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Assessing High Reliability Practices in Wildland Fire Management: An Exploration and Benchmarking of Organizational Culture

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Introduction

In an effort to improve organizational outcomes, including safety, in wildland fire management, researchers and practitioners have turned to a domain of research on organizational performance known as High Reliability Organizing[1] (HRO). The HRO paradigm emerged in the late 1980s in an effort to identify commonalities among organizations that function under hazardous conditions but experience fewer than their fair share of adverse events (see for instance: Klein and others 1995; Weick and others 1999; Weick and Sutcliffe 2001; Sutcliffe 2011).

The concept of high reliability was introduced to the U.S. wildland fire community in 1995 as part of a five-day workshop with the goal of more fully understanding the role of human factors in organizational performance and outcomes (Putnam 1995). Beginning in 2004, inter-agency fire management leadership, Federal fire research and the Wildland Fire Lessons Learned Center jointly sponsored three annual three-day workshops focused specifically on the principles of HRO (Keller 2004). These were followed, in 2007, by a five-day "train-the-trainer" workshop and teaching guide (Wildland Fire Lessons Learned Center 2008).

Weick and colleagues have used wildland fire as a muse for theorizing (for example, Weick 1993, 1995, 2011; Weick and Sutcliffe 2007); and others have qualitatively evaluated wildland fire actions and events through the lens of high reliability (for example, Dether and Black 2006; Knotek and Watson 2006; Thomas and others 2007). Yet, until this study, there was no quantitative assessment of high reliability in the wildland fire community. Linkages between HRO practices and related concepts (such as "upward voice," Edmondson 1999; and "organizational learning," Garvin 1993) have been widely theorized but, with the notable exception of Tim Vogus (Vogus and Wellbourne 2003; Vogus 2004; Vogus and Sutcliffe 2007a, 2007b), little empirical work was conducted to situate HRO practices in the broader context of organizational and work-group practices, and none was conducted in wildland fire.

[1] Also known as High Reliability Organizations. Throughout, we use HRO to refer both to the theory and organizations.

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Thus, in 2007, the first author initiated a collaborative effort to empirically establish the status of HRO practices in Federal wildland fire operations. The purposes of this study were to:

- develop the first comprehensive portrait of HRO practices in wildland fire,
- understand the relationships between HRO practices and those of other theoretically related organizations and workgroups describing high performance, and
- consider the implications of these findings on HRO theory and wildland fire management.

Understanding how HRO behaviors and related practices are structured in this community may lead to a clearer understanding of how safe and reliable performance emerges and may inform the specific practices and behaviors needed for further improvement.

This project has progressed in a series of phases, beginning with qualitative study and brief descriptive analysis. Initial efforts were used for some theorizing (such as Barton and Sutcliffe 2008, 2009), but development and exploration of the benchmark, practical model building and discussion of theoretical implications was only recently undertaken.

The purpose of this Note is to present the conceptual basis of our effort, describe the survey instrument, and present resulting emergent constructs that form the basis of subsequent analysis. After defining high reliability, we situate wildland fire in the HRO cosmology; briefly review previously studied relationships among high reliability, human resource practices, and related organizational practices; and construct a conceptual model driving development of our survey instrument and analysis. We then present initial results of the structure of these practices in the Federal wildland fire community.

Defining High Reliability

Typical high reliability organizations operate in uncompromising environments in which even small errors, oversights, or deviations from expectations may quickly propagate into disasters of significant magnitude. HROs are commonly described as suffering "less than their fair share of accidents" (Weick and Sutcliffe 2001). Teams and organizations that operate with high reliability are able to quickly identify undesired developments and contain them. Weick and others (Weick and others 1999; Weick and Sutcliffe 2001, 2007) described these functions as processes of anticipation and resilience, as mindfulness, and in terms of five principles (suites of practices) in which organizational members:

1. examine and track small failures as a window of health on the system (*preoccupation with failure*),
2. resist oversimplification and assumptions about what is faced (*reluctance to simplify*),
3. seek rich knowledge about current operations and their effects (*sensitivity to operations*),
4. develop a deep repertoire to manage unexpected events (*commitment to resilience*), and
5. take advantage of expertise wherever that lies, regardless of who holds it (*deference to expertise*).

(See Sutcliffe [2011] for an in-depth discussion of each of these attributes.)

HRO theorizing continues to evolve as researchers and practitioners explore the boundaries and features of HROs. Since the concept was initially articulated (in naval aircraft carriers, Rochlin and others 1987; air traffic control systems, LaPorte 1988), researchers have sought to understand:

1. how HROs differ from other types of organizations or do not (for example, Vogus and Welbourne 2003; Weick 2011);
2. how different industries structurally organize for high reliability (for example, space missions, Vaughan 1996; nuclear power plant operations, Marcus 1995, Bourrier 1996; health care, Wilson and others 2005, Carroll and Rudolph 2006, Vogus and Sutcliffe 2007a); and
3. how HRO concepts relate to other organizational practices (for example, human resources, Vogus 2004, Baker and others 2006; mindfulness, Vogus and Sutcliffe 2012).

Amidst this diversity, tracking organizational conditions may provide clarity (Table 1), particularly regarding:

- work-risk environment, technologies, suites of actors, and types of interdependencies (coupling);
- measures of performance, focus of safety and reliability, and organizational structure; and
- whether certain HRO principles and/or practices are emphasized over others.

We briefly compare these conditions in previously reported organizations with wildland fire to situate this industry within the HRO cosmology.

Work-risk environment, technologies, suite of actors, types of coupling

Traditionally, HROs are thought to share particular work-risk environments that differ from other industries. The challenge of distinguishing behaviors developed by HROs to manage their specific work-risk environment has resulted in a rich diversity of theoretical and practical perspectives, including debate as to whether other industries can or should aspire

Table 1—Emerging matrix of Highly Reliable Organization types.

	Naval aircraft carrier	Software startup	Health care	Wildland fire
Work-risk environment:				
Human life	High	Low	High	High
Property	High	Low	Low	High
Environment	High	Low	Low	Low-med
Organization	Low	High	Low	Mostly Low
Technology	Stable, complex	Emergent, complex	Stable, complex	Various, various
Actors:				
Number	Stable,	Dynamic,	Stable,	Dynamic,
Relationship - quality	Stable, robust	Fluid	Stable	Fluid, fragile
Relationship - type	Many-to-one	Many-to-one	Many-to-many	Many-to-many Many-to-one One-to-one
Coupling:				
Human-human	Tight	Variable	Tight	Loose-tight
Human-technology	Tight	Variable	Tight	Loose-tight
Greatest risk	Internal Tech-human Human-human	External environment	Internal Human-human	External, Internal environment, Human-human
Schulman's Typology	Holistic	Holistic	Decomposable	Both
Vogus & Welbourne	High reliability	Reliability-seeking	High reliability	Both

(Sources: Rochlin 1993; Klein and others 1995; Schulman 1993; Vogus and Welbourne 2003)

to emulate the practices of HROs (see for instance, Hopkins 2007).

On naval aircraft carriers and in nuclear power plants, errors often cause significant loss of human life and property as well as ecological damage. These organizations grapple with complex but stable technology and a stable, consistent suite of actors. There is tight coupling (dependencies in time and process) between human actors and in human-technology and technology-technology interactions (see for instance, Roberts 1990). Greatest risk tends to occur at the technology-human interface and in the dependencies among multiple actors.

