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COMPLEX SYSTEMS IN CRISIS:

Managing Response to Extreme Events

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Abstract

The events of September 11 demonstrated vividly that extreme events cross geographic, disciplinary, organizational, and jurisdictional boundaries. Mobilizing response operations across organizational and jurisdictional boundaries on a regional scale requires a collaborative effort among participating public, private and nonprofit organizations that is not yet defined by current administrative policy and procedures. I examine the 9/11 events using the analytical framework of a complex adaptive system, and propose that a well-designed information infrastructure can facilitate the flexibility and learning essential for adaptive response in extreme conditions.

Introduction

Etched indelibly in memory for most Americans is the searing image of United Airlines Flight #175 crashing into the South Tower of the World Trade Center in New York City at 9:03 a.m. on September 11, 2001. Eighteen minutes earlier, American Airlines Flight #11 had crashed into the North Tower, and the television cameras captured both towers engulfed in flames. The scene was replayed endlessly on CNN and television news stations around the world, so that virtually anyone with access to a television set has seen the powerful images, evoking horror in the minds of those who empathized with the victims. To some, the images undoubtedly elicited admiration for the boldness of the act or acknowledgment of the singular goals of the perpetrators, but to all, they represented an extreme event, one that could not be addressed by routine measures. When the towers collapsed, virtually the whole world knew of the extraordinary impact of the coordinated attacks upon U.S. civilian targets. The security of major U.S. cities had been breached, and public agencies, charged with legal responsibility to protect life, property and continuity of operations, mobilized in response.

For public agencies, the events of September 11 presented an extraordinary test of their capacity to function under the most severe conditions of disruption and destruction. Each of the public organizations and jurisdictions responsible for public security in New York, New Jersey and Virginia had emergency plans, but none had imagined an event that would turn civilian airliners into weapons of mass destruction. The challenge lies, first, in recognizing the danger and anticipating the scope of the damage. Extreme events demand resources and skills from a wider range of organizations than those in the immediately affected area. More difficult is the task of integrating multiple separate agencies and jurisdictions into a smoothly functioning inter-organizational, inter-jurisdictional response system under the urgent, chaotic conditions of full-scale disaster.

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The need for integration intensifies as the number of organizations engaged in response operations increases and the range of problems they confront widens. Since all organizations in the damaged area are affected, private and nonprofit actors become participants in the response system as well as public agencies. Some organizations may not have emergency plans, or may not have linked them to a larger community-wide response process. As the type and size of organizations involved in response operations varies, the disparity in skills, knowledge, access to information and equipment widens among the participants in the response process. Achieving coordinated action among a disparate group of actors depends fundamentally upon their access to timely, valid information and their capacity for information search, exchange, absorption and adaptation.

Reliable performance of information functions under stress is a critical factor in achieving coordination in action among a large and varied group of actors engaged in crisis response. This performance depends upon at least three basic sets of conditions that influence the interaction of agents involved in response to the event (Comfort 1999). The first set includes the technical structure needed to support information search and exchange. The second set of conditions involves the organizational policies and procedures that shape action both within, and among, the participating organizations. The third set involves cultural openness to new information, new strategies for addressing an unimaginable set of problems, and willingness to adapt to extraordinarily difficult conditions. These three sets of conditions shape in fundamental ways the evolution of an inter-organizational response system to the event. The interaction among the agents, further, shapes the next round of actions that each individual organization or agent takes. The result is the emergence of a complex, adaptive system that responds both to the demands from the environment and the degree of pressure or support given by other organizations as the response system evolves.

The 9/11 events were extraordinarily complex, with three different sites involved in the attacks and simultaneous demands made upon federal agencies from all three locations. At the same time, the evolving response system needed to integrate different state, regional, county and municipal agencies, as well as private and nonprofit organizations, into a coherent framework for action. The knowledge base to support response operations in such an event needs to be scalable. That is, it needs to provide specific information to support action by personnel operating at different sites within multiple jurisdictions and between multiple levels of jurisdiction simultaneously. Most public agencies have emergency plans, but they are not always current. Although some private companies and nonprofit organizations such as hospitals and schools have emergency plans, they often are not integrated with those of the public agencies to provide a comprehensive plan for a community, much less multiple communities in an affected region. Facilitating the evolution of response systems to extreme events in densely populated metropolitan areas is a major challenge in public policy and administration.

