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"ALL HAZARDS APPROACH" TO NETWORK-CENTRIC DISASTER MANAGEMENT: THE ROLE OF INFORMATION AND KNOWLEDGE MANAGEMENT, AND BOYD'S OODA LOOP IN DISASTER LEADERSHIP

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ABSTRACT

The ever increasing complexity of disasters demands utilization of knowledge that exists outside domains traditionally used in disaster management. To be operationally useful, such knowledge must be extracted, combined with the information generated by the disaster itself, and transformed into *actionable knowledge*. The process is hampered by the existing, business-oriented approaches to KM, technical issues in access to relevant, multi-domain information/knowledge, and by the executive decision processes based predominantly on historical knowledge. Consequently, as shown by many recent incidents, the management of large scale (mega) disasters is often inefficient and exceedingly costly. The paper demonstrates that integration of modified Information and Knowledge management with the concepts of network-centric operations (NCO) and network-enabled capabilities (NEC), and with Boyd's OODA Loop-based decision-making in unpredictable and dynamically changing environments may address some of these problems

Key words: disaster, disaster management, leadership, disaster recovery, information management, knowledge management, actionable knowledge, network-centric warfare, network-centricity, NEC, Network Enabled Capability, prodrome, telecommunications, NGN, Next Generation Networks

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INTRODUCTION

The 1883 explosion of Krakatoa portended the development of what is today known as the field of "disaster management." When it occurred, it was the largest recorded explosion heard over the longest distance (2,968 miles); it produced hitherto the largest recorded tsunami (30 meters), caused the highest number of deaths (36,417), and the most extensive material damage recorded up to that date (165 villages totally devastated. The cataclysm was associated with a number of other firsts: the use of telecommunications as the means of distributing the news of disaster, the first international relief effort, and the first incident that sparked the secondary, and vastly more long-lasting explosion of militant, ultra-orthodox Islam (Winchester, 2003).

Had the contemporaries of Krakatoa explosion bothered to conduct what is today known as "post-operational debriefing," a possibility exists, albeit small, that the calamities associated with the management of major disasters that followed later have been avoided. But, in those early days the concept of disaster management did not exist. "Disaster response" was simply the reflection of Victorian philanthropic sentiments, rather than the hard-core managerial/scientific approach (FEMA; Hutchinson 2000; 2001). In the process of transition from haphazard to "evidence-based" (Auf der Heide, 2006), disaster and crisis management changed: new knowledge has been created, recorded, stored, then forgotten or made inaccessible (Hodgson, 2006), merely to be re-discovered later, often after the immediate need for such knowledge has already passed, and almost always at a great expense (Thierauf and Hoctor, 2006).

In our previous papers (von Lubitz and Wickramasinghe 2006a; von Lubitz and Patricelli, in press) we have argued that despite the relative slowness of business-oriented Knowledge Management (KM), it may be also used in the rapidly changing and unpredictable environment of disaster management. Other authors (Boccardelli and Magnusson; 2006; Mcpherson et al., 2004; Howells et al., 2003) made similar observations as well. We have also discussed the role KM may play in the operations of network-centric organizations (von Lubitz and Wickramasinghe, 2006a; von Lubitz and Wickramasinghe, 2006b; Patricelli and von Lubitz, in press). Classically defined KM plays a pivotal role during the prodromic stage, i.e., the period of stability between critical events (Beakley et al., in preparation). However, *during* the critical event, the techniques of classical KM become insufficient, and their application may result in growing discrepancy between the level of pertinent knowledge acceptable at the prodromic stage (von Lubitz and Wickramasinghe, 2006a; von Lubitz,, in press), and the *actual* knowledge needs associated with the ongoing disaster. The ensuing divergence decelerates the observe-orient-decide-act process (Boyd, 1987) slows down the operational tempo, create deceleration of and lead to loss of operational effectiveness, efficiency, and may increase risk. Unsurprisingly, many of these problems affected the recovery following explosion of Krakatoa. Very surprising, however, is the fact that despite the current sophistication of Information/Computer/Communication Technologies (IC^2T), despite continuing development of the art of crisis and disaster management, and despite the existence of national and international agencies tasked with effective management of "all hazards," the catastrophic events of the past five years have shown that although much has dramatically changed since 1883, much has remained the same.

KNOWLEDGE MANAGEMENT AS TOOL IN DISASTER MANAGEMENT

Sensky (2002) observed that "Knowledge management sounds superficially like yet another of those topical expressions describing something that has been developed outside medicine and is possibly ill-suited for application within the field, but offering an excuse for yet more change. However, one of the distinguishing features of every profession is that it applies a body of specialist knowledge and skills to a defined purpose." In similarity to other fields (Jaspara, 2005), the amount of information and knowledge related to disaster management (e.g., direct and indirect causes of disasters, disaster avoidance or mitigation) increases exponentially. Some of that information has been consistently correct or is currently validated in the field, while aspects remain anecdotal and uncertain (Winchester, 2003).

Development of relations and dependencies among different pools of data and information, their consolidation into a uniform body of knowledge, and extrapolation of the latter into operationally relevant "best practices" are the task of knowledge management. Unsurprisingly, in similarity to medicine, where evidence-based approach forms the essential foundation of practice, evidence-based disaster management has been recently suggested as well (Auf der Heide, 2006).