In wildland fire, errors (missed signals or ineffective response, cascading misalignments or ineffective communications regarding goals, priorities, and/or existing and developing conditions) can quickly escalate into political, ecological, and/or human safety catastrophes. Technology varies from simple, rudimentary, and stable (hand tools, bull dozers) to rapidly changing, sophisticated systems (communications systems, aircraft). The suite of actors varies from small and stable to large and dynamic. While smaller incidents are generally managed by local units with local personnel, the larger the incident the greater the number of actors, and the longer the incident the more hand-offs between sequential teams. On larger incidents, personnel must be called in from elsewhere for assignments of up to 14 days. Thus, the suite of actors may constantly change as temporary teams operating at various hierarchical levels come together and then disperse over the course of the event. Human-human and human-technology interactions also vary. Some are loose with considerable opportunity for redundancy and resiliency and considerable independence, such as interactions between similar workgroups at the same operational level. Others are tight with little to no room for resiliency, such as flight operations in which multiple relays/technologies are necessary to enable communications between field operations and central command. Greatest risk tends to emerge from several locations:

- less predictable and uncompromising physical environment in which there are often rapidly escalating interactions between fire, topography, and weather;
- severe topography that impairs communication and movement;
- wear-and-tear such an environment has on human actors; and
- social environment of complex, dynamic, sometimes conflicting and often fragile social and political relationships between the managing group and affected external parties.

Performance, Safety, and Reliability and Organizational Structure

Klein and others' (1995) use of Schulman's (1993) organizational culture typology to assess several HROs provides one way to organize such variability. The authors found differences in organizational structure and culture depending upon the structures and behaviors most critical to cultivate

and maintain safety. Some were essentially "decomposable"—"actions and analyses to ensure safety are localized"; others were "holistic"—"actions and analyses to ensure safety are system-wide" (1995:791). This necessitates understanding the foci of safety and reliability, their relationship to performance, and implications for organizational structure—holistic or decomposable. Taking performance first, although performance is, in its positive aspect, safe and the goal is reliable safety (as several researchers have pointed out), reliability and safety are not always analogous (for example, Carroll and Rudolph 2006; Hopkins 2007). Similar to precision and accuracy, one may reliably produce unsafe results. Here, we equate high performance and high reliability and interpret this to mean the consistent (reliable) production of acceptable (safe) outcomes with only rare occurrences of unintended consequences amplifying into catastrophes (such as injury, death, or significant damage to ecological or real property or institutional relationships).

For nuclear power plants and naval aircraft carriers where the safety of all is achieved through the safety of tightly connected individual actors, the necessary organizational structure is holistic. Processes and practices are created to ensure broad, shared understanding of system function and loci of expertise. In nuclear power plants, for example, all work to ensure the safety of a single entity: the entire plant. On an aircraft carrier, many distributed systems must coordinate closely toward a single point of action: sequential take-off or landings of different, individual pilots and aircraft. Yet, it is not just strongly hierarchical organizations that need to be holistic. Software start-ups, the epitome of distributed decision making and localized innovation, also require holistic organization since the focus of protection is the organization, even as many individual members and teams may fail, frequently, without impairing organizational performance and survival. We might simplistically conceptualize these in terms of the number of actors in the system to the focus. As such, these all describe a many-to-one relationship.

Health care, in contrast, requires a decomposable structure: safety and performance is measured by the health of each patient, but this is a result of safe actions by multiple, interdependent individual actors and teams. We might characterize these as many-to-many relationships.

In wildland fire, safety is most often conceived of in terms of human well-being, although there are currently untracked performance objectives regarding ecology, finances, and organizational relationships. Each of these has a different scale of interest (that is, focus on safety and reliability): human catastrophes in wildland fire tend to be localized, (affecting a single unit—individual, aircraft, crew or division, or the public); political catastrophes tend to be general (affecting not just the incident management team and local unit, but the entire parent organization); and ecological catastrophes may be at any scale. A catastrophe may or may not impair incident-wide operations or alter other performance outcomes. In wildland fire, then, the risk of human mortality due to error or misidentification is high, the level of technology varies, the risk to programmatic stability varies with external opinion, and risk of organizational mortality is low (Table 1). The tasks at higher and mid-levels of the organization are to safely coordinate many personnel and resources at many ground locations simultaneously while maintaining productive external relationships. This situation indicates a need for holistic structure, but in many-to-one, many-to-many, and even some one-to-one relationships. The tasks at a particular ground location are to safely conduct ground-based operations, some of which are entirely independent (digging line) of and some are entirely interdependent (coordinated ground-air operations) on other parts of the incident. These situations indicate a need for a decomposable structure characterized by many-to-many relationships. As such, wildland fire appears to require characteristics of both holistic and decomposable organizational structures, further highlighting questions around how these systems connect and switch and what supports reliability.

High Reliability Practices

Given the variability of the work-risk environment of HROs, the unit that must be highly reliable, and the associated organizational structures to support this unit, the most valuable practices to achieve reliability likely differ. Indeed, Vogus and Welbourne (2003) found that initial public offering (IPO) software firms required a somewhat narrower mix of practices than traditional HROs. The IPO software industry is one in which the greatest risk comes from the external organizational environment, as opposed to typical HROs in which risk most often emerges from internal operating environment. In start-ups working toward IPO, the risk of human mortality is low but organizational mortality is high. Again, this is different from typical HROs in which the risk of human mortality is high but the risk of organizational mortality is relatively low. Vogus and Welbourne (2003) characterized this new type of firm as "reliability-seeking" organizations in contrast to "high reliability" organizations. Vogus and Welbourne's (2003) work indicated that these reliability-seeking organizations placed a premium on human resource practices that contribute to high levels of local innovation and resiliency. Organizational efforts to provide

cross-training, skill development, and communication stimulated an ability to be reluctant to simplify interpretations, build capacity for resilience, and be highly sensitive to internal and external operations. It should be noted, however, that this study did not evaluate possible practices to improve anticipation of failure or deference to expertise, thus the evidence is suggestive only.

Wildland fire management shares similarities with both traditional high reliability and reliability-seeking organizations: as much danger originates from the external operating environment (physical and social) as from internal human-human and human-technology interactions. Since coupling in wildland fire systems can vary from fairly loose with significant localized independence and decision-authority, to tight requiring very precise linkages in time, space, and expertise across large scales between individuals and between human and technology, sub-systems that take on holistic and decomposable structures may well reflect different combinations of high reliability principles. Holistic high reliability requires alignment of organizational parts (individuals and teams and their tasks) to the overall mission and strong linkages in communications (particularly development and maintenance of a collective awareness of the existing and developing situation). The ability to respond to emerging issues necessitates both decomposable and holistic capacity, depending upon the sub-system, and perhaps prioritizes the ability to select the appropriate balance of expertise and authority. That is, high reliability in wildland fire management may require all of the HRO principles, though with different emphasis under different scenarios and organizational positions. Placed in this frame, wildland fire appears to be both a potential bridge linking types of HROs and an arena for analyzing how these structures interact to achieve high reliability.

Assessing Performance—Components, Measures, and Related Concepts

A practical model of high performance in wildland fire must be capable of providing concrete suggestions, even prescriptions. This requires a shift in thinking from considering reliability solely as a descriptive characteristic to reliability as a performance indicator (Weick and Sutcliffe 2001; Ericksen and Dyer 2004). In subsequent analyses, we will address measures to assess human and organizational performance in wildland fire. Here, however, we assess the state of high reliability in the federal wildland fire community. For this, we take advantage of empirical work conducted elsewhere, including practices of high reliability as well as those of related human resource, leadership, and organizational learning practices.

