20 Minutes at H-2 – Linear Decision Making in an Exponential Fire Environment

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Abstract

In volatile burning conditions, the fire environment changes rapidly, and the fire itself often seems to spread at an ever-increasing pace and intensity. In fact, under extreme burning conditions in steep terrain, there is strong evidence the rate of spread is not linear and steady-state, but actually becomes exponential during the fire’s final run – intensifying far more rapidly than people’s perceptions and cognitions can readily reconcile. This appears to have been a significant factor on Cramer and other recent fatality fires.

Humans on the fireline tend to be linear thinkers, not readily adapted to assess processes that are accelerating exponentially – particularly in a volatile, rapidly-changing fire environment. Something doesn’t seem right... your “gut feeling” tells you this, but you just can’t quite put your finger on many specifics. As conditions deteriorate and fire spread accelerates, perceptions appear to also deteriorate. Perceptions, cognitions, emotional reactions, and judgments that would be entirely appropriate under normal circumstances fall short. Peripheral facts and evidence, suggest an intricate interaction of firefighters’ cognitions and resulting actions/reactions, and the rapidly-changing fire environment is a key factor in the tragic outcome on the Cramer Fire.

Introduction

Beyond a basic recap of the fire behavior and operational events, this discussion is not intended in any way to be a factual accounting of what transpired at H-2 on the Cramer Fire on July 22, 2003. Rather, it is intended to be a discussion of possible factors that influenced the final outcome, especially during the final 20 minutes prior to the fire in the Cache Bar drainage burning over H-2, from 1505h to 1525h. It is a theory, perhaps “one best theory,” based on existing factual information, peripheral indicators, and interpretation of human psychology, cognitive processes, and behavior. It is my sincere hope that such an examination of these factors will lead to a better understanding of what influenced the final outcome at H-2, and help prevent similar tragedies in the future.

Overview of Fire Behavior on the Cramer Fire

The following is a brief synopsis of conditions and fire behavior on the Cramer Fire, provided here for background information. Full details can be found in Appendix C of the Cramer Fatality Investigation Report (Donoghue et al., 2003).

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Prior Conditions

Fuels in the Cramer Creek drainage were generally short grass with scattered sage and ponderosa pine at lower elevations and on drier aspects. At mid-upper elevations, open mixed conifer stands became predominant; these became more continuous at the upper elevations and on northerly aspects. In the adjacent Cache Bar drainage, the primary fuels were short grass on the southerly aspects, and nearly continuous brush fields on the northerly aspect (Fig. 1a). These brush fields were a result of re-growth after an intense stand replacement fire in 1985, and were comprised primarily of shiny-leaf ceanothus littered with fallen snags. In the upper portion of the Cache Bar drainage, a few isolated stands of trees remained from the 1985 fire (Fig. 1b).

In 2003, central Idaho was in the fourth year of a prolonged drought. The winter snow pack had been near average, but spring rainfall was well below normal, and no significant precipitation had fallen in the area since June 25. The Energy Release Component (ERC) values for the two RAWS stations closest to the Cramer Fire were well above the 97th percentile, and one station was at the historic extreme. Temperatures in the previous 90-day period were 3-6 degrees F warmer than normal, and hot and dry conditions had persisted since late June. In the days leading up to the Cramer Fire, conditions had been getting progressively warmer and drier. Daytime temperatures surpassed 100 degrees and had been setting record highs, and relative humidity (RH) from 10-15 percent was common.

