what they do. To understand our own mind is to understand the minds of others due to common underlying processes. Trying to make sense of and report accidents are both mental fabrications, which arise yet because of other causes and conditions. It is well known that our minds can automatically delete old or add new memories to events such as accidents. This means the sooner you can collect witness statements, the more accurate they are likely to be. Thus all reporting is problematical.

A good accident guide is analogous to a good experimental design. In a well-designed experiment, the experimental design is paramount for what data to collect, how to collect the data and predetermines to a large degree the type of conclusions that can be logically drawn from the experiment; similar concerns apply for accident data collection and conclusions. Although wildland agency accident investigation guides are analogous to experimental designs, few administrators, guide creators or users have any depth of understanding the accident guide limitations, let alone their own limitations, as they investigate. The guides do not correspond to normal reality and investigators are usually untrained in both the guides and conducting investigations. Thus muddling through is the status quo with far reaching consequences.
Few people conduct good investigations because they do not question the assumptions that each guide makes about reality and our access to it. Psychologist and philosopher Ken Wilber (1997) has written extensively about reality and has a model for helping us understand this. Wilber describes an elegant framework for both understanding and creating changes in individuals, cultures and organizations. Specifically, Wilbur argues that for complex changes and clear understanding to take place we must explore and take action in "all four quadrants": intentional, behavioral, cultural, and organizational. If we change a Wilber figure on the four quadrants by modifying it for firefighting it would look something similar to the following:

**THE FOUR QUADRANTS OF REALITY**

| INTERIOR, INDIVIDUAL | EXTERIOR, INDIVIDUAL |
|---|---|
| ***INTENTIONAL*** | ***BEHAVIOURAL*** |
| Awareness<br>Consciousness<br>Mental Elements<br>Thinking<br>Human Error<br>Mindfulness<br>Resiliency<br>Meditation | Body<br>Brain<br>Neural Nets<br>Blood<br>Cells<br>Physical<br>Physiological |
| **I** | **IT** |
| **INTERIOR, COLLECTIVE** | **EXTERIOR, COLLECTIVE** |
| **WE** | **IT** |

| ***CULTURAL*** | ***ORGANIZATIONAL*** |
|---|---|
| Mutual Understanding | Firefighters & Crews |
| Common context | Fire behavior & Environment |
| Communications | Fire Orgs. : NIFC, NWCG, HROs |
| Leadership Principals | 10 & 18: Rules, Rewards, Punishment |
| Morals and Ethics | Locations |
| Cohesiveness | Function: What does it do? |
| Relationships | Wildland Fire Safety Awareness Study |
| Crew Risk Taking | Movement of Firefighters and Supplies |

Within this context up until 1995 the wildland fire organizations focused mostly on the exterior, physical IT quadrants because they were more scientific and physically orientated and neglected the more subjective, interior I and the WE quadrants which were less understood by firefighters and our society in general. Considerable work has been done and results implemented for cultural concerns following recommendations stemming from the South Canyon Fire in which fourteen firefighters died. The two key initiatives were the 1995 Human Factors Workshop (USDA, 1995) and the *Wildland Fire Safety Awareness Study* (TriData, 1998). However the “I” quadrant is still largely unexplored by the fire community and accident investigation guides. We ignore mental causal factors in our cultures and organizations precisely because we have been ignoring our own mental processes as individuals our entire lives. We know how to use our minds but know little about the underlying processes. Without a meditation practice most people confuse mental content with mental processes. This paper brings more focus to the “I” quadrant, by exploring the mind, *in and of itself*. The qualifying phrase "in and of itself" means without regards to anything except the <u>mental processes as directly observed in our own mind</u>. Specifically it does not refer to the content of the mind such as words, ideas, images, beliefs, thoughts, reasons, etc. We need to understand both content and processes since knowing the difference will help firefighters stay more mentally alert and make better decisions especially under highly stressful, risky conditions. For example stressors are additive and interfere with long term memory such as rules and safety precautions. Meditation exercises directly reduce stresses and enhance mental processes keeping firefighters more alert to make better decisions.

Wildland fire organizations typically focus on exterior quadrants and neglect to investigate how interior quadrants contribute to accidents. If we ignore quadrants, we fail to recognize how they contribute to confusion between the different types of accounts gathered in accident investigations. Ignoring quadrants shifts accident investigations results along the following continuum: away from the Truth to a True Story to a Story or worse, in cases of deliberate deception, to a Lie.

**Truth** can only be known in the present moment. The truth or reality, which occurred in the past, is non-recoverable since we and those involved in the accident cannot go back and replay the conditions and events. In our society we use the word Truth generally to imply speaking morally and ethically. When witnesses comment on what occurred, what they tell us are memories, which are mental constructions or stories about the event containing only partial bits of the original truth. Therefore it takes more effort to produce a **True Story** (or **factual account)** that closely approximates the truth (we can never fully capture the past in any account, no matter how complete or accurate it is, but some accounts come closer). A True Story necessitates that investigators and witnesses are skillful in their attempts to recover whatever evidence is available

for discovery. When some parts of the accident reconstruction do not make sense it is helpful to invite experts in to help fill in the gaps. A fire behavior expert can better reconstruct the movement of the fire; a sociologist the contribution of crew risk taking; and a psychologist for reconstructing likely patterns of mental errors that affected personal risks, beliefs and decision making. Since these experts are producing skillful probability accounts they are also fabrications and thus **Stories** about the accident. Stories can be **misleading accounts** (when a person lacks important information but weaves together an account; usually contains errors that can be verified with fact checking). When information is deliberately falsified or withheld, **Lies** occur. Lies are **deceptive accounts** (intentionally meant to manipulate information) and make it difficult to fully understand the causes and conditions and once suspected they undermine the credibility of the investigators, accident report, accident guide and organization. The four quadrant concerns help focus attention on the elements involved in discovering causes and conditions not only for accidents but for all that we do personally, socially and organizationally.
A warning is also appropriate: to use the methodologies of one quadrant in another quadrant invites distortions and misinterpretations, an example of which is when scientific techniques are used within the intentional quadrant and to a lesser degree in the cultural quadrant. See Wilber's (1997) writings for further implications of failing to make changes in all four quadrants within a common time frame. Fire personnel and organizations operate in the behavioral and organizations quadrants where they have considerable expertise. They have less expertise in the cultural and intentional areas where experts outside the fire organizations can offer additional insights. After considering how to discover reality in various situations we can now explore how the wildland fire agencies seek to discover what goes amiss in accidents and near misses.

## General Accident Guide Considerations

The Organizational Learning "Lessons Learned" Analysis Options (OLO) (2010) Forest Service guide provides some of the reasoning behind choosing their different accident investigation guides. **Administrative Investigations** are required if there is evidence of intentional recklessness, dishonesty, or substance abuse; **or** employees are not willing to talk openly and share results. A **Serious Accident Investigation** (SAI) using the Accident Investigation Guide (AIG) and is advised when: a fatality occurs, a serious permanent medical disability is likely, litigation against an employee is a serious concern or a well-intended employee would **not** have made the same mistake. Author's Note: This last concern is essentially a judgment to blame or not, and determines whether a SAI or an APA is appropriate. Thus traces of blame taint both guides. An **Accident Prevention Analysis** (APA) is advised when: employees are willing to talk openly and share results ***and*** the event indicates a possible organizational failure, a systemic cultural concern, a training program deficiency, or a doctrinal inadequacy; ***or*** Exposing the event and the conditions that enabled the accident could provide the larger organization with a powerful or unique learning opportunity.

With respect to the four quadrants the SAI primarily functions in the two exterior quadrants and the APA within the two collective quadrants. Both guides basically ignore the intentional quadrant. Thus the SAI and APA show a significant lack of understanding human error as a mental process. Human error is an almost constant by-product of the human mind in everyday use and as such it will not be lessened to any significant extent by studying cultural and organizational conditions, which is why it is called human error as opposed to cultural or organizational error.

If the OLO continues to maintain such biases, it should clearly state that the SAI and APA guides do not attempt to identify mental causes and conditions of accidents. To date the way wildland fire agencies conduct accident and fatality investigations are ironically inconsistent with their own organizational premises, one being that safety is a primary concern. The OLO seems to be suggesting what goes on in firefighters minds isn't of much importance since firefighters are under the control of cultural and organizational rules and regulations. What would be the best format for conducting accident investigations at all levels? It would be something akin to the Four Quadrant Analysis (4QA) in Appendix A. The 4QA model combines all four quadrants into a suggested outline for and full reality based accident investigation guide. Some of the reasons for implementing 4QA guide are based upon flaws routinely encounter in the practical applications of the SAI and APA guides.

Historically wildland fire entrapment investigations have operated with strong biases and typically left out entire quadrants of analysis, i.e. the cultural and intentional quadrants. Often these actions involve **deceptive accounts** but sometimes they involve **misleading accounts**. Why do people and agencies do this? Below are some of the reasons based on my personal observations:

*Reasons for deceptive accounts include:*

- Other organizations do it (such as structural and wild fire agencies, the Military, NASA, etc.).
- The agency will be sued if we don't
- Key individuals have suffered enough
- The Agency will look bad.
- We'll correct the situation when "the ashes have settled," but it seems the ashes never settle.
- Using political agendas to falsify or withheld accident causes
- Sending unskilled employees who aren't likely to find much to report

*Reasons for misleading accounts include:*

- Sending good, yet untrained people to investigate
- Seldom asking for highly trained investigators even when they have the relevant, necessary skills such as psychological, sociological and organizational experts
- Sending interested parties as investigators with known biases
- Sending only people with only firefighting expertise, as that is primarily what they will notice and report
- Removing witnesses and evidence before the team arrives
- Failing to preserve the accident scene
- Ineffective interviewing skills that lead to short, incomplete accounts, i.e., lack of sufficient detail to understand underlying human factor causes.
- Analyzing the accident using a set of rules (the 10 and 18) that is guaranteed to show firefighters did not follow them and then report superficially that firefighters failed to obey or follow them with a subsequent perennial easy fix: "Back to the Basics" of following the 10 and 18

- Quick turn-around, low cost investigations: If it's not reported, you don't have to fix it and can't be held responsible later for similar future occurrences including fatalities.

In the above list the people you send to an accident investigation differ greatly in their specific areas of expertise, if the expertise is relevant, and then generally find only what they already know. So in that sense you predetermine the accident causes by the investigators you choose. No sociologist implies no detailed looking for deeper cultural causes. You also predetermine the causes by the accident guide you choose i.e. AAR, FLA, APA or SAI. AAR's are usually conducted at the crew level so will reflect the crew's beliefs and experience levels. The FLA brings in people to facilitate the learning process thus some outside views. But how far do you go to find the reviewers? Are they still within a larger local organization such as a district or forest? The further you go from home the more the costs go up but the more likely you are to get a fresh look at your current practices. Serious non-fatal accidents suggest using the APA guide. The APA guide is based on looking primarily at latent cultural and organizational causes of accidents and leaves out the Intentional Quadrant. In my opinion this limits the causal elements to exploring no more than 50 percent of the possible causal factors.

Fatal accidents require using the SAI. The main difference between the APA and SAI is that the SAI considers punishing involved individuals from the start, *even when those individuals acted to the best of their ability at the time of the accident.* The SAI is the most scientific of the four OLO guides so the best model for physical causes of accidents. It is also a behavioristic model so recommendations take the form of new rules, regulations, rewards and punishments. It is the least effective guide if latent mental errors are the primary causes of the accidents, which is usually the case in wildland fire burnovers. Since science has no methods for looking at subjective mental elements, then mental errors, in effect, do not exist so no subjective lessons are learned. Thus individuals involved are typically punished because the false assumption is they intentionally cause the negative events by not following the endless rules. Both the SAI and APA guides ignore the potent effects of mental stressors, common in wildland firefighting, which make it very difficult to remember rules such as Fire Orders or the Eighteen Watchout Situations at the precise time they are most needed. Said another way mental skills bottom out in the late afternoon at the time when fire behavior becomes the most active or extreme.

Both the SAI and the APA show little understanding of mental processes. Out of this fundamental ignorance they tacitly imply that people always act intentionally (SAI) thus blaming firefighters is considered; or that firefighters mindlessly follow rules (APA) and therefore focus on changing cultural and organizational rules to control firefighter behaviors. Neither guide has procedures for uncovering or understanding mental processes or what to do with the information if it were collected. Both ignore that there are logical consequences of choosing one experimental design (guide) over another and that choice in turn limits results and interpretations. This fundamental ignorance arises due to expert firefighters and managers leaving their quadrants of understanding and venturing into quadrants where they have little expertise when they conduct investigations.

They are led astray because the guides they follow for fire accident investigations have already made the same errors. Perhaps those who write accident guides, like modern psychologists, are holding observations so strictly to scientific, objectively external behaviors that they fail to note the limits of scientific method and its inability to explore the Intentional Quadrant. Their tacit conclusion is that if the event can't be studied scientifically, it must not exist. They ignore the real Truth that rational logical people have been successfully exploring the

Intentional Quadrant for thousands of years before the Scientific method existed and that Science itself is dependent on methods derived from the very quadrant it tries to ignore. Science itself has profound uses but comes with its own limitations; limitations ignored by most users.

Consider the roots of the two accident guides for serious fatal and non-fatal accidents: the SAI and APA respectively. The SAI arose from accident models that involved airplanes, vehicles and boats. The APA arose from a hospital medical model. These models view Human Factors (HFs) as interfaces between people and machines in a mechanistic physical world. Neither model really spends much time or effort looking at how our minds influence what we do. Human behavior is seen simply as S→R meaning an environmental stimulus propels us into taking a discrete action. A more advanced version is the S→ Black Box →R model. That is to say it is the Stimulus (S) (conditions, rewards, punishments, rules and regulations) in the external environments that control Responses (R) or actions. You need not explore or consider subjective mental environments of individual human minds; which are the mental "Black Box". This is the classic behaviorism paradigm which deals primarily with observable behaviors based on controlling external rewards and punishments. Behaviorism is assumed in both the SAI and APA. What is missed in these models is that Rs or Responses are usually also Discriminative Stimuli (SDs) for triggering the next behavior in a much longer response chain. Thus a resulting R is the proximal cause for the next response. That should remind us that an error can be both a result and a cause, contrary to the simplistic thinking behind the SAI and APA.

Behaviorism is a reasonable methodology for exploring the objective quadrants but falls short in the subjective quadrants. The four quadrants are themselves a conceptual model created to remind us of flaws inherent in using two quadrant accident guides as we attempt to better understand the reality we exist in. Although we talk about separate quadrants they are so intimately connected that they rise and fall together as one entity. A fundamental truth is that there are no separate Behavioral, Organizational, or Cultural properties in existence that don't have their basis in the Intentional Quadrant. To fully understand one quadrant is to fully understand them all. To ignore one quadrant is to ignore them all.

Most accident guides ignore the Intentional quadrant. It is more difficult to understand your or other people's minds because there are very few courses in public educational or military training systems and none in fire training systems that promote understanding internal mental processes. When we ignore our own mental processes this guarantees that we are also ignoring the related correlates in the other quadrants. Because we, as individuals, are constantly producing mental errors we are also constantly distorting reality with respect to physical, cultural and organization entities as well. When we have mental distortions then everything we relate to is also clouded or tainted. We cannot ever really understand why accidents occur or how to promote safety without better understanding our own mental processes. Meditation is the fundamental way, the sine qua non for understanding mental processes. Do you meditate? Most of us would answer no, so the SAI and APA biases are not surprising at all. However that ignorance translates into a rough doubling of fatalities, accidents, injuries and close calls and thus should no longer be tolerated personally or by agency risk managers and administrators.

In the past fifteen years or so, wildland agencies have begun promoting High Reliability Organizations (HROs) tenets to a greater extent. The APA in particular says it models itself after such tenets. HROs are conceptual thus fabricated organizations that cannot exist unless their operational processes first exist in people's minds. We hear a lot about learning from errors to become more resilient. When considering resiliency, there are no resilient organizations unless there are resilient minds in those organizations. Yet HRO training for resiliency stresses properties of resilient organizations (Behavioral and Organizational processes) and rarely considers how to train your own mind to become more resilient (Intentional Quadrant). Mindfulness meditation is the optimal practice to maximize resiliency but seldom mentioned with respect to HROs. When mindfulness is mentioned in the West it usually refers more to awareness and attention as behavioristic concepts in comparison to the East where it is an elemental mental skill fostered through meditation practice (Weick and Putnam, 2006). To me there are no mindful HRO's unless they promote mindfulness meditation for their employees and are populated by mindful employees (in the Eastern sense of mindfulness). *Our accident guides ignore mental processes precisely because we are in the habit of ignoring mental processes as individuals, cultures and organizations.*

**SAI Guide Specifics**

The SAI is an older and more accepted type of accident guide. The SAI guide can be thought of as a classic scientific, physical, and behavioristic causal model. It does a much better job of looking at casual factors related to aircraft or vehicle accidents or on wildland fire accidents with respect to weather, fuels, and fire behavior. The SAI mostly stays in the two exterior quadrants. The SAI tells us what happened but seldom why it happened. The strength of the SAI is in data collection, when done properly. Properly here means to ask in-depth relevant questions, record it electronically and have printed out statements for witness signatures. In the SAI investigations I have been involved in firefighters have been willing to be truthful but clarify that they also want other firefighters, managers and supervisors to do the same, so responsibility exists on a level playing field. The data once collected **properly** becomes a gold mine of information. If the data is publically available, then even years later, readers and researchers may discover connections missed by the original investigation team. Such data also allows trend analyses to look for causal factors and assess the strength of those factors over years of data collection. The negative aspect of SAI is that proper interviews and data collection are not the norm and the data once collected is often hidden supposedly to protect firefighters; but more likely to protect the Agency and accident team personnel for failing to get right the first time. Hiding interviews and data are the biggest ways Agencies routinely cover-up accident causal factors or what they failed to do. Until there is transparency our Lesson Learned Center has too many inaccurate accounts of fire accidents. At the Lesson Learned Center there is also a noticeable lack of articles based on mental elements and training for better understanding of firefighter realities.

When dealing with firefighter's actions the SAI model considers rules, rewards, punishments and doctrines as orders for what firefighters should do. From SAI premises, accidents occur when rules aren't followed so rule breakers should be punished. The most visible rules are Lookouts, Communications, Escape Routes and Safety Zones (LCES), the 10 Standard Fire Orders and the 18 Watch Out Situations (the 10 and 18). If all the 10 Orders are followed, in essence firefighters would need to stay home and never engage the fire. Breaking the rules is tacitly reinforced, though not overtly, with rewards. As long as the rules are broken and no one gets hurt things are ok with supervisors and managers and infractions are routinely ignored. However when accidents and fatalities occur there is a management guarantee that some the "rules" have been broken and that a corresponding, **easy to implement,** management fix is always available: "**Just follow all the rules**" and all will be fine again. Typically the SAI blames individuals for the root causes of the accidents and in particular individuals closest to the accident and typically does not explore why involved people did what they did. There are no SAI guidelines for understanding how to explore mental causality so it is trivialized or ignored and as if it never existed.

This SAI process begs a deeper look at the unstated implications. Behaviorism suggests that management driven rules, regulations, rewards and punishment can fully control firefighter and employee behavior. If this is indeed the case, then involved individuals should never logically be held accountable. If firefighters erred in what they did, then managers and their rules are the causes of those mistakes. *The central issue here is the locus of control for individual behavior.* If it is external and mechanistic then managers and others who set the rules are fully responsible. We can't really hold managers responsible either since their cultures and another set of rules should be controlling them in this mechanistic accounting system. However, if the locus of control is even partly internal, then the SAI guide and management premises that rules can fully control behavior are out of touch with reality. People can only be held responsible when they can reasonably control their own behavior at the time of the accident. And if this is the case, then we must next ask what sort of training fosters such personal control and if management and organizations are accountable to teach it? If you need a non-fire example, look no further than the huge casualty losses in our military for warfighters returning from Iraq and Afghanistan with mental problems. Meditation means both mind training and mind protection, something lost to those who perennially claim to be managers of people.

Unfortunately the SAI seldom goes into any depth into the subjective quadrants to encourage individuals and crews to look deeper either into their minds or cultures for new methods of improvement. Since the SAI as written does not fully deal with human reality it should be abandoned for burnovers and reserved just for aircraft and vehicles accidents. There is constant interaction between rules and mental efforts to manage those rules and still get the work done. Due to limited mental processing people cannot follow all the rules all the time and mostly act on autopilot. You can't even hold you mind on a single object for more than a few seconds so how can we intentionally follow all those rules? We will continue to have rules but must also understand how our minds interact with those rules. Is the APA a better guide?

## The APA guide

Next consider the newer, 2010 version of the APA guide, presumably for use in less serious accidents with national level of interest. The APA limits the causal factors to considering cultural and organizational elements and thus cannot reach full validation concerning the entire range of accident causes. Like the SAI it is limited primarily to two of the quadrants. Thus we can never quite trust the stories that an APA spins out of limited analyses. The APA guide is full of quotes apparently to convince users it is worthy of use. The APA process is part truth for what it advocates and partly misleading for leaving out the intentional quadrant. The strength of the APA is that it does makes a stronger effort than the SAI to look at the Cultural and Organizational quadrants while tacitly accepting the Behavioral quadrant so credited with exploring three of the four quadrants. A latent flaw pointed out but still ignored by the APA is that it never specifically recommends bringing in a sociologist or organization specialist to aid in exploring more complex accidents. This is surprising because the APA guide states "*For* *example, a ―human factors specialist‖ can be enormously valuable to illuminate human factors, as well as the cultural and social influences extant before and during the accident.*" When the APA team has a sociologist or "taboo" psychologist onboard, their written results will appear in a Human Factors Appendix yet these specialists <u>and</u> their Human Factors Report are not mentioned anywhere in the APA guide. So we have to question if the APA seriously explores cultural and organizational causes as stated. It is interesting that many readers of past APA accident reports based on a 4QA Human Factors analysis, written by me, have commented the HF section should be the primary focus of the report, rather than the section currently written up as the official "Story." The APA cites Karl Weick as someone who loves a good Story yet does not cite his caution that "what you look for is what you get." At what cost are we losing a better 4QA Story?

Unlike the SAI, the APA advocates less factual data collection. When we recall an event our recollections are always partial versions of the truth. What we recall always lacks the original causes and conditions of the events that arose and fell away at the time of the accident. APA Team interviewers can conduct interviews and either write down or trust their own memory for recalling the firefighter's words. Whereas the SAI may have an actual recording of the witness testimonies, the APA initially produces only a partial written version of the partial witness testimonies. Later even those team notes may be destroyed. Both the SAI and APA allow the witnesses a chance to correct what has been recorded in the accident testimonies or story, respectively. When we read a partially true APA story we are a long way from the actual causal elements. We have if you will…partial firefighter memories, partially recorded by team member notes or memories, which are partially used to spin an APA story. When we read the APA story it is a part, of a part, of a part, of the original Truth. I personally recommend recording all witness testimonies unless witnesses refuse to be recorded. In that case there should be multiple interviewers writing down what is said and those notes should be typed and preserved. Telling a version of the Truth using the more colorful adjectives found in stories makes duller facts come to life. The APA story approach is a plus if it can stay close to a True Story.

A real issue is whether firefighters will be punished in some way. Not even the APA can guarantee that no punishments will ensue. Firefighters have overwhelmingly told me they will be honest and take blame and criticism for their actions if managers and supervisors do the same. For all these stakeholders the climate should be to identify the causes and conditions and how to promote improvements in all four quadrants. The entire fire culture and the larger culture we live in are full of blame, judgment, criticism, etc. and *Just Culture* rhetoric will not change that. We blame each other out of ongoing habitual, unconscious mental processes yet fail to note similar mental processes led firefighters astray on the fireline. The key for changing blame cultures is refraining from negative behaviors both administratively and personally by reacting less to thinking and talking about blame when it arises. Rather in your mind note that "blame has arisen" then shift to exploring deeper levels of understanding the event. This necessitates exploring your own mental processes in the Intentional Quadrant, which is missing in the APA guide.