High Reliability and Collective Mindfulness

Weick and Sutcliffe (2001, 2007) developed a series of audits (short questionnaires) to help organizations characterize their internal practices for each of the five principles. The authors described high reliability as mindfulness, a collective attribute shared among HRO members that brings to life a culture of safety and reliability. In a study of hospital nursing units, Vogus and Sutcliffe (2007) developed and validated a nine-item survey scale called the Safety Organizing Scale (SOS) that captures the behaviors of collective mindfulness. For at least the hospital environment, empirical evidence indicates that the five principles do not show up as discrete practices but can be described as a single, collective suite of practices. Conversely, Vogus and Welbourne's (2003) study of software firms illuminated the value of measuring the five principles discretely.

As part of our assessment, one question we seek to answer is whether HRO practices in wildland fire community are best captured by the collective scale or by measures of individual principles. The answer has implications for future assessment work and training.

Related Concepts and Measures

Intuitively, HRO practices/collective mindfulness do not occur spontaneously. Previous research (see for instance, Campbell 1990; Weick and Roberts 1993; Edmondson 1999; Weick and others 1999; Weick and Sutcliffe 2001; Vogus 2004; Vogus and Sutcliffe 2007) suggests that enactment of the five principles of HRO/collective mindfulness depends to some degree on conditions for communication at the unit level. HRO practices also appear closely linked with concepts of learning organizations, high performance human resource practices, and high functioning teams. Baker and others (2006) drew connections between teamwork and the particular requirements of high reliability: "Teamwork is not an automatic consequence of co-locating people together and depends on a willingness to cooperate for a shared goal. … Teamwork is distinct from taskwork… teamwork depends on each team member being able to anticipate the needs of others; adjust to each other's actions, and have a shared understanding of how a procedure should happen." (Baker and others 2006: 1579). Their enumeration of the characteristics of effective teams contains aspects of trust, leadership, and mutual valuation that are echoed in the attributes of collective mindfulness and the five principles. Specific constructs previously tested with respect to HROs are:

- Respectful interaction—Based on Asch's moral imperatives (Campbell 1990; Weick 1993) of respecting both your own and others' reports and being able to integrate these various perceptions without denigrating either. High Reliability

Organizing focuses on building a group and organizational culture where it is the norm for people to respectfully interact.

- Heedful interrelating—HRO fosters a culture where people interact to become more consciously aware of how their work fits in with the work of others and the goals of the system and are able to place the value of the overall goal above their own (Vogus 2004).
- Leadership—HRO recognizes that the tone set by a unit leader regarding openness to receiving differing perspectives, and how the leader handles subordinates' comments influences whether or not someone is willing to voice their observations or ideas (Edmondson 1999; Thomas and others 2005).
- Learning—The ability to cultivate a deep individual and team understanding of the task process and dynamics is intuitively aided by a culture that values innovation, consistent reflection on outcomes, and incorporation of lessons learned into future operations (Senge 1990).
- Goal clarity—Scholars of organizational learning hypothesize that clarity and alignment around mission is a strategic building block (Yang and others 2004) and is intuitively linked to performance.
- Task complexity and task interdependence—Vogus (2004) hypothesized that the complexity of a task and the relative independence or interdependence of individual actions should be related to collective mindfulness.

Conceptual Model and Research Questions

Conceptual clarifications are needed in HRO theory to determine (a) whether practices that distinguish HROs from other organizations are distinct from attributes of high functioning, learning teams and organizations, and (b) if related, how. Our conceptual model (Fig. 1) proposes that collective mindfulness as measured by the SOS (Vogus and Sutcliffe 2007a) and five principles of high reliability (Weick and Sutcliffe 2001, 2007), are simply different names for the same construct. However, because it is difficult to explain, train, or measure progress on interrelated practices, it would be ideal if the five practices were distinct.

Further, our conceptual model indicates that the expression of HRO practices is distinct from constructs and practices for encouraging upward voice, building a strong group culture, and facilitating organizational learning. Upward voice, as initiated by leaders who are both open and responsive to the ideas of the team, intuitively supports the HRO practices (sensitivity to operations, deference to expertise, reluctance to simplify), which require that team members speak up and share their different perspectives. Such behaviors are also likely to create an atmosphere in which the interpersonal behaviors of high performing teams flourish (for example, trust, honesty, and respect that characterize strong group culture). An orientation to learning also seems essential to practices of high reliability,

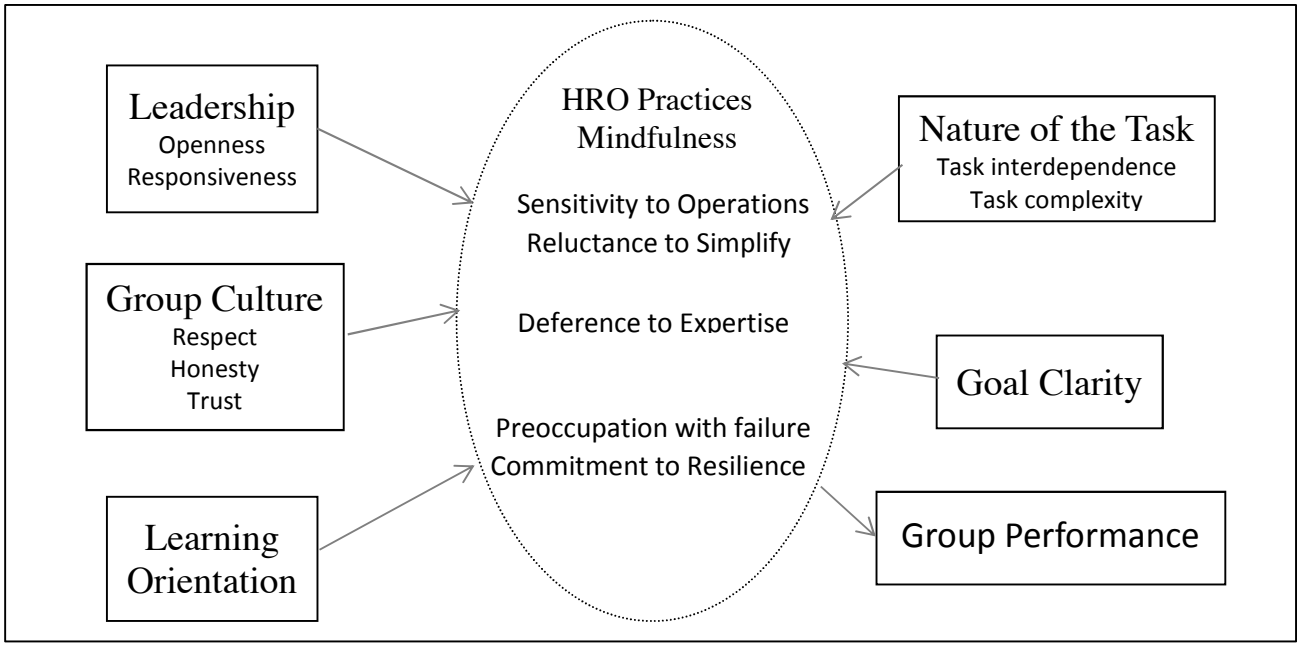

Figure 1—Survey constructs as identified in the literature.

particularly commitment to resilience and preoccupation with failure.

Finally, our conceptual model recognizes that several other features of the task context may influence HRO practices. These previously measured constructs include the nature of the work itself (task complexity, task interdependence) and direction as perceived by the group (goal clarity), which were found to be important in hospital nursing units (Vogus 2004).