Mobilizing response operations across organizational and jurisdictional boundaries on a regional scale requires a collaborative effort among participating public, private and nonprofit organizations that is not yet defined by current administrative policy and procedures. In an earlier essay (Comfort 2002), I discussed the need to identify the potential points of breakdown, or fragility, in inter-organizational systems that evolve rapidly in response to extreme events. In this essay, I address the converse need to strengthen the capacity of the emerging response system in order to respond more effectively to threats on a regional scale. In doing so, I will undertake four tasks. First, I will briefly discuss the difference between linear and nonlinear models in public policy and administration, and the conceptual shift to nonlinear operations in the dynamic context of disaster. Second, I will examine briefly the theoretical background of response systems in extreme contexts as complex adaptive systems, identifying their characteristics and modes of adaptation in changing environments. Third, I will use incidents from the 9/11 events to illustrate different modes of adaptation among the multiple agents involved in response operations. Finally, I will conclude

with recommendations for a preliminary model of auto-adaptation among public, private and nonprofit organizations on a regional scale to extreme events.

The dynamic context of disaster

The effective mobilization of response to extreme events on a large scale is one of the least understood problems in public management. This process requires the rapid search, exchange, and absorption of valid information regarding sudden, damaging events transmitted through a network of organizations that crosses disciplinary, organizational and jurisdictional boundaries. It requires pre-disaster planning among organizations to identify what information will be required and how this information may be accessed. It entails the rapid comprehension of danger that, under ordinary circumstances, is unimaginable. It requires the capacity to use that powerful insight to anticipate the spread of risk through an interdependent community and to devise actions that will interrupt or limit the risk. It means discovering the 'logic' that will govern the ensuing uncertainty in technical and organizational performance (Comfort 1989). This is an inference process that functions more through the rapid recognition of signals and symbols (Feldman and March 1988) and the use of mental models (Weick 1995), than on rule-based reasoning (Hayes-Roth, Waterman and Lenat 1983).

Extreme events pose a distinct problem for theorists in public policy and administration. In the past, practicing managers preferred to consider these events rare occurrences, calling them "acts of God" or calculating the chances of occurrence vs. costs of mitigation in terms of defining "acceptable risk" (Kartez and Kelly 1988). But when extreme events do occur and public agencies fail to respond promptly and efficiently, the political as well as social and economic consequences are severe (Gawronski and Olson 2000; Carley and Harrald 1997). Public agencies bear legal responsibility for the protection of lives, property and continuity of operations, and local agencies bear the brunt of first response. Consequently, disaster management remains the quintessential function of government, and public managers at all levels of government are rethinking their odds on the probability of disaster.

The extraordinary losses incurred on September 11 compel a review of the capacity of government agencies to mitigate and respond to extreme events. While much work has been done to assess planning and response activities at municipal and federal levels (Mileti 1999; Platt et al. 1999; Sylves and Waugh 1996), little attention has been given to structuring inter-organizational response to extreme events on regional levels. Nor has there been careful study of how response systems, once constituted, could contribute to the capacity of the region to mitigate recurring risk. The challenge to current administrative theory and practice is how to design and support governmental systems that are able to adapt readily to the urgent demands and complex operating conditions in extreme events.

The standard administrative approach toward solving complex problems has been to organize work involving multiple agents and tasks hierarchically (Simon 1981; Newell and Simon 1972). Hierarchy is used to establish control, specify tasks, allocate responsibilities and reporting procedures, and presumably gain reliability and efficiency in work flow. This approach works reasonably well in routine circumstances when there is time to plan actions, train personnel, identify problems and correct mistakes. Under the urgent, dynamic conditions of disaster, however, such procedures almost always fail. Carefully developed emergency plans may not fit the specific conditions of the disaster. Information required by disaster managers may be old or incomplete. Key personnel may be missing or unavailable for decisions. Under cumulative stress, hierarchical organizations tend to break down, and personnel are hindered by a lack of information, constraints on innovation, and an inability to shift resources and action to meet new demands quickly (Comfort 1999).

In extreme events, public organizations need the capacity to adapt quickly and effectively to rapidly changing conditions. Such capacity relies upon a continuous exchange of timely, valid information among multiple participants regarding their shared goal in dynamic operating conditions. The two types of operating environments – routine and extreme – illustrate the difference between linear and nonlinear systems in theory and the difference between organized hierarchy and complex adaptive systems in practice. Routine environments assume a complete knowledge base with all relevant information available, so that organized hierarchy can apply known information efficiently to known problems. In this context, linear systems function well. Extreme environments, in contrast, acknowledge that all relevant information is not known, and that previously known conditions may be in a state of flux. Relations between organizations and their operating conditions are nonlinear, and actions must be based upon incoming information integrated with known information to adapt effectively to the changing environment. This fundamental difference in operating conditions shifts the system's focus from control based upon known information to continuous search and exchange processes to develop valid information as a basis for action.