The APA limits investigators to considering *objectively observable* behaviors. As a behavioristic model the APA can realistically only recommend solutions that remove, change or create new rules, regulations, rewards and punishments such as the 10 and 18 i.e. typical external behavioristic methods of control. What the APA model specifically excludes is latent mental causes of accidents, which are almost always the predominant causes of burnover and fireline accidents if not all accidents. That exclusion means there will be no recommendations for improving firefighter minds.

The APA is "mindless" in that it assumes the accident causes are generally not connected to mental intentions, mental observations and mentally planned actions of the involved firefighters but rather due to what the agency or culture… "made" the person do though rules, etc. The authors of the APA argue that if we consider mental errors that this locks us into blaming the firefighters for the accident, just like the SAI, and runs counter to their adoption of the principals of a "Just Culture" where no one should be blamed for causing the accident. This, in turn, suggests no one is responsible for what they do and that firefighters are mindlessly irresponsible for their actions. The APA doesn't formally state the preceding but implies it in its tenets.

Thus, the APA needs to refocus and look at all the human factor causes of accidents: intentional, cultural and organizational. Combining these three with the fourth behavioral area, completes a "mentally healthy" consideration of the possible causal factors. Realistically, we live in a blame culture and even if an APA report doesn't blame specific people, our natural mental tendencies will be to blame them anyway. Just Cultures are somewhat fictitious in that they rarely exist other than as ideals. Day in and day out we are constantly blaming and judging. It is **just** a natural, human mind process to do so. All errors and mistakes are ultimately human and ultimately fabrications as well. Note that we rarely refer to "happy accidents" as due to positive errors because we wish to claim intentional credit for positive outcomes. And we claim to be collectively and individually responsible for earning those positive outcomes. It is people as individuals in cultures and organizations who make the rules which result in errors, mistakes and accidents. So blame is acceptable when the APA targets cultures and organizations conveniently "forgetting" they are peopled by individuals. Positive and negative outcomes are stories spun out of the same mental yarn; it is our judgments that split them apart and suggest when and where to deposit blame.

Although the APA does not embrace the intentional quadrant it does try to bring it in a back door. The APA tell us that "*In effect, an APA's ―causal factors are organizational, cultural, and individual human performance-shaping conditions—not causes—that obscure risks, normalize deviations from intentional risk management, encourage at-risk behaviors, or enable simple and inevitable human mistakes to trigger an unintended outcome.*" Most readers will note that "human mistakes" as accident triggers sure sound and function like human errors. Unfortunately ignoring errors won't make them go away. There are many factors in operation that produce human error but that **human error most certainly does cause accidents**. Errors are both consequences and causes: a virtual endless chain. They are two perspectives of the same event. Mental errors are based on ignorance of how our minds work. We are continually making mental errors, and those errors are part of the natural consequence of having human minds. Mental errors based on ignorance cloud our minds to keep the error process going. We mostly notice our errors in higher risk environments but they are always with us just the same. Looking for the source of the errors only in the workplace or organization is pure folly. We always have the option to mentally override both cultural and organizational rules and pressures. We must first attach to those rules or they can have no influence on our minds or our subsequent actions.

With mindfulness training we can learn the skill of non-attachment, stress reduction and to be mindful in our present environments. Thus reduction of mental errors is a learnable skill.

Many APA statements are classic scientific, behavioristic misconceptions based upon extending principals of one quadrant into a different quadrant, namely the objective into the subjective quadrants. The primary context in which errors occur is the very context of the mind in and of itself, without reference to the world. Reason, Dekker and the APA authors simply have yet to meet and observe their own minds as they are operating moment to moment. And failing to better know your own mind sadly means you can't truly see that the minds the involved persons in an accident are the main causal source for those accidents. Furthermore this is not to blame such persons, since they too do what they do out of ignorance as to how their minds work. Ignorance is almost always a prime cause and condition for most of our actions, though largely unconscious. Mindfulness makes normally unconscious mental processes observable and then begins to nullify the negative processes that cloud our minds.

A hospital type environment is significantly less hostile and life threatening to its employees and more controllable organizationally; thus many errors, such as failures to wash your hands, are easier to correct by an APA style of guide so it is no surprise that the APA has historical roots as a medical model. What firefighters need is a model that detects where and how the errors occur and what they can do to improve their own minds to keep up with their dynamic high stress jobs in much higher risk environments.

The APA states that the emphasis of their analysis "does not focus on where employees —made mistakes, nor does it attempt to identify what *should* have been done. Rather, its significance is to illuminate *why* employees actions seemed reasonable at the time." In truth the APA makes no real effort to "illuminate *why* employees actions seemed reasonable at the time" because the only possible way to do so is to enter the psychological, Intentional Quadrant. Hence the APA fails to do more than record what firefighters **report about their personal reality and says nothing as to how people perceive reality in the first place nor how to enhance those perceptions to minimize future accidents**. This in turn suggests that the APA deliberately ignores human error so the involved cultures and organizations can also ignore human error and absolve themselves from collective responsibility to take actions to minimize the 50 percent of accidents occurring due to individual based human error. Ignoring 50 percent of accident causes means firefighter and employee safety will never be number one as "mindlessly" claimed.

### SAI and APA guides

Collectively, the SAI and the APA guides fail to give true accountings of all the discoverable relevant causes, conditions, etc. of accidents. The APA considers one more quadrant than the SAI but it still misses fifty percent of the causes and conditions compared to the thirty percent missed for the SAI. Both effectively fail to account for how firefighter's minds affect what they do on or off the fireline or what can be done to make firefighter minds more aware, make better decisions and choose better actions. Since both the SAI and APA look almost exclusively at firefighter behaviors, rules and regulations etc. and physical conditions they will both implement their findings through adding, eliminating or changing cultural rewards, punishments, rules and regulations. If you encourage investigators to consider mental causes of accidents then the relevant recommendations for improving firefighter minds would be to promote skills like concentration and eastern mindfulness through meditation practices. With better mental skills, significantly fewer rule are necessary. Such skills are suggested in the key finding from an analysis of wildfire safety after the South Canyon Fire: "The ability to make decisions under stress represents what may be the single most important skill needed to improve firefighter safety. It is arguably the most important human factors change needed in the organizational culture" (TriData Report, 1998, p 5-50). Accident guides that do not promote looking at mental errors and considering mental recommendations are simply out of touch with wildland firefighter's work conditions and their collective reality.

**4QA guide**

Simply put both SAI and APA guides ignore the reality that *mental events are the most potent latent causes* for most human events including accidents. We are in this predicament, due in part, to Western psychology losing its historical focus on mental events and focusing almost exclusively on outward behaviors; (losing its mind, perhaps)? Currently Western psychology also focuses on rewards, punishments, and sadly drugs to control patient behavior. Once we ask the question: "Are accident causes latent in the mind?" i.e. due in part to mental errors, that we become willing to explore mental intentions, perceptions and conditions as casual factors. If we have minds and use them to guide our actions then mental causes exist and we should focus on what relevant skills are needed to improve our minds. How can we then improve our minds?

The answer is meditation with special emphasis on mindfulness due to its characteristic of enhancing awareness of where we are at, moment by moment, and mindfulness's other main characteristic of neutralizing habitual latent mental elements that cloud our minds. Additionally meditation protects our minds from becoming overcome by stress that is present on the fireline and other high risk activities such as combat. Meditation has a proven track record at least 3000 years old. In understanding this, wiser leaders and managers can foster mindful organizations by offering **mindfulness training** to individuals in those organizations. Blaming naturally recedes and personal responsibility increases at all levels through learning, practicing and promoting meditation in ourselves, our cultures and our organizations. The immune system enhancement plus brian changes in the positive emotion and decision making part of the brain is well documented. Mindfulness is the catalyst needed to best use all our other knowledge and training to keeping us maximally resilient to change and open to new insights. A note of cautions is in order. In the West use of the term mindful organizations is characteristically <u>behavioral</u> in nature. Generally it refers to techniques to foster better attention and discrimination. In the East mindfulness is a mental skill acquired through meditation; thus a mindful organization would be one that <u>teaches and fosters</u> mindfulness meditation for its employees. Consider Matthew Flickstein's (2010) brief summary of eastern mindfulness:

<u>"There are three elements necessary for Mindfulness</u>

1. Bare Attention
2. Concentration
3. Clear Comprehension

1. <u>"Bare Attention"</u> is bare of:
    a. Judgment
    b. Decision
    c. Commentary

2. Concentration does not refer to one-pointed concentration which is exclusive of all other objects; here it refers to momentary concentration that sticks to each successive object in the present moment.

3. Clear Comprehension means being aware in the present moment of the three characteristics of existence:

a. Impermanence; everything is constantly changing
b. Unsatisfactoriness; nothing lasts
c. Selflessness; not driven or determined by a lasting Self. Each self lasts no longer than momentary object contact so there is no unchanging or permanent self to cause the next moment.

When investigators have training in mindfulness meditation and apply mindfulness and the 4QA guide to their analysis then mindful investigations are possible.

Consider the dog and lion parable for learning the Truth (adapted for this paper). SAI and APA investigators are asked to act like dogs while 4QA investigators are asked to act like lions. When you throw a stick at a dog, it chases the stick. When you throw a stick at a lion, it chases the person who threw the stick. SAIs and APAs chase rules, the 4QA chases the Truth: how behavioral, cultural, organizational and intentional elements come into existence in the first place, how they interact and how to improve people's actions by a four quadrant driven analyses. In summary, True Knowledge of accidents and True Stories are dependent upon exploring all four quadrants to best understand the underlying events. Considering mental errors as causal elements in accidents prompts us to recommend mind training to reduce that class of errors. Such training is not considered in the current versions of the SAI and APA.

## Historical accident investigations with questionable reporting

The following historical accidents are based on my personal experience and involvement, which will help demonstrate the need for better guides, stories and oversight of the entire accident investigation process.

*Mann Gulch 1949*

I began my firefighting career in 1963 and worked three seasons on district fire crews. I was first introduced to the Mann Gulch Fire in which 13 firefighters died, while training as a Smokejumper in Missoula in 1966. As a new recruit who had never been on a really dangerous fire Mann Gulch was more a story than a crucial fire lesson. One needs more fire experience to truly know the deeper meaning of such tragedies and how to profit as a firefighter from the telling of the story. In 1992 Norman Maclean's "Young Men and Fire" provided the first detailed and widely read account of the Mann Gulch fire. Prior to Maclean's book I had seen "*Red Skies Over Montana*" several times. The movie was entertaining as long as you didn't let the fake fire scenes bother you. By the time I read Maclean's book in 1995 I had become highly skilled at analyzing firefighter actions when confronted with burnovers and by then was the Forest Service leading expert for conducting the fatality site analysis part of the investigations.

My first entrapment investigation began with the Battlement Creek Fire in 1976. Years later as a member of the 1990 Dude Fire fatality investigation team I wrote a special report on the fatality site specifics resulting in the deaths of six firefighters. This skill was captured as a primary duty in my formal job description as of March 1994 and said *"Conducts complex and detailed analysis of firefighter entrapments to determine interactions of firefighter behavior, the equipment used, fire behavior, and the resulting injuries or fatalities. Specialist is the pioneer in advancing scientific knowledge in this area*." Thus I read Maclean's book after the South Canyon Fire from the viewpoint of a very skillful fire fatality specialist.

In the reading of Maclean's book I was aware of many fire behavior points he made that were fictional elements as opposed to factual elements. For example saying people will be burned breathing in 140º F air when research shows people have breathed in air temperatures up to 450-500º F. This indicated that Maclean did not have the advice of a fire accident expert at the time of collecting the book materials who could skillfully interpret the relevant evidence or more importantly, notice the **lack of it**.

Of more significance was my reaction to the book as a whole soon after finishing it. I began explore my psychological observation that District Ranger Jansson had a classic guilt complex based on Maclean's account of the ranger's life after the Mann Gulch fire. I next posed the question "What was the ranger guilty of?" Immediately my question was answered with a flash of insight that the ranger had set the fire that killed the thirteen firefighters. That insight burned deeply into my mind more than anything Maclean had written. Whereas Maclean's story lacked a ring of truth my insight had that ring to it. Part of what I saw in my mind's eye was someone looking up just after lighting a fire, seeing something uphill and immediately, frantically trying to put out the fire he had just started. When a small whirl of fire burned this man, he stopped trying to put it out and fled. From accounts of Mann Gulch the only person known to be at the bottom of Mann Gulch, about the time the "spot fire" ignited, was the district ranger as he himself testified. What is noteworthy is that only the district ranger was allowed to talk about the spot fires in the bottom of Mann Gulch. At the Board of Review hearing no one else was allowed to contradict or question the ranger's story.

I also knew instantly why the ranger might have lit the fire that killed the firefighters because I had a near miss fire experience of my own, early in my career as a district firefighter. I was with a crew burning a large clearcut. The clearcut had roads contouring across it so we had started at the highest road igniting the fuels above it with propane burners. When we had worked down to a road about a quarter of the way below the top of the clearcut I heard someone yelling above the sounds of the propane torch I was using and the resulting fire above me. Looking up from igniting fuels and seeing another crew member waving franticly, screaming and then pointing downhill caused me to look downhill too. I saw a huge wall of flames coming uphill from below and beginning to surge towards my location. As I ran I began to wonder how any fire could have got below us. Later the district Fire Management Officer (FMO) told me the district ranger had lit the fire below our burnout crew. The FMO went on to explain that it was embedded in the District Ranger psyche, possibly from forestry school contacts, "that it is ok to do such acts in order to create a large scale fire on your district." As the "fire boss" you then get your name in the news and notoriety within the Forest Service; in short name recognition. With ranger name recognition, comes job upward mobility. Previously I had observed several times as a smokejumper, on fires with district personnel, that someone was tossing burning materials outside our fireline soon after we had moved on to another part of the fire. At the time I reported this to my Jumper Foreman and he just smiled and said welcome to the darker side of wildland firefighting.

At Mann Gulch the ranger had said embers from that main fire had traveled to the bottom of the gulch by winds flowing counter to the prevailing winds, counter winds that only he observed. He then saw spot fires and fire whirls and the fire in the bottom begin to spread. The ranger was burned by the fire in the bottom of the draw before he left Mann Gulch. In summary, there is time, location and possible intent to connect the ranger to the "spot fires" that killed the thirteen firefighters. Four of these spot fires are all in a row next to a trail which today would immediately suggest arson.

Whereas the above suggests but doesn't prove the ranger lit the fire, I strongly feel the Board of Review Investigation was a cover-up from the start, especially in its failure to take a closer look at the nature of the "spot fires" and the rangers' behaviors. This was obvious to me when I read the report after reading *Young Men and Fire*. A careful, critical analysis of the *Board of Review: Mann Gulch Fire, Helena National Forest, August 5, 1949* shows that the ranger's testimony was taken first and all other testimony bended to match it. When other witness mentioned testifying what they saw in the lower part of Mann Gulch they were interrupted and ask to talk about something else. Much of the ranger's testimony talked about a string of highly improbable events occurring simultaneously to create the fire that subsequently ran uphill to burn over the firefighters. One event was embers traveling against prevailing winds and another was about fire pushing downhill to his location against the up canyon winds. The ranger talked about a crown fire burning uphill to where the men died yet photo evidence shows a grass fire, not a crown fire, caught the fleeing men. Extreme pressure was put on the three survivors to cooperate with the Agency's Storyline and Timeline. Later the ranger said he too had been pressured into a common timeline. The ranger refused to look any of the board of review members in the eye and gave his testimony sitting in a chair with his pack towards the board members. For most of us, lack of eye contact suggests a person is not telling us the truth. What caused the spot fires that killed the firefighters rests solely on the ranger's testimony. Most witness accounts of the fire behavior, wind direction, flame heights, etc. disagree with the ranger's testimony but was not seen as problematical by the Board of Review.

A Fire Expert who wanted to observe the spot-fires' origins was forbidden to do so by the Team Leader, since it was not in the scope of the investigation. In the case of the Board of Review it is <u>what they ignore</u> and don't talk about that screams of a cover-up. Why would the Board of Review become involved in a cover-up? Just follow the money. If the ranger started the killing fire the Forest Service was libel as well as embarrassed should that Truth come out. There is evidence the ranger was also pressured to tell the story the way he told it. The only person on record to investigate the fire start in the bottom of Mann Gulch was Harry Gisborne, a local and nationally recognized fire behavior expert who worked at Rocky Mountain Research Station next door to the Missoula Smokejumper Base. Jansson was one of Gisborne's students at a University of Montana fire class. He and the ranger went back to Mann Gulch together to look for evidence of fire whirls and crowning that Jansson had reported. Gisborne had preexisting heart problems and died on the way out of Mann Gulch; so possibly the fourteenth fatality? Did Gisborne observe something that upset him enough to trigger a heart attack? Or did the only witness to his death, the ranger, tell the Truth when he said Gisborne found evidence to support his own board of review testimony?

Later, Wag Dodge, the supervisor of the men fleeing the blaze below, told a fellow smokejumper "We were burnt out from below". Dodge did not elaborate. Why not? It would be normal to add in the details. To stop short and clam up to a friend suggests that he opened a door for all hell to break loose and quickly slammed it shut before the mental flood-gates burst open. Was the ranger guilty as I have suggested and were Jansson and Dodge keeping explosive mental pressures just barely in check? By May 1951, Dodge learned he had Hodgkin's disease and died January 12 1955; Mann Gulch's 15thfatality? In 1964 Jansson contacted incurable kidney disease and died in 1964; Mann Gulch's 16th fatality? My psychological instinct notes both deaths were likely stress induced and/or accelerated. Do we now have our fifteenth and sixteenth fatalities? I think so as I have observed similar tendencies with other fatal entrapments. It is far better to tell the whole truth up front because otherwise an axe is hanging over both Agency and firefighter heads for a long time. I have been told some firefighters they would have preferred the truth up front, even blame, so they can deal with the pain now, given a chance to let it go and get back to less stressful living. We do no one a favor by protecting them from public knowledge of their actions in accidents.

This leads to another related mystery. How could Maclean miss something so obvious? Was Maclean deceived from the start? Maclean had no access to an expert for advice and was not familiar enough with wildland fires or investigations to see the obvious discrepancies. Did the Forest Service, in what help it gave to Maclean, deliberately lead him astray? Maclean did not finish his book before his death, though could have. Did he let it sit on the table until his death because he began to see a larger truth? Lots of questions and many of the answers are now known and other parts of this cover-up are still under investigation. From an accident analysis perspective the ranger lighting the spot fires is the least complicated explanation, thus the most likely one to be true. The highly improbable fire scenarios and elaborate cover-up efforts **make sense** if the ranger lit the killing fires.

My summary points are that Mann Gulch was an elaborate cover-up from the start, did little to help future firefighters and mostly protected upper level managers and the Agency's images. I invite readers to go back and take a more thorough look at the available evidence and to realize, like I have, that the Mann Gulch investigation set the pattern for later fatality investigations, namely that it is ok to cover-up the truth and blame firefighters and fire behavior than mental errors, cultures, managers or organizations. If our accident investigations don't promote finding and telling the Truth then Lessons Learned, firefighter safety and High Reliability Organizations are just convenient buzz words; lullabies numbing us out rather than keeping us awake to underlying conditions and causal elements which best account for our collective firefighter realities.

*South Canyon fire 1994*

On the South Canyon Fire July 6, 1994, fourteen firefighters were entrapped by a wildland fire near Glenwood Springs Colorado, not far from the 1976 Battlement Creek Fire. The entrapment investigation was conducted under an SAI type of procedures and protocols. True to such protocols the investigation mostly sought to determine what had happen and to blame those responsible. From the beginning there was more emphasis on speed to get the report out than on a quality factual report. Much was made about firefighters failing to follow the Ten Standard Fire Orders or to adequately use the Eighteen Watch Out Situations. As said earlier these accident elements follow behavioristic interpretations of accident causes. Early in the investigation someone on the team leaked information to the press that the firefighters had too much of a "Can Do" attitude. I pointed out the whole fire culture reinforces a Can Do attitude as a positive trait but it had already become a convenient way to blame the dead firefighters. As a team member I then felt that the leak was clearly designed to shift most of the blame downhill onto the firefighters and away from local BLM management miss-directions that preceded the fire ignition and continued throughout the fire suppression efforts well after the fourteen died. Months later the federal OSHA investigation brought some blame back to the Grand Junction District of BLM as did John Maclean in his **story** version of the South Canyon Fire: "Fire On the Mountain". Despite these and my own efforts to get the larger Truth out, several years after the South Canyon Fire most of the blame was still on the firefighters themselves. I was the only team member who did not sign the South Canyon report and was ordered to say why in a letter to the Chief of the Forest Service…my Chief. I said much in the report was incorrect, misleading and contradictory so should have been changed. However I said my biggest reason was that we had stopped at reporting **what** had occurred and said almost nothing about **why** it had happened. Our Agency heads were all too willing to let the investigation end without knowing other, more fundamental causes.

Many causal factors for the deaths at South Canyon were never mentioned in the official report. This was not a direct reason why I did not sign the report. I did not sign the report mostly due to it being poorly written as stated above. Too many errors were present which would lead readers into false conclusions; likely by design to shift blame away from BLM managers onto the dead firefighters. I had marked up three pages that were more of what most people would consider "editorial" in nature. The causal factors being covered up were not part of refusing to sign the report because our team leaders told us that the report being printed for "public analysis" was the best we could do in the allotted 45 days. Team leaders assured other team members that the final report would include all the casual factors after we better understood them by continued analysis. Historically I do not know if this was an up-front lie or if the decision to axe the final report came later. Thus the South Canyon report has elements of deliberate cover-ups like Mann Gulch and elements of partial cover-ups, with the promise that another report is coming and "trust us to fix the problems later." No later team report was written. Had I known that no further report was going to come out then the primary reason for not signing the report would have been the failure to report all the prime causal factors for the fourteen deaths.

I was ready to "go public" by telling what I knew to a willing press source. I was asked by a Deputy Chief to wait and give the Agencies a chance to improve. As part of waiting I insisted the Agencies support an in-depth look at the entire fire safety culture. This became the B-1 initiative and was later contracted to the TriData Corporation in 1995 and the results are now known as the *Wildland Firefighter Safety Awareness Study.* Because I had not signed the South Canyon report I was "blackballed" from attending most meetings for the rest of my career. The group putting the B-1 contract together would call me at night at home and ask for my opinions on how to write the contract. However they could not allow me to come to their location to help them write the work statement face to face. This contract team could not decide what the contract work statements should be so "lifted" them out of the recommendation section of a February 1995 article I had written on South Canyon. I received hundreds of positive emails from the article which introduced Human Factors to wildland firefighters. With such overwhelming positive feedback, in early 1995 I asked and received funding to sponsor a Human Factors Workshop in Missoula in June (see USDA Forest Service, 1995). Both studies have been instrumental in keeping HFs present in the collective consciousness of the wildland fire community. Later I asked fire experts at the Rocky Mountain Research Station in Missoula if they could provide clarity to the physical aspects of the fire that overran the firefighters. In a cooperative venture we produced the most accurate fire behavior or "<u>What</u>" account of South Canyon Fire to date (Butler et al, 1998). Most of these extra efforts arose because I did not sign the report but much has been lost by not telling a Truer Story of South Canyon from the beginning.

*Alabaugh Canyon fire 2007*

In 2007 I was asked to participate in the Alabaugh Canyon Fire accident investigation team. I was told that the accident was technically a SAI but that upper managers had agreed to conduct the investigation using the APA guide and protocols. I was very concerned about the team results being used to blame or punish the involved firefighters and was told that the APA we would use protected the firefighters from any punishment. I went so far as to say it was a condition of hire for my participation and was again assured that there would be no punishments administered. I learned I was hired to bring credibility to the APA process itself. This now seems absurd since I have suggested changes to the APA for years and my suggestions have been almost totally ignored. This failure to adopt reasonable changes to the APA was a major reason for writing this article.