The primary reason to employ knowledge management disaster operations is the need to create asymmetric competitive advantage within one's operational environment (action space – see von Lubitz and Wickramasinghe, 2006 a,b). The latter is, in turn, obtained through uncompromised access to resources existing both within and without the operational space (Grant, 1991). Thus, continuous availability of such access constitutes the critical asset assuring that the actor operating within a rapidly and unpredictably changing environment maintains advantageous asymmetry in his interactions with that environment (Lubitz and Wickramasinghe, 2006 a,c). The existing evidence indicates that the absence of uncompromised access to data, information, and pertinent knowledge (von Lubitz and Wickramasinghe, 2006a) at the ground, mid- and executive levels of the response effort was among the principal contributors to the series of failures in management of the recent national and international "mega-disasters" (e.g., Cooper and Block, 2006; Brinkley, 2006**).**

The process of knowledge creation is highly structured, hierarchical and encompasses a series of sequential steps. During the first stage, data are gathered form a wide range of

sources then transformed into coherent information. Subsequently, multi-source information (von Lubitz and Wickramasinghe, 2006c) is transformed into a usable knowledge (Alberthal, 1995; Courtney, 2001). Five theoretical approaches to knwoedge creation have been identified (Blackler, 1995; Nonaka et al., 1996; Spender, 1996; Alavi and Leidner, 2001; see also Award and Ghaziri, 2004, Wcickramasinghe and von Lubitz, 2007; see Table 1). The applied theory notwithstanding, the *quality* of the new

TABLE 1 Theories of knowledge creation

THEORY	PROCESS OF KNOWLEDGE CREATION
People-centric	**Nonaka's model:** Recognizes the existence of **tacit** and **explicit** knowledge and stresses the dynamic nature of knowledge creation and the continuous conversion of the existing tacit knowledge into new explicit knowledge and vice versa ("knowledge spiral"; Nonaka et al., 1996).
People-centric	**Spender's model:** Explicit and implicit knowledge are recognized in both an individual and social sense (Spender, 1996)
People-centric	**Blackler's model:** Knowledge exists in several forms whose extreme forms are tacit (embrained) and explicit (encoded) knowledge. The embedded, embodied and encultured knowledge types are created by varying combination of tacit (implicit)/explicit forms and provide bridges between the two extremes (Blackler, 1995)
Tech-centric	**Several main proponents:** Technology-based methods (e.g., Knowledge Discovery in Databases – KDD) used to extract, analyze, and transform data contained within discrete and often unrelated data sets into knowledge (see van Bommel, 2005)
Process-centric	**Boyd's model:** Differs diametrically from the preceding models and uses the concept of domain destruction and creation in which destructuring of pre-existing domains, selection of their relevant components, followed by recombination of the selected components into an entirely new domain relevant to the activities within the changed environment. The model also incorporates both people- and technology-centric concepts (Boyd, 1987; von Lubitz and

Wickramasinghe, 2006a)

knowledge is critically determined by the quality of its constituents (i.e., data and information), the sampling rate of constituents, and the capability to place the new constituents in an appropriate operational context (Brown and Duguid, 1991).
Data and information quality may have very significant repercussions in the operational context of disaster management. Thus, incorrect or intentionally distorted information (disinformation) if repeated with sufficient frequency, particularly by either persons of authority or government-associated agencies, may ultimately be perceived by the recipients (e.g., the affected population) as the objective representation of reality. Subsequent discovery of true facts lead to debilitating political, economic, and purely operational consequences (Lagadec, 1993; Rosenthal et al., 2001; Cooper and Block, 2006). The disastrous economical, political, and humanitarian consequences caused by the governmental support and propagation of rumors about Iraqi weapons of mass destruction as the reason for the invasion of Iraq in 2003 (Ricks, 2006) provide a perfect example of the impact misrepresented data and information may have on the downstream events (see also Beke and Molka-Danielsen, 2007). There is thus not only the requirement that data and information are collected from a wide range of independent, possibly event unrelated sources, but also for the exceedingly stringent verification corroboration criteria if the new knowledge is to offer a reliable operational basis.

The process-centric approach to generation of new knowledge appears to be the most suitable in the context of disaster management, especially when used in conjunction with the network-centric doctrine of operations (von Lubitz and Wickramasinghe, 2006a)**.** The process-centric approach incorporates the two other major models (people- and tech-centric) and also allows a significant degree of automation in data/information extraction, manipulation, and organization. Human participation is, however, necessary for the ultimate selection, verification, and reconfiguration of the originally domain-centered knowledge elements into a new, operationally relevant entity (Boyd, 1976). Based on such criteria, the process-centric model may be viewed as a seamless fusion of a “super-Decision Support System” and “Man-in-the-Loop” (MIL) concepts. Recent simulations (Au et al., 2001) indicate that such combination may be particularly suitable for implementation in the context of disaster management.

Despite advantages, the process-based approach to KM is associated with a number of flaws (Table 2). The limitations should not be surprising: theories of knowledge creation and management have been created as operate in the environments characterized by incremental evolution, with action time-frames measured typically in days or months (or even years).

Table 2 Limitations and advantages of process-based KM in the context of disaster management

LIMITATIONS	ADVANTAGES
Inherent slowness in incorporation of real-time constituents	Significant during prodromic and recovery stages
Low agility of penetration to the ground responder level	Rapid executive/upper management penetration at intra/inter-agency levels
Complexity often exceeds the needs of ground responders	Senior and executive management personnel provided with a "broader picture"
Knowledge based on historical constituents may be irrelevant to the response to the current ground situation	Historical constituents ("what went wrong?" important in the development of large scale response plans
Limited role in tactical level media/public/rumor control	"Best practices" background in agency-level media/public/rumor control

Disasters, on the other hand, are characterized by the significantly contracted time-scale, their essential unpredictability, and a broad range of often equally unpredictable political, economical, and social consequences. The nature of these consequences often depends on a wide variety of contributory yet quite predictable *pre-disaster* (i.e., prodromic) factors (e.g., Rosenthal et al., 2001), the capability to prevent/reduce the impact of these factors *prior* to the disaster (Lagadec, 1993), contain their influence *during* the critical event, and mitigate further evolution into *post-disaster consequences* at the recovery stage (Lagadec, 1993; Rosenthal et al., 2001). For the most part, all these elements, while having a significant bearing on the course of events, are of historic nature and are of prodromic origin. However, a crisis or disaster generates in a rapid sequence a series of new elements which are event-specific. Classical methods of KM are too slow to incorporate these elements in the new body of operational knowledge. Thus, the classically defined KM has a preeminent value in the development of preparedness (von Lubitz and Wickramasinghe, 2006c). However, in order to be applied across the entire operational spectrum of disaster management, the needs to be modified.