Terrain in the Salmon River drainage is steep and rugged, with limited visibility due to the pronounced relief (Fig. 2). Slope in much of the Cramer Fire area exceeds 60 percent. Night inversions produced a strong thermal belt effect on the Cramer Fire, promoting active burning conditions until about 0300h each day. Night time RH recovery seldom exceeded 60-65 percent. Topography also has a strong influence on surface winds, and thermally-induced diurnal slope and canyon winds are the norm. This was the case from mid to late July, during which time a large ridge of high pressure dominated central Idaho. However, forecast models indicated that a weak “short wave trough” would move through the area on July 22, having an effect similar to a dry cold front. This would change the typical diurnal wind patterns to a more synoptic pattern, with strong west to northwest winds.
Fire Behavior Chronology

The Cramer Fire was started by lighting on July 19, 2003. Through the morning of July 22, fire behavior was considered typical for the fuels and conditions. The fire spread by backing, flanking, short uphill runs from rolling burning material, and occasional single-tree torching (Fig. 3a). The typical diurnal winds were in place, and the fire burned actively until 0230-0300h each day as it was in the middle of a thermal belt. Each day, the fire doubled in size, and it was over 200 acres on the morning of July 22.

At 1830h on July 21, fire was first noticed spreading into the Cache Bar drainage by the Air Tactical Group Supervisor (ATGS). As the fire spread laterally westward from the Cramer Creek side, it burned below the end of a retardant line from the previous day, crossed the West Ridge and began to back into the Cache Bar drainage underneath the brush (Fig. 3b). By 2000h, the estimated fire size was near 200 acres, and the west side of the fire appeared relatively quiet.

On July 22, the fire again burned actively until about 0300h. The Zone fire weather forecast from the National Weather Service (NWS) was discussed at the morning briefing, as was the progressive warming and drying trend the previous few days. The forecast called for a change in wind direction to westerly then northwesterly, a result of the impending short-wave passage. However, the local initial attack crews generally found the daily NWS forecasts to be so inaccurate as to routinely disregard them, instead basing the expected weather and fire behavior for the day on trends from the previous 2-3 days.
At about 1430-1440h on July 22, winds began to increase in speed and shift direction to westerly as the short-wave disturbance moved into the area. Smokes from the backing fire in the Cache Bar drainage had become established near the bottom of the drainage, and soon erupted into an active fire front. Pushed by winds in alignment with the drainage, the fire began moving up-canyon. As the fire fanned out across the brush-covered slope below H-2, it was further intensified by numerous fallen snags and areas of under-burned brush from the previous 24 hours. Flame lengths at the head were estimated at 30-50 feet.

By 1520h, the fire front in the Cache Bar drainage had become even more intense, described by the ATGS as “a big flash front...[that] just kind of swept over the rocks, and it looked like the rocks were burning too” (Donoghue et al., 2003). The winds had shifted direction to more northwesterly, and speeds at H-2 were estimated to be 20 mph steady with gusts to 30 mph or more. The main fire front reached the base of the slope below H-2, hugging the steep slope and pushed by winds now driving the fire directly upslope.

As the intense surface fire entered the stand of trees below H-2, it gradually climbed into the canopy, becoming an active crown fire in the upper part of the stand with flame lengths estimated at well over 100 feet. Thick smoke moved rapidly up the slope, over the ridge past H-2, and merged into the massive column developing in Cramer Creek. At H-2, surface temperatures surpassed 1,500 degrees F. Cramer Creek was impacted by the same winds, and the entire drainage had erupted in crown fire. A thick, dark column climbed to 12,000 feet, dropping ash at the Cove Creek Helibase, 13 miles away.

**Fire Spread and Firefighter Travel in the Cache Bar Drainage**

**Accelerating Spread Rates in the Cache Bar Drainage**

Fire behavior predictions systems currently in use make extensive use of models, and in particular, Rothermel’s mathematical rate of spread model (Rothermel, 1983). This has served us well for many years, and provides a good estimate of fire behavior under defined environmental conditions. A basic assumption of this model is that once a newly-ignited fire accelerates to a steady-state rate of spread (McAlpine and Wakimoto, 1991), the expected rate of spread will remain relatively constant until there is a change in one or more factors in the fire environment, all other things being equal.
More recently, Viegas et al. (2005) have shown that under certain conditions – steep slopes and V-shaped canyons, and continuous fuels – the rate of spread will continue to accelerate rather than remaining at a constant rate of spread. He asserts such terrain features may often be predisposed to this type of fire behavior, even with little or no wind. Through a study of past “blowup” fires under such conditions, he further showed that the continued acceleration of spread is in fact predictable and quantifiable (Figures, 4a, 4b). Lanoville (2006) also provided a very detailed documentation of a similar fire spread in similar terrain and heavy coniferous fuels (Figure 4c). Lanoville discussed the accelerating convective processes that draw indrafts at the base of the canyon, feeding the developing fire front and convective column, which in turns pulls in stronger and stronger indrafts. This process is iterative, and the fire spread continues to accelerate rather than the more typical case of reaching a predicted steady-state rate of spread.