As a team we began the interview process by assuring those firefighters being interviewed that there would be no punitive actions taken and encouraged them to tell us the whole truth. The interviews were written up, modified by the witnesses as needed and then signed. It was only later as we were doing final editing of the report that I began to feel uneasy. I was aware of no team meetings where any of the team members suggested blaming the firefighters, who got injured, for their own injuries. But the hint is always there when anyone implies all firefighters must always follow the Ten Standard Fire Orders. Thus over ten times I tried to eliminate that threat by removal of the "Ten.". My concern was that even if our team did not apply blame to the injured firefighters that the report, as written, still implied blame it by mentioning the "Ten" were not strictly followed.

Specifically the report says on page 5 "This investigation was also conducted in the spirit of the "Foundational Doctrine" for fire suppression activities. A fundamental difference in how this investigation was conducted, from those of the past, is that the team looked at how the Ten Standard Fire Fighting Orders, Watch Out Situations, LCES, and Downhill Line Construction Checklist were complied with, <u>not as absolute rules</u>, but rather as principles that require sound assessment and reasonable decisions. Consequently, the team sought an understanding of not only what choices were taken, but why individuals made the decisions. The team looked at the actions of the incident command team and individual firefighters with the philosophy that: "*employees are expected and empowered to be creative and decisive, to exercise initiative and accept responsibility, and to use their training, experience, and judgment in decision making to carry out the leader's intent"* (Foundational Doctrine, 2006). However, the Foundational Doctrine does not relieve leaders of accountability." We conducted the investigation under the guidance of the above paragraph, yet the last sentence is the un-doer of all that precedes it as it leaves the door wide open to judge, blame and punish.

When it became apparent that the "Ten" were going to remain in the report, I wrote and "we" used paragraphs like the following on page 6 to add perspective back into the report "The ability to assess and assimilate situational awareness and operational risks naturally degrades under extreme and chaotic conditions. The Operations Section Chief and the Division Supervisor are less likely to notice relevant information that may have altered their decisions and the subsequent events. Such conditions are also trigger points for considering disengagement from the fire. Consequently several of the LCES factors, standard firefighting orders and watch out situations were not followed, which led to the entrapment and shelter deployment." If you clearly understand the above paragraph and know from a psychological perspective that long term memory fails under stress, you also have a clearer understanding why cultural and organizational rules across the board also fail. They are rarely "mentally present" when all hell breaks loose. Yet they are then foolishly used to blame firefighters who performed their best under extreme conditions for not obeying all the rules, which are impossible to follow under the best of conditions.

The APA suggests the firefighters must see the future consequences that their actions will cause harm and do them anyway with deliberate intent as a basis for punishment to occur. At no point did we find deliberate intent as a team. Yet after the report was finished the two firefighters who were injured and their fireline supervisor were punished. Not only was this subsequent punishment barbaric and unjustified but it also went against the entire intent of the approval to use the APA in lieu of the SAI process. Not to mention that it also condoned lying to those same firefighters who were assured that if they spoke openly about what had happened then no punishment would follow. Clearly I was hired under false conditions that the Forest Service contractually did not follow. A small moral and ethical inconvenience to the Agency compared to those at Mann Gulch and South Canyon yet still a shameless act.

To a lesser degree this has led to my punishment as well. I was asked to join this team so my reputation to tell the truth would add credibility to the new APA guide. Since I told those firefighters they had no fear of punishment I have experienced the guilt and shame of unintentionally deceiving them. I have since met and apologized to two of the firefighters but there is really no way to undo what a mindless supervisor later did to them. We hear a lot about Just Cultures but should firefighters ever buy into more rhetoric that sounds good but never lives up to expectations since, after all, we still live in Unjust Cultures including our own Unjust Minds. Recall again that the punishments exist as part and parcel of our behavioristic analysis of fire cultures and organizations due to the behavioristic SAI and APA processes. We need clauses in the APA to allow punished firefighters a means for holding their punishers accountable. I have also been told my own reputation suffered due to this aspect of the investigation thus another reason to expose the lack of Justice fostered using both the SAI and APA.

Earlier at the start of this paper I argued that supervisors are clearly just as guilty, if not guiltier, and should have been given even worse punishments. The Foundational Doctrine is flawed when says "*employees are expected and empowered to be creative and decisive, to exercise initiative and accept responsibility, and to use their training, experience, and judgment in decision making to carry out the leader's intent"* but does not defend those same employees when events turn sour. Neither does Foundational Doctrine provide the funding for those employees to get all the training needed to function at the level of firefighting they find themselves embedded in; and especially training to reduce the effects of mental stressors. We still blame the dead and injured and yes … blame still rolls downhill.

To change for the better, the APA must enter into the Intentional Quadrant, and bring balance into fire accident investigations by using all four levels of analysis to improve firefighter safety. Without it APA Stories deteriorate towards telling Lies rather than reflecting the Truth. Real understanding of this inherent problem starts with yourself and changing yourself begins when you become a student of your own mind by actually observing your own **mental processes** (not content)…processes so near at hand, perhaps "near in mind," yet so far away in their actual observation.

*Crandall Ranger Station tree felling accident 2010*

Briefly, the Crandall Ranger Station Tree Felling Accident (USDA, 2010) began as a FLA process. After presenting the results to the Shoshone National Forest staff the general feeling was that the real causal factors were not completely known. The Shoshone National Forest has adopted the principals of HROs and thus more concerned than most agencies to look for the underlying causes to stay resilient as employees and as an organization. Since the report was short on **sensemaking** (Weick 1995) the FLA facilitator, Matt Gibson, recommended bringing in a HF psychologist to help make or bring more **sense** to understanding additional causal factors. This shifted the investigation towards an APA process and more specifically into exploring the Intentional Quadrant.

Consider the following excerpt from the Crandall Human Factors section I wrote:

*"The AFEO (Assistant Supervisory Operator, the injured tree faller) had agreed to meet with some of the team to return to the accident site. Concerned that the normal response is to become defensive amidst a group of investigators looking over his shoulders we opted to ask the AFEO to join our team. The AFEO was to be our felling expert and conduct an ASI (Accident Scene Investigation). As such we asked him not to focus on what happened but to just follow physical evidence and tell us in detail what he was observing and what the evidence meant.*

*Initially the AFEO was hesitant to go directly to "the stump" as it was too traumatic. Showing some resilience, another team member (Gibson) suggested starting the process by analyzing the stump, butt end, and other downed logs associated with the tree cut by one of the A fallers. The AFEO warmed into this analysis and demonstrated a wealth of knowledge showing us he indeed did have the prerequisite skill to size up and mitigate related felling hazards. When quizzed, he also had some misunderstandings. When the SFEO (Supervisory Engine Operator) agreed with the AFEO we learned the mistake was common to both of them. (As the one most ignorant of the fine art of felling trees, I learned a lot about complexities involved).*

*After a break the AFEO came back to the immediate area of the accident and soon began to look at the physical evidence and tell us what it meant. He took time to discuss the hazards and his reasons and expectations concerning mitigating them. Next he executed a detailed sequence of actions showing where he went, what he did there, and why he did it that way. One team member followed his actions of gunning the saw and was surprised to see that when sighted from below in the position the AFEO had been in, the sight line was near the base of the tree. The surprise* *came because when looking at the sight line up at the level of the stump, the sight line was lined up pretty much where the tree fell. This did not make up for the many errors but was clearly related to why the AFEO's expectations were so far off the actual outcomes. As a team it was quite literally worth the extra effort to "see what they saw at the time of the accident" and to "... truly understand why the decisions and actions leading up to the accident made sense to them at the time. We have come full circle back close to where we started. We have learned much and are grateful for the chance to have learned it. We hope what the AFEO and accident taught us extends to readers and others as well*."

The essence of the above excerpt is the interaction by the injured tree faller, the facilitator and myself to all get involved to create an environment for clarifying the very difficult understanding of interactions between what the timber faller was professionally trying to do Intentionally, along with some of the supporting Cultural aspects to allow all of us to appreciate what went amiss. With the resulting Human Factors section added to the report, the forest administrators felt this addition helped bridge the gap of understanding and the investigation report was completed and formally accepted. It exemplifies the potential robust nature of the four methodologies in the OLO guides and the ability to shift emphasis as needed. In showing the relevancy of the Intentional Quadrant it also exposes the fatal flaw in the APA guide.

## Recommendations

1. Consider combining the APA and AIG (SAI) into a single four quadrant document. If two guides are still needed it would make more sense to have the AIG used for vehicle and aircraft accidents and other machine-human interfaces. The APA would handle non-vehicle accidents, including fatalities, where all four quadrants are paramount...such as in burnovers.
2. Both guides should be written to include and promote all four quadrants. If they do not do so then there should be clear statements, up front, in these guides that state they will not look at certain classes of data; for example mental errors or causal elements and the clarification this results in a loss of 50-70 percent of recoverable causal factors.
3. Implement a guide or matrix for when to bring in quadrant specific skilled investigators such as sociologists, organizationists, and psychologists, for example. Both guides are already robust with respect to bringing in behavioral experts for weather, fire behavior, equipment, fuels, etc. because the team members are mostly firefighters.
4. Create and maintain a list for professionals skilled in the various quadrants. For less serious events keep another list for agency firefighters who also have undergraduate degrees in these same areas. Many firefighters with degrees in sociology, organizations, psychology or decision making etc. can help explore the quadrants for less cost when it is deemed appropriate by Administrators, the Team Leader and others. The lists are necessary so these specialists can be called upon quickly.
5. All team members who will conduct interviews should have 3-5 days of formal training in how to conduct interviews. They must also understand what questions should be asked for each quadrant. If no one asks cultural related questions then it will appear there are no cultural causal elements and the team would miss such causes even if cultural causes were the most crucial to learn.

6. It would help to have a chart that guides interviewers in what observations or questions are pertinent in each quadrant something like:

| INTENTIONAL | CULTURAL | ORGANIZATIONAL | BEHAVIORAL |
|---|---|---|---|
| Thinking | Trust | IMT Members | Fire Behavior |
| Perceptions | Respect | NIFC Response | Weather |
| Focus | Mutual Views | Rules and Regulations | Individual |
| Feelings | Cohesiveness | Qualifications: Red Card | Yrs. Experience |
| Hunches | Crew Image | Safety | Red Card Rating |
| Views | Conventions | Support & Equipment | Clothing |
| Stresses | Professionalism | Organization Chart | Fire Shelters |
| Truthfulness | Relationships | Rewards & Punishments | Fitness |
| Self Image | Leadership | Skill Mix | Skill Level |

Note: Many of these items could be found in more than one quadrant.

7. Related to interview techniques is requiring digital recordings for all interviews. Interviewers should also take notes for immediate team use. It is helpful for interviewers to later compare their hand written notes with digital copies to see if they have any systematic biases for what they record. The other reason for better data collection is that if the team members miss trends in the data, later researchers may discover them. All data except graphic body photos etc. should be made publically available to maximize lessons learned.
8. Develop a guide for firefighters and employees about interaction with accident teams. What is expected, required, optional, etc. Procedures to follow if your rights are violated. Since cover-ups are more the rule than exceptions, develop penalties for deliberate cover-ups, how to report them and have the offenders removed from the team...even deputy chiefs. Learning lessons is very difficult when investigation teams have the option to lie to witnesses or refuse to look for or report sensitive causal factors. We hold firefighters responsible now and we are long overdue to hold accidents teams accountable for their behaviors.
9. The APA promises no punishments, reprimands, loss of promotions earned but never given, etc. But if later negative actions against involved parties appear to be due to the fire or accident events, then what are your options for review? What are procedures for holding supervisors accountable for more professional behavior?

**Discussion and Summary**

The SAI has remained essentially the same for forty years but is currently under revision. The SAI does a good job at accidents involving aircraft and vehicles but only a fair job in burnovers where firefighters are the center of what went amiss. This state exists due to the SAI roots in aircraft and vehicle (physical orientated) accident protocols that primarily consider externally observable human behaviors and not mental processes per se. Thus the SAI is essentially a WHAT happened process likely to uncover only 30 percent of discoverable causes.

Since there is no deep understanding of the mind the SAI is left with blaming the body and hence the person involved in the accident. After all, the body is just another vehicle.

The Newer APA also delves primarily into the WHAT and meekly into the WHY if it appears to have cultural or organizational roots but views mental roots as too blame tainted to explore. Since mental roots are the sine qua non of all human involvement, the APA mostly pays lip service to the WHY aspects of accidents. Partly this is a natural result of the APAs roots as an epidemiology "blame" model taking its cues from the medical profession. The APA seems to have missed that firefighting is not a medical profession and that the medical model was inappropriate from the beginning. Relevant wildland fire accident guides should target firefighter's struggles to stay aware of and make decisions in fast tempo, high-risk environments where mental processes are acutely necessary. Considering the above the APA is likely at best to uncover 50 percent of discoverable causes. Said another way the SAI and APA guides use are associated with tripling or doubling accident rates, respectively, for what they ignore.

Some form of a **4QA** guide is the only model likely to uncover up to 100 percent of discoverable causes, thus the only viable type of guide for people in high-risk environments. The 4QA guide gives us the best opportunity to maximize safety and minimize accidents.

Accident investigations are like experiments. You need to decide what you want to know before you can know how to get it without inducing unwanted errors into your data collection and conclusions. What the present accident guides show is a blatant disregard for sound observations, data collecting and how the design (guide) limits conclusions and searching for underlying causal elements. All accident guides should therefore clearly state what they are designed to find and what they are designed to ignore. Choice of the relevant guides predetermines your accident results. Do you want to consider the two-quadrant SAI, the three-quadrant APA or create a new four-quadrant 4QA guide? This predetermines the percent of causal factors you may uncover: from 30, to 50 and up to 100 percent respectively. Actual percentages also depend on the skill of the investigators, the willingness of the witness to testify truthfully, the time and costs allowed for the investigation, and so forth.
One way to consider what adding the Intentional quadrant brings to an accident analysis would be to read the Human Factors sections of reports from accidents where I have been a human factors team member and added in mental causal factors. These four-quadrant reports are:

1. Alabaugh Canyon Fire, 2007
2. Cascade Complex Fires, 2007
3. Indians Fire, 2008 and
4. Crandall Ranger Station Tree Felling Accident, 2010.

The Indians Fire contains an added comparative account as it has essentially two human factors sections. My section emphasizes the intentional quadrant and one by Jim Saveland emphasizes the behavioral aspects of the cultural and organizational quadrants per APA guidelines. These reports are available at the Lessons Learned Center: www.wildfirelessons.net.

With respect to accident investigations I am convinced, as an expert accident investigator, that the current accident guides are more than twenty years out of date. Problems include:

- Failure to promote using all four quadrants, especially the mental, intentional quadrant.

- No current accident guide recommends that firefighters **tell the truth** and that what they say be made **publically available**. This information is crucial for determining human factors causal factors. Such data is also needed for trend analyses and possible later insights into new causal factors.
- Little to no formal training for investigators. We tend to muddle through with whoever is available at the time. Most often investigators are fire experts with little understanding of mental, cultural or organizational processes.
- Fictitious concerns for firefighter's protection. "Firefighter's won't tell the truth if everyone knows what they have said." Firefighters actually say they are willing to tell the truth and accept responsibility for their decisions…if others, including management do the same on a level playing field.
- In the APA there is too much Just Culture rhetoric which misses the point that blame is inherent in **fire** and **human** cultures because it is inherent in the way our minds process information. Stopping at WHAT begs our minds to **automatically** apply blame. You cannot stop your mind from applying blame but you can change your relationship with your mind by noting that blame has occurred then proceed directly to exploring the WHY. By examining our mental processes with mindfulness, we acquire skills to move beyond blame directly without the Just Culture rhetoric which, after all is just more rules and regulations.
- In accident investigations, as with examining our own lives, it is cheaper, quicker, and less immediate stress on us to use blame and punishment than on more costly, longer term, and farther reaching techniques using rewards and mental enhancements to improve decisions and understanding.
- No formal documents clarify firefighter rights during an accident investigation. There is a need to explore choices and rights during testimony and how to take actions against investigators who distort or lie about the investigation procedures or processes. There should be steps taken against supervisors and manager who apply blame and punishment indiscriminately as is now the case in the wildland community.
- No document, like the OLO, exists to guide Administrators and the initial Accident Team Leaders for determining what team members are needed for a specific accident event. Too often experts are left off the team or brought in well after the data collection and initial interviews are finished. This process results in skewed data collection and the experts miss the most accurate witness comments which are most truthful just after the events occurred. Days or weeks later the Truth has already gravitated towards Stories in the minds of those involved. This trend is not deliberate lying but more deceptively, occurs automatically because that is the natural way our minds react to such involvements. Experts cost more and may not always be necessary but it helps if criteria are set up to suggest or trigger when experts are needed up front. Once the Team Leader has a rough idea what happened they must decide if they need specific experts from any of the four quadrants. It may be simpler to always have them for fatalities and strongly considered for severe injuries. Such OLO trigger points are necessary in guides because they improve the decision process

when administrators and accident teams are themselves under stress and time constraints to act quickly.

- The following table briefly summarizes the fires covered in this report. Punishments refer to known or formal punishments and do not include less obvious ones such as not being promoted, loss of respect and so forth. This table is based on what I know about the referenced fire events:

| FIRE NAME | FULL COVER-UP | PARTIAL COVER-UP | NUMBER OF QUADRANTS | INVESTIGATOR QUALIFICATIONS QUESTIONABLE | PUNISHMENT METTED OUT | |
|---|---|---|---|---|---|---|
| MANN GULCH | Y | N | 1:B | Y | Y | |
| SOUTH CANYON | N | Y | 2:B,O | Y | Y | |
| ALABAUGH CANYON | N | N | 4:B,O,C,I | N | Y | |

Note: the quadrant letters refer to the first letter of the quadrant name i.e. B for Behavioral.

- In reviewing several accidents it is apparent that there is some deliberate covering up of causal factors by the agencies in charge of the investigations. This is an administrative problem and continues to exist because there are no counter deterrents in place. In truth, agencies like to have the option to protect the Agency’s image, protect their managers and to ignore unsavory causal elements. This criticism is somewhat independent of which accident guide is used.
- Many actual causal processes are never looked at during the entire investigative process. This may be a result of not having the right “quadrant” professional on the team. You usually only find what you are trained to find… given that it is there to find. Few investigators really look closely at all the processes, logic, conclusions, report sections, data verification, soundness and omissions that are necessary for the report to have integrity and a “ring of Truth.” Such breadth of skills is more likely from those with higher degrees.
- The APA is long on rhetoric but short on a real, deeper understanding of accident processes. Both guides can boast they rival industry and other government standards but it only points to the fact that most organizations do not want to look at deeper subjective factors. All accident guides, even those poorly written, can produce reasonably good reports if they have top notch people on the teams. This reflects the deeper truth of this paper. Namely that good minds and thinkers can override rules, regulations, doctrines, rewards, punishments …and accident guides… to produce quality products. Or on the darker side poor minds and thinking, in the same environment muddle through…with few observations, weak accident reports and loss of learning from mistakes.
- We are long overdue in organizing to promote mindful employees by exploring and providing training in the Intentional Quadrant, which is where true mindfulness and resiliency reside.

This paper began by suggesting a common thread exists between accidents, accident guides, stories and Truth. The common thread is our minds. An accident investigation analysis is simply a group experiment to tell the truth and the Four Quadrants are our experimental guidelines to enable us to come closer to that Truth.

Human minds are the root source for all Storytelling; in essence an ongoing Storyteller. Things begin to get problematical when we believe that our own Stories, thoughts, concepts, beliefs, etc. are somehow ultimately true when at bottom they are always mental constructions. Such fabrications are automatic processes of our minds and you can't stop these processes without specific mind training. What is needed is to observe your own mind as it spins all its stories and realize they are **just stories**. Our mental constructions only become problems when we **attach** to them. Attaching leads to cloudy minds with resultant future problems. By now it should be clear that the biggest Story of all is our **Self Story** Letting go of all our stories brings clarity and freedom. By staying unattached we are ready to enjoy the next story or event clearly because we have already let the previous one go. Hopefully you will begin advocating changes in the entire accident investigation arena and begin personally observing your own mental processes with mindfulness.

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## APPENDIX-A

**A BRIEF FOUR QUADRANT ANALYSIS (4QA) ACCIDENT INVESTIGATION GUIDE**

Accidents and events have processes at play in all four quadrants. Different quadrants may dominate depending on the event. The methodologies differ in each quadrant and thus should not be used in adjoining quadrants without entanglements. Adapted from a table and guides in Ken Wilber's *A Brief History of Everything*.

| INTERIOR, INDIVIDUAL | EXTERIOR, INDIVIDUAL |
|---|---|
| ***INTENTIONAL*** | ***BEHAVIOURAL*** |
| Mental/ Mind /Consciousness<br>Latent Human Errors<br>Thinking, Images, "Slides"<br>Introspective Psychology | Body/ Fitness/Nutrition<br>Environment<br>Personal Behavior<br>Operant Conditioning Psychology |
| **I** | **IT** |
| **INTERIOR, COLLECTIVE** | **EXTERIOR, COLLECTIVE** |
| **WE** | **IT** |
| ***CULTURAL*** | ***ORGANIZATIONAL*** |
| Mutual Understanding<br>Communications<br>Leadership<br>Shared Beliefs & Consensus<br>Situational Work Ethics | Crew Structure<br>Fire Organizations<br>NIFC/NWCG<br>Doctrine/Rules/Standards<br>Rewards/Punishments |

**Cited Accident Guides and Outputs:**
SAI: primarily uses the Exterior Quadrants: Behavioral and Organizational
APA: primarily uses the Collective Quadrants: Cultural and Organizational
4QA: recommends using all four Quadrants: especially the intentional/mental quadrant

SAI places blame on what is objectively seen with recommended changes in organizational regulations, policies, rewards and punishments.
APA places blame on cultures and organizations with recommended changes to the corresponding regulations, policies, rewards and punishments.
4QA places responsibility on people in all quadrants by noting what people are aware of and reacting to in the present moment with recommended quadrant specific training for personal improvement.

# Wildland fire suppression related fatalities in Canada, 1941-2010: a preliminary report

Martin E. Alexander[A,C] and Paul Buxton-Carr[B]

[A] University of Alberta, Department of Renewable Resources and Alberta School of Forest Science and Management, Edmonton, AB, T6G 2H1, Canada.
[B] British Columbia Wildfire Management Branch, 3080 Airport Road, Kamloops, BC, V2B 7X2, Canada. Email: wildland@cfff.ca
[C] Corresponding author. Email: mea2@telus.net

**Abstract.** This paper compiles for the first time a comprehensive summary of firefighter deaths associated with wildland fire suppression operations in Canada covering the period from 1941 to 2010. It is based on three sources of information: (i) annual reports of forest fire losses published and/or compiled by the federal forest service in Canada (1941-1990); (ii) annual reports of the Canadian Interagency Forest Fire Centre (1991-2010); and (iii) a summary being compiled for the Canadian Firefighters Memorial based on information supplied by fire management agencies and private aircraft companies. According to all of these records, there have been some 165 reported wildland fire suppression related fatalities in Canada over the past 70 years. This represents an average of at least two fatalities per year. There were no known fatalities reported in 23 of those 70 years. The maximum number of fatalities (16) in any given year occurred in 1955 in British Columbia, which also incurred 45% of the 132 firefighter deaths reported in Canada from 1941 to 1990. Many of the firefighter deaths have involved aircraft accidents.

**Additional keywords:** Canadian Fallen Firefighters Foundation, Canadian Interagency Forest Fire Centre, fatal accident, fire safety, fire statistics, line of duty death, wildland firefighter.

## Introduction

Approximately 45% of Canada’s land mass is covered by forests (Rowe 1972). With respect to wildland fires in Canada, noted global fire historian Dr. Stephen J. Pyne (2007) had this to say:

> Fire is a defining element in Canadian land and life. With few exceptions, Canada’s forests and prairies have evolved with fire. Its peoples have exploited fire and sought to protect themselves from its excesses, and since Confederation, the country has devised various institutions to connect fire and society.