ACTIONABLE KNOWLEDGE

To insure validity in the disaster response environment, the consecutive steps of the classical approach to knowledge generation needs to be substituted with the operation of simultaneous gathering systems whose merged outputs provide the exact picture –

actionable knowledge – that describes the operational space *at any time within its temporal evolution.* Creation of actionable knowledge substitutes the hierarchical order of data/information gathering and transformation with a process in which parallel and near-simultaneous extraction, processing, structuring, management, dissemination, and storage take place.

In the ultra-complex setting of mega disasters, decision makers must process vast amounts of multidisciplinary, often poorly organized, disparate data and information into relevant and useable knowledge (Courtney, 2001; Drucker, 1993; Boyd, 1976; Nonaka, 1994; Nonaka et al., 1996; Award and Ghaziri, 2004; Newell et al., 2002, Schultz and Leidner, 2002; von Lubitz, in press). Therefore, in the context of disaster management, several critical issues become apparent:

- Due to their complexity and comparative slowness in generation of knowledge Wickramasinghe and von Lubitz, 2007), KM methods are most useful at the prodromic and recovery stages.
- Current KM tools are useful at the level of senior/executive management (strategic level), they have very limited relevance at the operational (tactical) level of disaster management (von Lubitz, inpress).
- During the evolution of the critical event and immediately thereafter, KM could serve two separate yet closely interrelated operational functions: that of rumour identification, containment, and elimination, and that of gathering, sorting, and transformation of data and information into operationally reliable intelligence (Beke and Molka-Danielsen, in press).
- To assure effectiveness of effort, the KM results, i.e., the newly generated event-pertinent knowledge, must be disseminated with equal agility among *all* actors within the response chain (senior executive as well as tactical levels, e.g., Rosenthal et al., 2001)
- Dissemination of truthful, relevant facts to all members of the response chain, the media, and the public (Lagadec, 1993)

These issues reflect on the operational utility of KM which must be seen in the context of the overall nature of operations planning, decision-making, execution, and post event analysis. Consequently, all disaster response operations must be considered first from the standpoint of the characteristics of effectiveness, efficiency, and risk involved, and then in terms of the constantly emerging operational trade-offs.

In the world of military planning, heavily detailed contingency war plans are modified in real time through Intelligence Preparation of the Battlefield (IPB, e.g. Satterly et al., 1999). The process involves augmenting the original plan with near real time intelligence collection. Combined with appropriate processing methodology, the approach allows precise assessment/updating of all warfare relevant factors (e.g., weather, terrain, buildings, infrastructure, non-combatant population, order of battle, etc.) including all specific threats in the area of deployment. The goal is to develop maximum situational awareness, and the function of IPB is to describe how all elements will act and react

during operations, and how will they affect activities of the deployed forces (Rand Corporation).

Since the attacks on the World Trade Center and Pentagon, a concept similar to IPB emerged among law enforcement agencies (e.g., Los Angeles Terrorism Early Warning (TEW) Group). Known as Intelligence Preparation for Operations (IPO), it provides a standard tool set for situational recognition, course-of-action development, and response rehearsal (Sullivan, 2000). This process bridges the gap between deliberate planning and crisis action planning for all facets of a unified multi-organizational response organization. (Sullivan, 2005). Public safety-centered IPO is an ongoing, demand-driven process governed by the user needs for actionable intelligence. The process is particularly suitable for prodromic operations, and the analysis of all inputs generates the Operational Net Assessment (ONA), which provides subsequent operational background for responders to crime and terrorism (Joint Forces Command, 2004).

During critical events, the dynamics of the involved processes should be the principal mechanism determining IPO's acceleration rate. During crises and disasters, the principal task of IPO is to rapidly develop a comprehensive initial Situational Awareness (SA), followed by an equally rapid generation of a Common Operational Picture (COP) relevant to *all* involved agencies. It becomes apparent that in events of "all-hazards" type (terrorism included), both the gain of orientation and situational awareness and the decisions on *effectiveness-efficiency-risk* trade-offs will be a function of actionable knowledge rather than actionable intelligence alone as it is during the "steady-state" prodromic intervals. Thus, during crises and disasters, IPO evolves into a higher level Knowledge-Based Preparation for Operations (K-BPO). The latter assures that that *all* available data and information are transformed into a reliable substrate for intelligence analysis, followed by the conversion of the results into a comprehensive body of operationally applicable knowledge – *actionable knowledge*. The latter serves as the foundation for all strategic and tactical decisions

ACTIONABLE KNOWLEDGE IN CRISIS/DISASTER ENVIRONMENTS

Every disaster introduces a dramatic change in the affected environment. The informational content is explosively increased by a number of new, often poorly understood elements (decreased environment transparency). The orderly nature of original information that the environment contained and by which it was characterized prior to the disaster (granularity) is now disrupted, and the granularity of the environment increases (Fig. 1; von Lubitz and Wickramasinghe, 2006a). Knowledge derived through

