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Dynamic decision processes in complex, high-risk operations: The Yarnell Hill Fire, June 30, 2013

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ABSTRACT

Recreating the information flow in decision processes after serious accidents enables researchers and policy makers to identify both the threshold points at which action begins to fail and gaps in information processes that could be corrected to reduce risk in future incidents. The Yarnell Hill Fire of 30 June 2013 occurred in a rapidly changing, high-risk environment of the Arizona highlands in which the interaction among the physical terrain, wind and vegetation conditions, technical support structures, and organizational decision processes led to the collapse of the firefighting strategy and the loss of nineteen members of the Granite Mountain Interagency Hotshot Crew. Based on documentation from operational management manuals, accident reports, and agency records, simulation methods are used to retrace the information flow in this complex decision process and reveal fresh insights into the limitations of standard firefighting practices in rapidly escalating, dangerous, wildfire conditions.

1. Introduction: Decision making in dynamic, urgent environments

Decision making in complex, urgent environments creates extraordinary challenges for public personnel when time and resources are constrained and the consequences of failure are severe. Risks are high, both for public personnel taking action and for the population whose lives and properties they seek to protect. As social systems become more interdependent with physical and technical systems, the array of possible interactions among individuals, groups, organizations, and the context in which they function increases, and the number of factors that influence potential actions and outcomes in constructive or destructive ways also increases. Consequently, response to extreme events becomes an emerging, large-scale, sociotechnical system of individuals, groups, organizations, and jurisdictions that necessarily need to coordinate their actions to mobilize coherent, effective operations in an often disrupted and dangerous environment. Many of the participating individuals and organizations may not know one another, and may not be familiar with the particular context for action, but presumably they rely on a common base of knowledge and training. Yet, as demonstrated in the Yarnell Hill Fire of June 30, 2013, with its devastating loss of the field firefighting unit, the Granite Mountain Interagency Hotshot Crew, the physical and technical demands of these events may exceed the organizational capacity of the emerging response system.

We examine the decision processes and interactions among policies, procedures, and practice in the context of the Yarnell Hill Fire of June 30, 2013 in order to identify the critical points at which the complex coordination of the interagency sociotechnical system mobilized to respond to this event failed. Further, we explore how decision processes might be improved to enable emergent, large-scale, sociotechnical systems to function in similar urgent, dynamic environments.

Decision making in fire management has been studied by many scholars (Weick, 1993; Klein, 1998; Wybo et al., 2001), each contributing perceptive insights to this extraordinarily difficult task. Our analysis focuses on interactions among different levels of decision making in the whole response system to investigate how component units lose or maintain their capacity for shared operations. The organizational task for each component of the system is to maintain both a detailed grasp of its particular functions within

Abbreviations: ASM, Aerial Supervision Module; AZSF, Arizona State Forestry Division; BLM, Bureau of Land Management; COP, Common Operational Picture; DIVS A, Division Alpha (GM IHC Superintendent); DIVS Z, Division Alpha (BlueRidge Superintendent); SPG, Structure Protection Group; IAP, incident action plan; ICS, Incident Command System; ICT, Incident Commander Type; GM, Granite Mountain; IHC, Interagency Hotshot Crew; LCES, Look out, Communication, Escape Route, Safety Zone; OSC, Operation Section Chief; SEAT, Single Engine Air Tanker.

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the limits of supporting technologies in the overall response operations, and simultaneously, a clear vision of how its performance fits into the operation of the whole system, with peripheral awareness of the impact of its functions on related components. Such a task is cognitively demanding for individuals, subject to error in groups, but critical to the coherent performance of the whole system. We explore requirements for maintaining such dual level cognition in large, sociotechnical systems operating in response to extreme events.

Wildfire suppression represents a particularly challenging set of conditions for interagency operations. The physical conditions are demanding, with rugged terrain, hot, dry temperatures, and dynamically changing wind directions. In these conditions, technical support ordinarily used in firefighting may not be available or accessible. Consequently, field crews are dependent on shared training, clear organizational structure, and continual communications with their support staff and one another to maintain their role in operations. Scientific knowledge of the likely shifts in wind direction and interpretation of the characteristics of wildfire activity are crucial to maintaining accurate situation awareness at all operating levels of the response system. The capacity to adapt and adjust to dynamically changing conditions is fundamental to effective performance at all levels of the system, lest action by one component adversely affect performance or limit options for action by others.

Given increasing frequency of extreme events and increased cost of mobilizing large-scale, sociotechnical systems to respond to them, we present a profile of the complex interactions among components of an interagency response system, based on computational model, as a means of evaluating the design of such systems and improving their performance in extreme events.