For an appreciation of the significance of wildland fires in Canada, here are a few basic national statistics (after Hirsch and Fuglem 2006):

- About 8600 fires occur each year, burning over an area of some 2.5 million hectares.
- Lightning is responsible for approximately half the number fires, the majority of which occur in June and July, and roughly 85% of the total area burned.
- Fire management expenditures have reached $500-600 million annually and are growing.

Wildland fire suppression is an inherently dangerous activity (Jackson 1948, 1950). As a result, fatalities unfortunately do occur from time to time. In contrast to the extensive reporting on wildland fire suppression related fatalities in the US (Wilson 1977; NWCG 1997; Mangan 1999, 2007, 2010; Munson and Mangan 2000), there has been no similar effort undertaken in

Canada to date. To our knowledge this paper constitutes the first attempt at a comprehensive compilation of data on wildland fire suppression related fatalities in Canada, representing two distinctly different, but parallel efforts by the authors unknown to each other until October 2010.

**Annual reporting by the Government of Canada's forest service**

Canada's federal forest service began annual reporting of nation-wide forest fire statistics in 1909 based on data supplied by provincial, territorial, and federal wildland fire agencies (Van Wagner 1988; Murphy *et al.* 2000). Beall (1982) provides an excellent historical overview of the evolution of this process. The information included in this annual reporting gradually expanded in scope. In 1940, the first attempt to begin reporting the 'number of fatalities' nationally was initiated, although it wasn't until the following year when every agency provided data on this particular fire statistic. Such reporting continued up until 1990 and typically provided a 10-year average. Thus, a 50-year database of fire suppression related fatalities by province/territory readily exists, and except for seven years (1970-1976), is a matter of published record. The data sources, according to their various formats (Fig. 1) as described by Beall (1982), are as follows:

- 1941-1947: from within the annual reports of the Dominion Forest Service.
- 1948 -1957: from reports of the Canada Forestry Branch (Anonymous 1949-1958).
- 1958-1969: from reports of the Canada Department of Forestry (Anonymous 1960, 1961; Lockman 1966, 1969, 1970, 1972; Maclean and Lockman 1967*a*, 1967*b*; and Mactavish and Lockman 1962, 1963, 1964).
- 1970-1976: from unpublished "Forest Fire Losses in Canada" summaries, Environment Canada, Canadian Forestry Service, Forest Fire Research Institute, Ottawa, ON.[1]
- 1977-1990: from the Canadian Forestry Service (Brady 1979; Higgins and Ramsey 1992; Ramsey and Higgins 1981, 1982, 1986, 1991).

This first time compiled summary of the 'number of fatalities' from the above sources is presented in Table 1. This effort was started in the late 1990s (Alexander 2010*b*).

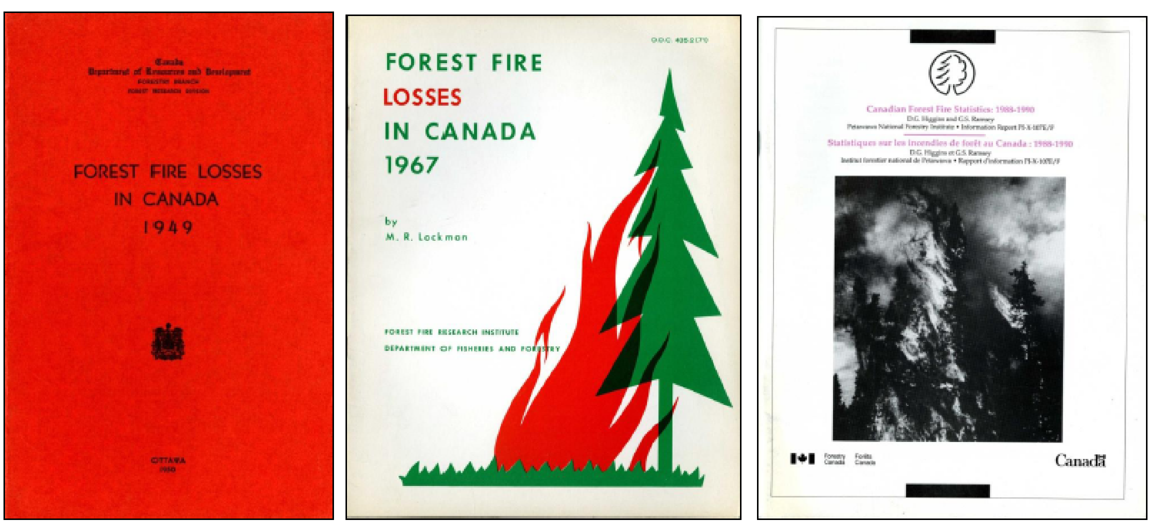


**Fig. 1.** Three examples of the annual reports on national fire statistics published by the Government of Canada's federal forest service over the period from 1941-1990.

[1] On file with Natural Resources Canada, Canadian Forest Service, Northern Forestry Centre, Edmonton, AB.

**Table 1. Number of wildland fire fatalities by Canadian province/territory as reported in the annual forest fire statistics compiled by the federal forest service, 1941-1990**

| Year | BC | AB | SK | MB | ON | QC | NB | NS | PE | NL | NT | YK | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1941 | - | 1 | - | - | - | 5 | - | - | -- | -- | -- | -- | 6 |
| 1942 | 1 | - | - | - | - | - | - | - | -- | -- | -- | -- | 1 |
| 1943 | - | - | - | - | - | - | - | - | -- | -- | -- | -- | 0 |
| 1944 | - | 2 | - | - | - | - | - | - | -- | -- | -- | -- | 2 |
| 1945 | - | - | - | - | - | - | - | - | -- | -- | -- | -- | 0 |
| 1946 | - | - | - | 1 | - | - | - | - | -- | -- | - | - | 1 |
| 1947 | - | - | - | - | - | - | - | 1 | -- | -- | - | - | 1 |
| 1948 | - | - | - | - | 11 | - | - | - | -- | -- | - | - | 11 |
| 1949 | - | - | - | - | 3 | - | - | - | -- | - | - | - | 3 |
| 1950 | 6 | - | - | - | - | - | - | - | -- | - | - | - | 6 |
| 1951 | 3 | - | - | - | 1 | - | - | - | -- | - | - | - | 4 |
| 1952 | 2 | - | - | - | - | - | - | - | -- | - | - | - | 2 |
| 1953 | - | - | - | 1 | - | - | - | - | -- | - | - | 1 | 2 |
| 1954 | - | - | - | - | - | - | - | - | -- | - | - | - | 0 |
| 1955 | 11 | - | - | 3 | 2 | - | - | - | -- | - | - | - | 16 |
| 1956 | 5 | 1 | - | - | - | - | - | - | -- | - | - | - | 6 |
| 1957 | - | - | - | - | - | - | - | - | -- | - | - | - | 0 |
| 1958 | 6 | 2 | - | - | - | - | 1 | - | -- | - | - | - | 9 |
| 1959 | 1 | - | - | - | 1 | - | - | - | -- | - | - | - | 2 |
| 1960 | 3 | - | - | - | - | - | - | - | -- | - | - | - | 3 |
| 1961 | - | - | - | 2 | 1 | - | - | - | -- | - | - | - | 3 |
| 1962 | 2 | - | - | - | - | - | - | - | -- | - | - | - | 2 |
| 1963 | - | - | - | - | - | - | - | - | -- | - | - | - | 0 |
| 1964 | - | - | - | - | - | - | - | - | -- | - | - | - | 0 |
| 1965 | - | - | - | - | - | - | - | - | -- | 1 | - | - | 1 |
| 1966 | - | - | - | - | - | - | - | - | -- | - | - | - | 0 |
| 1967 | 5 | - | - | - | 3 | - | - | - | -- | - | - | - | 8 |
| 1968 | 2 | - | - | - | - | - | - | - | -- | - | - | - | 2 |
| 1969 | - | - | - | - | - | - | - | - | -- | - | - | - | 0 |
| 1970 | - | - | - | - | - | - | - | - | -- | - | - | - | 0 |
| 1971 | - | - | - | - | - | 1 | - | - | -- | - | 6 | - | 8 |
| 1972 | - | - | - | - | - | - | - | - | -- | - | - | - | 0 |
| 1973 | - | - | - | - | - | - | - | - | -- | - | - | - | 0 |
| 1974 | 4 | - | - | - | - | - | - | - | - | - | - | - | 4 |
| 1975 | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| 1976 | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| 1977 | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| 1978 | - | - | - | 2 | - | - | - | - | - | - | - | - | 2 |
| 1979 | 1 | - | - | - | - | - | - | - | - | - | - | - | 1 |
| 1980 | - | - | 2 | - | - | - | - | - | - | - | - | - | 2 |
| 1981 | - | - | - | - | - | - | - | - | - | - | - | 1 | 1 |
| 1982 | - | - | - | - | - | - | - | - | - | - | - | - | 0 |
| 1983 | - | 1 | - | - | - | - | - | - | - | - | - | 1 | 2 |
| 1984 | 4 | - | 1 | - | - | - | - | - | - | - | - | - | 5 |
| 1985 | 3 | - | - | - | - | - | - | - | - | - | - | - | 3 |
| 1986 | - | - | - | - | - | 5 | - | - | - | - | - | - | 5 |
| 1987 | - | - | - | - | - | 3 | - | - | - | - | - | - | 3 |
| 1988 | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 |
| 1989 | - | - | 1 | - | - | - | - | - | - | - | - | - | 1 |
| 1990 | 2 | - | 1 | - | - | - | - | - | - | - | - | - | 3 |
| *n* = 50 | 61 | 7 | 6 | 9 | 22 | 14 | 1 | 1 | 0 | 1 | 6 | 3 | 132 |

Note: BC = British Columbia; AB = Alberta; SK = Saskatchewan; MB = Manitoba; ON = Ontario; QC = Quebec; NB = New Brunswick; NS = Nova Scotia; PE = Prince Edward Island; NL = Newfoundland-Labrador; NT= Northwest Territories; YT = Yukon Territory.

There are a couple of points to note in regards to Table 1. The Yukon Territory and Northwest Territories did not start contributing data to the national fire statistics database until 1946 (Murphy *et al.* 2000). Similarly, Newfoundland-Labrador didn't begin until 1949. Finally, Prince Edward Island only began reporting in 1974. However, based on local knowledge (D. McAskill, Prince Edward Island Department of Environment, Energy and Forestry, pers. comm., 2009) and other sources (e.g. Janzen 1990), it is believed that no wildland fire suppression related fatalities occurred in any of these jurisdictions between 1941 and the time they began reporting such statistics to the federal forest service. The 1971 Canada-wide total in Table 1 includes one (1) fatality on 'Other Federal Lands' but the specific location remains unknown.

On the basis of the data contained in Table 1, the following facts can be reasonably deduced about the wildland fire suppression related fatalities in Canada during the 50-years from 1941-1990:

- There was a total of 132 reported fatalities.
- The mean value (2.6) would suggest that on average there are about 2-3 fatalities per year.
- There were no known fatalities reported in 15 of the 50 years of record.
- The maximum number of fatalities in any given year (16) occurred in 1955.
- British Columbia sustained the highest number of fatalities (61), followed by Ontario (22) and then Quebec (14). Prince Edward Island was the only jurisdiction to have not registered a single fatality during this time.

Fig. 2 provides a general indication of the geographical distribution of the 132 reported fatalities.

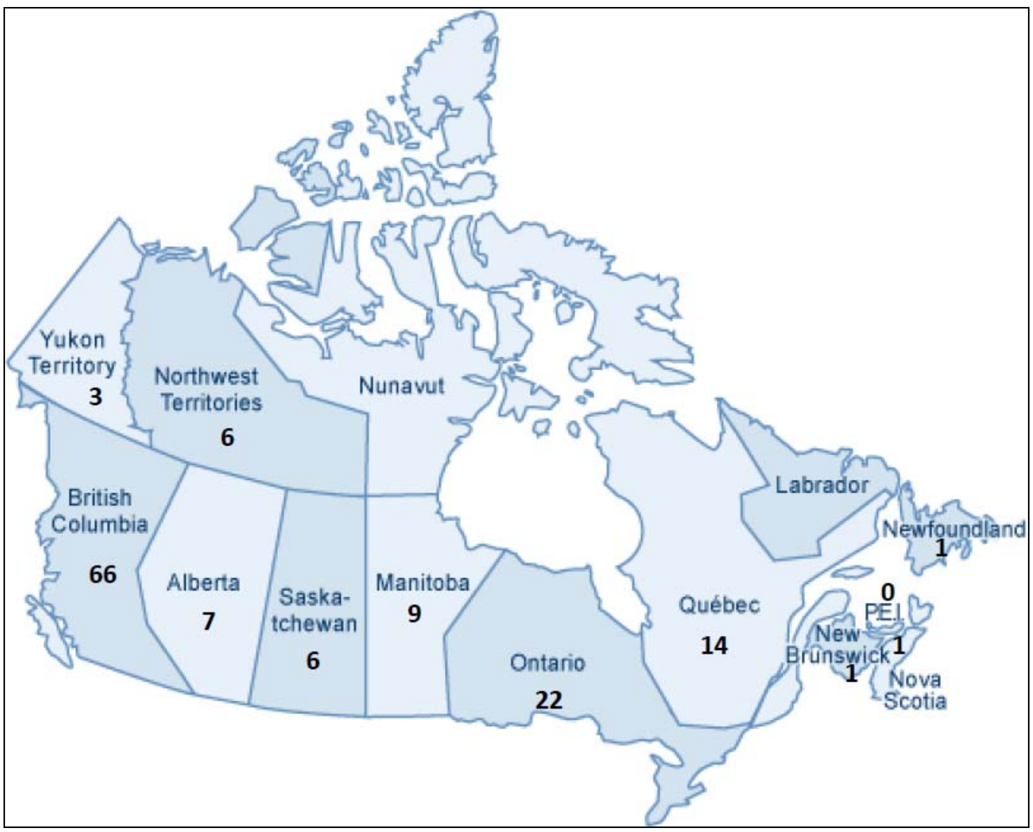


**Fig. 2.** Map illustrating the number of wildland fire suppression related fatalities in Canada for the 50-year period from 1941-1990 according to the provincial/territorial totals given in Table 1.

With the downsizing of the Canadian Forest Service (CFS) in 1995 and closing of the Petawawa National Forestry Institute, the compilation and reporting of national forest fire statistics by CFS fire research ceased. The National Forestry Database Program operated by the CFS (http://nfdp.ccfm.org/fires/quick_facts_e.php) continued to compile forest fire statistical data but not on fire suppression related fatalities. In 1997, the Canadian Interagency Forest Fire Centre (CIFFC) began producing annual reports which included data on firefighter fatalities in Canada but only the total number (http://www.ciffc.ca/). In other words there was no jurisdictional breakdown (Table 2). According to the data reported in Table 2, there were a total of 33 reported wildland fire suppression related fatalities in Canada during the 20-year period from 1991-2010, for a 70-year total of 165. The mean value (2.4) would also suggest on average at least two fatalities per year. There were no known fatalities reported in 23 of the 70 years of record.

**Table 2. Total number of wildland fire suppression related fatalities for the period 1986 to 2010 as reported by the Canadian Interagency Forest Fire Centre (from CIFFC 2011)**

| Year | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 00 | 01 | 02 | 03 | 04 | 05 | 06 | 07 | 08 | 09 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Fatalities | 6 | 3 | 3 | 0 | 3 | 4 | 2 | 0 | 2 | 4 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 3 | 2 | 0 | 3 | 3 | 2 | 1 | 5 |

To our knowledge, the forest services of Alberta and British Columbia are the only two organizations in Canada that have specifically developed ways to memorialize wildland firefighters that have died in the 'line of duty' (Figs. 3 and 4). In this way, as Gulliford (1997) phrased it, 'The living have remembered the dead, and therefore, the dead go on living'.

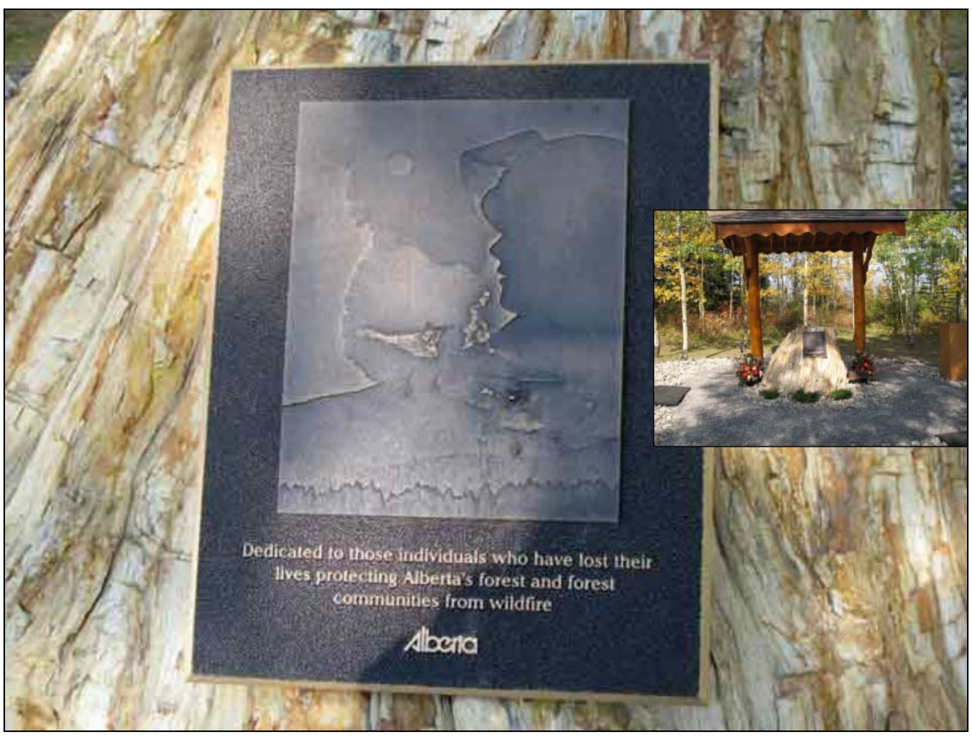


**Fig. 3.** Alberta Fallen Wildland Firefighter Memorial located at the Hinton Training Centre, Hinton, AB. Photos courtesy of B. Mayer, Alberta Sustainable Resource Development.


**Fig. 4.** Copy of the print that is prominently displayed in some 40 offices of the British Columbia Wildfire Management Branch. Courtesy of D. Marek, British Columbia Wildfire Management Branch.

**The Canadian Fallen Firefighters Foundation initiative**

The Canadian Fallen Firefighters Foundation (CFFF) was founded in 2003 (http://www.cfff.ca/). The CFFF includes paid and volunteer structural, wildland, military, and industrial firefighter fatalities. The CFFF began holding an annual ceremony starting in 2004. The CFFF have been working towards the establishment of the Canadian Firefighters Memorial in Ottawa, Ontario, scheduled for unveiling in September 2012. The intent is to include the names of all firefighters who have died in the 'line of duty'. The current list, dating back to 1848, includes the name of the firefighter, the incident date, and city/province, and can be viewed on the CFFF website (Fig. 5).

Paul Buxton-Carr currently serves as the wildland firefighter representative on the CFFF Board of Directors. Beginning in 2005, an effort was made to seek details on wildland firefighter fatalities, including pilots and flight crew, using a network of contacts in fire management agencies across Canada as well as private aircraft companies. The initial focus was on gathering basic information related to name, age, residence, location and date of incident, and cause of death. To date (April 2011), information on 149 fatalities has been compiled.

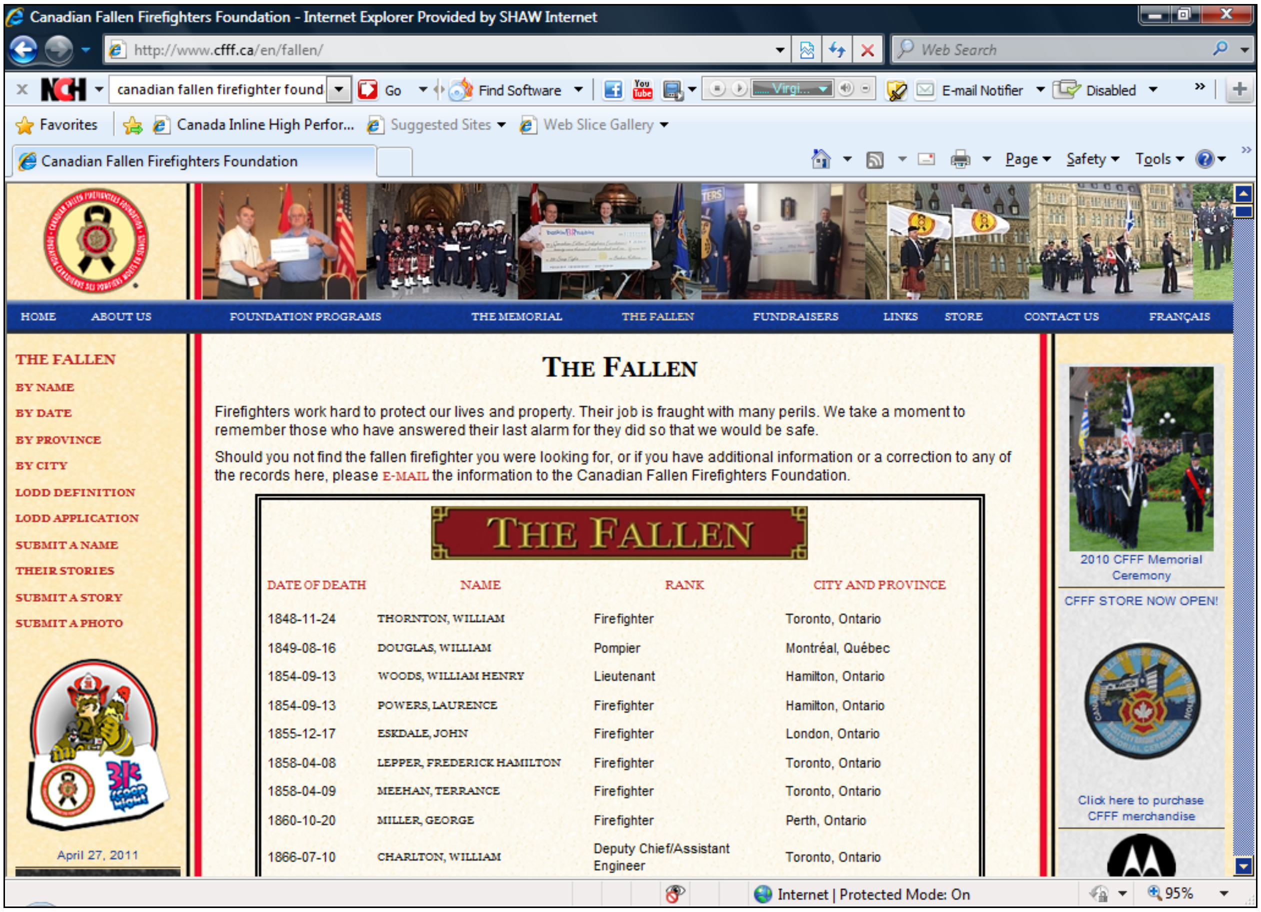


**Fig. 5.** Screen capture from the Canadian Fallen Firefighters Foundation website that lists firefighters that have died in the 'line of duty' (http://www.cfff.ca/).

## Causes of wildland firefighter fatalities in Canada

The federal forest service reports specify that the tabular data simply indicate 'The number of fatalities due directly to fire or while in the act of controlling a fire' (Brady 1979). The annual reports issued for the period 1948-1969 quite often, but not always, included some general comments (Table 3).

Unfortunately, the statistics reported in the federal forest service annual reports did not include fatalities related to prescribed fires. One notable example is the seven deaths associated with the Geraldton PB-3/79 incident in north-central Ontario on August 22, 1979 (Alexander and Thomas 2006, p. 17), otherwise known as the Esnagami Lake tragedy (Kirkpatrick 2004, pp. 177-178).

The CFFF website currently includes short summaries for some but not all of the wildland firefighter fatality incidents (Fig. 6). In the compilation effort associated with the Canadian Firefighters Memorial, the specific cause of death has not yet been determined for all of the reported fatalities. As a result, it is premature to attempt to provide a breakdown of the fatalities by cause, such as burnover or entrapment, aircraft accident, vehicle accident, heart attack, falling tree/snag or drowning, among others.