This appears to be the case for the fire run in the Cache Bar Drainage on July 22, 2003. In fact, this was one of the cases Viegas studied in his research. From the time the rappellers checked in with the helibase at 1443h to request a helicopter, and through their continued conversations with the helibase, the fire environment and the fire behavior changed rapidly. Once an active fire front became established in the lower part of the Cache Bar drainage after 1440h, the convective processes Lanoville and Viegas described began to form. The fire’s rate of spread and intensity were increasing, and continued to increase exponentially. The ATGS described “…strong updrafts at the leading edge and downdrafts at the trailing edge, causing him to gain and lose 1,000 feet of altitude, an effect he had experienced on previous fires that were ‘blowing up’” (Donoghue et al., 2003). The rate of spread continued accelerating, fueled by strong convective processes developing in the steep drainage, and further amplified by the developing winds that were aligning with the drainage itself and the slope below H-2.

Fire Spread versus Escape Routes and Safety Zones
In all too many entrapments and fatality burnovers, firefighters attempt to outrun the advancing fire front; fire’s rate of spread ultimately exceeds their travel rate, and the fire overruns their positions. Viegas (2005) and Rothermel (1993) both provide an interesting look at this on the Mann Gulch Fire. There are two travel rates for people – with gear (slower), and without (faster).
For a period of time, these were faster than the fire’s rate of spread. However, as the fire’s spread continued to accelerate, it eventually exceeded the travel rate of people, and overtook them.

On the Cramer Fire, there appear to have been only two viable options for reaching a safe area on foot. One was down the ridgeline below H-2 to a safety zone, the black from the previous two days (Figure 5a). The other, the direction the two rapellers appeared to be headed, was around the head of the drainage to a rocky area on the other side (Figure 5b). They probably did not consider crossing the ridge to the Cramer Creek side; there was intense crown fire developing there, and an intense surface fire making runs up toward the ridgeline near H-2. There was a safe area, and useable helispot, 800 yards farther up the ridgeline. However, it was a long, steep climb, and would have taken in excess of 25-30 minutes to reach – and therefore not a viable option.

Travel time on foot to the safety zone is about 3.5 to 4 minutes, assuming H-2 as a starting point. It’s 330 yards, downhill from H-2, and relatively straightforward other than negotiating a couple of small rock jumbles. Travel time across the head of the Cache Bar Drainage would be more involved. Moving cross-slope, it’s level to slightly uphill, and a distance of about 600 yards – an estimated total travel time of about 6 minutes, again assuming a starting point of H-2.

To reach the safety zone down the ridge, they would have to have left H-2 before approximately 1516h to arrive before the fire front would have cut off their access on the ridgeline. To cross the head of the drainage ahead of the advancing fire front, they could have left H-2 a little later, but would have needed to leave H-2 by about 15:18h. It is apparent that at 1519h, they were still at or near H-2, waiting for the helicopter. This is evidenced by their call to the helibase at that time, asking about the status of the helicopter.

Figure 5. Two potential “escape options” form H-2: down the ridge into the burn from 7/20 (5a), and across the head of the Cache Bar drainage to rocky areas on the other side (5b).