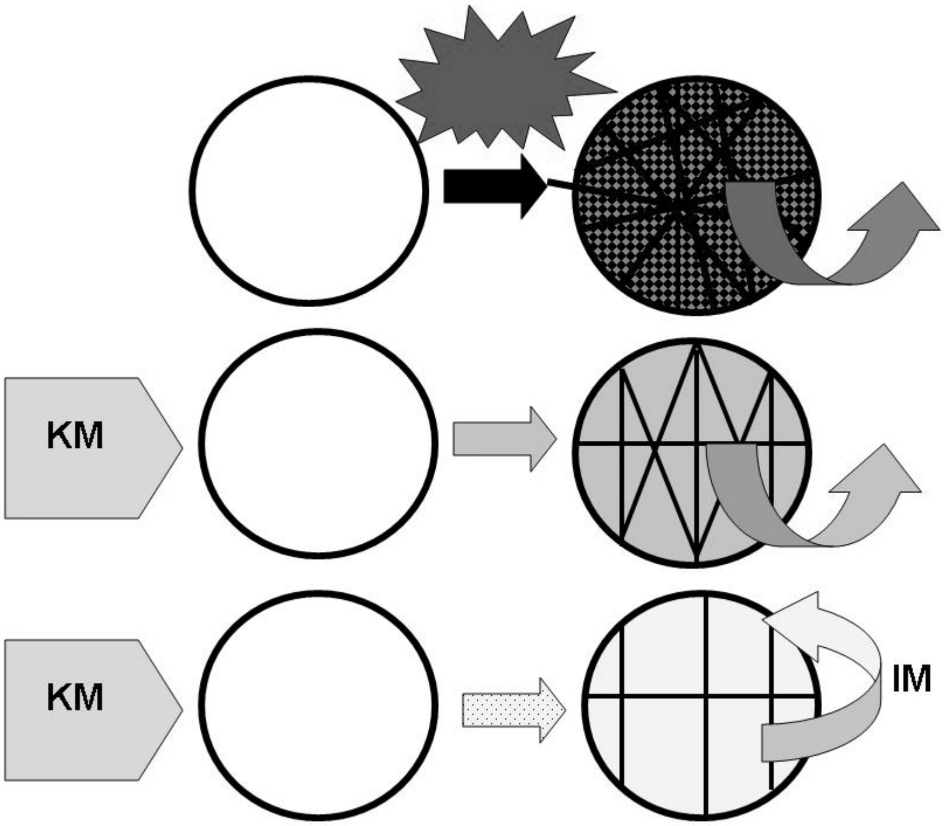

FIG 1 Prior to a disaster, the environment is known (transparent) and the information it contains is finely ordered (low granularity – left circle). Following a disaster, chaos in the environment (its opacity) increases drastically, and the environment becomes disordered (coarsely granular - right uppermost circle). New, disaster-generated information (right up-ended arrow) increases environmental chaos (dark and light grey upended arrows on the right side). Implementation of KM alone (middle row) is less effective in the reduction of post-disaster opacity and granularity than simultaneous use of IM and KM (bottom row). In the latter case, environment-derived information processed by IM combines with the pertinent knowledge generated by KM activities. The consequent creation of real-tie actionable knowledge is the essential ingredient required in the process of reconstituting order within the disaster environment (right upward curving arrow)

prodromic application of KM plays an important role in the mitigation effort. However, new information continuously generated during the entire time course of the critical event obscures of situational awareness and impairs the disaster-mitigating efforts. *Actionable knowledge* derived through the process of effective, *real time* management and fusion of new, disaster-generated information with the equally efficient use of the pre-existing