**Table 3. Comments related to the reporting of the number of fatalities in the annual reports of the Government of Canada's federal forest service for the period 1948-1969**

| Year(s) | Comments |
|---|---|
| 1948 | Eleven persons lost their lives as a result of forest fires in 1948. This number, although considerably higher than any other in recent years, is fortunately much smaller than those resulting from some of the disastrous fires earlier in the century. |
| 1949 | Three lives were lost – all in Ontario – as a result of forest fires during the year. |
| 1950 | There were six fatalities, all in British Columbia, as a result of forest fires in 1950. This is almost double the average for the past ten years. |
| 1951 | Four people lost their lives as a result of forest fires in 1951, which represents a decrease of two as compared with the lives lost during the previous year, but an increase as compared with the 10-year average ... Deaths attributed to forest fires are not necessarily caused by the fires concerned. A firefighter killed en route to a fire, for instance, would be classed as having lost his life as a result of fire. |
| 1952 | Two lives were lost as a result of forest fires in 1952, both in British Columbia ... This is the same number as in 1951, and is somewhat lower than the average for the previous decade. |
| 1953 | On person in Manitoba and one in the Yukon Territory died through forest fires in 1953. The yearly average for the previous decade was three lives lost. |
| 1954 | No lives were lost through forest fires in 1954. The yearly average number of fatalities for the previous decade remained at three. |
| 1955 | Sixteen people lost their lives as a result of forest fires in 1955 ... Canada-wide statistics of this item go back only to 1940, but none of these previous years showed such a large total. Only two of the 16 killed were fire fighters, neither of who was included in the 11 fatalities suffered in British Columbia. |
| 1956 | Reports indicate that six persons lost their lives as a result of forest fires in 1956. Five were in British Columbia and one in Alberta. |
| 1957 | No deaths were attributed to forest fires in 1957. |
| 1958 | The regrettable increase in the number of fatalities attributed to forest fires is also noted. |
| 1959-63 | No comments. |
| 1964 | For the second consecutive year, no deaths were attributed to forest fires in 1964. |
| 1965-66 | No comments |
| 1967 | Even more tragic, however, than all other forms of losses recorded in 1967, are the many fatalities suffered as a result of forest fire protection activities. A total of 8 deaths were reported across Canada. Three water-bomber pilots and two flying fire-observers were killed in the air crashes in British Columbia while three men also lost their lives in Ontario. Only two fatalities were reported on an average over the past ten years. |
| 1968-69 | No comments. |


**Fig. 6.** Screen captures from the Canadian Fallen Firefighters Foundation website illustrating two examples of the 'Their Stories' element to memoralizing wildland firefighters that have died in the 'line of duty' (http://www.cfff.ca/).

The details of the specific cause of death for some of the fatalities that have occurred in Canada are, however, generally well known as a result of the case studies included in firefighter safety training (Thorburn *et al.* 2000; Alexander and Thorburn 2001; Thorburn and Alexander 2001). The wildland fire literature also contains reference to specific firefighter fatalities. The publication by Fogarty and Alexander (1999), for example, was dedicated to a volunteer firefighter who perished as a result of burns sustained from being burnover in a grass fire in central Saskatchewan. Janzen (1990) also wrote that during the 1971 fire season in the Northwest Territories, 'two men were killed on the fireline by falling snags and another four were involved in an aircraft accident when two Canso water bombers collided'. Kirkpatrick (2004) describes some of the wildland firefighter fatalities that have occurred in Ontario in the past. Other than two firefighter fatalities in northern Alberta in 1944 (B. Mayer, Alberta Sustainable Resource Development, pers. comm., 2011) and another such incident in southern British Columbia in 1962 (Keller 2002), it is believed that there have been no other known incidents involving multiple deaths as a result of entrapments or burnovers.

**Implications and concluding thoughts**

Canada has reportedly experienced some 165 wildland fire suppression related fatalities over a 70-year period from 1941-2010. This equates to just over two fatalities per year on average. The following 10-year totals suggest a downward trend over time:

| 10-year period | 1941-1950 | 1951-1960 | 1961-1970 | 1971-1980 | 1981-1990 | 1991-2000 | 2001-2010 |
|---|---|---|---|---|---|---|---|
| No. of fatalities | 31 | 44 | 16 | 17 | 24 | 12 | 21 |

However, all of this masks the wide variability in the number of fatalities from year to year as illustrated in Fig. 7.

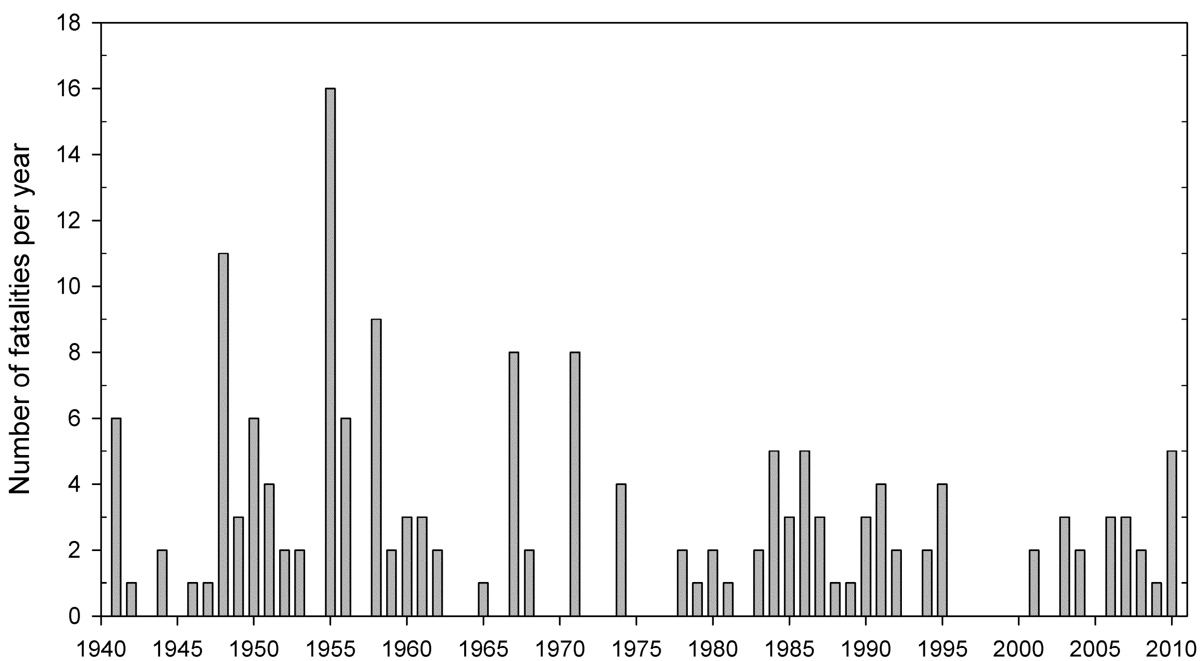


**Fig. 7.** Number of wildland fire suppression related fatalities by year in Canada from 1941-2010 according to the annual reports of Canada's federal forest service and CIFFC.

The firefighter fatality statistics contained in the CIFFC annual reports are periodically cited (e.g. Hendrickson and Greer 2001) without any thought as to what the geographical distribution of the Canada-wide totals might be or what, if any, the long-term trends are. Now, for the very first time, we have some insights into those issues.Canada has not suffered near the magnitude of wildland fire suppression related fatalities that the US has endured. For example, there were 196 wildland fire suppression related fatalities in the US during the 10-year period from 2000-2009 alone (Sutton 2010) or in other words, about 20 fatalities per year, in contrast to a total of 16 fatalities in Canada during the same decade. However, it must be borne in mind that the US averages about a hundred thousand wildfires per year (Flannigan *et al.* 2000; Omi 2005). Considering the relative differences in fire incidence between Canada and US, the mean annual occurrence of wildland firefighter fatalities between the two countries is quite comparable.

The various institutions that comprise Canada's wildland fire management community include the forest services of its ten provinces and two of its three territories plus several federal government agencies with land management responsibilities. Such a situation often complicates the collection of national records. The efforts chronicled in the paper should thus be regarded as a 'work in progress'. There is still much to do. For example:

- There is an obvious need to reconcile the differences in the number of fatalities being reported by the various reporting methods (i.e. the so called 'official published record' based on the federal forest service reported and the CIFFC reported data versus the CFFF compilation effort).
- There is a need to extract a breakdown on the number of fatalities by province/territory for the period from 1991 to 2010 from CIFFC in order to supplement the federal forest service record for the proceeding 50 years.
- Written summaries need to be developed for all of the wildland firefighter fatalities for inclusion within the 'Their Stories' element of the CFFF website.

Finally, a statistical breakdown of wildland firefighter fatalities should be undertaken once the above tasks have been completed. The early indications are that ~85% of the wildland fire suppression related fatalities in Canada are aircraft-related crashes (both rotary- and fixed-wing). Again, this is not surprising considering the magnitude of aerial fire suppression action in combating wildfires in Canada (Simard 1979; Murray 1986).

Mangan (2007) analyzed the cause of death associated with 310 wildland firefighter fatalities that occurred in the US from 1990-2006. He found that more than 20% of fatalities continued to occur as a direct result of bunrovers and entrapments. He acknowledged that Wilson's (1977) original common denominators were just as important in the 21st century as they were in the 20th. However, as the major causes of firefighter fatalities tend to shift, he suggested that additional factors need to be considered and in this regard, offered the following list of '21st century common denominators for wildland fire fatalities':

1. Firefighters are most likely to die in an aircraft accident. Before every flight, fire managers must ask, 'Is this flight essential?' and 'is everyone onboard essential to the mission?'
2. Firefighters are nearly as likely to die in a vehicle accident as in an aircraft accident. Driving too fast for the conditions, failure to wear seat belts, rushing to a fire, and driving home while exhausted from firefighting kills firefighters.
3. Firefighters can reduce their risk of dying from heart attack on the job by staying fit, maintaining their body weight, and having regular medical checkups.

4. Unexpected events such as falling snags, rolling rocks, downed power lines, and lightning strikes cause more than 8 percent of fatalities during wildland firefighting operations. Firefighters and fire managers can reduce fatalities by learning to expect these unexpected events.

One of the guiding principles of the Canadian Widland Fire Strategy Declaration is that ‘public safety—including the safety of firefighters—is paramount’ (Canadian Council of Forest Ministers 2005). The growing number of wildland-urban interface fire incidents and forest health issues in Canada coupled with concerns about climate change should be a cause for concern in the future in regards to the safety of not only the general public but wildland firefighters as well (Mangan 2000; Thorburn *et al.* 2000; Alexander and Stam 2003; Alexander 2010*c*).

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# Current understanding of wildland firefighter safety zone guidelines

B. Butler[A B], J. Forthofer[A], D. Jimenez[A], K. Shannon[A], P. Sopko[A]

[A] US Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, 5775 Hwy 10 W, Missoula, MT 59802
[B] Corresponding Author: bwbutler@fs.fed.us

**Abstract:** Wildland firefighter safety zone guidelines were developed in 1996, 15 years ago. This presentation reviews the assumptions behind those guidelines and evaluates the weaknesses of them. Recommendations are made for development of new guidelines that consider the impact of convective energy transport on safety zones.

**Additional Keywords:** wildland firefighting, safety zones, firefighter safety

## Introduction

Wildland firefighters are required to always identify a safety zone. It was relatively recently that quantitative information about safety zone size was proposed (Butler and Cohen 1998a; Butler and Cohen 1998b). This previous work was based on the assumption of radiant heat, vertical flames, and flat ground. The minimum safe distance for a firefighter to be from a flame was calculated as that corresponding to a radiant incident energy flux level of 7.0kW-m$^{-2}$ which was determined to be the level at which exposed human skin will develop a second degree burn in less than 90 seconds when covered with a single layer of fire retardant clothing. An approximate correlation was derived from this model that indicated a minimum separation between the firefighter and fire should be equal to four times the flame height. For a circular safety zone, this would be equal to the safety zone radius. When fires are burning on flat terrain, convective energy transfer is primarily upward in the plume while radiant energy transfer occurs out ahead of the fire front. Current firefighter safety guidelines are based on the assumption that radiant energy transfer is the dominant energy transfer mode. Qualitative comparisons against measurements from wild and prescribed burns indicate that the separation distances generated by the current safety zone model of Butler and Cohen (1998) are relatively accurate. However, it is not clear that the model holds up for instances when convective energy transport could be considered to be substantial. For example, when steep slopes are located near a safety zone, convection along the slope could require greater separation distances. It is also clear from site visits to designated safety zones on numerous wildland fire incidents that considerable ambiguity exists regarding identification or creation of true 'safety zones,' versus 'deployment zones.'

This study presents the current understanding of wildland fire safety zone analysis and discusses efforts to extend it to include convective energy transport.

## Discussion

When considering wildland fire, burn injury can occur by several different energy transport modes. Conduction is likely not a relevant energy transport mode in wildland fire injury, but convection and radiation are likely. Very little work has been completed relating

Table 1—Burn injury thresholds

| **Convection Air Temperature (C)** | **Exposure time (sec)** | **Test conditions** | **Injury level** | **Reference** |
|---|---|---|---|---|
| 120 | 420 | Dry air | Pain | (DiNenno *et al.* 1995) |
| 150 | -- | Dry air | Maximum survivable breathing temp | Nat. Res. Council of Canada |
| 180 | 180 | Dry air | Severe burn | (DiNenno *et al.* 1995) |
| **Radiation Flux (kW/m$^2$)** | | | | |
| 2.5 | 40 | Bare skin | Pain | (Stoll and Chianta 1969) |
| 4.2 | 30 | Bare skin | 2$^{nd}$ degree burn | Stoll and Chianta 1969 |
| 5 | 75 | 1 layer Nomex | 2$^{nd}$ degree burn | (Ackerman 2010) |
| 7 | 50 | 1 layer Nomex | 2$^{nd}$ degree burn | Ackerman 2009 |
| 10 | 10 | Bare skin | 2$^{nd}$ degree burn | Stoll and Chianta 1969 |
| 23 | 3 | Bare skin | 2$^{nd}$ degree burn | Stoll and Chianta 1969 |
| 25 | 12 | 1 layer Nomex | 2$^{nd}$ degree burn | Ackerman 2009 |

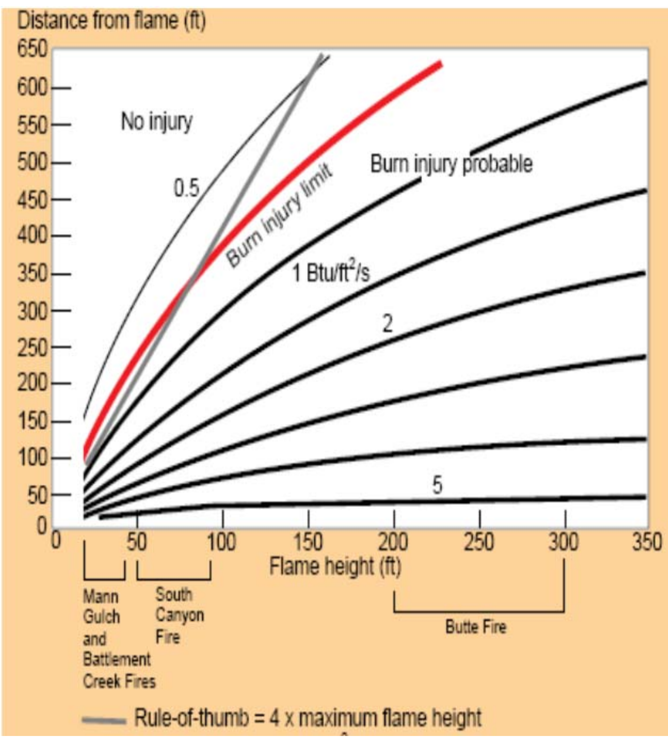



**Figure 1--Original results of safety zone model from Butler and Cohen (1998). Fires noted on horizontal axis indicate approximate flame heights associated with them.**

heat exposure to burn injury. Table 1 summarizes the data relevant to wildland fire burn injury thresholds.

Current standards were developed by correlating the energy distribution in front of the simulated spreading fire to the injury levels for human skin covered in a single layer of Nomex. 7kW/m$^2$ was selected as the threshold above which no injury would occur. From this correlation shown in Fig. 1 the linear model was fit to the injury line. The slope was approximated at four, thus the four times flame height correlation. As shown this model over predicts the separation distance for flames greater than 33m in height and slightly underpredicts for flames between 0 and 33m. Fig. 2 presents a set of measurements of radiant and convective energy from wild fires in Western Montana during 2008. The data indicate that radiant energy fluxes are much higher than the threshold for burn

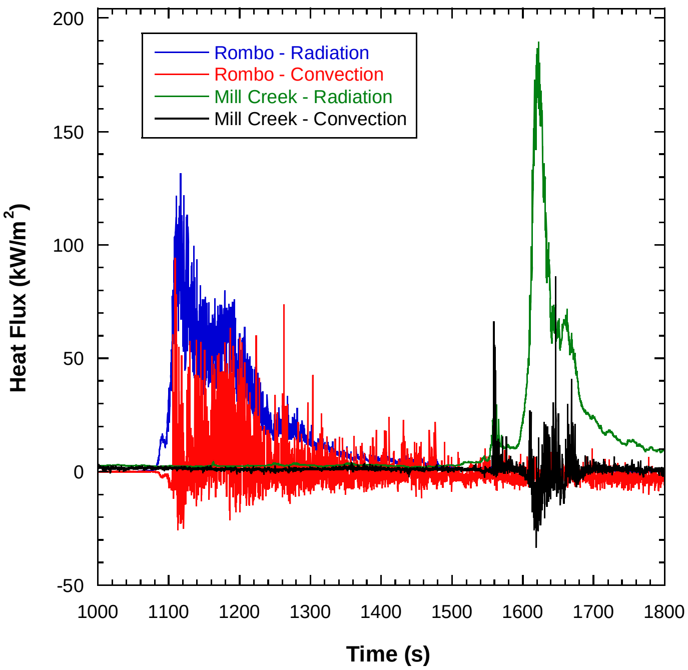



**Figure 2--Measurements of heating levels in wildland fires.**

injury. Convective energy fluxes are also substantial but also show wide fluctuation between cooling and heating, indicating the dependence of convection on turbulence in the flow field.

Fig. 3 presents an idealized image of the geometry explored by computer modeling of energy transport from wildland fires. A fire is ignited at the base of the slope and allowed to burn up the slope. Virtual heat flux sensors are placed along the slope and the relative energy levels quantified. Wind speed, slope angle and fuel load are primary variables for the simulations.

Fig. 4 presents output from the simulation model. The data indicate the distribution of energy along the slope.

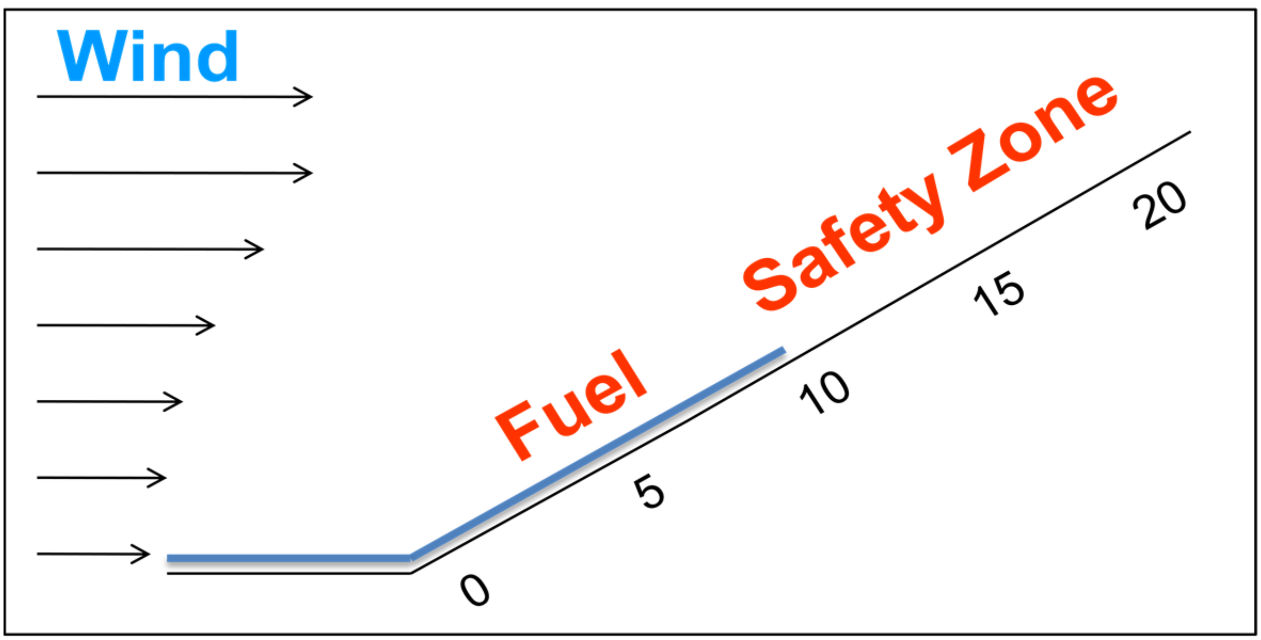
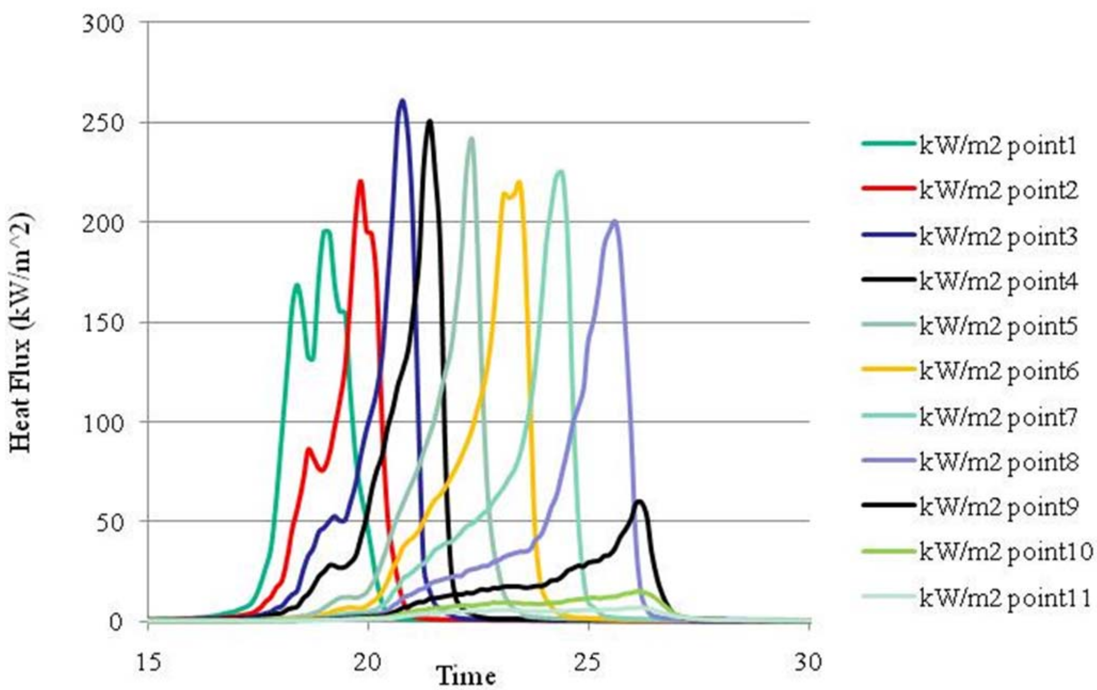



**Figure 3--Image of computer model simulation of fire on slope.**

The decrease in heating level at the point where the fuel ends and the safety zone begins is also indicated. These simulations will be repeated for a range of input variables to develop a correlation between wind speed, slope angle and fuel load to convective and radiant heating levels. These heating levels will be compared against burn injury levels to evaluate the accuracy of the current safety zone guidelines and if needed modifications will be developed.