Decision Gates and Windows of Opportunity

Perceptions at H-2

Figures 6a-6d illustrate the estimated progression of the fire in the Cache Bar Drainage from the development of an active fire front at about 1440h to the burnover at H-2 at about 1524h. The transcribed radio traffic from the Central Idaho Dispatch records is also included in Table 1. This, and the tone of voice of the actual recorded transmissions examined during the Cramer Fatality Investigation in 2003, begins to shed light on what was occurring at H-2.

The words themselves convey part of the story; much more telling, however, was the calm,
professional tone of voice in the radio transmissions from H-2 to the helibase through 1520h\(^2\). The tone seems to imply a certain sense of concern, but no panic, fear, or sense of imminent danger – even when they were telling the helibase they had fire below them. Could this indicate the two rappellers didn’t think they were in imminent danger? Quite possibly. It may also have had an impact on perceptions at the helibase of the degree of immediacy at H-2.

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**Figure 6.** Estimated fire progression in the Cache Bar drainage from 1500 through 1524. Wind directions shown indicates the effect of the short wave disturbance, with winds shifting from westerly to northwesterly. Communications between H-2 and the helibase for this time period are shown in grey for reference.

This raises the question of whether the rappellers at H-2 were able to make an accurate assessment of the fire’s rate of spread, particularly in such volatile conditions. It is very possible they assessed the fire’s spread from the ridgeline and estimated a certain amount of time it would take before the fire would reach them. They thought they had plenty of time, when in fact, given the rapidly accelerating spread of the fire, they had far less time than they may have thought (Figures 7, 8). “Windows of opportunity” to get to a safe area were closing rapidly. In addition, it appears they were convinced the helicopter would get them off H-2 long before the fire would reach that location, and thus they probably stayed near H-2 most of the time.

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\(^2\) The audio recordings of radio traffic on the Cramer Fire were available for use and analysis during the investigation, but are not publicly available at this time.
Table 1. Radio traffic on SCF Forest Net, Cramer Fire, July 22, 2003.

1443h  H-2 tells the helibase they need about another 45 minutes to finish.
1505h  H-2: “We’re ready for pickup… send ‘em in a hurry, bud.”
1509h  H-2: “What’s the status of 193 [H-193, Type 3]?
       Helibase: “They’re still on the ground… they’ll be spooling up shortly to come pick you up.”
       H-2: “Bud, we need them right now.”
       Helibase: “We copy. We’re sending 166 to get you right now.”
1512h  Helibase: “The helicopter needed some fuel, but it’s going to start spooling here right now. Any
       problems right at the moment?
       H-2: “…o, bud ³, we just got fire below us and the smoke’s coming right at us, so just make ‘em hurry
       up.”
1519h  H-2: “What’s the status of 166?
       Helibase: H-166 is off the ground… he should be there shortly.”

Figure 7. Acceleration of rate-of-spread over time in the Cache Bar Drainage (from Viegas et al., 2005).
Communications between H-2 and the helibase and specific events, by time, are overlaid for reference. At 1442, the
rappellers indicated they would need another 45 minutes to complete their task; at 1505, they requested a ride out and
had packed all their gear and stowed it at H-2. Smoke was starting to significantly increase in the Cache Bar drainage
at this time.

³ There was some uncertainty during the investigation as to whether the verbage was “oh God” or “no bud” due to part
of the first word being cut off in the recording, but given the calm tone of voice, the latter is more likely.
Other perceptions may have also fed into this scenario. The perception, for example, that fire spread in shiny-leaf ceanothus was generally benign and not a concern. And the perception that travel time to the safety zone would be about 2 minutes – assessed from the air prior to being dropped off at H-2 in the morning (Donoghue et al., 2003), and about half the time actually needed to reach that location on foot. There was also some initial confusion during the transition between the lead plane and Air Attack upon Air Attack’s return to the area at about 1500h, as well as confusion created by similar first and last names being used interchangeably on the radio. Were the two rappellers still on H-2 or not? Was the advancing fire in the Cache Bar Drainage a concern or not? It appears some personnel were not sure.