Research questions flowing from this conceptual model are both theoretical and practical. Fundamentally, we want to describe HRO and related practices in the Federal wildland fire community. Theoretically, we are interested in whether the five practices can be measured and evaluated individually or whether collective mindfulness is a single construct on its own. We are also interested in whether theoretically related constructs describing organizational culture and high performance teams—group culture, leadership, and learning orientation—are also functionally contained within collective mindfulness or are distinct constructs. Practically, we seek to establish a baseline measure for the fire community that can provide concrete suggestions for improving performance. In this paper, we present results of this first set of questions. In related work (Black and McBride 2013), we assessed similarities and differences among sub-groups of the survey. With these results, we will then probe further into the questions of how wildland fire does or can negotiate the apparent need for both holistic and decomposable organizational structures while achieving high levels of safety, reliability, and performance.

Methods

Survey

We began with a survey. It included measures described previously and new items developed during the initial phase of this study (Barton and Sutcliffe 2009). It was designed to measure:

- each of the five principles of high reliability as separate constructs (deference to expertise, sensitivity to operations, reluctance to simplify, preoccupation with failure, commitment to resilience);
- the SOS as a single construct of collective mindfulness;
- two constructs describing human resource practices that support strong group culture (heedful interrelating, respectful interaction);
- three facets of leadership (leadership openness, leadership response, and leader framing);
- a single construct for learning orientation;
- two constructs capturing the nature of the task (task interdependence, task complexity);
- a single construct to assess goal clarity; and
- a single construct to assess group performance (Tables 2 and 3).

These were captured using 70 5-point Likert-scale items (statements that participants are asked to respond to).

We also captured respondent and incident demographic characteristics, including type and complexity of the incident, respondent's agency, full-time job, incident position, age range, experience in fire management, and gender. For each incident, we asked respondents whether there were any injuries during their assignment, their perception of the group, and their perception of overall fire performance (See Black and McBride 2013 for analysis of these demographic-related items).

The survey population included permanent seasonal and full-time employees filling primary fire positions (including fire, fuels, dispatch, and fire aviation) in the USDA Forest Service (USFS), and US DOI Bureau of Land Management (BLM) and National Park Service (NPS).[2] Within each agency, these personnel fill ground-, middle-, and upper-level positions during an incident. All incident position qualifications and descriptions are managed by the interagency National Wildfire Coordinating Group. Ground-level ("boots-in-the-black") positions include engine captain, crew foreman, hotshot superintendent, and helitack crewmembers who work directly on firelines. Mid-level positions include local staff such as fuels and fire management officers, fire education prevention specialists who provide local knowledge and support, and incident positions such as Division Supervisors, and Task Force Leaders whose work includes significant supervisory functions. Some, such as Division Supervisors and Task Force Leaders, are assigned to a fireline with responsibility for multiple tactical ground resources. Upper-level positions include managers for fire, fuels, aviation, and dispatch from the Forest Supervisor's office, National Park Headquarters, and BLM State Offices, as well as command and general staff on Type 1 and Type 2 Incident Management Teams.

[2] For all five Federal wildfire agencies (of which the three included here comprise the bulk of fire employees), internal agency calculations put the population of permanent employees who bill at least 51% of their time to fire at nearly 10,000, with approximately 7,000 in primary fire positions (Halbeurk pers. comm.). We estimate that we have surveyed approximately 10% of the population.

Table 2—Survey items designed for theorized principles of High Reliability Organizing (see Vogus and Sutcliffe 2007a; Sutcliffe 2011).

Construct	Survey item
Preoccupation with failure	We actively looked for instances of small things going wrong to try to learn what was happening. Leaders on the fire actively looked for problems. People were rewarded or thanked for spotting potential trouble spots.
Reluctance to simplify	We were encouraged to express differing points of view. We assessed each situation on its own rather than assuming it would be similar to other situations we'd experienced. When members had different opinions, we tried to understand one another's views.
Sensitivity to operations	There was always someone with authority to make decisions available and accessible in the event that something unexpected came up. People were familiar with what was going own beyond their own part of the fire. Leaders were constantly monitoring workload and span of control to reduce them when that became necessary. We had access to sufficient resources when we needed them. We constantly kept one another in the loop about our activities. Our superiors checked in with us frequently. We checked in with our superiors frequently.
Commitment to resilience	Leaders involved in this fire were concerned with developing people's skills and knowledge. Leaders encouraged individuals to take on roles in this fire that challenged and stretched them. Most people involved had the skills necessary to respond to any unexpected problems that arose.
Deference to expertise	People most qualified to make decisions made them, regardless of hierarchical rank. People in the group valued expertise and experience over hierarchical rank. It was generally easy to obtain expert assistance when something came up that we didn't know how to handle. Less experienced members of my group brought up some important issues or ideas during the fire.

Because incident positions are temporary, we necessarily conducted sampling based on normal organizational positions, defined our initial sampling frame by agency and permanent position (day job), and coded responses for analysis based on the incident position respondents provided as part of the survey.

A random stratified sample of administrative units was drawn from complete lists of USFS Forests, BLM State Offices, and NPS Parks with fire programs to reflect the relative proportions of Federal fire personnel. Major units (such as Parks, National Forests, and BLM State Offices) were randomly selected. Where multiple sub-units occurred for a given major unit (such as multiple Ranger Districts on a National Forest), these were again randomly sampled and complete telephone lists were obtained for the head office and selected local unit. With a target of 700 surveys, individual respondents were randomly selected from these lists to reflect the relative proportions of fire personnel in each administrative level (57% of surveys from ground-level, 29% from mid-level, and 14% from upper level positions), and agency (400 USFS—57%, 200 BLM—29%, and 100 NPS—14%).

The final random sample was drawn and the 15-minute telephone survey was administered by an independent polling organization (the University of Montana's Bureau of Business and Economic Research) during October and November of 2007. Individuals were asked to think back to their most recent fire event and answer with respect to the group they worked with most closely on that event. We accepted all fire events—suppression, wildland fire use (the designation at the time for managing fire for resource benefit), and prescribed fire. The dates of these events ranged from the day of the survey to six months earlier, with the majority occurring within two to three months of the interview.

Analysis

To condense the data yet discern underlying dimensions of the data structure, we used principal components analysis (PCA) with a varimax orthogonal rotation (using a sub-set of 60 Likert-scale items from the full survey). This maximally distinguishes emerging constructs and yields clear, interpretable results (Hair and others 1998; Field 2009). Prior to conducting PCA, we visually examined the correlation matrix, the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, and Bartlett's test of sphericity to assess the appropriateness for PCA (Field 2009; Hair and others 2009). Accordingly, we retained all 60 Likert-scale items.

We performed series of PCAs using a cut-off value of 0.40 as our criterion for deciding which loadings were significantly associated with a given component (Hair and others 2009). This level delineates the higher from the lower loadings in the matrix (Tabachnick and Fidell 2001). Non-significant and cross-loaded items in the initial PCA solution were excluded and the remainder were re-submitted. Iterations were conducted until a final PCA solution was obtained in which all

Table 3—Survey items for related constructs. [Items adapted from: collective mindfulness, Vogus and Sutcliffe 2007a; leadership and learning orientation, Edmondson 1999; goal clarity, task complexity, task interdependence, respectful interaction, and heedful interrelating, Vogus and Sutcliffe 2007b.] *Reverse-scored.