The distinctive advantage of human organizations is that the individuals within them are able to learn. This ability to learn from incoming information and observation creates the potential for developing self organizing agents or auto-adaptive systems in dynamic environments (Gell-Mann 1994; Holland 1995). It acknowledges the organizational and policy processes that contribute to change, learning, and innovation in dynamic environments (Peitgen, Saupe and Jurgens 1992; Argyris 1993; Comfort 1994), but it considers these processes on a different scale, that of system-wide response to a massive event.

While the collapse of organizational capacity to act under extreme conditions has been vividly documented in actual cases (Weick 1993; Carley and Harrald 1997; Comfort 1999), the opposite phenomenon, the design and development of communities capable of innovative and responsible performance under threat of extreme danger has not been studied systematically. There has been no rigorous effort to model the effects of the rapid spread of information regarding risk on the performance of communities under threat, or to estimate the economic costs and social benefits of making the investment in information technology and organizational training that would be necessary to achieve 'reliable performance' in extreme events. This paper will examine modes of increasing the capacity of inter-organizational systems to adapt to extreme events.

Theoretical background

The concept of adaptation in inter-organizational systems draws upon findings from four distinct research themes in public administration and organizational theory. First, it is informed by the broadly interdisciplinary literature on complex adaptive systems (Holland 1995; Axelrod 1997; Axelrod and Cohen 1999; Kauffman 1993; Prigogine and Stengers 1984). A key concept in this literature is self organization, or the capacity to reallocate resources and action to meet changing demands from the environment (Kauffman 1993). This capacity refers to change in behavior that is initiated by the actor, not imposed by any external force. Rather, the agent seeks change in order to achieve a better fit with its environment. Self organization has been observed in physics (Bak and Chen 1991), biology (Kauffman 1993) and public policy (Comfort 1999; Comfort and Sungu 2001). Extending this concept of self organization by a single agent to adaptation among a set of interacting organizations is critical to understanding the dynamics of response to extreme events.

Second, recent work on decision making under conditions of uncertainty offers a valuable perspective to adaptation in inter-organizational systems. Karl Weick (1995, 2001), a psychologist, and his colleague Kathleen Sutliffe (Weick and Sutliffe 2001) present the concept of sensemaking as a process of scanning the environment for information and using it to develop a plausible course of action in a difficult or shifting context. Gary Klein (1993) developed a more detailed model

called recognition primed decision making based upon his observation of fire commanders directing operations in the dynamic context of a fire ground. Klein finds that fire commanders make decisions not on a basis of a rational review of alternative strategies, but upon recognition of situations they have seen before. They craft a strategy of action from a repertoire of previous events that are similar to the situation they are confronting. Rhona Flin (1995) confirms this process of naturalistic decision making in her observations of emergency operations chiefs performing under stressful conditions. Weick and Roberts (1996) move from observations regarding decision making by single operations chiefs to the interaction among members of a crew on an aircraft carrier. Their concept of "heedful interrelating" refers to a state of mindful attention among a group of actors that evolves from common training, intense communication, and a distinct culture derived from shared experience. The authors use this concept to explain the high reliability in performance that is achieved by ordinary human actors in the dangerous operating environment of an aircraft carrier. Each of these concepts offers insight into decision making in difficult, dynamic conditions, but none addresses this process in the context of a region-wide inter-organizational response system.

Third, research on uses of technology by social organizations documents the emergence of sociotechnical systems (Goodman and Sproull 1990; Gell-Mann 1994; Comfort 1994). A socio-technical system integrates humans, computers, and technical agents in an interactive system that transmits, receives, stores and acts upon information from the environment. The capacity to learn from incoming information in a dynamic environment alters significantly the operating context of organizations responding to threat. An inter-organizational response system is dependent upon access to information and the range and quality of the information available to operations personnel. This capacity can be enhanced by a technical infrastructure that establishes contact and communication with a wider range of sources of information and support to organizational personnel, but it can also be limited if the technical information infrastructure fails, or vital communications can not be made. It is the interaction between human actors and technical infrastructure that extends or limits the operating capacity of the response system.

Fourth, modes of adaptation in inter-organizational response systems depend upon the initial conditions of the participant organizations. Analyzing rapidly evolving response systems following earthquakes, I identified four types of adaptation (Comfort 1999) that may be applicable to inter-organizational systems emerging in response to other types of hazards, including terrorist attacks. This initial characterization gives a beginning classification of types of adaptation demonstrated by inter-organizational systems under differing technical, organizational and cultural conditions. Each type can be characterized by technical, organizational and cultural indicators. Technical indicators include measures of reliability for the technical structures, e.g. transportation, electrical power, communications. Organizational indicators include measures of organizational flexibility, e.g. adaptability to changing conditions, style of communication among members, leadership or lack thereof. Cultural indicators include measures of openness and innovation, e.g. willingness to accept new concepts or initiate new patterns of action. The emerging systems vary in terms of their characterization by these indicators, and interaction among the three sets of conditions limits the system's capacity for adaptation to a damaged environment. The response systems reflect these limits, defined largely by the initial conditions in which the damaging event occurred. The four types of adaptive systems identified in field studies of earthquake response systems, briefly, are: nonadaptive systems, emergent adaptive systems, operative adaptive systems and auto-adaptive systems (Comfort 1999).