## Conclusions

Current research focused on safety zone guidelines suggests that convective energy heating

**Figure 4--Simulation model output.**

levels are significant and should be accounted for in the safety zone analysis. This applies primarily to safety zones located on or near slopes where convective energy heating can be significant. Ongoing work will continue to apply deterministic models to the simulation of heating levels.

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***The Cost of Safety on Wildland Fires: How Much is Too Much?**

Dick Mangan[A]

[A]Blackbull Wildfire Services, 11400 Kona Ranch Rd, Missoula, Montana, 59804, USA, blackbull@bigsky.net

## Abstract:

Wildland fire fatalities, accidents and close calls over the past few years, with the resultant investigations and reviews coupled with the fear of criminal and civil liability, have caused some fire personnel and Line Officers to take extreme measures to increase the chances of survival should a firefighter become injured. Some of these measures include flying a "short-haul capable" helicopter over 1000 mile to be available on-site of a wildfire; requiring a helicopter be sole-use dedicated in case an evacuation might be needed; and requiring EMTs and Advanced Life Support Paramedics be assigned at the Crew and Division levels on a wildfire.

This talk will address the risks involved in wildfire operations, the historical record of serious and fatal accidents that have occurred on the fireline in recent years, and the implications of establishing a new "Standard of Care" that might be difficult and/or impossible to meet under normal fire season conditions. It will not only address the actions that occur on major wildfires managed by Incident Management Teams, but also the impacts of these new proposals on initial attack and extended initial attack fires.

*Abstract appears as it was originally submitted.

***Advances in Protective Clothing and Equipment for Wildland Firefighters**

David Moore, Jr.[A]

[A] Glendale Fire Department, 30 Village Square, Glendale, Ohio, 45246, USA,
dmoore@glendaleohio.org

**Abstract:**

Changes and advances are consistently being made to protective clothing and equipment for wildland firefighters. Are all of these changes actually advances? Are they worth the money? Are the safe? How can you be sure?

*Advances in Protective Clothing and Equipment for Wildland Firefighters* will explore how and by whom changes and advances are made in wildland protective equipment. This session will focus on NFPA 1977, Protective Clothing and Equipment for Wildland Firefighters. Attendees will learn the details of NFPA 1977, how to use it to better protect and manage personnel and resources. They will also learn how to give much needed feedback on the standards to drive the next wave of changes impacting wildland firefighting equipment and protective clothing.
Additionally, students will learn ways to determine the safety and effectiveness of wildland equipment and protective equipment that may not be addressed, tested or governed by globally recognized bodies. Time will also be spent on how to differentiate between testing and advertising of wildland protective clothing and equipment.

Finally, this session will review some of the proposed safety changes to NFPA 1977 and wildland PPE and equipment in general as we move forward into another decade of wildland fire across the globe.

*Abstract appears as it was originally submitted.

# *PTSD: T stands for Trauma. T stands for Training

Bill Arsenault[A]

[A]Wildland Fire Rescue, 7945 Wilbeth Lane, Nampa, Idaho, 83686, USA,
barsenault.idaho@yahoo.com

## Abstract:

Post Traumatic Stress no longer is a military only related problem. Each year wildland firefighters are hurt or killed in the line of duty. And each year will also see an increase in the number of returning combat veterans applying for wildland fire positions. This presentation will provide all members of the wildland community no matter their level of qualification important "Watch-Out" situations regarding those who may experience some form of PTS. This information will come from the eyes of the beholder.

*Abstract appears as it was originally submitted.

## *2009 National Wildland Fire Reform, "The Palmer Perspective"*

January 29, 2009

by Robert Palmer

### ***Short History***

My world changed on July 25, 2008. I lost faith in the "fire world's ability to help one of their own."

I had just returned from a 14-day wildland fire assignment in Northern California, when my Fire Management Officer meet me in the parking lot to tell me about my younger brother, also a member of a wildland fire staff; "Rob, Andy was hit by a tree this afternoon and isn't doing well. I'm going to drive you to the airport and fly you back down to California." I made it to the airport, 15 minutes away, when I received a call informing me that Andy had died en route to the hospital.

He was 18 years old, a recent high school graduate, enrolled in college for the fall, and lived a vigorous life. After a couple of weeks of training, this was his first fire assignment and first day of real work when he died. Andy's incident provided me with a very raw and a very distinct perspective considering my experiences. I now understand what it means to lose a loved one tragically. I know what it is like to watch a falling tree kill a fellow crewmember and the frustration of not being able to change anything. I also know how Fire Management operates after serving over 10 seasons in fire and as a crew supervisor with the National Park Service (NPS).

### ***Problem***

I have protected our national lands, I have worked with some of the finest employees in this country, and I have fought for their interests. I now need your support as I fight for my brother's; we have a National Fire Management Program that cannot provide for the safety of its most important resource, its employees. Several weakness's and human factors contributed to Andy's death, but Andy is not alone. One would be naïve to attempt to focus corrective actions on one factor, for we have a much larger problem. We aggressively engage too many fires. We need to ask the questions, "Why are we doing this? and Why are we here?"

## ***Objective: Golden Hour Response***

Determine response and engagement based on the capability to deliver any injured fire personnel to an appropriate medical facility in less than 60 minutes. This will:

- Decrease engagement to SAFELY mitigate risks during response
- Establish Emergency Medical Standards on an Incident
- Dramatically decrease costs associated with wildland fire
- Decrease impacts to the ecosystem

We must decrease our engagement because we do not have the capacity to evacuate injured fire staff safely.

## ***Necessary Actions***

Given a lack of rescue and prompt evacuation capacity, we must decrease our engagement until our emergency evacuation capacity complements our engagement. In the short term, we will therefore limit our exposure until we have the capacity to rescue any fire personnel to an appropriate medical facility within 60 minutes, the golden hour. The "golden hour" of trauma defines that if one suffers massive life-threatening injuries reaches an appropriate receiving hospital within 60 minutes, the individual has the greatest survival rate. "Historically, wound data and casualty rates indicate that more than 90% of all casualties die within the first hour of severe wounding without advanced trauma life support".[14] Instead of reacting and floundering through an emergency within an incident, we will determine future wildland fire response tactics based on the principles of the golden hour, invoking the first radical change in the history of wildland fire.

## ***Intended Outcome***

*Mitigation: Golden Hour Response within an Incident*

Severe life-threatening injuries are probable during any aggressive wildfire operation. Preseason planning would ensure the hospital(s) and local transport agencies are prepared, equipped and staffed to receive and respond to such life threatening burns and injuries. If ground units cannot evacuate any and all injured fire personnel within 60 minutes, then current serious medical plans rely on helicopters. If we rely on helicopters, then they must be prepositioned, capable of flying in limited visibility, and they must have hoist and short-hual capacity. Wildfires by their very nature produce smoke, haze, and decrease visibility for flight operations. The more important management question, "Do the hazards, vulnerabilities, and risks involved with rescue operations match the cost/benefit/risk analysis of the fire assignment?"

Given the fact that fires and inversions create visibility restrictions that can limit aviation to Instrument Flight Rules (IFR), I will argue we cannot rely on medical evacuation helicopters. If we cannot utilize medical evacuation helicopters, then we are limited to ground transportation. Assuming competent providers are associated with every deployed fire resource (Strike Team, Task Force, Module –Engine, Crew, Helicopter, Dozer, etc), then the Golden Hour Response must account for the patient assessment, patient packaging, and time to ground transportation. The question then relies on data from past medical incidents, "On average how long does it usually take to deliver a critically injured person to an appropriate medical facility?" If the answer is more than an hour, then the resources are overextended. Incident Commanders and Incident Management Teams have a duty to provide for safe work environments and to mitigate hazardous situations. Given the hazardous conditions and remote work environments, we will only mitigate the wildland fire risks with the principles of a Golden Hour Response. Every person assigned to a non-initial attack fire shall be provided the ability to reach an appropriate medical facility with 60 minutes of a life threatening injury.

> "We must beat the clock. We have only recently explored the advantages of forcing the full impact of American medicine into that first 60 minutes following trauma on the battlefield. It isn't simply a golden hour; every minute is golden." [14] Strawder, 2006

*Preparedness: Implement Emergency Medical Qualifications on an Incident*

In order to facilitate the Golden Hour Response, we must shift our emergency medical approach to wildland fire planning. Medical Unit Leaders (MEDL), those responsible to lead medical care on an incident, currently only have to be qualified as an EMT-B. Aside from the ethical issues caused by placing an unqualified person in charge of incident medical control, the policy imposes significant personal liability. An EMT operates under the license of a physician, therefore can not act independently as Medical Control. When presented with difficult decisions, a MEDL as an EMT may be acting outside their scope of practice. A paramedic is good, a physician assistant is better, but only a competent physician is best. This is not a question of duty, but of standard of care and scope of practice. Prolonged care and minor injuries commonly seen in a medical unit are outside the legal scope of any EMT. An EMT is trained for emergency trauma; not stress/strain injury consultation, not blister treatment, not long-term wound/burn treatment, or providing treatment for "camp crud." These common injuries must be treated by a qualified and competent medical professional like: an athletic trainer working with a physical therapist, nurses or physicians assistants working with a physician (MD, DO), nurse practitioners, and naturopaths. The weakness and lack of incident medical accountability demand significant reform.

Currently, the Interim NWCG Minimum Standards for Incident Emergency Medical Services NWCG#010-2008 [9], approved June 30, 2008 epitomize the wildland Fire Management attitudes. The minimum requirement of one (1) Emergency Management Technician Basic (EMT-B) to 499 incident personnel or two (2) EMT-B's for 1000 incident personnel only facilitates system failures. A quick glance at similar industries like: structural fire, military units, or high school football games, indicates that wildland fire, arguably the highest risk second to some military operations, also has the most room for improvement.

- **Wildland Fire—1 EMT per 499 Employees or 0.2%:** The lowest medical ratio in the industry combined with inadequate physical fitness standards demonstrates room for improvement. Current 310-1 Wildland Fire Qualification System Guide[16] does not classify an EMT as a fireline position and therefore EMT's do not have physical requirements like that of other fire personnel. MEDL do not have a physical fitness requirement.

- **Structure Fire—*1 EMT per Employee or 100%:*** The basic requirement for entry level (paid) structural fire personnel includes an EMT-B. This means that an engine with five fire personnel will have five EMT-B's.[8] Fitness standards vary by department, but the standard Candidate Physical Ability Test involves multiple stations and a time limit.[5]
- **Military—*1 Medic per 8-16 Employee, 6-13*%:** Military references are limited, but they use Health Care Specialists (68W/91W[8]) who are qualified in the civilian world between an EMT-B and EMT-P.[11] Requirements vary but minimum staffing levels identify at least one 68W per squad[1] (8-16 military personnel)[12] and the 68W works for a local Physicians Assistant or Physician, providing accountability. Different branches and units have different physical standards all of which exceed those of wildland fire.
- **High School Football— *2 to 4 EMS per 22 Players, 13%:*** During high school football games, the standard includes: one paramedic unit (an EMT-P and EMT-B or two EMT-P's), Certified Athletic Trainer(s), and generally one physician. [4] The medical team increases in staffing and qualifications through college and professional football.[6,10]
- Finally, rodeo medical teams may provide insight for another model involving an advanced incident medical unit.[13] Research into rodeo and recent military operations would provide ample support for portable Emergency Rooms. The concept of a portable Emergency or Operating Room adequately staffed would complement the Golden Hour Response. Issues of training, pay, and recruitment may provide opportunities for an "Incident Team Residency" sponsored by a medical school. This mitigation would allow for extended activities distant from a local hospital but still abiding by the Golden Hour Response.

Most incident personnel involved with wildland fire management do not have the knowledge, skills, or abilities to safely mitigate acute emergency medical responses, I propose the following:

- Require arduous duty fitness requirements for the EMT-B position.
- Require all EMT to also be qualified at the FFT2 level with at least 2 assignments prior to functioning as a field EMT.
- Mandate a minimum of one field EMT per 10 line personnel, a 10% ratio. For example,
    - A 12-person strike team of Type 6 engines must have at least two EMT's.
    - Type 2 Initial Attack or Type 1 crews must have one EMT per Initial Attack module: 1 EMT per 5-7 fire personnel, 14-20% ratio.
    - Type 2 crews must have 2 EMT's: 1 EMT per 10 fire personnel, 10% ratio.
- Falling modules must have a single resource boss (FELB, CRWB, ENGB, etc) and should have an EMT attached to the module, but must have an EMT within 5 minutes. This allows an EMT to safely work with multiple falling modules.
- Implement incident medical control with competent and qualified licensed providers for non-initial attack incidents.
- Utilize the military, football, and rodeo medical models at remote Incident Command Posts:
    - Advanced trauma management provided by physicians and physician assistants similar to that of the Combat Health System Level I/II (the lowest levels). [14]
    - Remote Type 1 incidents, those more than an hour away from an operating room, need to provide a surgical unit probably positioned at the Incident Command Post.
- If fire personnel are in hazardous conditions to warrant Hazard Pay, then Advanced Life Support must be readily available.

I understand we cannot mitigate nor save all injured fire personnel, but we can at least raise our medical capacity to the standard of care defined by our peers. If anybody questions or states the cost that such *Emergency Medical Qualifications* are too high, then the cost of engagement is therefore too high. No fire is worth killing or permanently disfiguring an employee.

> "In instances during Iraqi Freedom where units were thinking far-forward and joint, the successes were monumental and were responsible for a died-of-wounds rate of about 1 percent...Far-forward surgery enjoyed unprecedented success. Forward Resuscitative Surgical Squads supporting the Marine Corps lost none of the casualties they received. For the first time ever, the Army attached a forward surgical team with every brigade [2000-5000 personnel] committed." [14] Strawder, 2006

## ***Human Effect***

It has taken me 10 years working as an EMT-B, 10 years working with Fire Management, and losing my youngest brother to understand the issues currently facing wildland Fire Management. We cannot continue as we have done in the past, for our actions have devastated too many families, paved too many bricks in Boise, and buried too many "boots with Honor." I know we cannot bring our fallen home, but we can aggressively change our strategies such that more can walk home. If you tolerate wildland fire's current engagement strategies and accept the casualty rate, then maybe I do not understand "Objective 1: Provide for Safety First".[7] I know we are charged with protecting resources but our most important resource, our employees are dying. We must learn from our weaknesses to challenge our historical practices and apply the appropriate management response.

## ***Contact Information***

Robert Palmer
FJ40ROB@hotmail.com

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# Are you firefit?

Livingston, Bequi[A]

[A]Regional Fire Operations Health and Safety Specialist, 333 Broadway SW, Albuquerque, NM 87102. E-mail: blivingston@fs.fed.us

## Abstract

This poster was submitted to the'Electronic Poster Session' for the 2010 Safety Summit to display the most current information regarding the FireFit program alongside information from the Missoula Technology and Development Center (MTDC) in relation to it's recent publication, "Fitness and Work Capacity, 2009 Edition."

**Additional Keywords**: FireFit, wildland firefighting fitness, fitness and work capacity

## Introduction

Fitness can be defined as the body's ability to perform physical activity without distress or injury. Although most people rarely engage in arduous physical activity as part of their daily jobs, wildland firefighters know that physical fitness not only plays an important role in personal wellness and job performance, but also is critical in the dangerous environment in which we work. Research suggests that by incorporating a balanced fitness program into our daily work, including the work on the fireline, we enhance our health and safety, while mitigating our risk of injury and illness and increasing our ability to do work safely. Arguing the significance of fitness to work capacity, Sharkey and Gaskill (2009) write, "Work capacity is the employees' ability to accomplish production goals without undue fatigue and without becoming a hazard to themselves or coworkers. Work capacity is a complex composite of aerobic and muscular fitness, natural abilities, intelligence, skill, experience, acclimation, nutrition, and motivation. For prolonged arduous work, fitness is the most important determinant of work capacity" (p. 25).

## Fitness and the Firefit program

Fitness continues to be one of the most important components of a balanced wellness program. Like it's counterparts, which include nutrition and stress management, fitness has a unique importance of its own especially when it comes to the job performance of wildland firefighters. When firefighters are in good physical condition, they tend to work harder and are more productive. Being in good physical shape is a factor in lowering absenteeism and improving morale both individually and as a crew, not to mention how it positively affects decision-making ability. Wildland fire tends to challenge the physical and mental abilities of firefighters who find themselves in stressful environments that can transform into life or death situations. Fitness and wellness is a personal responsibility that carries implications for individual health as well as job performance.

FireFit, an interagency wildland firefighter fitness program, was created in 2006 with support from the Federal Fire and Aviation Safety Team (FFAST) with the intent to provide the interagency wildland fire community with a comprehensive, easy-to-follow, fitness program with the ultimate goal of improving firefighter safety and health and reducing injuries. This unique program provides a basic format that allows individuals or crews to develop a well-balanced fitness program that can be augmented as local levels see fit. The program provides essential information, specific to wildland firefighter fitness and wellness, allowing them to individualize the program based on their specific goals and objectives. The unique components of the program ensure that all the essential components of fitness are utilized in order to provide balance and promote injury prevention. Program success will rely on support at every level of fire management as well as the individual's motivation to participate.

The FireFit task group, as sanctioned under FFAST, includes representation from the major Federal wildland fire agencies combined with each primary wildland firefighting resource (hotshots, smokejumpers, helitack, engines and leadership); as well as subject matter experts (e.g., exercise physiologist and fitness specialist) including individuals from the Missoula Technology and Development Center. Due to the efforts of this task group, and continued support provided through Federal fire and Aviation Safety Team (FFAST), Safety and Health Working Team (SHWT), and National Wildfire Coordinating Group (NWCG); the task group continues to improve this successful program which is outlined on our website: http://www.nifc.gov/FireFit/index.htm.

FireFit incorporates three specific modules that address pre-season, fire-season, and post-season fitness. Each module is unique as it provides a basic fitness program 'framework,' specific for each season that will enable the wildland firefighter to develop a balanced and consistent fitness program while incorporating all the essential components of fitness; aerobic fitness, muscle strength and power, muscle endurance, core strength and stability, and flexibility. The modules can easily augment existing fitness programs to encourage consistency and safety, year-round fitness, injury mitigation, and the promotion of wellness.

The FireFit program has evolved, recently becoming a committee falling under the Risk Management organization under the National Wildfire Coordinating Group (NWCG). With this new organization comes an official group charter which outlines the group's mission and intent. As of 2010, FireFit has continued to collaborate with Missoula Technology and Development Center (MTDC) creating a unique partnership to ensure that there is consistency in our focus of wildland firefighter health, wellness, and safety.

**Conclusion**

FireFit continues to lead the way when it comes to wildland firefighter fitness with many firefighters worldwide utilizing the program for their individual and crew needs. Firefit continues to address other wellness components that include mental fitness, team building, injury prevention, core stability, and the development of mental checklists. The FireFit committee corresponds regularly to provide updates to the website including the most current and relevant information for the wildland fire community, such as the development and implementation of wildland firefighter fitness assessments. We invite you to visit our booth at the 2010 IAWF Safety Summit in Missoula, Montana.

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Proceedings of 11th International Wildland Fire Safety Summit, April 4-8, 2011, Missoula, Montana, USA
Published by the International Association of Wildland Fire, Missoula, Montana, USA

# *Measuring Productivity and Efficiency of Suppression Resources and Evaluation of Exposure to Firefighters to Fireline Dangers

Jon Rieck[AB], Dave Calkin[A]

[A]USFS - Rocky Mountain Research Station, Missoula, Montana, USA, jrieck@fs.fed.us, decalkin@fs.fed.us
[B]Corresponding Author

**Abstract:**

In recent years, management of large wildland fires has become more complex and expensive. New tools to identify the productivity and efficiency of firefighting resources could improve strategic management response and assist federal fire management agencies in addressing concerns regarding the value of investments in wildfire management identified by the GAO and OMB. In order to better understand the productivity of labor and capital resources engaged in fighting larger wildfires, we developed a spatially explicit approach to quantify both the productivity and efficiency of suppression resources. The analysis includes spatial and temporal measures of how different types of fire fighting resources are deployed on a large wildland fire in terms of the terrain, fuels, weather, and fire progression. By matching resource assignments from the daily shift reports with the fire perimeter and developed fire lines, the productivity and effectiveness of resources may be measured. Beyond measuring productivity and efficiency, geospatial analyses allow for enhanced evaluation of exposure of firefighter to fireline dangers. We will demonstrate how the application of simple geospatial tools with readily available daily reporting typically maintained within larger fire camps can allow improved management of fire fighter exposure and strategic learning within after action reviews.

*Abstract appears as it was originally submitted.

# *Understanding Emergency Medical Services on the Fireline

Bill Arsenault[A]

[A]Wildland Fire Rescue, 7945 Wilbeth Lane, Nampa, Idaho, 83686, USA,
barsenault.idaho@yahoo.com

**Abstract:**

Give the Incident Commanders, Safety Officers, and other operational leaders in all fields a clear understanding of medical care capabilities of those who provide care as well as the fundamentals of providing proper care.

Objective: To provide the attendee with an understanding of EMS license types for those who provide medical care on the fireline. This includes personal, local and contracted EMS agencies, and Air-Medical Resources that are often the secondary care providers when a firefighter is injured or becomes ill.

Allow the attendees to receive a basic overview of recent Accident Investigation Reports, Facilitated Learning Analysis of fires that involve Incident Within Incident, and Lessons Learned in preplanning for medical emergencies.

To give leaders of crews of all types the basic fundamentals of understanding of the need for EMS base-line training and continuing education for the maintaining of skills and knowledge.

*Abstract appears as it was originally submitted.

Proceedings of 11th International Wildland Fire Safety Summit, April 4-8, 2011, Missoula, Montana, USA
Published by the International Association of Wildland Fire, Missoula, Montana, USA

# Simplified control of a relay pumping system

Stephen Shoap [A]

[A]IFFC LLC, 12 Sheffield Rd. Wakefield MA, steve.shoap@alum.mit.edu

**Abstract:**

Relay pumping can supply water over long distances, but existing equipment requires continuous monitoring of pressures and flows at each booster pump. A firefighter must be dedicated to monitoring and controlling each pump. Each firefighter must be able to communicate with all of the other firefighters on the relay to insure that pump pressure and flow changes are coordinated. On a long relay, a firefighter, or a crew, is forced to remain at a location that might become dangerous. If they leave the location, the relay may fail.

By adding a data network to a relay system, all of the pumps in the relay can be controlled by a personal computer that is driven from a control panel. Once the hose and pumps of the system are deployed, there is no need to dedicate a firefighter to control each pump. Firefighter safety is enhanced since there is no need to remain with a pump that is in an area that might be overrun by a fire.