Construct	Survey item
Collective Mindfulness	We had a good understanding of each other's talents and skills. We talked about mistakes and ways to learn from them. We discussed our unique skills with each other so we knew who on the fire had relevant specialized skills and knowledge. We discussed alternatives as to how to go about our work activities. We discussed what to look out for, when giving reports to new teams or units. We took advantage of the unique skills of our colleagues, when attempting to solve a problem. We spent time identifying activities that we did not want to go wrong. When errors did happen, we discussed how we could have prevented them. When something went wrong or a problem developed, we rapidly pooled our collective expertise to address it.
Leader openness	My boss actively sought input from a broad range of folks when making decisions. My boss actively encouraged subordinates to question decisions that didn't make sense to them. My boss encouraged people to bring up potential problems.
Leader response	My boss listened to the less experienced members of my group when they brought up ideas or issues. My boss actively listened when different views were presented. My boss responded defensively to feedback from others.* My boss rejected or ignored input from others.*
Leader framing	My boss told us to pay attention to one another's input or ideas. My boss told us that our task required us to work well together. My boss stated that he/she was confident in our group's ability to do the work.
Goal clarity	Our mission or objectives for each day were clear at the beginning of the day. Our mission and objectives for each day were clear throughout the day. The lack of clear mission/objectives made it difficult to do our work.*
Task complexity	The tasks that my group was involved in were quite routine. We knew what actions were required to achieve the outcomes we wanted. The tasks we were involved with required a broad range of skills and functions. The tasks we were involved with were quite complex.
Learning	After the fire, we discussed what we learned. After the fire, we discussed whether there were ways we could have predicted or prevented problems that arose. Changes to procedures were recommended as a result of what we learned from our experiences on this incident.
Task interdependence	Each person's performance was dependent on others performing well. Achieving our objectives required close coordination within our group. The way each person performed their work had a significant impact on how others were able to perform their work.
Group performance	Information flowed well within our group. I felt uncomfortable with our approach to the work.*
Respectful interaction	People showed a great deal of respect for each other. The individuals I worked with were trustworthy. We honestly reported what we perceived to each other.
Heedful interrelating	Individuals paid attention to what others were doing. Most of the individuals I worked with understood how their actions contributed to the functioning of the entire response team. We actively looked out for one another.

retained variables had a significant loading on a single component (Hair and others 2009). The internal reliabilities of the final components were assessed using Cronbach's α, ,the primary evaluation statistic.

To better interpret the resulting components, we conducted a single round of PCA on each of the five emergent components separately. All PCA analyses were performed using SPSS Statistics Gradpack 17.0 software (SPSS Inc., Chicago, Illinois).

Results and Discussion

Sampling Response and Statistical Adequacy

Total responses (n = 668) closely matched the proposed sampling scheme in terms of levels (15% upper-level, 27% mid-level, and 58% ground-level) but were more uniform in terms of agency proportions (40% USFS, 23% BLM, and 37% NPS). Prior to analysis, we scrubbed the dataset by

Table 4—Final 5-component solution. [Non-significant and cross-loading items identified in initial solution have been excluded. Component loadings <0.4 have been suppressed to allow for easier viewing of the matrix.] REV = reverse-scored.

	Rotated component matrix				
	Component				
Survey item	**1**	**2**	**3**	**4**	**5**
Leaders encouraged individuals to take on roles in this fire that challenged and stretched them.	.640				
There was always someone with authority to make decisions available and accessible in the event that something unexpected came up.	.629				
We checked in with our superiors frequently.	.612				
Leaders on the fire actively looked for problems.	.611				
Leaders involved in this fire were concerned with developing people's skills and knowledge.	.609				
Leaders were constantly monitoring workload and span of control to reduce them when that became necessary.	.607				
People were familiar with what was going own beyond their own part of the fire.	.598				
Our superiors checked in with us frequently.	.597				
We constantly kept one another in the loop about our activities.	.586				
People most qualified to make decisions made them, regardless of hierarchical rank.	.585				
It was generally easy to obtain expert assistance when something came up that we didn't know how to handle.	.584				
We were encouraged to express differing points of view.	.560				
Most people involved had the skills necessary to respond to any unexpected problems that arose.	.516				
People were rewarded or thanked for spotting potential trouble spots.	.516				
When members had different opinions, we tried to understand one another's views.	.473				
People in the group valued expertise and experience over hierarchical rank.	.457				
We assessed each situation on its own rather than assuming it would be similar to other situations we'd experienced.	.429				
We had access to sufficient resources when we needed them.	.421				
My boss actively listened when different views were presented.		.767			
My boss encouraged people to bring up potential problems.		.728			
REV_My boss rejected or ignored input from others.		.728			
My boss listened to the less experienced members of my group when they brought up ideas or issues.		.724			
My boss actively encouraged subordinates to question decisions that didn't make sense to them.		.687			
My boss actively sought input from a broad range of folks when making decisions.		.684			
My boss told us to pay attention to one another's input or ideas.		.609			
My boss told us that our task required us to work well together.		.569			
REV_My boss responded defensively to feedback from others.		.557			
My boss stated that he/she was confident in our group's ability to do the work.		.465			
The individuals I worked with were trustworthy.			.720		
We actively looked out for one another.			.657		
We honestly reported what we perceived to each other.			.621		
Achieving our objectives required close coordination within our group.			.618		
People showed a great deal of respect for each other.			.611		
We took advantage of the unique skills of our colleagues, when attempting to solve a problem.			.568		
We had a good understanding of each other's talents and skills.			.536		
The way each person performed their work had a significant impact on how others were able to perform their work.			.523		
We spent time identifying activities that we did not want to go wrong.			.499		
After the fire, we discussed whether there were ways we could have predicted or prevented problems that arose.				.719	
After the fire, we discussed what we learned.				.665	
Changes to procedures were recommended as a result of what we learned from our experiences on this incident.				.541	
We talked about mistakes and ways to learn from them.				.532	
The tasks we were involved with required a broad range of skills and functions.				.518	
We discussed what to look out for, when giving reports to new teams or units.				.493	
When errors did happen, we discussed how we could have prevented them.				.486	
The tasks we were involved with were quite complex.				.469	
We discussed alternatives as to how to go about our work activities.				.452	
We discussed our unique skills with each other so we knew who on the fire had relevant specialized skills and knowledge.				.438	
Our mission and objectives for each day were clear throughout the day.					.786
Our mission or objectives for each day were clear at the beginning of the day.					.766
REV_The lack of clear mission/objectives made it difficult to do our work.					.607
We knew what actions were required to achieve the outcomes we wanted.					.601
Information flowed well within our group.					.578
REV_I felt uncomfortable with our approach to the work.					.546
Eigenvalues	15.43	3.00	2.77	2.25	1.88
% variance	29.1	5.7	5.2	4.2	3.5
Cronbach's α	.911	.886	.858	.803	.774
Total variance explained: 47.8%					

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 7 iterations.

eliminating all records with more than two missing values. For records with fewer than two missing values, we inserted the mean score for that item, resulting in a final dataset of 574 responses. Comparison of the demographics and scores of the 94 excluded cases indicated no bias in non-respondents.

The KMO measure verified the sampling adequacy of the Likert-scale data for PCA (KMO = 0.941). Bartlett's test of sphericity was significant ($\chi 2$ [1770] =16824.158, p<0.001), indicating that correlations between items were sufficiently large for PCA.

Emergent Dimensions of Organizational Safety Climate

Examination of the initial scree plot and trial iterations indicated that the extraction of five components achieved the most representative and parsimonious solution. The final PCA solution (53 items) explained 47.8% of the variance in the data; all components have high internal reliability (Table 4).

Component 1—HRO practices. The first component comprised all but two items that measure the five theorized principles of HRO (Table 4). The remaining two—one from the original preoccupation with failure scale and one from the original deference to expertise scale—did not load significantly on any component and were dropped from the analysis. None of the items measuring collective mindfulness from the SOS loaded on this component. No items from other *a priori* scales loaded onto this component.

Subsequent PCA suggested some support for three subdimensions around communications connecting the group to higher levels of the organization (roughly sensitivity to operations), developing and maintaining a rich understanding of the situation (roughly reluctance to simplify), and the ability to value expertise over hierarchy (deference to expertise). However, only deference to expertise loads uniquely (Table 5).