2. A conceptual framework for system adaptation and change

Decision making under conditions of uncertainty has a long tradition in organizational theory (Simon, 1997; March, 1988, 1991; Weick, 1993, 1995). Much of this work has focused on decision making by individuals. Other work has focused on decision making among individuals as they are engaged in organizations. Weick (1993), in his classic article on the disintegration of organizational structure in the Mann-Gulch Fire of 1949, identified the concept of 'heedful interrelating' among members of a team as essential to maintain the coherence of coordinated action. Weick recognized the importance of maintaining continual awareness of a changing situation and its impact on other members of a team as the basis for adapting one's own actions. This capacity, more intuitive and psychological than rule-directed or command-driven, is more reflective of organizational culture than structure. Consequently, it is learned most often in the context of operations, rather than from standard training manuals or procedures.

Klein and his associates (1993), in their work on 'recognition-primed decision making,' acknowledged the importance of learning from experience and noted the capacity of seasoned emergency personnel to draw on vignettes from past experience and assemble them quickly to create an innovative approach to an immediate problem. Klein (1998) expands on this concept in developing his characterization of decision making by teams of firefighters facing dynamic, urgent situations and the emergence of leadership in these groups as other members recognize the validity of an example being set in a specific context, even as the action may depart from formal rules.

The concept of 'distributed cognition' articulated by Edwin Hutchins (1995) acknowledges the process of creating a common base of knowledge for action from insights contributed by different members of a team with different backgrounds and disciplinary perspectives. In complex, decision making environments, this insight acknowledges the limits of any single actor or organization in understanding the full set of constraints in an operational environment. Similarly, Fligstein and McAdam (2012) delineate a theory of changing 'fields of action,' in which actions taken in one field change conditions or set constraints that affect actions in another, related field. The authors acknowledge the difference between 'proximate' or fields of immediate action and 'distal' or distant fields that, nonetheless, may exert a critical, indirect influence on operating conditions. The authors also note the force of emotional ties both among members of a group and their commitment to a larger goal for action.

While each of these authors contributes thoughtful insights to the problem of decision making under uncertainty, none of them addresses the larger, more complex problem of system integration in decision support for large-scale, sociotechnical systems operating at multiple levels of authority in rapidly changing, urgent environments. The intent of this study is to explore the potential of computational modeling to make explicit the particular interactions among physical conditions, technical support, organizational structure, and individual cognition to create a basis for system-wide operations in dynamic environments. We use as the basis for this study the case reports on the Yarnell Hill Fire prepared by the Arizona State Forestry Division (09.23.2013) and the Wildland Fire Associates (November, 2013). The reports followed the detailed procedures outlined by the Interagency Serious Investigation Guide (December, 2013) adopted by US federal agencies to investigate accidents that involve the loss of life and serious property loss. Parameters identified from these reports are then entered into a computational model using the AnyLogic software (AnyLogic 6, 2013) to display the profile for the necessary interconnections among the organizational units for the whole system to function effectively. This method of investigation incorporates elements of the methods proposed by Wybo et al. (2001) to provide independent characterization of actions in a system involving diverse participants, but adds to this approach the computational power that can display the changes essential to system performance at different situations. The resulting profile is a detailed presentation of essential connections among system components at different levels of operation as conditions change over time. It provides an assessment of the changing conditions in which the Yarnell Hill sociotechnical response system operated and the requirements for adaptation by the whole system to these conditions.

3. The Yarnell Hill Fire, 30 June 2013

Facts are retrieved from both accident reports (WFA, 2013 & Serious Accident Investigation, 2013) (see Map 1):

On June 28, 2013, at approximately 5:00 p.m., lightning strikes ignited several small fires in dry chaparral on a mountainous ridge west of the town of Yarnell, Arizona. The area had not experienced fire since 1966, and the fuel load in the region was dangerously high, given drought conditions and temperatures consistently over 100 °F. The fire was reported to the Arizona State Forestry Division (AZSF), which was monitoring 37 active fires burning statewide. The Yarnell Hill Fire was documented initially as only a half-acre in size, and crews were assigned for operations the next morning.

On June 29, the AZSF firefighter coordinated operations with a Bureau of Land Management (BLM) Duty Officer in monitoring the fire. Two Single Engine Air Tankers (SEATs) arrived to drop retardant on the fire. Since the fire was holding on all four sides, the Incident Commander, Team 4 (ICT4), released the Air Attack planes for duty in response to other fires burning in the state.

At 4:00 p.m., the wind increased fire activity, and the fire spread to approximately 100 acres. The ICT4 requested more resources, an Incident Management Team Type 2, and three Interagency Hotshot