Nonadaptive systems are systems that are low on technical structure, low on organizational flexibility and low on cultural openness to new information. They function under threat largely dependent upon outside assistance, but revert to previous status after the threatening event. Emergent adaptive systems are low on technical structure, medium on organizational flexibility,

and medium on cultural openness to new concepts of operation and organization. These systems develop a mode of organization and action to cope with threat during disaster operations, but are unable to sustain collective action after the immediate threat passes.

Operative adaptive systems are those that are medium on technical structure, medium on organizational flexibility and medium on cultural openness to new information. These systems function well in response to threat, but prove unable to translate methods of response into new modes of sustained operation and threat reduction. Auto-adaptive systems are those systems that are high on technical structure, high on organizational flexibility, and high on cultural openness to new information. Such systems represent a rare achievement, but in practice, these systems prove effective in response to threat and are able to transfer lessons learned from prior experience into a sustained reduction of threat. For threats of unbounded uncertainty, such as terrorism, the preferred type of adaptation is an auto-adaptive system that is able to learn from incoming information, re-allocate its resources and attention, re-order its relationships with other entities, and act promptly to reduce the threat or respond to destructive acts.

While the concept of auto-adaptation fits the requirements for inter-organizational response to extreme events, the conditions needed to support its development in practice and the dynamics by which it evolves have had little attention in research. In order to apply this concept to a strategy of inter-organizational response in extreme events, its characteristics need to be developed more fully. Auto-adaptation by a single actor is a form of individual learning, but it moves to group learning when it occurs in an organization, and to broader collective learning when it occurs in an inter-organizational system. Auto-adaptation is a form of mutual adjustment among the component units of an organization and again, among the component organizations of an inter-organizational system. It is a means of managing change of different types at different rates among different units or agents that allows the formation of a coherent strategy of action for the inter-organizational system.

In addition to meeting the initial conditions stated above, an auto-adaptive system appears to move through five distinct phases in its response to extreme events. These phases are: 1) information search or scanning; 2) information exchange, or 'heedful interrelating' with other agents in the system; 3) sensemaking, or selection of a plausible strategy of action, given the situation and resources available; 4) adaptation, or action taken to implement that strategy; and 5) evaluation of actions taken and modification of succeeding actions on basis of observed results. In the next section, I will present brief vignettes of auto-adaptation in situations when the response system did function well, as well as brief vignettes when it did not.

Modes of adaptation to the 9/11 events

While the full record of damaged conditions and actions taken during the intense hours, days and weeks immediately following the 9/11 terrorist attacks is not yet complete, sufficient information regarding key aspects of the response is available to allow preliminary observations and interpretation. This analysis is based upon accounts of the events and actions taken from news reports, agency situation reports, and notes from interviews with key participants.[i] It is also important to set this analysis in administrative context. In terrorist incidents, two types of response operations are initiated simultaneously. The first is crisis management, or the effort to identify and pursue the perpetrators of the incident. Under the National Contingency Plan, the Department of Justice (DOJ) is designated as the lead agency for crisis management, and coordinates its work with other agencies involved in pursuit of individuals who may have engaged in illicit activity. These agencies include the Federal Bureau of Investigation (FBI), the Central Intelligence Agency (CIA), when international agents are involved; the Immigration and Naturalization Service (INS), which governs entry and exit of foreign nationals across US borders; and the Bureau of Alcohol, Tobacco and Firearms (ATF), which tracks the entry of illegal

substances across US borders. These agencies operate within the bounds of security required for a criminal investigation.

The second type of response to a terrorist attack is consequence management, or the immediate mobilization of search and rescue operations to save lives of people harmed by the incident, as well as disaster assistance to the people who suffered losses from the incident, and recovery and reconstruction of the damaged communities. The Federal Emergency Management Agency (FEMA) has lead responsibility for consequence management, focusing first on lifesaving operations and second on assistance to the victims, recovery and reconstruction of the community. Under the Federal Response Plan, ten agencies in addition to FEMA play lead roles in disaster operations, with all twenty-eight federal agencies assigned responsibilities under twelve specified emergency support functions. The lead agencies include the Departments of Transportation (DOT), Defense (DOD), Health and Human Services (HHS), Housing and Urban Development (HUD), Agriculture (DOA), National Communications Service (NCS), Environmental Protection Agency (EPA), General Accounting Office (GAO), and the US Forest Service (USFS). The American Red Cross (ARC), a nonprofit organization, is designated as the lead agency for mass care. FEMA is responsible for information management as well as urban search and rescue operations (Federal Response Plan 1999).