As in the medical community, HRO practices hang together, but in the wildland fire community this is captured, not by the SOS, but by the audit-based items capturing the five principles individually. Close examination of these seem to distinguish human interactions by group identity and communications-related from task-related functions. That is, the sub-components of the HRO scale suggest interactions among those within the work group differ from interactions with external entities. For instance, items related to communications between the work group and supervisors (largely those measuring sensitivity to operations) are distinguishable from communication-based items that concern inter-group functioning (reluctance to

Table 5—Rotated component matrix for Component 1-HRO Practices with a priori construct.

A priori construct	Survey item	Component 1	2	3
HRO_S2O	Our superiors checked in with us frequently.	.795		
HRO_S2O	We checked in with our superiors frequently.	.755		
HRO_S2O	There was always someone with authority to make decisions available and accessible in the event that something unexpected came up.	.678		
HRO_S2O	Leaders were constantly monitoring workload and span of control to reduce them when that became necessary.	.658		
HRO_D2E	It was generally easy to obtain expert assistance when something came up that we didn't know how to handle.	.573		
HRO_S2O	We constantly kept one another in the loop about our activities.	.554	.500	
HRO_C2R	Leaders encouraged individuals to take on roles in this fire that challenged and stretched them.	.509	.457	
HRO_PwF	Leaders on the fire actively looked for problems.	.500		
HRO_S2O	People were familiar with what was going own beyond their own part of the fire.	.498	.410	
HRO_C2R	Leaders involved in this fire were concerned with developing people's skills and knowledge.	.495	.416	
HRO_C2R	Most people involved had the skills necessary to respond to any unexpected problems that arose.	.438	.521	
HRO_R2S	When members had different opinions, we tried to understand one another's views.		.730	
HRO_R2S	We were encouraged to express differing points of view.		.719	
HRO_PwF	People were rewarded or thanked for spotting potential trouble spots.		.705	
HRO_R2S	We assessed each situation on its own rather than assuming it would be similar to other situations we'd experienced.		.635	
HRO_D2E	People in the group valued expertise and experience over hierarchical rank.			.810
HRO_D2E	People most qualified to make decisions made them, regardless of hierarchical rank.			.789
HRO_S2O	We had access to sufficient resources when we needed them.	-*	-	-

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 6 iterations.
HRO = High Reliability Organizing, S2O = Sensitivity to Operations, D2E = Deference to Expertise, C2R = Commitment to Resilience, PwF = Preoccupation with Failure, R2S = Reluctance to Simplify. * did not load significantly.

simplify). Items originally proposed as describing commitment to resilience, preoccupation with failure, and deference to expertise tended to describe task-related rather than communications-related behaviors. Overall, we interpret the emergent HRO practices construct as describing practices that keep the group successfully integrated into the broader environment and encouraging a rich situational awareness.

Based on these results, we reject our initial expectation that the measures of the five HRO principles replicate those of the SOS (collective mindfulness). There is also evidence to partially accept and partially reject our expectation that the principles are distinct.

Component 2—Leadership. The second component comprised all items that measure our leadership construct (Table 4). No other items loaded on this component. Subsequent analysis indicates a sub-component on task framing, but most other items indicate considerable cross-loading (Table 6).

The *a priori* Leadership construct hangs together well and focuses on behaviors that nurture upward voice, or speaking up in a team. While there was no evidence that the two constructs of openness/response are separate, there was a clear distinction between leader-group interactions and how the leader encouraged the group to work together.

Component 3—Group Culture. The third component comprised 10 items, including all three items of respectful interaction and one of the three items of heedful interrelating (Tables 4, 7). This component also comprised all three items of task interdependence and three of the nine SOS items. The remaining two items from the original heedful interrelating scale cross-loaded with Component 1 and were dropped from analysis.

Further analysis cleanly breaks this component into two distinct sub-components: task interdependence, which exactly replicates the *a priori* construct, and a new construct that incorporates the remaining items in this component (Table 7).

Previously theorized, and empirically found by Vogus (2004) to be separate constructs, we found that heedful interrelating and respectful interaction are part of broader construct describing Group Culture. This emergent component speaks about how the group interacts. It first describes the tone of inter-group dynamics (group interaction), which captures the knowledge of and social interactions between members of a team. Second, it provides insight into their mental models about their tasks (task interdependence), governing their awareness of how each member of the group is needed to successfully complete the group's work.

Component 4—Learning Orientation. The fourth component also comprises 10 items, including all three items testing for a learning orientation, two of the four task complexity items, and four of the SOS items (Tables 4, 8).

Further analysis reveals three distinct sub-components (Table 8). The first sub-component groups four items of the SOS together, reflective of group sense-making. The second exactly replicates the *a priori* learning orientation construct and speaks to group actions to reflect upon and incorporate lessons learned. The final component, task complexity, incorporates two of three items of the *a priori* construct that concern the nature of the task itself.

The resulting Learning Orientation construct is found to be more comprehensive and nuanced than originally thought. Survey respondents said they perceive that learning is not simply about post-event reflection and integration but involves in-the-moment sense-making about tasks, approaches, and outcomes. The construct also suggests that the degree of complexity of a task is linked to learning behaviors.

Component 5—Mission Clarity. The fifth and final component comprises six items: all three of the goal clarity items, both of the group performance items, and the remaining item measuring task complexity (Table 4). Further analysis indicates this component is indivisible.

It appears that it is not simply clarity of the goal that is important, but that this clarity is linked to clarity of how the task may be achieved (within-group knowledge), to how well information flows within the group (within-group performance), and to comfort level with the assignment (safety perception). The emergent construct of Mission Clarity thus incorporates understanding of expectations, knowledge of how to achieve them, within group information flow, and perception of safety.

Conceptual Model—Revisited

The emergent components require us to revise our conceptual model, even before we address the strength or direction of linkages (Fig. 2). Some of our *a priori* constructs dissolve in the presence of a more complete suite of social and organizational practices. In addition to the breakdown of relationship between the mindfulness (SOS) and high reliability practices, we found that reflective aspects of mindfulness and the complexity of a task are part of a group's learning orientation, while interactive aspects of mindfulness and degree of task interdependence are associated with group culture. We also found our measures of group performance are linked with communication flow and goal clarity in a way that creates a more coherent component around mission clarity. The emergent construct of high reliability practices seems to highlight sensitivity to operations, reluctance to simplify, and deference to expertise. Items pertaining to a preoccupation with failure diffuse, raising the

Table 6—Rotated component matrix for Component 2-Leadership showing *a priori* construct.

A priori construct	Survey item	Component 1	Component 2
LEADER Task Framing	My boss told us that our task required us to work well together.	.814	
LEADER Task Framing	My boss told us to pay attention to one another's input or ideas.	.811	
LEADER Task Framing	My boss stated that he/she was confident in our group's ability to do the work.	.637	
LEADER Openness	My boss actively encouraged subordinates to question decisions that didn't make sense to them.	.586	.528
LEADER Response	My boss responded defensively to feedback from others.		.776
LEADER Response	REV_My boss rejected or ignored input from others.*		.761
LEADER Response	My boss actively listened when different views were presented.	.483	.704
LEADER Response	My boss listened to the less experienced members of my group when they brought up ideas or issues.	.463	.642
LEADER Openness	My boss encouraged people to bring up potential problems.	.553	.609
LEADER Openness	My boss actively sought input from a broad range of folks when making decisions.	.503	.567

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 3 iterations. * Reverse-scored.

Table 7—Rotated component matrix for Component 3–Group Culture showing *a priori* construct.