“Decision Gates” and Consequences

Paul Gleason wrote of “decision gates” in the Kate’s Basin Fire Fatality Investigation Report (Gleason, 2000). In Appendix 6 of that report, he describes decision gates as “…gates that were passed through, each with only a few minutes (in some cases seconds) in which to make the decisions. Once the decisions were made, they could not be reversed because of the timing…”

In the Cache Bar Drainage, there were several such “gates:” (1) the decision to leave H-2; gear was packed and stowed at H-2, and they called for a ride out at 1505h; (2) the decision to remain near H-2 at 1509h after hearing the helicopter was still on the ground; (3) the decision
again to remain near H-2 at 1512h after again being told the helicopter was still on the ground, and confirming to the helibase there was fire below them; (4) the decision again to remain near H-2 at 1519 after being told the helicopter was on its way; and (5) the decision to travel in the direction they did a minute or two after 1520h, when they were told the helicopter couldn’t land.

Given the necessary travel time from H-2 to either the safety zone or across the head of the drainage to the rocky areas, the most critical “gate” appears to be the decision to remain near H-2 after 1512h. This meant they would miss the window of time needed to reach the safety zone before the fire would cut off their escape route down the ridge. A second critical “gate” was the decision to remain in the area after confirming the helicopter was en route at 1519h. By 1520h, when the helicopter affirmed it could not land, both escape routes would likely be compromised before they would be able to reach a safe – or survivable – area.

### Sensemaking in a Rapidly-Changing Environment

In his analysis of the Mann Gulch fire, Weick (1993) discussed sensemaking as an “ongoing accomplishment that emerges from efforts to create order and make retrospective sense… sensemaking emphasizes that people try to make things rationally accountable to themselves and others.”

Sensemaking can be generally described as the cognitive process of assimilating, filtering, and processing information, and interpreting it in order to make sense of our environment. Weick claims that we don’t interact directly with the environment. Instead, we interact directly with our perceptions of that environment. Our perceptions are influenced by past experience, learning, communication with others, expectations, and other available input. From the available information we are filtering in this way, we select an interpretation. That interpretation becomes how we literally make sense of our environment. We then act upon the sense we have made of the situation. Thus, sensemaking is more than interpretation because it emphasizes how we act upon the interpretation we select.

In his analysis of the South Canyon fire, Weick (1995) explained how once we have selected an interpretation and have committed to a course of action, it may become difficult to change course even when we encounter new information. His analysis showed that this tendency becomes even stronger when we have publicly committed to a course of action with others. As a result, members of the fire community have called attention to “situational awareness” which emphasizes the need to continually reassess the environment to see if it still matches our previous interpretations (e.g., Putnam, 2001, 2005). When environmental conditions no longer match our interpretation, we must revise our sensemaking, according to Weick (1995) or risk staying on a dangerous course.

Let’s now examine sensemaking on the Cramer Fire: First, crews expected what they had seen in previous days. Second, they failed to recognize fire potential. Third, the helicopter was their standard mode of transportation to and from a fire.

First, the rappellers on H-2 likely expected the fire behavior in the brush fields to be benign, nothing to worry about. That was the perception of local initial attack crews in general. They expected the weather to be the same as the previous two days, as it usually was. Most importantly, they expected a moderate, linear rate of spread in the Cache Bar drainage, giving them more than adequate time to leave H-2 by helicopter.

This leads to the second point, that they hadn’t realized the true potential of the fire in that drainage. Putnam (1995) wrote about linear thinking an exponential fire environment as follows: “Studies also show that our linear thinking tends to underestimate hazards, particularly if the
hazard is increasing at a logarithmic or exponential rate as can happen on the fireline.” An example would be estimating rates of spread… People who tend to underestimate the rate of spread have difficulty deciding on an appropriate course of action. And the third point, that the helicopter is their standard mode of transportation, appears to have influenced their decision to remain near H-2 until they had actual confirmation the helicopter couldn’t pick them up.