This analysis deals only with consequence management operations, which are led by the FEMA in conjunction with other civilian federal and sub-national governments and agencies. While the interaction between the DOJ agencies and FEMA is critical to the overall operation of the disaster response system in response to a terrorist attack, the records of the agencies supervised by the DOJ are not open for public review as the criminal investigation is still on-going.

The initial conditions in which the incidents occurred shaped distinctively the emergence of the response systems at the World Trade Center and the Pentagon sites. At the World Trade Center, the physical devastation was catastrophic. The attacks caused not only the collapse of the 110-story twin towers, with an estimated 20,000 people in the buildings at the time of the attacks, but also the complete or partial loss of five smaller buildings in the immediate campus area, and heavy damage to twelve other buildings in the roughly six square block area in which the towers were located. In addition, the electrical power generation and distribution system for lower Manhattan was destroyed; the water distribution system, dependent upon electricity for pumping water, was disabled; gas pipelines were heavily damaged, and the telephone and telecommunications services were seriously disrupted.[ii] The technical infrastructure that enabled people to live and work in this densely populated, interdependent urban environment was decimated, and the site was dubbed appropriately "Ground Zero."

Organizationally, the New York Fire and Police Departments responded immediately to the event. In terms of professional experience and training, both departments had seasoned, well-trained and well-equipped personnel. Neither department, however, had confronted events as catastrophic as this. Both departments responded within their standard framework of operations for a major fire. But without an assessment of the interdependent effects of the collapse of the technical infrastructure needed to support their operations, the responders themselves became victims. The loss was greatest in the New York Fire Department, when 343 fire personnel were lost. This number included personnel who were in the buildings seeking to rescue others when the towers collapsed, as well as departmental leadership on duty when their Command Post, established in the ground floor of the North Tower, was destroyed.

Culturally, the emergency response departments of New York City have well-developed, coherent professional beliefs and values regarding their departmental performance. Less well developed, however, was their awareness of the need for information from other departments in order to craft an effective strategy of action for this extraordinarily difficult event. With little experience in

suppressing fire in 110-story buildings, the Fire Department did not consider the possible collapse of the buildings themselves. Without an assessment of the structural damage to the building and its state of fragility, standard departmental procedures placed their own personnel at risk.

At the Pentagon site, the Boeing 767 struck a section of the building that had just been reinforced against possible attack. Consequently, the physical reinforcement of the building, including $10,000 windows and fire-resistant walls between sections of the building, limited the damage greatly. Fortunately, the advanced structural design of the building largely confined the damage to one section, facilitating response and enabling the occupants of the other sections of the building to leave unharmed. Organizationally, Pentagon forces were both a target of the attack and a responder to the event. With personnel trained in battlefield management, the Department of Defense was uniquely suited to respond to this event. Located in Arlington County, Virginia, the Pentagon site drew its first responders from the Arlington County Fire Department and the Fairfax County Search and Rescue Team. With familiarity developed from prior training and joint exercises, the local emergency response agencies moved quickly to joint operations with the Defense Department's Security Force, and together the two sets of agencies created an effective response system. This was an unusual situation, as it integrated a federal force directly with County emergency response teams, without the usual intervening state jurisdiction. The significantly lower death toll at the Pentagon site, 184 persons, documented both less devastating conditions and a smoother inter-organizational transition to response than at the World Trade Center.

Auto-adaptation in practice

Elements of auto-adaptation were evident in local response at both sites, but the difference in the magnitude of disaster at the two sites also affected the interaction between the local site response sub-systems and the wider national response. The response to the World Trade Center attacks involved a much larger loss of life, a far greater number of organizations, a significantly higher cost in damage, and a more profound impact on the economic, social and emotional state of New York City, the state and the nation. Responsible actors at both the Pentagon and World Trade Center sites requested assistance from FEMA, and FEMA personnel responded promptly to both sets of requests. The response to the Pentagon site was managed by a joint federal-local task force and was largely under control within four days. The response to the World Trade Center site was a much more complex operation that is still in progress. This analysis will review the five phases of a preliminary model of auto-adaptation against actual practice, focusing on the response to the World Trade Center site and the interactions among the participating jurisdictions as the more complex, dynamic set of operations.