A priori construct	Survey item	Component 1	Component 2
RESPECT INTRXN	The individuals I worked with were trustworthy.	.843	
RESPECT INTRXN	People showed a great deal of respect for each other.	.792	
RESPECT INTRXN	We honestly reported what we perceived to each other.	.714	
HEED INTERRELN	We actively looked out for one another.	.702	
MINDFULNESS	We had a good understanding of each other's talents and skills.	.627	
MINDFULNESS	We took advantage of the unique skills of our colleagues, when attempting to solve a problem.	.567	
MINDFULNESS	We spent time identifying activities that we did not want to go wrong.	.539	
TASK INTERDEP	The way each person performed their work had a significant impact on how others were able to perform their work.		.816
TASK INTERDEP	Each person's performance was dependent on other's performing well.		.761
TASK INTERDEP	Achieving our objectives required close coordination within our group.		.683

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 3 iterations.

Table 8—Rotated component matrix for Component 4–Learning Orientation with *a priori* construct.

A priori construct	Survey item	Component 1	Component 2	Component 3
MINDFULNESS	When errors did happen, we discussed how we could have prevented them.	.771		
MINDFULNESS	We discussed alternatives as to how to go about our work activities.	.749		
MINDFULNESS	We discussed what to look out for, when giving reports to new teams or units.	.730		
MINDFULNESS	We talked about mistakes and ways to learn from them.	.727		
LEARNING	After the fire, we discussed what we learned.		.868	
LEARNING	After the fire, we discussed whether there were ways we could have predicted or prevented problems that arose.		.852	
LEARNING	Changes to procedures were recommended as a result of what we learned from our experiences on this incident.		.655	
TASK COMPLEX	The tasks we were involved with required a broad range of skills and functions.			.840
TASK COMPLEX	The tasks we were involved with were quite complex.			.832

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 5 iterations.

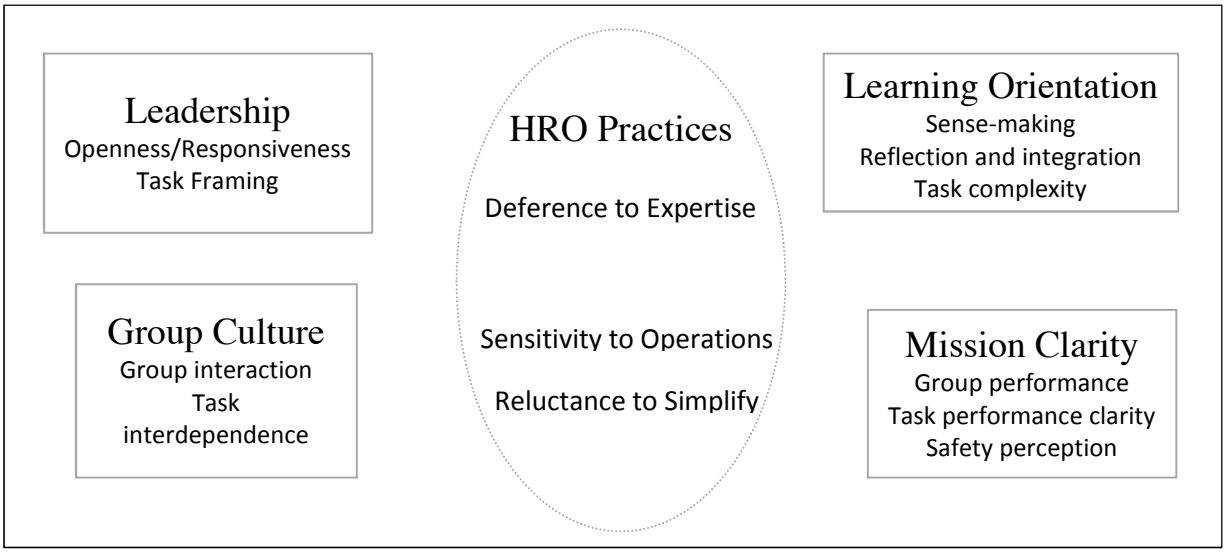

Figure 2—Constructs and sub-constructs as they appear in the Federal wildland fire community.

question of whether this is a strength or a weakness. Items related to commitment to resilience cross-load with (that is, relate to) both sensitivity to operations and reluctance to simplify, indicating a practical link.

Implications and Next Steps for HRO and Safety Culture in the Wildland Fire Community

Our findings suggest that the Federal wildland fire community currently functions in ways that support and extend prior theorizing about high reliability.

In the Introduction, we posited that wildland fire appeared to have structural, risk, and safety characteristics of highly reliable and reliability-seeking organizations (Vogus and Welbourne 2003) as well as holistic and decomposable organizations (for example, Schulman 1993; Klein and others 1995). Our statistical results support this. Results point to some suites of behaviors that seek to build internal group functioning and performance (Leadership, Group Culture, Learning Orientation, and some HRO Practices), which are attributes of both decomposable and reliability-seeking organizations. Others function to build and maintain connection to the broader system through communication (other HRO Practices and Mission Clarity), which are attributes of holistic and high reliability organizations. Attributes of the latter seek to achieve and maintain alignment with the broader mission and place a premium on alignment to ensure human safety; attributes of the former build strong, curious groups that foster learning and resiliency. Given that the wildland fire community places considerable responsibility for safety on individuals in local units, the presence of both of these features is reassuring.

These findings allow us to see the previously separate organizational spectrums and types in a single, broader frame—one that includes both formal and informal structures. Results also expand insight into how theoretically related formal and informal organizational behaviors interact with the classic behaviors and practices of high reliability. Although not providing results as to the connection between constructs (see Black and McBride 2013; Jahn and Black in prep.), by looking at the specific groupings within each construct, we gain insight into how high reliability practices are related to organizational learning, leadership, and human resource practices. In particular, for both theoretical and practical purposes, it now appears necessary to:

- consider the perceived level of task interdependence as part of the structure of group culture;
- recognize the distinct but complementary role of supervisory behaviors to model openness and help the group recognize its interrelatedness;
- acknowledge that team learning is more than simply engaging in post-incident practices but also includes in-the-moment practices to puzzle through, and the team is integrally linked to the complexity of the task it faces;
- recognize that perceptions of group performance may or may not be an outcome, but they are certainly linked to how clear and comfortable a group is with its assignment and in the wildland fire community;

- explore the suggestion that sensitivity to operations, a reluctance to simplify, and deference to expertise are the most readily visible and distinguishable principles of high reliability.

Finally, results raise theoretical and practical questions about how these components relate structurally to each other and whether the relationships are stable across the entire system or among different hierarchical or functional sub-systems. Such information will further illuminate this relationship between holistic/decomposable structures and will likely provide some insight as to how these two types might successfully transition and interact. We will also explore further the relative weighting of high reliability/reliability seeking practices in this system. Future research is necessary into the linkages between these structures, their sub-components, and performance.

Further inquiry into how this community engages in a preoccupation with failure and commitment to resilience is also warranted. Our finding that these attributes are scattered among the components as opposed to grouping together raises the question of whether these are strengths of the system or cause for concern. In new work, we explore these questions (Jahn and Black, in prep).

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References

Baker, D.P., Day, R. and E. Salas. 2006. Teamwork as an essential component of high-reliability organizations. Health Services Research, 41(4): 1576-1598.

Barton, M. and K.M. Sutcliffe. 2008. Mindfulness as an organizational capability: evidence from wildland firefighting. Revue Für Postheroisches Management/Heft, 3: 24-35.

Barton, M. and K.M. Sutcliffe. 2009. Overcoming dysfunctional momentum: organizational safety as a social achievement. Human Relations, 62(9): 1327-1356.