And so it is important to understand the limits of how we process information and the common types of errors that can occur. Evidence from the Cramer fire suggests that the rappellers at H-2 may have underestimated the rate of spread. This was evidenced by their calm tone of voice while waiting for the helicopter, even when conveying to the helibase that they had fire below them. With somewhat limited fire experience, they didn’t have the depth of fire behavior observations a more “seasoned veteran” might have had, particularly under extreme burning conditions. What they did have was some ability to use currently available fire behavior prediction models to assess the potential fire behavior, models that do not account for exponential spread rates. As a result of these expectations and difficulties in predicting, they may not have perceived the increasingly dangerous conditions.

At 1443h, the rappellers at H-2 told the helibase they needed about another 45 minutes to complete their task. No sense of urgency, no sense of any immediacy. However, at some point their interpretation (and sensemaking) appears to have changed. The first such point was at 1505h, just 20 minutes after saying they needed 45 additional minutes. They called the helibase and requested a ride out, adding, “…send them in a hurry, bud.” During the next few conversations with the helibase, they continued to convey some sense of urgency, emphasizing they needed the helicopter “right now,” and checking on the status every few minutes. Over the course of the afternoon, things increasingly did not fit their perception and the beliefs that were associated with it. Something wasn’t making sense with the interpretation they had of their environment. The situation was exceeding their past experiences. Winds were increasing, smoke was getting thicker, and the fire behavior in the brush fields was far exceeding their expectations. Yet the tone of voice from H-2 remained calm, with no obvious signs of stress or sense of immediate danger at H-2.

When stress increases, we can revert to simplest, previously learned behaviors (Putnam, 1995; Weick, 1993). The first point at which this was apparent at H-2 was the likely stress form whatever made the rappellers decide to cut their mission short. With that, they fell back to what they were most familiar with, their standard mode of operation – getting a helicopter ride out as they had done many times before. With continued delays and worsening conditions, the situation fit their perceptions less and less well, yet they continued to follow this original course of action. When they received confirmation that the helicopter could not get them, more stress likely entered into the situation, they finally made different sense of the situation and may have attempted to reach a safety zone. Unfortunately, the gates had closed and it was too late.

Conclusions and Closing Thoughts

An examination and analysis of the events during the final minutes at H-2 on the Cramer Fire builds a compelling and powerful story. Though all the facts will never be known, evidence and interpretation of known human factors on past fatality fires (particularly South Canyon) indicate a strong interaction of cognitive processes, and actions and reactions, against the backdrop of a volatile and rapidly-changing fire environment.

From this, it appears that many factors at play on the Cramer Fire were those that were implicated in the outcome on the South Canyon Fire – many of which have been analyzed and
discussed some years prior (e.g., from Putnam and Weick). Until we can break the cycle, these same mistakes are likely to be repeated again and again.

Where to go from here? A few things… first, the Fireline Leadership curriculum, which was initiated in 2001 and received significant strengthening from the national office of the U.S. Forest Service after the Cramer Fire, is addressing important leadership and situational awareness issues. Perhaps as part of situational awareness training, we should emphasize that there may be a gap between perception and sensemaking. We can be responding somewhat to changing conditions without fully revising our sensemaking about them; sometimes we need to do so. The Lessons Learned Center is also filling a much-needed role for information archival and sharing, critical to continued learning and understanding.

Second, we may need to examine how firefighters, especially the less experienced ones, are assessing and perceiving potential fire behavior – particularly in steep terrain and/or under extreme conditions. And the “closing gates” should be emphasized in training related to escape routes and safety zones; it may be an effective way to convey to firefighters why it is important to give adequate travel time to get to safety zones.

The tendency toward linear thought processes can too often cause firefighters to underestimate fire potential. And the dynamic interaction of sensemaking and human behavior in a rapidly-changing fire environment can have a critical influence on the outcome when there is a significant gap between perceptions and interpretations and reality.

Acknowledgements

Dedicated to the memory of Paul Gleason – friend, mentor and teacher. We must always be students of fire.

References