Information Search

The interdependence among the response organizations' technical information infrastructure, their organizational procedures and capacity to assess accurately the risk to which they were exposed, and their willingness to explore alternative strategies in response to the extraordinary damage is clear. This interdependence is vividly demonstrated by the mixed signals, costly delays and painful misjudgments that exacerbated the loss of life in the 71 minutes that included the crash of United Flight #11 into the North Tower at 8:48 a.m., the second crash of American Airlines Flight #175 into the South Tower at 9:03 a.m., and the collapse of the South Tower at 9:59 a.m. The final collapse of the North Tower at 10:28 a.m. added a scant 29 minutes to potential evacuation time for the occupants of the North Tower.

In retrospect, it is difficult to portray the unimaginable horror that emergency personnel confronted as these events were unfolding. Information search was seriously limited, resulting in a severe lack of information as a basis for decision in this urgent, uncertain, swiftly moving context. The

communications infrastructure was disabled. The Verizon cables in the base of the North Tower were destroyed, and telephone communication lines were disrupted. As people turned to cell phones, the number of calls increased by over 1000%, overloading the base stations and rendering them useless. Police and fire personnel turned to radio communications, but their call channels were also overloaded. In this extremely dangerous environment, thousands of people frantically sought safety. Fire personnel entered the towers seeking to suppress the fires or guide the occupants to safety, but without adequate communication, they lost contact with departmental leadership and had little or no information about the growing instability of the towers. Information search at the site level failed to provide a sufficiently timely assessment of this volatile set of conditions to support coordinated action. Departmental procedures developed for fires of lesser scale proved inadequate in this inferno.

Information exchange

The capacity for information exchange is directly related to the performance of information search processes. On scene at the World Trade Center collapse, information exchange in the first hours after the attack was limited by the same failure of communications infrastructure that hindered information search. Without information exchange, coordination between leadership of the response organizations and their personnel, as well as among organizations and jurisdictions, was delayed and disrupted. The need for a Joint Information Center among federal, state, municipal and borough operations was acute, but the extraordinary physical destruction in the immediate area of the WTC complex made it difficult to find space close to operations to establish a joint information center. Separate jurisdictions established separate information centers, asserting that they were joint, but in fact presenting different accounts of operations to news and agency personnel. Conflicting reports hindered cooperation and detracted from efforts to build trust and coordinate action among the agencies and jurisdictions in an extremely difficult, uncertain operations environment.

On the federal level, information exchange reached the level of near auto-adaptation for agencies engaged in consequence management. At FEMA Headquarters in Washington DC, senior personnel activated the Emergency Operations Center immediately upon seeing the second plane crash into the South Tower on the television news. Personnel from Health and Human Services began to mobilize the Disaster Medical Assistance Teams (DMAT) and Disaster Mortuary Teams (DMORT) to respond first to New York, and minutes later, to the Pentagon. Army Corps of Engineers personnel recognized that debris removal would prove a major problem for New York and planned ways in which they would offer their services to New York City personnel.

In Washington, DC and in the cities near New York, the physical information infrastructure remained intact. Communication lines were not damaged, and information was exchanged freely via telephone, fax, radio and e-mail. Daily conference calls between the Regional Operating Centers and FEMA Headquarters maintained an open, two-way exchange of information that informed decisions at both locations. Twice a day briefings at FEMA Headquarters kept both staff and leadership focused on actions planned and actions taken. In the intense first hours after the attacks, decisions were made and resources committed among agencies on the basis of verbal agreements. This informal process revealed the degree of common understanding among the senior personnel of the principal response agencies. It reflected a high degree of mutual respect, shared goals and trust among responsible personnel gained from working together in previous disaster operations. This kind of information exchange represented “heedful interrelating” among the personnel, with participants paying careful attention to the actions and needs of the other agencies in order to achieve coordinated action among all participants in response operations. Even members of Congress set aside partisan differences to show a unified approach to counter this sobering national threat.

Problems did arise, however, in integrating information from the consequence management set of operations with reports from crisis management operations to present a comprehensive profile of disaster operations to the President. At times, reports of the state of disaster operations were conflicting or information presented to the public was not carefully checked. The result was apparent confusion among agency personnel and the public, with the unfortunate outcome of missed opportunities for detection in the anthrax cases or conflicting statements made regarding the level of risk to which postal workers or others were exposed. The credibility of the information processes is cumulative, with the quality of information exchanged dependent upon the degree of care taken in information search.