Black, A.E. and B.B. McBride. 2013. Safety climate in the US federal wildland fire management community: influences of organizational, environmental and individual characteristics. International Journal of Wildland Fire, Published on-line May 6, 2013. doi

Bourrier, M. 1996. Organizing maintenance work at two nuclear power plants. Journal of Contingencies and Crisis Management, 4: 104-112.

Campbell, D.T. 1990. Asch's moral epistemology for socially shared knowledge. Pp. 39-52 In Irwin Rock (Ed.), The Legacy of Solomon Asch: Essays in Cognition and Social Psychology. Hillsdale, NJ: Erlbaum.

Carroll, J.S. and J.W. Rudolph. 2006. Design of high reliability organizations in health care. Quality and Safety in Health Care, 15(suppl 1): i4-i9.

Dether, D. and A.E. Black. 2006. Learning from escaped prescribed fires—lessons for high reliability. Fire Management Today, 66(4): 50-56.

Edmondson, A. 1999. Psychological safety and learning behavior in work teams. Administrative. Science Quarterly, 44: 350-383.

Ericksen, J. and L. Dyer. 2004. Toward a strategic human resource management model of high reliability organization performance. Working Paper no. 04-02. Center for Advanced Human Resource Studies; Corenell University, School of Industrial and Labor Relations. Working Paper Series: 36 p.

Field, A. 2009. Understanding Statistics Using SPSS. Thousand Oaks, CA: Sage Publications, Inc.

Garvin, D. 1993. Building learning organizations. Harvard Business Review, 71(4): 78-91.

Hair, J.F., Anderson, R.E., Tatham, R.L. and W.C. Black. 1998. Multivariate Data Analysis (5th ed.). Upper Saddle River, NJ: Prentice Hall.

Hopkins, A. 2007. The problem of defining high reliability organizations. Working paper no. 51. National Research Centre for Occupational Health and Safety Regulation. The Australian National University, Canberra, ACT. 15 p.

Jahn, J., and A.E. Black. In prep. Integrating structure and action approaches to high reliability to derive a more complex theory. (note: now submitted)

Keller, P. (Ed.) 2004. Managing the unexpected in prescribed fire and fire use operations: a workshop on the High Reliability Organization. RMRS-GTR-137. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 73 p.

Klein, R.L., Bigley, G.A. and K.H. Roberts. 1995. Organizational culture in high reliability organizations: an extension. Human Relations, 48: 771-793.

Knotek, K. and A.E. Watson. 2006. Organizational characteristics that contribute to success in engaging the public to accomplish fuels management in the wildnerness/non-wilderness interface. Pp. 703-713 In Andrews, P.L. and B.W. Butler (Comps.), Fuels Management—how to measure success conference proceedings. Proc. RMRS-P-41. Fort Collins, CO: US. Department of Agriculture, Forest Service, Rocky Mountain Research Station.

LaPorte, T.R. 1988. The United States air traffic system: increasing reliability in the midst of rapid growth. Pp: 215-244 In R. Mayntz and T. Hughes (Eds.), The Development of Large Scale Technical Systems. Boulder: Westview Press.

Lessons Learned Center. 2008. The first basic teaching guide for introducing high reliability organizing to the wildland fire community: from field to line officers. March 2008. Wildland Fire Lessons Learned Center. Available: http://wildfirelessons.net/documents/HRO_Teaching_Guide_final_0520.pdf.

Marcus, A. 1995. Managing with danger. Industrial and Environmental Crisis Quarterly, 9: 139-52.

Putnam, Ted. 1995. Findings from the wildland firefighters human factors workshop. Improving wildland firefighter performance under stressful, risky conditions: toward better decisions on the fireline and more resilient organizations. 12-16 June 1995; Missoula, MT. Missoula, MT: U.S. Department of Agriculture, Forest Service, Missoula Technology and Development Center. Available: http://fsweb.mtdc.wo.fs.fed.us [July 6, 2007].

Roberts, K. 1990. Some characteristics of one type of high reliability organization. Organization Science, 2: 160-176.

Rochlin, G.I., LaPorte, T. and K. Roberts. 1987. The self-designing high reliability organization: aircraft carrier flight operation at sea. Naval War College Review, 40: 76-90.

Schulman, P.R. 1993. The analysis of high reliability organizations: a comparative framework. Pp. 33-35 In K.H Roberts (Ed.), New challenges to understanding organizations. Old Tappan, NJ: Macmillan.

Senge, P.M. 1990. The Fifth Discipline: The Art and Practice of the Learning Organization. New York: Random House. 424p.

Sutcliffe, K.M. 2011. High reliability organizations (HROs). Best Practice and Clinical Anaethesiology, 25: 133-144.

Tabachnick, B.G. and L.S. Fidell. 2001. Using Multivariate Statistics (4th ed.). Boston: Allyn & Bacon.

Thomas, D.A., Black, A.E., Dether, D., Hetts, K. and M. Dueitt. 2007. The jungle prescribed fire review: an experiment in learning. U.S. Department of Agriculture, Forest Service. Available: http://wildfirelessons.net.

Vaughan, D. 1996. The Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA. Chicago: University of Chicago Press.

Vogus, T. 2004. In search of mechanisms: how do HR practices affect organizational performance? Dissertation. University of Michigan, Ann Arbor.

Vogus, T.J. and K.M. Sutcliffe. 2007a. The Safety Organizing Scale: development and validation of a behavioral measure of safety culture in hospital nursing units. Medical Care, 45: 46-54.

Vogus, T.J. and K.M. Sutcliffe. 2007b.The impact of safety organizing, trusted leadership, and care pathways on reported medication errors in hospital nursing units. Medical Care, 45: 997-1002.

Vogus, T.J. and K.M. Sutcliffe. 2012. Organizational mindfulness and mindful organizing: a reconciliation and path forward. Academy of Management Learning & Education, 11(4): 722-735.

Vogus, T.J. and T.M. Welbourne. 2003. Structuring for high reliability: HR practices and mindful processes in reliability-seeking organizations. Journal of Organizational Behavior, 24: 877-903.

Weick, K.E. 1993. The collapse of sense-making in organizations: the Mann Gulch disaster. Administrative Science Quarterly, 38: 628-652.

Weick, K.E. 1995. South Canyon revisited: lessons from high reliability organizations. Wildfire, 4(4): 54-68.

Weick, K.E. 2011. Organizing for transient reliability: the production of dynamic non-events. Journal of Contingencies and Crisis Management, 19(1): 21-27.

Weick, K.E. and K. Roberts. 1993. Collective mind in organizations: heedful interrelating on flight decks. Administrative Science Quarterly, 38: 357-381.

Weick, K.E. and K.M. Sutcliffe. 2001. Managing the Unexpected: Assuring High Performance in An Age of Complexity. University of Michigan Pressing Problem Series. San Francisco: Jossey-Bass.

Weick, K.E. and K.M. Sutcliffe. 2007. Managing the Unexpected: Resilient Performance in An Age of Uncertainty (2nd ed.). University of Michigan Pressing Problem Series. San Francisco: Jossey-Bass.

Weick, K.E., Sutcliffe, K.M. and D. Obstfeld. 1999. Organizing for high reliability: Processes of collective mindfulness. Pp. 81-124 In R. Sutton and B. Staw (Eds.), Research in Organizational Behavior, 81-124. Greenwich, CT: JAI.

Wilson, K.A., Burke, C.S., Priest, H.A. and E. Salas. 2005. Promoting health care safety through training high reliability teams. Safety in Health Care, 14: 303-309.

Yang, B., Watkins, K.E. and V. J. Marsick. 2004. The construct of the learning organization: Dimensions, measurement, and validation. Human Resource Development Quarterly, 15(1): 31-55.

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