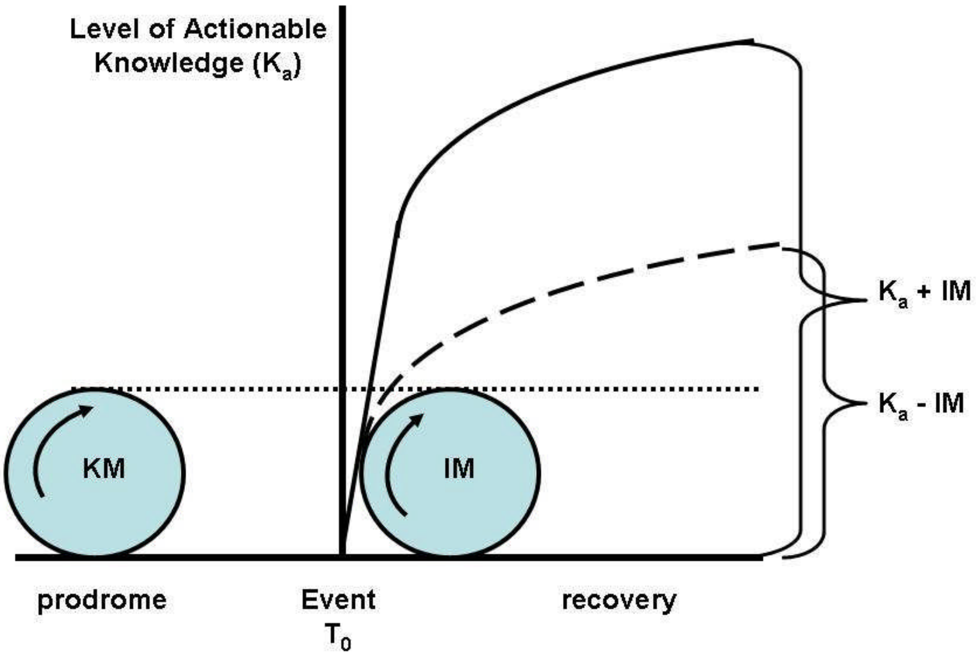

FIG. 2 The effect of KM (prodrome) and IM (recovery) alone and combined I/KM on the level of Actionable Knowledge (K_a). Immediately following the critical event knowledge generated during the prodrome (KM) becomes historical. Its content (dotted line) does not change since it is based on previous (i.e., historical) observations. The critical event generates large amounts of new information (area above the horizontal line) which must be analyzed and acted upon during response/recovery stages. Combination of KM with effective post-event information management (IM) results in a very rapid increase of *Actionable Knowledge (K_a* – solid curve) and equally rapid decline of informational chaos (area above the curve). In the absence of effective IM (stippled curve), the acquisition of K_a is much slower, and informational chaos (environmental opacity and granularity) much greater. Ultimately, the generated K_a is incorporated into the general body of pertinent knowledge. Consequently, the resulting *new* prodromic level of knowledge available during the prodrome preceding a new critical event will be consequently higher. The process results in a stepwise increase of pertinent knowledge required in preparedness development (von Lubitz and Wickramasinghe, 2006c)

knowledge (traditional KM operations) provides the essential tool to increase the transparency and reduce the granularity of the disaster environment. The parallel use of

KM and IM (I/KM) in disaster environments is essential for improved situational awareness and for the ability to respond to sudden and unpredictable challenges that the disaster environment may generate (Figs. 1,2). I/KM is therefore among the most essential elements needed for the enhancement of *operational readiness* (von Lubitz and Wickramasinghe, 2006c)

The parallel use of IM and KM as separate yet collaborative processes is not new. Following the post-WW2 explosion of new sensor- and weapons systems, Royal Navy substituted its traditional approach to fighting ships with the concept of Action Information Organization (AIO.) The main task of the organization is to fuse the pre-existing knowledge characterizing operational space with the continuously updated and analyzed tactical information. The result of parallel implementation of IM and KM results in an extremely well characterized, real time image of the action space (situation awareness) allowing instantaneous, correct responses to the presenting threats. Properly functioning AIO is also capable of generating meaningful predictions of the future dynamics within the action environment, and the course of its short- and long-term evolution.

The parallel, "tactical," use of IM and KM does not invalidate the knowledge generating hierarchy described in the preceding section. However, time frames of naval engagements are too short to allow generation of new knowledge *during* action. Instead, information generated thorough operational use of I/KM is *post facto* amalgamated into the body of the pre-existing knowledge causing expansion of both pertinent and actionable knowledge bases relevant to the future engagements.

Founded on the already existing and well-tested military models, Action Information Organization (AIO) concept offers a number of advantages in disaster and crisis management: it is scaleable, it is networkable, and it allows simultaneous access to multisource/multispectral information. Moreover, functional AIO facilitates maintenance of continuous operational readiness. In the context of network-centric operations discussed in the present and in the previous papers (Patricelli and von Lubitz, 2007; von Lubitz and Wickramasinghe, 2006a), a local (municipal/county) Disaster Action Information Organization (DAIO) would represent the critical node of the operations layer of the network.

The Information and Knowledge Management approach (I/KM) suggested in the preceding paragraphs and its associated product – actionable knowledge - allow for the essentially instantaneous, forceful, and target-directed response. Confronted with the reality of cataclysmic disasters, the combination of I/KM generated actionable knowledge, and the development of regional and national/international DAIO centers capable of using, producing, and *disseminating* such knowledge in a time/place specific manner to *all* actors within the response system may represent the only path to truly effective consequence mitigation (von Lubitz, in press).

To be functional, I/KM needs more than flawlessly functioning technologies and their physical support (von Lubitz and Wickramasinghe, 2006d, Patricelli et al., in press). It also requires adoption of a new intellectual approach to interaction with dynamically changing, highly unpredictable environments. The theory and practical implementation of the involved principles have been developed by Boyd (Boyd, 1987; see also von Lubitz 2006, and von Lubitz and Wickramasinghe 2006b)

THE OODA LOOP

Boyd's OODA Loop (Boyd, 1987) provides the conceptual framework governing human behaviour in unpredictable, dynamically changing environments. We have previously discussed the critical role of OODA Loop-based thinking and in disaster-related process of decision-making, and will return to this important subject at length in the forthcoming study (von Lubitz, 2003a; von Lubitz et al., 2004; von Lubitz and Wickramasinghe, 2006c, von Lubitz, in press; von Lubitz et al., in preparation). Therefore, the following discussion will concentrate only on those aspects of the Loop that are relevant to the issues analyzed in the present paper

OODA Loop comprises four principal, tightly interconnected and sequential stages of Observation, Orientation, Decision (at times also known as Determination), and Action. In addition to the sequential relation of the major steps, several feed-back elements representing tacit and implicit factors are also included. The latter represent intangible factors of experience, cultural background, etc. and affect, often in a critical manner, the process of decision making, and, together with further links enhance operational context, flexibility, and the precision of the Loop's revolutions.

The Observation stage of the Loop is associated with several direct inputs from both *outside* and *inside* the operational environment. The outside inputs are based on the pertinent, historical knowledge and represent the "static" foundation of the Observation stage. The inputs provided by the *unfolding circumstances* represent new information generated throughout the evolution of the critical event. Any type of *active interaction* with the environment that has been *generated by the critical event* will therefore modify the informational content of that environment. Hence, further modifications of the environment will be introduced. In order to retain efficiency of action, the responding actor must be clearly aware of these changes. It is important to note that actionable knowledge is also generated at the Observation Stage, and stress invariably associated with crises and disasters (e.g., Boin et al., 2005) may have adverse impact on the involved processes. Stress has a demonstrable, negative effect on human information processing and interactions with chaotic environments (Orr, 1985; von Lubitz, 2006; von

Lubitz and Wickramasinghe, 2006c). Hence, the effective use of IM and KM, and the implementation of semi- or fully automated analytical systems (Decision Support Systems, DSS) may be particularly important in reducing stress-induced human errors

(Wallace and De Balogh, 1985; Assilzadeh and Mansor, 2004; Asghar et al., Intl. J. Sim. on line). Moreover, the usefulness of actionable knowledge depends on the breadth, quality, and extraction speed of information and knowledge, outputs provided by I/KM integrated with effectively operating DSS may constitute one of the most critical parameters determining the quality and usefulness of actionable knowledge.