Sensemaking

The ability to act in difficult, urgent situations depends upon sufficient understanding of the context to formulate a plausible strategy of action, given the existing constraints and available resources. This capacity depends, in turn, upon the preceding processes of information search and exchange. In coping with this seemingly incomprehensible event, few persons initially understood the danger to which they were exposed. Most painful were the accounts of security guards urging occupants of the South Tower to return to their desks, after the North Tower was struck. In an effort to maintain order and based upon inadequate information, responsible managers informed employees that they could safely remain in the building and return to work. Precious minutes were lost in evacuating the building, as employees followed instructions instead of checking the validity of the information against their own perceptions (*New York Times* September 12, 2001). The limitations of human cognitive capacity are nowhere more apparent than in the inability to absorb information that is startlingly divergent from one's previous experience (Cohen and Levinthal 1990). The potential collapse of the towers was not recognized by managers, individuals, or emergency personnel in time to implement immediately the strategy of evacuation that appears obvious only in hindsight.

At the federal level, away from the horror of burning buildings and failed infrastructure, sensemaking spurred action in anticipation of requests for assistance. For example, federal officials, recognizing the extraordinary extent of damage, pre-positioned mobile emergency response support (MERS) units to send communications equipment to New York to facilitate immediate response.[iii] From previous experience, senior officials recognized the type of assistance that would be needed to function in this demanding, urgent environment. They acted effectively to provide support to the on-scene managers, constructing meaning from a collage of prior events in disaster operations. The contrast in ability to make sense out of this seemingly incomprehensible situation reflected not only the difference in experience between senior emergency management personnel and on-site security guards, but also the long-recognized observation that human problem solving ability drops under stress (Miller 1967; Weick 1993; Comfort 1999; Flin 1996, 2001). In the actual environment of disaster, the demands of the situation often exceed human problem solving capacity.

Adaptation

Sensemaking represents a form of learning, the ability to construct meaning from perceptions that may be disparate or scattered, but that lead to recognition of a coherent strategy of action. The ensuing action constitutes a change from previous behavior that fits environmental demands more appropriately. Two incidents indicate adaptation of response units to urgent needs from the disaster environment. At the Pentagon site, local emergency response units from Arlington County and the FEMA-sponsored Urban Search and Rescue Team from Fairfax County responded immediately to the crash scene. Since the Department of Defense was the victim, the scene immediately became a federal disaster. Federal resources were made available to local managers, and the response system evolved essentially as a federal-local set of operations, with little involvement from the State of Virginia, despite formal requirements for state agencies to act as the intermediary between federal

and local units. In this case, the experience and professional capacity of the local Arlington and Fairfax County responders, coupled with the immediacy of federal assistance, made formal intervention by state agencies, located in Richmond several hours away, virtually unnecessary.

The same situation prevailed in New York City, where federal agencies provided support directly to New York municipal agencies, without direct involvement of New York state agencies located in Albany two hours away. The urgency and scope of assistance required in response operations in New York City demanded federal resources, and prior relationships between federal and municipal officials established the trust and collaboration essential to coordinate actions under the stress of this uncertain disaster environment. Prior procedures proved inappropriate, given the size and scope of this disaster. Taking reasoned action to save lives, reduce risk, assist those who had been harmed and restore basic services in the damaged area meant adapting practice to this severely altered environment. Slowly, order emerged at both sites, but with significant adjustment of prior practices to meet the enormity of the tasks. In the process, it became clear that the role of state agencies in managing extreme events requires review.

Inter-organizational learning

The final phase in adaptation to a changed disaster environment includes evaluation of actions taken and modification of succeeding actions on the basis of observed results. This phase could initiate system-wide change as the action of one organization affects the performance of its near-neighbors in the response system, triggering a ripple of change throughout the interdependent set of organizations. It is too early to assess whether changes initiated by organizations as they modified prior practice in this event will remain in place. To the extent that they do, these changes will represent learning among organizations in a permanent alteration of conditions that lead to the disaster. A candidate for this type of permanent change among organizations responsible for public security is the newly formed Office of Homeland Security. This Office, as presently conceived, would integrate functions of crisis and consequence management in a unified approach to reduction of risk and response to terrorist or other types of threats. Although there is widespread recognition of the need to reduce risk of threats to public security, the precise mechanisms for bringing about this reduction are not clear.

At issue is the balance between governmental authority used to protect the public good and the rights of individuals to freedom from unwarranted breaches of their privacy. A secondary issue is interdependence among government agencies. Whether agencies currently operating under the Department of Justice would be limited in their functions of pursuing perpetrators of terrorist acts by sharing information more widely with other governmental agencies remains to be seen. Clearly mutual adaptation among the agencies will occur over time, but the direction, rate and intensity of this change will vary among the participant organizations and with the scope of the continuing threat. Equally important will be the evolution of the relationships among the jurisdictions in countering and responding to terrorist threats. Whether the emergence of direct federal-local relationships will continue or be replaced by wider, regional networks of preparedness and response will depend upon the interplay of threat and developing governmental capacity at sub-national levels. The lasting form of a response system for extreme events will certainly be intergovernmental, but the precise mix of federal-state-local participation will likely depend upon public investment in building an information infrastructure sufficiently advanced to manage the intense flow of information search, exchange and sensemaking among the respective levels of government needed to support coordinated action in risk reduction and response.