**Additional Keywords:** relay pumping system, firefighting safety, hose data network

## Introduction

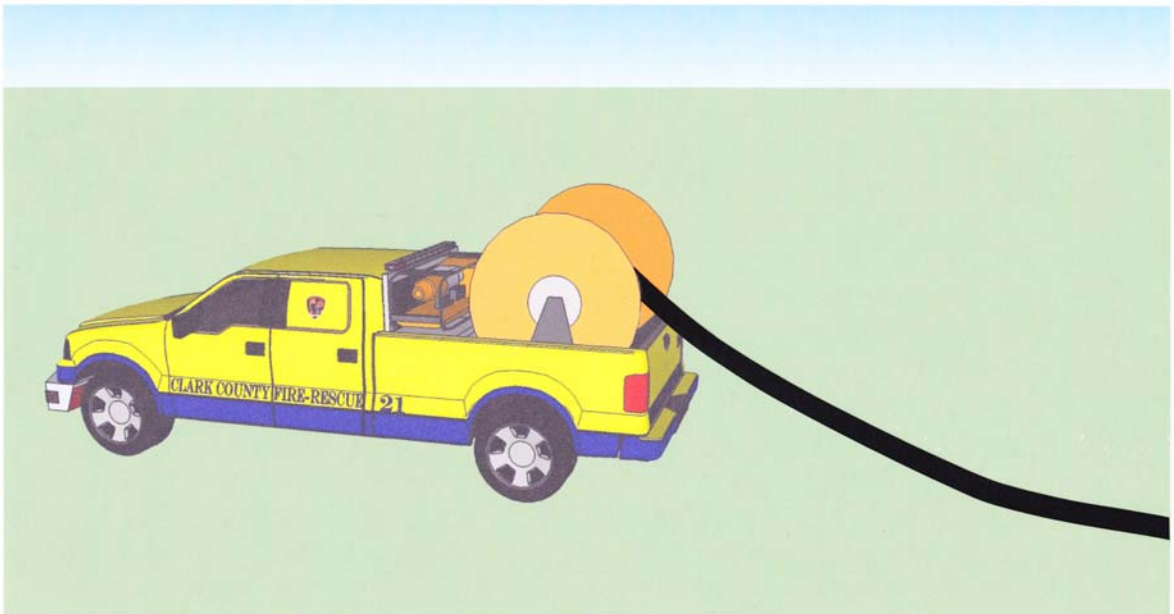
Relay pumping can supply water over long distances, but existing equipment requires continuous monitoring of pressures and flows at each booster pump. A firefighter must be dedicated to monitoring and controlling each pump. Each firefighter must be able to communicate with all of the other firefighters on the relay to insure that pump pressure and flow changes are coordinated. On a long relay, a firefighter, or a crew, is forced to remain at a location that might become dangerous. If they leave the location, the relay may fail.

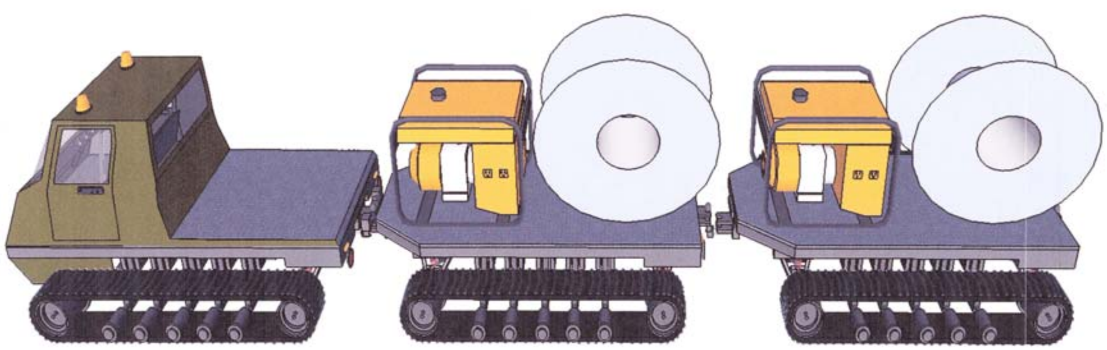
By adding a data network to a relay system, all of the pumps can be monitored and controlled by a single firefighter using a personal computer. The data network requires the addition of a small gauge wire pair onto the hoses used in the relay.

## Feasibility

Bob Harcourt, president of All American Hose (which recently acquired Snap-Tite Hose) currently sells a fuel carrying hose with a single embedded wire that is used to ground static electricity. He states that placing two wires in a hose is not a problem (B. Harcourt, personal communication, March 5, 2011). Additionally, the voltages and currents in the data network wires are very small and completely harmless.

If existing fire roads are used, the hose can be deployed from reels mounted on a 4WD vehicle as shown in Fig. 1. The vehicle also carries the diesel or gasoline booster pump that is monitored and controlled by the network. Alternatively, if existing fire roads are not available, the hose can be deployed from reels mounted on tractors or plows as shown in Fig. 2. A diesel or gasoline pump would also carried by the tractor or plow.



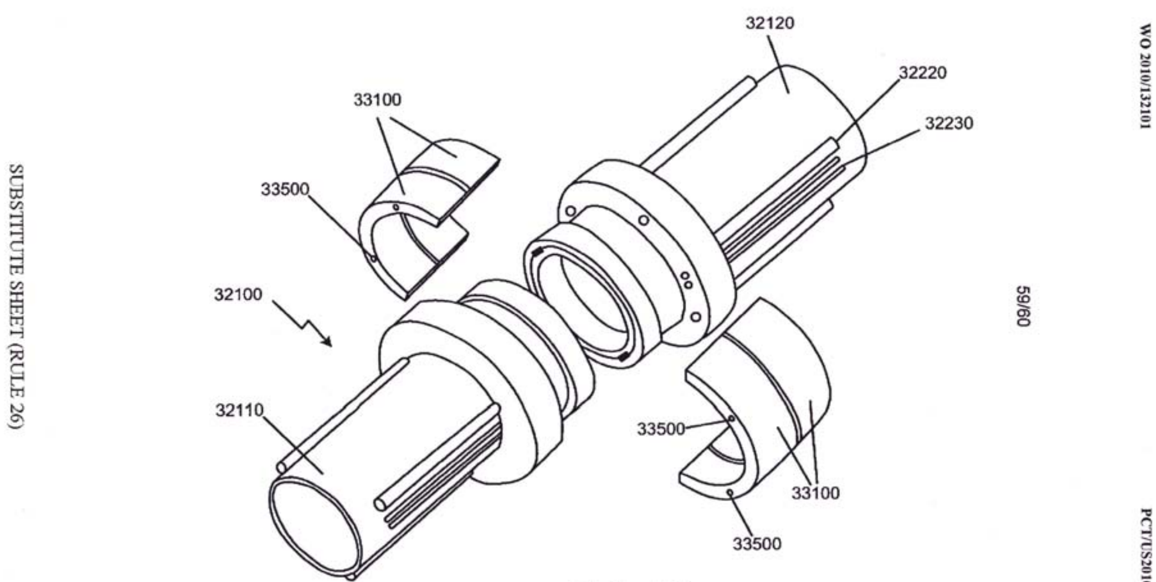



FIG. 42

A relay system can be cached near a high-value facility, and can be rapidly deployed when there is a fire threat. There is no apparatus limit on the length of the relay, and the wire pair network can be added to both large and small diameter hoses.

Many pump companies are using microprocessors to control the engines and pumps on firefighting vehicles. Mike Laskaris, the engineering manager of Hale Pumps, stated that it is possible to connect the microprocessors on his pumps to a data network that runs on the wire pair in the hoses (M. Laskaris, pers. comm., April 18, 2011). That data network can extend for many miles. One example of a, low-cost network is the LonWorks System from Echelon Corporation (http://www.echelon.com/).

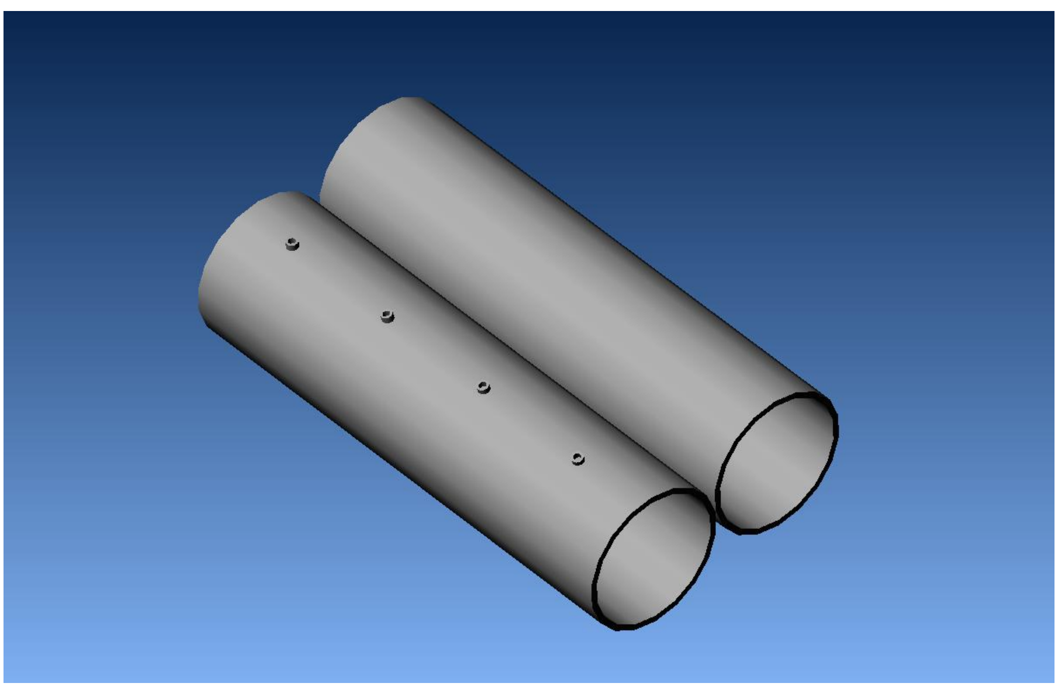
The author of this article designed and constructed a large data network using the Echelon LonWorks system in 1995. The network was constructed for Motorola in Scottsdale, Arizona. LonWorks is a mature and widely used industrial networking technology.

**Details of the Process**

The data network electrical signals in the wire pair on one hose must pass through the hose couplers to the wire pair in the adjacent hose. Fig. 3 shows a proposed new Storz type hose coupler for connecting hose sections together. The proposed coupler does not require exposed electrical contacts that might be affected by dirt and water. Each coupler contains an electrical coil which forms one half of an electric transformer. When the two couplers are connected, the data network signals are transmitted across the coupler via magnetic fields. No metallic contact is required.

A small diameter wire pair (24 to 16 AWG) will allow the Echelon Data Network to send its signals long distances. Electrical repeaters at each pump allow the network to support any number of pump/hose sections.

A proposed new type of hose has two separate fluid carrying chambers. (Fig. 4)



One chamber is used for transporting the fluid to the next pump. The other chamber is used to create a water curtain by placing small holes along the length of the hose. The hose is designed to lay flat to insure that the holes point upwards for a proper water curtain spray. The transport section of the hose can use a percolating design to protect the hose from fire.

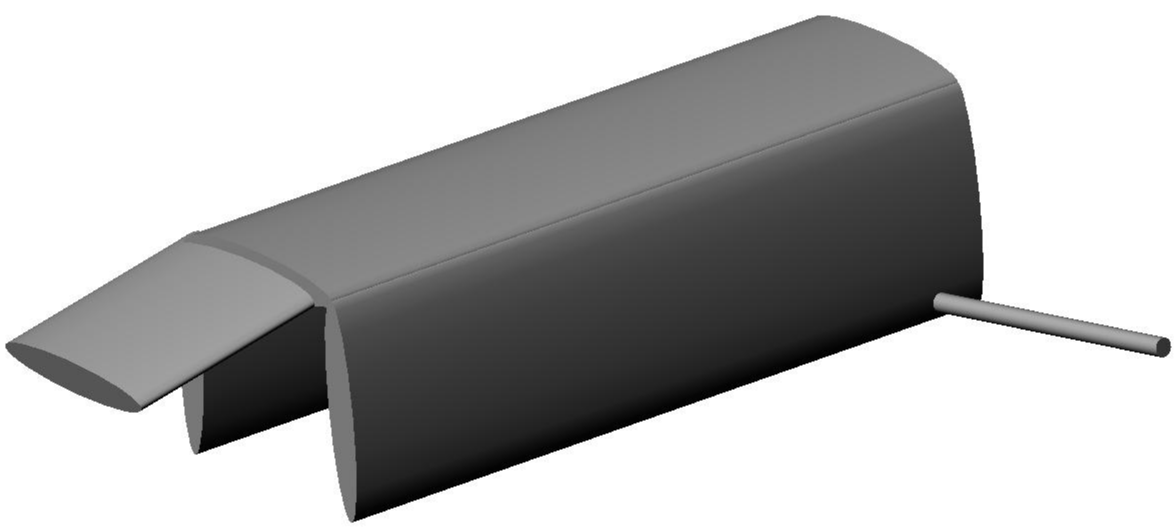
The enabling of water curtain flow in each segment is done by remote control from the system computer. A valve at each pump in the relay determines whether water will enter the water curtain section of hose.

The remote controlled water curtain feature makes the system useful for surrounding a prescribed fire before ignition. The water curtain option can be selectively enabled in hose segments where the fire is nearing the hose. No water is wasted on sections that are not at risk of escape.

A GPS unit can measure the altitude of a tractor location, and can be connected to the data network. If the terrain is hilly, the data network can be used to communicate the elevation of the tractor as it travels. The tractor might carry a variety of hose lengths on different reels. A program on the system computer could use topographic maps and the tractor location/elevation to determine the best hose length selection for the next leg of the relay. A shorter hose would be required if the next leg had a large increase in elevation.

The data network can enhance crew safety by providing an alternate system for communication between the vehicles and the base. Radio communication can be lost because of obstacles to radio wave propagation.

Since tractor crews and nearby firefighters have access to water from a hose relay, they might carry a protective shelter tent that can be filled with water from the hose. The water should give enhanced thermal protection to firefighters trapped in a burnover. (Fig. 5)



A long relay might be used to fill a portable pool, near a fire, that could supply water to helicopters carrying buckets. The relay would reduce the distance that the helicopters would have to fly to refill their buckets.

If the tractor based relay system reaches an obstacle it cannot go around, a helicopter could be used to continue the relay over the obstacle.

I propose that a helicopter carry one or more reels of hose, and that each reel contain an electric pump at its center (for details www.electric-fluid-pipeline.com). The hose is deployed as the helicopter flies over the ground. When a reel has deployed all of its hose, it is lowered to the ground. The electric pumps are powered by power wires that are embedded in the hose. The electric pumps are part of the relay, and are connected to the data network for monitoring and control. The electric power comes from an electric generator that is powered by a generator on the last vehicle of the ground relay. The helicopter might be used to continuously spray water onto a fire.

Another version of the proposed relay system has electric power wires embedded in the hoses. These wires have high voltages and currents which power electric pumps. No diesel or gasoline pumps are used. On the website, an example system is shown which can deliver 400 gpm over 8 miles through 6 inch hose. The system uses the same Echelon Data Network for monitoring and control. The advantage of an electric pump system is that there is no need to refuel the pumps. Once they are deployed, they can run unattended for days or weeks.

Digital data networks like Ethernet have become widely used.
People have Ethernet and WiFi networks in their homes, and the devices are amazingly low in cost and high in performance. A data network can be added to a relay pumping system, and similarly, can provide many useful services at a modest cost.

The inventions in this article are protected by US Patents 7,819,345, 7,942,350, and
Australian Patent 2008-302-447. A Canadian patent is pending.

***Physical Training for Injury Prevention in Wildland Firefighters**

Katie Sell[AB], Jayne Kitsos[A]

[A]Hofstra University, 342 East Hudson St., Long Beach, New York, 11561, USA,
[B]Corresponding Author, Katie.Sell@hofstra.edu

## Abstract:

Inappropriate or unsafe physical training practices may lead to joint, muscle, and other soft tissue injuries, which could be avoided through correct and safe exercise selection and program implementation. Furthermore, inadequate levels of physical fitness, muscle weakness or imbalance, and lack of sufficient joint range of motion may further predispose wildland firefighters at risk of acute or chronic injury. Evaluations of occupational task movement patterns can and should be used to identify functional exercises that can be safely implemented in a strength and conditioning program to enhance occupational performance and reduce injury risk. Current literature concerning physical training practices for rehabilitation and occupational performance continuously emphasize the inclusion of core and shoulder stability exercises to address or decrease lower back and both upper and lower extremity injuries. However, physical training for injury prevention does not necessitate an isolated battery of exercises. The progressive addition of structural, weight-bearing, multi-joint, and closed-kinetic chain exercises, using free-weights and/or dynamic resistance modalities (e.g., sandbags, bands, kettlebells) is recommended. Specific exercises should also be performed in a manner reflective of the movement patterns of occupational tasks to facilitate optimal benefit (muscle adaptation and proprioceptive capabilities). The purpose of this overview is to provide suggestions and strategies for optimal exercise selection with an emphasis on strengthening, stretching and conditioning for areas of the body susceptible to overuse and injury in wildland firefighters. Safe physical training practices and appropriate, functional exercise selection can help optimize the benefits of in-season and off-season conditioning and decrease risk of injury.

*Abstract appears as it was originally submitted.

# Initialization of high resolution surface wind simulations using National Weather Service (NWS) gridded data

J. Forthofer[A], K. Shannon[A] and B. Butler[A B]

[A] US Forest Service, Rocky Mountain Research Station, Fire Sciences Laboratory, 5775 Hwy 10 W, Missoula, MT 59802
[B] Corresponding Author: bwbutler@fs.fed.us

**Abstract:** Version 2.1.0 of WindNinja is now available for download and use from www.firemodels.org. WindNinja is a standalone computer model designed to provide the user with simulations of surface wind flow. It is deterministic not a forecast model, but rather calculates the instantaneous windfield that would exist given the input data. The user initializes the flow calculation using the National Digital Forecast Database, or point sources such as Remote Automated Weather Stations (RAWS) or other weather observations. With this release, the flow calculations can be based on forecast model output. Therefore by stepping forward in time with changing forecast data the fine scale output from WindNinja can simulate changing weather conditions.
**Additional Keywords:** Fire modeling, wind modeling

## Introduction

Changes in wind speed can affect fire intensity by as much as two hundred times (Lopes 2003). For this reason a more accurate understanding of wind speed and direction at local scales can significantly increase the effectiveness of fire management operations. Methods available for providing high resolution wind information to fire managers are limited or nonexistent. WindNinja is a standalone computer model designed to simulate surface wind flow over terrain. The WindNinja simulator calculates the interaction between wind and terrain to provide high resolution information about wind speed and direction for fire management decisions. It is based on previous work (Forthofer 2007) and is being updated regularly with new features and is available at www.firemodels.org

## Discussion

Weather and wind models can be categorized into two general types: diagnostic and prognostic. Diagnostic models simulate the wind field at one point in time, and are sometimes called 'steady-state models' because they do not step forward in time. They are useful for situations requiring fast simulations, limited computing resources and casual users such as disaster response teams. Prognostic models step forward in time and often include substantially more physics than diagnostic models thereby accounting for moisture and energy transport through a substantial portion of the atmosphere. Most models used for weather forecasts are prognostic.

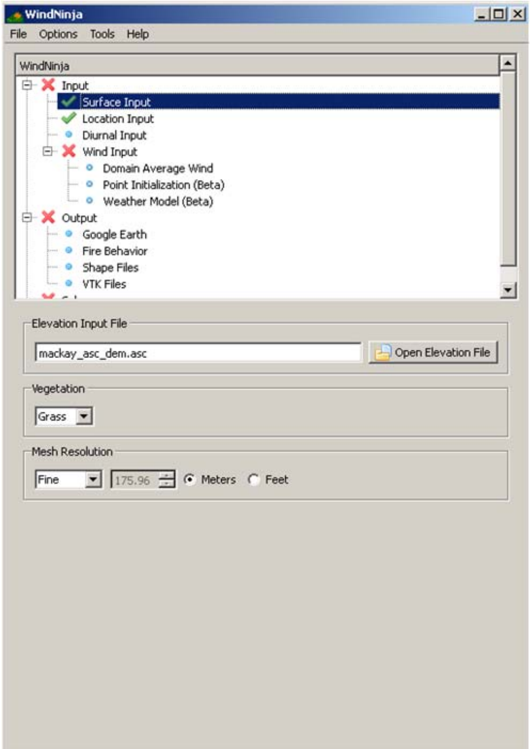



**Figure 1--Image of input screen at startup of WindNinja.**

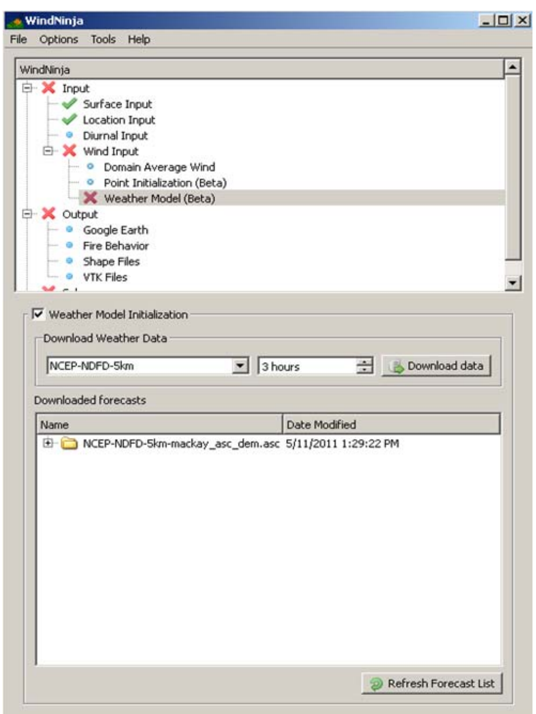



**Figure 2--Image of screen where user selects input data for wind simulation.**

Diagnostic models fall into three categories according to the amount of physics incorporated. The simplest category models are based only on conservation of mass, termed here mass-consistent models. The second diagnostic group solves a linearized momentum equation. Computation times are similar to the mass-consistent models; but non-linear momentum effects occurring in steep terrain are not accurately simulated, primarily because of numerical errors introduced by the steep terrain gradients. The third type of diagnostic model considers conservation of mass and momentum with some form of turbulence closure and conservation of energy.

Prognostic models, also called transient models include equations for the physics relevant to weather prediction such as conservation of mass, momentum, energy, moisture and radiant transfer. Because of the added physics, prognostic model forecasts require significant computing resources, have complex initial and boundary conditions, and require highly trained specialists to run them.

Some of the most widely used prognostic weather models in the United States are the Weather Research and Forecasting (WRF) model, the National Center for Atmospheric Research (NCAR)/Penn State Mesoscale Model 5 (MM5), and the Global Forecast System (GFS) model. The US National Centers for Environmental Prediction (NCEP) run operational forecasts at 12 km resolution. Other non-operational models are commonly run at 4 km resolution. From a fire behavior standpoint these resolutions are relatively coarse, many important terrain influenced flow effects cannot be captured at this scale. Fires are often influenced by winds at the 10-100m scale, consequently the need for high resolution wind information.

In an effort to include the physics of prognostic models in the high resolution of simpler diagnostic models, WindNinja has been modified to initialize the flow calculation based on input from widely available prognostic models.

The process for calculating the wind field using WindNinja is relatively straightforward. The first step is to start WindNinja. On startup the user is presented with a screen as shown in Fig. 1. On this screen the user specifies the location of the elevation data file.

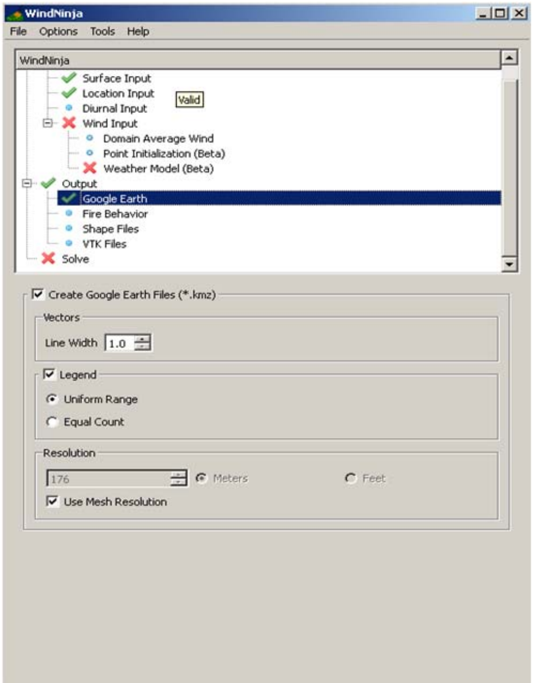



**Figure 3--Image of window where user selects output file format in WindNinja.**

Directions on how to find and download elevation data are included under the 'Help' pull down menu tab. Next the user selects the method for initializing the flow (Fig. 2). At this point the user may select one of three options. Here the user can elect to enter a single domain average wind speed and direction, or select to specify locations where wind data have been gathered such as weather stations or observations, or they may choose to download data from a national weather service prognostic model to initialize the flow calculation. This option results in WindNinja being used as a physics-based interpolation tool, essentially downscaling the coarse resolution forecast data to the fine scale resolution relevant to wildland fire behavior.