The Orientation Stage shapes the course of the two following stages: Determination and Action. At the Orientation stage, information and knowledge gathered during the Observation segment of the Loop are subject to final analysis. Military users of the OODA Loop codify the Orientation stage as that at which development of *situational awareness* or *clarification* of the situation within the operational environment takes place (Wyle et al., 1981; Orr 1985). Interestingly, the presence of intangible factors affecting the Orientation phase of the Loop (e.g., genetic, cultural, or experiential factors) led some authors to a highly speculative conclusion that this stage concentrates primarily on the psychological/behavioral inclinations of the actor (Phatic Communion, 2006). In reality, at the Orientation stage, the actor begins to reassert his control of the environment and introduces the first steps need to reorganize it into the pre-disaster configuration (von Lubitz and Wickramasinghe, 2006c; see also Richards, 2004). Orientation is nothing but the act of "getting one's bearings" in the post-disaster chaos by cognitive grouping of the disorganized structure of the disaster environment into cohesive and easily recognizable blocks, then realigning these blocks into even larger and better organized mental assemblies (cognitive maps of the disaster environment). Properly designed I/KM support, particularly when assisted by DSS, provides substantial enhancement of all processes contained within the Orientation stage (e.g., Wallace and De Balogh, 1985; Assilzadeh and Mansor, 2004), and also increases both the speed and the efficiency with which the Decision stage can be reached.

The third stage of the Loop defines the nature and characteristics of the action(s) to be taken, and at the Action stage the planned activity is fully implemented. As we have discussed in our previous paper (von Lubitz and Wickramasinghe, 2006c), the Loop revolves in time *and* space (von Lubitz 2006, von Lubitz and Wickramasinghe, 2006c). The efficiency in the execution of processes comprising each stage of the Loop reduces the time needed for the completion of the entire Observation – Action cycle ("tighter loop"). The immediate consequence of progressively tightening the loop (reduced Action-Action interval) during a series of its cycles is the increased frequency, intensity, and efficacy of all interactions with the environment. In other words, shortening the Action-Action interval by increasing the efficiency of the intermediate Loop stages serves as the *amplifier* of the effect of all the involved processes, i.e., the improvement of actionable knowledge quality, enhancement of response efficiency, better definition of the price of efficiency/effectiveness/risk tradeoffs, etc. However, since actionable knowledge constitutes one of the most important "outside information" inputs that shorten the time required for the completion of the Observation and Orientation stages of

the Loop. Hence, actionable knowledge generated at the end of the full revolution of the Loop facilitates processes taking place at the Observation/Orientation stages of the following revolution: the speed of the Loop becomes progressively higher. Ultimately, the individual stages are near or completely simultaneous: Observation takes place while the preceding Action has not fully ended, while the ongoing Decision stage is still affected by the continuous input from the preceding Orientation. At this point, the interaction of the actor with the environment looses its exploratory nature, and transforms into a tightly focused, intense, and sustained "counterattack" (von Lubitz and Wickramasinghe, 2006.)

Altogether, the combination of I/KM and OODA Loop-based enhances prospects of the successful disaster containment and recovery to a greater degree than the separate employment of either of these tools seen on previous occasions (e.g., Prague Flood vs. Hurricane Katrina, see Harris and Kononczuk, 2005; Cooper and Block, 2006). Conversely, failure in the consequent use of actionable knowledge derived from the combined I/KM – OODA Loop activity resulted in inefficient or badly compromised response and recovery efforts (e.g., Hurricane Katrina, Indian Ocean Tsunami, Kashmir Earthquake.)

INFORMATION AND KNOWLEDGE MANAGEMENT IN CRISES AND DISASTERS: RELEVANCE OF MULTIDISCIPLINARY, CORSS-DOMAIN APPROACHES

Even in mega-disasters that may affect very large geographical regions, the response is, essentially, local (Clarke and Chenoweth, 2006). Nonetheless, the response efficiency depends as much on the level of the local, national, or even international preparedness as on the degree of response readiness, and the level of preparedness is closely related to the extent of the pertinent (relevant) knowledge available to the disaster-responding agencies at the prodromic (pre-disaster) stage. On the other hand, the level of *readiness*, i.e., the ability to mobilize immediately all readily available resources (von Lubitz, 2006) depends, o the other hand, on the speed and efficiency of actionable knowledge-generating process, and on the ultimate quality of such knowledge. Highly localized calamities will have relatively small demands for actionable knowledge: the intellectual tools required for fighting a small house fire will have been already incorporated in the firefighters' pool of pertinent knowledge through training and prior experience. However, the need for actionable knowledge increases dramatically in complex disasters (e.g., major chemical spills, weather-related phenomena, certain types of terrorism, etc., see Inglesby et al., 2000; Katzman, 2000; Broughton 2005; Radon et al., 2006; Nature, 2006; Schipper and Pelling, 2006). Other critical factors are also at play:

- the complexity and breadth of actionable knowledge increase proportionately to the intensity and scope of the disaster (Lagadec, 1993).
- the need for actionable knowledge may be highly specific, and time and space critical (von Lubitz, 2006).
- relevant sources of actionable knowledge may exist within intra- and inter-agency "stove-pipe" repositories with no bridging standards, processes, or platforms (von Lubitz and Patricelli, 2006).
- repositories may belong to disaster unrelated domains (von Lubitz and Wickramasinghe, 2006a).