A preliminary model of auto-adaptation in emergency response

From this brief analysis, a beginning model of auto-adaptation in emergency response may be sketched. Auto-adaptation is a nonlinear process that depends upon early recognition of indicators

for change. In contrast to linear models that have clear demarcations of authority and specific tasks for different levels of operation, nonlinear models have overlapping authorities and multiple points of entry into, or exit from, an operations field. Instead of a step-wise progression through categorical stages of change, the organization may proceed with a cumulative assessment of changing conditions that warrant reconsideration of risk and reformulation of strategies that shift responsibilities for action according to need and capacity. Identifying, measuring, and monitoring a set of critical conditions that place a community or region at risk become primary methods of providing decision support to practicing managers in terms of reducing their exposure to risk and determining the need for preventive action.

Auto-adaptation is primarily a learning strategy. It depends upon the development of a scalable knowledge base and information infrastructure to support inter-organizational operations among the multiple agents that make up the potential response system. While the exact form of this socio-technical infrastructure is not yet defined, it would likely have the following characteristics:

1. *Information search*. Search processes will be most effective if they are linked to current assessments of conditions and facilities vital to continuing operations in the community at risk. Establishing and maintaining the knowledge bases and updating the technical requirements to conduct rapid information search and aggregation functions to provide comprehensive views of the state of vulnerability for the community are the first steps in mobilizing that community's capacity to manage its own risk.

2. *Information exchange*. These processes are necessarily inter-organizational, and the boundaries of the information exchange will be defined, in part, by the state of technical advancement of the infrastructure that supports it. More important, the quality and effectiveness of the information exchange will be defined by the organizational processes of training, receptiveness to incoming information that may be inconsistent with prior assumptions, and willingness to share information regarding actual performance. Instead of following traditional jurisdictional boundaries, information exchange will more likely be defined by regions that share similar types of risk, or are bounded by functional interdependencies such as transportation systems or electrical power and water distribution systems.

3. *Sensemaking*. The capacity to interpret the signals and shifts in conditions of routine operations depends significantly upon the socio-technical infrastructure that has been established for information search and exchange processes. It also depends upon the cognitive capacity of those responsible for action. Understanding the limits of human cognitive capacity and using technical means of decision support to augment this capacity in extreme situations are fundamental to increasing the ability of an inter-organizational system of governmental agencies to take timely, informed action in response to risk. This function is likely most effective when performed on a regional scale. Municipal governments are too limited to manage extreme events with only their resources. State governments may be inadequately informed regarding the specific details of operations in local governmental jurisdictions. National governments may be too broad to provide the specificity in action needed for effective risk reduction and response over the range of local regions exposed to risk. Regional systems of risk reduction and response are likely to emerge in metropolitan areas as the most effective balance between size, capacity and specificity needed for effective action.

4. *Adaptation*. Particular forms of adaptation to manage extreme events are likely to continue to develop. The federal-local partnership proved effective in the 9/11 response at both the World Trade Center and Pentagon sites, but it is an expensive alternative. When costs are considered in assessing alternative forms of inter-organizational

response over the long term, increasing the capacity of regional networks may prove a more efficient, viable alternative. Most important will be fostering the dynamic of individual, organizational and inter-organizational learning that leads to lasting change.

5. *Auto-adaptation.* The conceptual model of auto-adaptation is a system of interacting units, each performing at its own rate but adjusting performance to that of its near-neighbors in response to incoming information from the environment. Thus, information entering the system becomes immediately accessible throughout the system in a synergistic adaptation to threat and reallocation of resources and responsibilities to meet that threat. It is a system of continuous learning, and fosters initiative and responsible action at all governmental levels, through mutual adjustment and reciprocal exchange of information and resources. It is guided by a common goal of public security for the community, region, state, and nation.

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Notes

[i]. The analysis of this case study draws heavily upon the daily news reports published by **The New York Times**, September 12 - October 6, 2001; situation reports prepared by the Department of

Health and Human Services and the Federal Emergency Management Agency, and semi-structured interviews with key operations personnel in the Federal Emergency Management Agency, the Department of Health and Human Services, and the US Army Corps of Engineers. The report is also informed by observations from professional researchers who were also engaged in studies of response to the World Trade Center-Pentagon Attacks, but who have not yet published their findings. To protect the confidentiality of the respondents, names will not be identified.

[ii] FEMA Situation Report #1. Washington, DC. Federal Emergency Management Agency. September 11, 2001.

[iii].Interview, Director of Operations, Federal Emergency Management Agency, Washington, DC, January 28, 2002.

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