The weather service model data option allows the user to select from one of four forecast models from which to base the high resolution flow calculations. Depending on which model is selected the user then selects the time period over which to simulate the flow and the computer automatically imports the appropriate prognostic data files needed for the simulation. The spatial resolution of the input wind field varies with the prognostic model chosen.

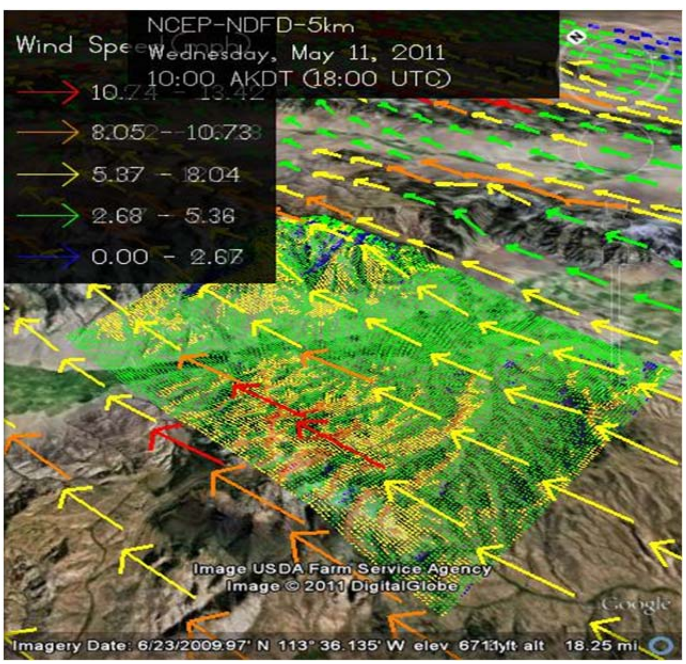



**Figure 4--Image of output from WindNinja in Google Earth.**

Finally the user selects the output file types. Four options are available to the user; Google Earth .kmz files, fire behavior files (used for input into models like FarSite), shape files, and .vtk files which are of interest primarily to advanced users.

The user then selects the number of processors available for the calculation. Once the solve button is selected typically the solution is complete within a few seconds to minutes. At completion the user is provided with a button that will automatically open a window with a path to the output files.

The output is easily viewed and explored in Google Earth. For example, if the user chooses to use input from a weather model, the prognostic data are presented on the image as large scale widely spaced vectors and the higher resolution WindNinja data are presented as a second layer of smaller scale more densely distributed vectors (Fig. 4).

As shown in Fig. 4, the model accounts for local terrain influence on the larger scale wind field produced by the meso-scale weather model. While some impacts such as turbulence on the downwind side of ridges are not included (because the model does not account for this phenomenon) many terrain influences are shown.

These images can be useful for identifying areas where higher winds and subsequently higher intensity fire behavior may occur. Conversely, they can show areas that would not be influenced by terrain effects on the wind and in fact could lead to lower intensity fire behavior.

## Conclusions

WindNinja represents a high-resolution surface wind model that includes the option to initialize the flow calculations from prognostic weather model simulations. This capability is unique in that it provides a physics-based method for downscaling relatively coarse scale prognostic model data to 100-200 m resolution.

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***Enhancing Fire Science Exchange: The Joint Fire Science Program's National Network of Knowledge Exchange Consortia**

Vita Wright[A]

[A]US Forest Service/ National Park Service, Branch of Wildland Fire, 650 Wolfpack Way, Kalispell, Montana, 59901, USA, vwright@fs.fed.us

## Abstract:

The Joint Fire Science Program is developing a national network of knowledge exchange consortia comprised of interested management and science stakeholders working together to tailor and actively demonstrate existing fire science information to benefit management. This poster describes the background, vision, and goal behind the network, provides an overview of existing regional consortia, and illustrates examples of the types of activities and services the consortia provide.

*Abstract appears as it was originally submitted.

# An epilogue: the story behind the conference theme 'Promoting the Story of Wildland Fire Safety … From the Local to the Global'

Jennifer A Ziegler[A,B]

[A]Program Committee Chair, Eleventh International Wildland Fire Safety Summit, International Association of Wildland Fire.
[B]Valparaiso University, Department of Communication, Valparaiso, IN, 46383, USA. Email: Jennifer.Ziegler@valpo.edu

**Abstract.** The theme for the Eleventh International Wildland Fire Safety Summit is explained. "Promoting the Story of Wildland Fire Safety: From the Local to the Global" extended an invitation to members of the wildland fire community from a variety of geographic locations and positions within the fire service, and honored the emerging role of storytelling in learning from the past and in conveying safe practices in wildland firefighting.

**Additional keywords:** lists, stories, safety, organizational learning, globalization

When searching for a conference theme for the 11th International Wildland Fire Safety Summit, we strove to identify something that would inspire people not only to attend the summit but also to submit an abstract for consideration because we seemed to be up to something new and different. Given the IAWF's international and pan-agency reach, we also searched for a theme that would invite participation from a diverse range of people within the wildland fire community, both geographically and positionally (i.e. from a variety of levels in the fire service).

As part of our search, we discussed what sets the Safety Summit apart from other conferences. Ideally, we reasoned, the Safety Summit is a place where people can share stories about 'what happened' and 'what works', where they can present new ideas in development, and where they can voice perspectives that may not yet have outlets elsewhere. Indeed, as we thought more about it, we realized that 'learning from stories' – at a variety of levels and in a variety of places – was a trend that had been cohering in recent years. Allow me to explain.

Over the centuries we have moved from primarily oral (story telling) cultures where history was passed down through the spoken word, to primarily literate cultures where the written word helped us to form more complex societies, in part by imposing some order on the world in a way that did not depend on human memory (Ong 2002). Some communication philosophers say that all of our communication takes the form of either list making or storytelling. That may be oversimplifying things a bit because even literate cultures have their written stories and even oral cultures have their lists (Browning 2006). It may be best to think about contemporary communication as having vestiges of both stories and lists through their oral and written forms. And it may be best to think about communication as an 'interplay' between lists and stories, which would suggest that ideally we need both (Browning 2006; Ziegler 2007).

When I attended my first Safety Summit about six years ago I'd been looking at the written word in wildland firefighting for about a decade already, and I had been very moved by some of the stories I'd heard. But I also sensed a concern that wildland firefighting practice (particularly how safety was being managed) may have become too dependent on lists (Thackaberry 2004; Ziegler 2007). Perhaps the pendulum had swung too far in one direction and needed a kind of corrective to recover more of the story mode. And indeed, in recent years there have been a variety of conscious efforts to recover more of the narrative dimensions of wildland fire safety.

Consider the following 'story' related trends and initiatives that have emerged in the safety field in recent years. All of these acknowledge either the importance of narrative in learning from tragedy, or, of equal importance, the use of storytelling in disseminating ideas about safety and safe practices, or both:

- The 'staff ride' approach to training, which attempts to put people 'inside the story' of a particular incident, inviting them to face the same decision points with the same information that would have been available to those who were there at the time (http://www.fireleadership.gov/toolbox/staffride/index.html).
- Emerging alternatives to traditional accident investigations (APA, FLA, etc.), which attempt to 'tell the story' of an incident in a different way, from different points of view, and even for different audiences (http://www.wildfirelessons.net/documents/APA_FLA_Guides_2011.pdf).
- Globalization and the emergence of social media, which have made stories of tragedy fires from other locations in the world (e.g. Greece, Australia, France, Russia, etc.) more immediate, more compelling, and which have made the global wildland fire community feel smaller and more interconnected than ever before.
- Increased public scrutiny over tragedy fires, leading 'the official story' to be written, rewritten, and then revisited again years later. Consider the Thirtymile Fire as one example (Thackaberry 2004). The instability and contestability of 'the' story of a fire has implications for recovering from and learning from tragic incidents.
- Research by Dave Thomas and Dorothy Leonard on 'deep smarts', which tries to capture wisdom from people before they retire, including through the stories they tell (http://www.wildfirelessons.net/documents/Deep_Smarts_Final_052107.doc).
- Marty Alexander and others' emphasis on case study research, not only to learn from particular cases but also to advance the case study method itself as a way to enhance our collective (research) memory in wildland fire.
- The Wildland Fire Lessons Learned Center, which seeks to be a central repository for written incident reports (near misses, accidents, etc.) and other data, but which is also expanding to include online tools for sharing individual and crew stories.
- The most talked-about Safety Summit sessions in recent years, which have been the memorable powerhouse stories: the story of the Cedar Fire, Kim Lightley's journey to recovery after South Canyon, the impromptu Australian panel about the recent Black Saturday Fires that emerged at the 10th Summit, etc.
- My own research on the Fire Orders and Watch Out Situations, in which I have sought to recover the story behind established wildland fire safety practices which might have become unmoored from the lists that remained, thus concealing the original intent (Ziegler 2007, 2009; Ziegler *et al.* 2009).

So, combining our two goals for a theme – appeals to diversity in geography and in rank on the one hand, coupled with highlighting the emergence of 'story' methodologies, on the other hand – we decided upon 'Promoting the Story of Wildland Fire Safety … From the Local to the Global'. We emphasized the word story as a way to recognize the role that stories and storytelling play in keeping people safe in wildland fire, not only in terms of yarns told around the campfire, but also to call forth the stories of some of these more systematic efforts that have emerged in recent years to acknowledge and incorporate storytelling in safety research and practice. I invite you to look for these themes in the contributed papers throughout these proceedings.

We also programmed specific items to capitalize upon the story theme. On the evening of the pre-conference, our kickoff speaker Dave Turner offered a very gripping rendition of the Mann Gulch Fire, a story that is part of the DNA of wildland firefighting culture and which is appropriate to revisit while in Missoula. The following evening, we viewed a different (and at times amusing) rendition of the Mann Gulch story in the special screening of *Red Skies of Montana* at the Wilma Theater.

In his keynote address on the first day of the conference, Gordon Graham discussed what we might learn from the seven rules of retired Navy Admiral Hyman Rickover. He spoke quite masterfully for two hours, and (as someone pointed out) with no notes and with only the low tech aides of an overhead projector and some colored pens. If you listened carefully, you might have noticed that he used the list of seven things as a kind of scaffolding upon which he hung a number of stories he's told many times over and over. The list of seven items was probably handy memory aid for him, but those of us who attended the session can also probably look back at them and better remember some of the stories he shared.

At a plenary session on the second day, Dave Thomas shared some of the work he has been doing to capture the wisdom of some of our most experienced firefighters in story form, and in such a way that it can be passed along to others. Sessions later that day focused on ways that stories are helping people to learn, from individual firefighters to crews to teams to agencies to communities. That evening, Marty Alexander hosted a standing room only 'hotstove session' that focused on learning from one other by swapping stories of close calls and near misses. On the final day, the conference theme continued in sessions that addressed learning in organizations and across cultures. In our closing summit presentation, Robert Palmer conveyed the story of his brother, Andy Palmer, in a gripping narrative that concluded with some powerful action items for the wildland fire community to consider.

We hope that this emphasis on stories and storytelling at a variety of levels proved productive and useful. In particular, we hope that attendees went away from the conference with new stories to reflect upon and to share, and with a deeper appreciation of storytelling in general as a fruitful mode for learning about safe practices – and ultimately for transforming our groups, organizations, and cultures in wildland firefighting – in ways that lists alone may have fallen short.

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# International Association of Wildland Fire

**11th International Wildland Fire Safety Summit**
**Missoula, Montana, USA – April 4-8, 2-11**

Alexander, Marty
University of Alberta
Box 11, Site 65, RR4
Sherwood Park, Alberta
Canada

Ansell, Rocky
State of Alaska DNR/DOF
101 Airport Rd, Aviation Hanger
Palmer, Alaska 99645
United States

Arsenault, Bill
Wildland Fire Rescue
7945 Wilbeth Lane
Nampa, Idaho 83686
United States

Balfour, Paul
Idaho Dept. of Lands
3284 W Industrial Loop
Coeur d Alene, Idaho 83815
United States

Baxter, Greg
FPInnovations
8008-188B Street
Edmonton, Alberta
Canada

Beck, Steve
MT DNRC
3150 Maverick Ln.
Missoula, Montana 59804
United States

Bertsch, Ronald
Forest Service: NIMO
415 South First Street, Suite 110
Lufkin, Texas 75901
United States

Best, Jesse
MT-DNRC / NWLO
655 Timberwolf Parkway
Kalispell, Montana 59901
United States

Black, Anne
790 E. Beckwith Ave
Missoula, Montana 59801
United States

Branine, Allen
MT DNRC
34925 MT Hwy 83
Swan Lake, Montana 59911
United States

Bushey, Chuck
IAWF President
1333 Colton Blvd.
Billings, Montana 59102
United States

Butler, Bret
RMRS
Missoula Fire Sciences Lab, 5775 W US Highway 10
Missoula, Montana 59808
United States

Campbell, Corey
CDC/NIOSH/WSO
P.O. BOX 25226
DENVER, Colorado 80225
United States

Cannon, Kyle
US Forest Service - Entiat IHC
7276 Entiat River Road
Entiat, Washington 98822
United States

Carlson, Neil
MT DNRC
48455 Sperry Grade
Greenough, Montana 59823
United States

Cassidy, Dan
MT DNRC
655 Timberwolf Parkway
Kalispell, Montana 59901
United States

Ching, Wayne
Hawaii Div. of Forestry & Wildlife
1151 Punchbowl St Rm 325
Honolulu, Hawaii 96822
United States

Connelley, Bryan
Central Valley Fire Dist
205 E Main St
Belgrade, Montana 59714
United States

Corn, Troy
2371 Albin Dr.
Entiat, Washington 98822
United States

Davis, Dennis
USFS MTDC
5785 Highway 10 West
Missoula, Montana 59808
United States

DeGrosky, Michael
The Guidance Group
201 Baumgartner Place N.
Eatonville, Washington 98328
United States

DeVos, Tim
Missoula Rural Fire District
2521 South Ave. W
Missoula, Montana 59804
United States

Domitrovich, Joseph
US Forest Service Missoula
109 Ironwood Place
Missoula, Montana 59803
United States

Dupuis, Howard
Ministry of Natural Resources
Aviation & Forest Fire Mgmt, 70 Foster Dr Ste 400
Sault Ste Marie, Alberta
Canada

Ekstrom, Michelle
MT DNRC
3206 Maverick Lane
Missoula, Montana 59804
United States

Everett, Jan
Forest Service
Aerial Fire Depot, 5765 W Broadway
Missoula, Montana 59808
United States

Fletcher, Paul
The Lighthouse for the Blind, Inc
2501 S Plum St
Seattle, Washington 98144
United States

Gakill, Steven
32 Campus Drive
Missoula, Montana 59812
United States

Goeller, Mark
NWCG Risk Mgmt Committee
Oklahoma Forestry Services, 2800 N. Lincoln Blvd.
Oklahoma City, Oklahoma 73105
United States

Gossard, Boyd
US FS
PO Box 314
Seeley Lake, Montana 59868
United States

Graham, Gordon
Graham Research Consultants
6475 East Pacific Coast Highway, #136
Long Beach, California 90803
United States

Hakes, Kevin
Hinton Trtaining Centre
Hinton Trtaining Centre 1176 Switzer DR
Hinton, Alberta
Canada

Hall, Matt
MT DNRC
3206 Maverick Lane
Missoula, Montana 59804
United States

Hansen, Jonathan
MT DNRC
3206 Maverick Ln.
Missoula, Montana 59804
United States

Harbour, Tom
US Forest Service, F&AM
201 14th Independence Ave., SW,
Mailstop: 1107 - 2nd Fl., 2S
Washington, DC 20250
United States

Hedrick, Matt
MT DNRC, Fire and Aviation Bureau
2705 Spurgin Road
Missoula, Montana 59804
United States

Infanger, Rocky
Wolf Creek / Craig FSA
2107 Craig River Rd
Wolf Creek, Montana 59648
United States

Jahn, Jody
University of California Santa Barbara
4415 Social Science & Media Studies Bldg.
Santa Barbara, California 93107
United States

Konantz, Lily
UCR Fire Unit
611 Darlene Ct.
Grand Junction, Colorado 81504
United States

Kopitzke, Michael
MT DNRC
1401 27th Avenue
Missoula, Montana 59804
United States

Lange-Navarro, Risa
Northern Rockies Training Center
PO Box 460042
Huson, Montana 59846
United States

Lattin, Robert
USFS- Retired
414 Kroupa Rd
Curlew, Washington 99118
United States

Leboeuf, Jules
Alberta Sustainable Resource Development –
Forestry Division
Provincial Forest Fire Centre 10th Floor,
9920-108 Street, Great West Life Bldg
Edmonton, Alberta
Canada

Lewis, Alexis
712 NW 16th ST
Corvallis, Oregon 97330
United States

Livingston, Bequi L.
USDA Forest Service
333 Broadway SE
Albuquerque, New Mexico 87102
United States

Lommen, Mary Jo
USFS
5765 W. Broadway
Missoula, Montana 59808
United States

Madden, Gene
US Forest Service-NIMO
1114 Greybear Court
Tallahassee, Florida 32311
United States

Mangan, Dick
Blackbull Wildfire Services
11400 Kona Ranch Rd
Missoula, Montana 59801
United States

May, Nicole
U.S. Forest Service/ NF's MS
100 W Capitol Street Suite 1141
Jackson, Mississippi 39269
United States

McCrea, Rich
LarchFire LLC
1490 Shenandoah Drive
Boise, Idaho 83712
United States

Merriman, Nick
MT DNRC
655 Timberwolf Parkway
Kalispell, Montana 59901
United States

Moore Jr., David
Glendale Fire Department
30 Village Sq.
Glendale, Ohio 45246
United States

Mutch, Robert
Fire Management Applications
9752 W Fork Rd
Darby, Montana 59829
United States

Nanke, Mark
MT DNRC
3150 Maverick Ln
Missoula, Montana 59804
United States

O'brien, Patty
US Forest Service
5785 Highway 10 W
Missoula, Montana 59808
United States

O'Hara, Pat
The Lighthouse for the Blind, Inc
2501 S Plum St
Seattle, Washington 98144
United States

Okon, Randy
Missoula Fire Department
1165 Neon Moon
Florence, Montana 59833
United States

O'Leary, Brian
6216 119th Ave East
Puyallup, Washington 98372
United States

Ostman, Randy
122 E. Circle Drive
Newport, Washington 99156
United States

Outka-Perkins, Lisa
USDA-FS-MTDC
5785 Highway 10 West
Missoula, Montana 59808
United States

Owens, John
BLM - NIFC
3833 S. Development Ave.
Boise, Idaho 83705
United States

Palmer, Stan
NIFC-BLM
4775 Shawnee
Boise, Idaho 83709
United States

Palmer, Charlie
University of Montana
1403 26th Avenue
Missoula, Montana 59804
United States

Palmer, Robert
Seattle, Washington
United States

Parrish, Deana
USFS - NIFC
3833 S Development Ave
Boise, Idaho 83705
United States

Peralla, Ryan
2135 Makiki Hts. Dr.
Honolulu, Hawaii 96822
United States

Peterson, Janette (Jan)
BLM
1387 S. Vinnell Way
Boise, Idaho 83709
United States

Poncin, Greg
MT DNRC
655 Timberwolf Pkwy
Kalispell, Montana 59901
United States

Pris, Jeremy
MT DNRC
655 Timberwolf Parkway
Kalispell, Montana 59901
United States

Putnam, Ted
Mindful Solutions
3431 Flicker Lane
Missoula, Montana 59801
United States

Raymond, Stephen
NSW Rural Fire Service Association
PO Box 845
Penrith BC, 2751
Australia

Robinson, Mikel
International Association of Wildland Fire
1418 Washburn
Missoula, Montana 59801
United States

Roessler, Jim
CSKT Tribal Forestry
38614 Round Butte Road
Ronan, Montana 59864
United States

Rogers, Brett
USDA Forest Service
111 Airport Road
Grangeville, Idaho 83530
United States

Rogers, Gene
Wildland Fire Technologies Inc
1041 Vista Way
Klamath Falls, Oregon 97601
United States

Russoniello, Vinnie
Missoula Fire Department
625 East Pine
Missoula, Montana 59802
United States

Ryan, Kevin
USDA Forest Service, Fire Sciences Laboratory
5775 US Hwy 10 W
Missoula, Montana 59808
United States

Sachara, Mark
Ponderosa Fire Dept
PO Box 12
Flagstaff, Arizona 86002
United States

Sandy, MD, Curtis
1711 Bachelor Circle
Pocatello, Idaho 83201
United States

Satterfield, Keith
USFS
215 Melody Ln
Wenatchee, Washington 98801
United States

Saveland, Jim
US Forest Service, Rocky Mountain Research Station
240 West Prospect Road
Fort Collins, Colorado 80526
United States

Scholz, Bryan
USFS, Ochoco National Forest, COFMS
3160 NE 3rd Street
Prineville, Oregon 97754
United States

Scott, Joe
Pyrologix
520 Ford Street
Missoula, Montana 59801
United States

Sell, PhD, Katie
Hofstra University
342 East Hudson St.
Long Beach, New York 11561
United States

Shanafelt, Jeff
US Forest Service
5242 HWY 89 South
Livingston, Montana 59047
United States

Shannon, Kyle
Rocky Mountain Research Station
5775 Highway 10 West
Missoula, Montana 59808
United States

Shoap, Steve
Inventor
12 Sheffield Road
Wakefield, Massachusetts
United States

Sinclair, Alan
1229 E Geona CT
Queen Creek, Arizona 85140
United States

Solverson, George
9890 W. Java Ct
Boise, Idaho 83704
United States

Stragis, Don
4603 E Deer Lake Rd
Loon Lake, Washington 99148
United States

Strickland, Roger
Country Fire Authority Victoria Australia
P.O. Box 357
Gembrook, Victoria 3783
Australia

Sullivan, Michael
Forest Protection Services
PO Box 8142
Kensington, Whangarei 145
New Zealand

Super, Cindy
MT DNRC
1401 27th Ave
Missoula, Montana 59804
United States

Sutton, Larry
US Forest Service
3833 S. Development
Boise, Idaho 83705
United States

Tappe, Steve
MT DNRC
8001 N. Montana Ave
Helena, Montana 59602
United States

Thomas, Dave
Renoveling
2334N 500W
Ogden, Utah 84414
United States

Thompson, John
Bureau of Land Management
106 N. Parkmont
Butte, Montana 59701
United States

Thompson, Matthew
U.S. Forest Service
P.O. Box 7669
Missoula, Montana 59807
United States

Thomson, Kat
285 South 2nd St, Apt. 2
Brooklyn, New York 11211
United States

Throop, Wes
US Forest Service Missoula
5785 Highway 10 West
Missoula, Montana 59808
United States

Tolosano, Peter
US Forest Service, Pacific Southwest Region
3237 Peacekeeper Way, Suite 101
McClellan, California 95652
United States

Turner, David
5335 Glass Drive
Helena, Montana 59602
United States

Tuss, Charles
BLM
106 N. Parkmont
Butte, Montana 59701
United States

Voss, Lindsay
AUVSI
24 Dunthorte Ln
San Antonio, Texas 78250
United States

Wakefield, Keith
USFS
180 N. Jefferson
Republic, Washington 99166
United States

Walsh, Justin
Missoula Fire Department
625 East Pine
Missoula, Montana 59802
United States

Williams, Wayne
MT DNRC
1126 Taylor Street
Missoula, Montana 59802
United States

Wright, Vita
RMRS/ NPS Branch of Wildland Fire
650 Wolfpack Way
Kalispell, Montana 59901
United States

Yandell, Dick
Wildfire Environmental
16311 NE Cameron Blvd.
Portland, Oregon 97230
United States

Ziegler, Jennifer
Valparaiso University
Dept of Communication
Schnabel 6, 1809 Chapel Drive
Valparaiso, Indiana 46383
United States