Consequently, while employment of inter-domain/cross-disciplinary actionable knowledge could measurably change the course of action, the users may have no access to it. More often, the users are entirely unaware that such knowledge exists. The fragmentation of information/knowledge sources essential for the development of high quality actionable knowledge has been strikingly revealed in the analyses following the destruction of World trade Center and Hurricane Katrina (The 911 Commission Report; GAO 2006); see also Kershaw and Mason, 2005; Torres, 2005; Cooper and Block, 2006; Brinkley, 2006).

The issue of access to inter-domain knowledge is an important one. In similarity to many other disciplines, e.g., finance, economy, or healthcare (Mandelbrot 2004; von Lubitz, 2006; von Lubitz and Wickramasinghe, 2006a; Wickramasinghe and von Lubitz, 2007), pertinent knowledge relevant to management of specific disaster conditions is often contained within several unrelated domain silos. As the result, only the knowledge contained in the most obvious repositories associated with the domains of *immediately apparent* relevance are routinely exploited. Yet, in most cases, simple common sense would dictate the need of searching beyond the most obvious. An example bordering on ludicrous is provided by astonishment and fears among the foreign workers involved in Tsunami 2004 relief operations caused by the personal dangers caused by local political instability (Kershaw and Mason, 2005). Yet, pre-deployment access the readily available and ample sources of pertinent knowledge about the political, ethnic, and economical situation of the affected regions would have built adequate level of preparedness, and prevented the subsequent morale problems.

It has been demonstrated that Information of critical importance for successful interaction with a chaotic environment may be hidden in *seemingly* irrelevant repositories that are entirely obscure to the majority of responders (von Lubitz et al., 2005; Wickramasinghe and von Lubitz, 2007; von Lubitz, in press). Moreover, although suggestions for their implementation have been made (Auf der Heide, 2006), the notion of "evidence-based" disaster management based on "best practices approach" used in modern medicine (von Lubitz and Wickramasinghe, 2006d) is still poorly developed in the crisis and disaster management world. The existing databases are predominantly "platform-centric," widely dispersed and typically incompatible, and for these reasons alone largely irrelevant to both long-range development of preparedness plans and to the development of immediate readiness. Simply put, the disaster management equivalent of medical Advanced Cardiac Life Support (ACLS) concept does not exist.

Part of the problems related to knowledge management applications in disaster response operations is the very nature of the involved operations: overall size of the disaster notwithstanding, the response is always *local*. Ultimately, it is the local community that is affected, and the overall size of the disaster is determined by the number of the communities affected. Hence, all protocols and procedures are developed and implemented locally, in the context of local environments, and of the probability of specific disaster events at that particular site. Consequently, if unlikely events ever occur, the responding agencies "do what they know, instead knowing of what they should be doing" as stated by the French marshal de Saxe commenting on the military performance of his contemporary XVIII century commanders.

The problem of selecting relevant and working solutions to unusual disasters is compounded by the availability of ready access to the relevant information and knowledge. Results of an ad-hoc survey (von Lubitz, unpublished) in which 50 middle-level US and EU responders were queried about the sources of their professional information and knowledge revealed that the primary sources of information and knowledge center on the relatively infrequently attended training courses and conferences, Web-based resources, or personal exchanges. Relevant papers published in high-level academic and professional literature are largely bypassed either because the existence of journals containing the articles is unknown or the journals inaccessible due to the costs associated with their purchase. The problem is compounded by the fact that, as in medicine, the veracity of readily accessible "best practices" published on-line may be frequently questionable: in many instances it may be based on anecdotal evidence, hearsay, and may be simply misleading (von Lubitz, 2003). Thus, the unquestionable competence with which local level disasters are handled is largely due to the dedication, extreme professionalism, and experience of responders rather than the result of employment of available knowledge resources. Correspondingly, the persistent failures of leadership and upper level disaster management are unsurprising in view of the continuing deficiencies in the development of suitable I/KM and leadership tools (e.g., Boin et al., 2005).

NETWORK-CENTRIC OPERATIONS AS THE SOLUTION TO I/KM DEFICIENCIES IN CRISIS AND DISASTER MANAGEMENT

Network-centric operations (NCO) have been recently proposed as the solution to the major information/knowledge deficiencies and requirements seen in complex, large scale operations such as healthcare, disasters, or global business and government operations

(Cebrowski and Garstka, 1998; von Lubitz and Wickramasinghe 2006a,b,d; von Lubitz and Patricelli, 2006).

The concept of network-centricity emerged at the US Department of Defense as the response to the urgent need for better time, space, and asset organization and management in the increasingly fluid, technology-governed battlefield (Alberts et al, 2001; Garstka, 2004). The US military version of network-centricity is intensely technology driven, and based on an intermeshed, multilayered complex of collaborating networks and their associated analytic entities (nodes). Together, the components of the network connect battlefield sensors, command, and action execution elements ("shooters") into an integrated, "organic" entity (Fig. 3).

Functionally, the "super-network" provides and assures free, unfettered flow of information is accessible to all layers of the network and its all constituents. The nodes are tasked with the analysis of information and network-wide dissemination of results in form of structured information and/or knowledge. In practical terms, the network-centric operations (NCO) concept offers vastly increased command and control of the battle space, enhances battle space awareness, permits combat situation-dictated "swarming" or dispersion of units, and, finally, operational independence at the "shooter" level. The most important consequence of network-centricity is not only the enhancement of real time operational awareness, but also the reduction the heavy-handed influence of distant command centers on the tactical ground situation. The net effect of network-centricity is

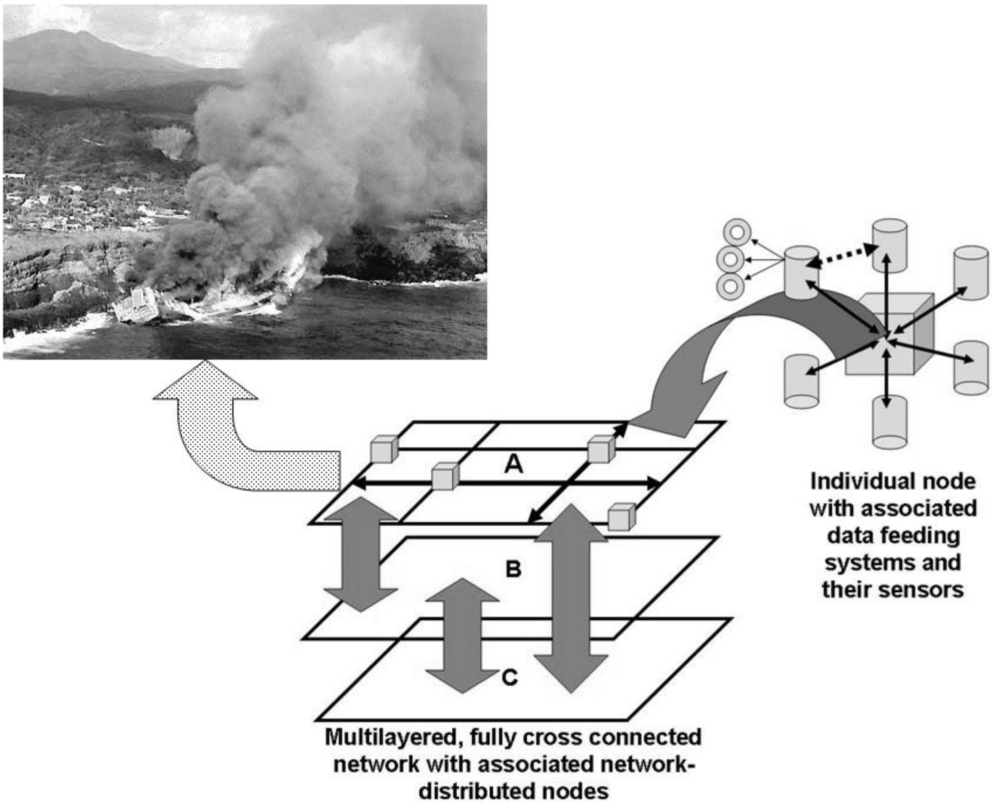

Fig. 3 Civilian network-centric (NEC) environment in action (only layer A has its structure indicated). The disaster depicted is the grounding and fire of M/V Hual Europe on Izu-Oshima near Tokyo following a typhoon in October 2005. The disaster resulted in an oil spill, evacuation of large number of people, an the destruction of the 57.000 GRT ship. NEC system consists of a joint ground tracking/responder network (A) devoted to asset movement control, tracking, ground resource utilization, etc. Layer A assets respond to the disaster (light gray arrow.) Data network (B) provides shared environment status, shared awareness of present environment and its development trends, and force control. Executive planning network (C) generates shared objective understanding, intent, and global asset (force) coordination within the entire environment. All layers communicate with each other in real time. Each layer is associated with a number of data/information/knowledge collecting and disseminating nodes (cubes - see von Lubitz and Wickramasinghe, 2006b). Each node is associated with its own data reporting and receiving entities (cylinders, bidirectional arrows) which also communicate among each other (stippled arrow). Each reporting system in turn is linked to a number of field sensors (human or automated) that extract information from the environment. A node can represent a governmental agency, a corporate entity, large military component HQ, disaster management center, etc. Unfettered information flow among networks and their constituents, essential in order to obtain

full collaboration, is indicated by vertical arrows (photo courtesy of Countryman & McDaniel Cargolaw©)

a much greater operational and tactical freedom of individual units that supports the most effective execution of "commander's intent," and operational coordination of all activities within the entire spectrum of the assigned missions (e.g., Jonas, 2005).

Although sporadic, civilian implementation of network-centricity proved its significant operational value (Cebrowski and Garstka, 1998; IBM 2006; News@Cisco, 2006; Tucker, 2006). However, the already conducted civilian network-centric operations are rooted in the concept of enterprise-wide platforms that are unsuitable for nation- or worldwide use in disaster management (Beakley et al., in preparation). To by-pass the problems of de novo creation of a suitable system, it has been proposed recently that military networks will be open to disaster management operations (Ackerman, 2006). However, the complexities of merging civilian and military infrastructures, difficulties in solving the involved security issues, development of mutually acceptable standards, etc., place such operations into a very distant future.

Many of the obstacles faced by the US military in the development of its network-centric capabilities are overcome by the *network-enabled capability* (NEC) approach selected by the EU (Beakley et al., in preparation). Contrary to the technology-driven NCO, NEC utilizes the rapidly developing civilian Next Generation Networks (NGN, see von Lubitz and Patricelli, 2006). The resulting system, although less capable than its fully-fledged US counterpart, offers robustness and flexibility that satisfies requirements of civilian use.

NEC has the potential to address many of the critical issues related to the inadequate, vertical distribution of pertinent knowledge and operationally relevant information. Implementation of NEC-based operations supports free information flow within the network, assures the quality and reliability of outputs, and provides ready access to sources that allows "just-in-time" extraction of Information and knowledge by all network users. Incorporation of automated Decision Support Systems (DSS) as part of NEC network has the potential to enhance the usefulness of NEC by providing automated assistance in discovery, retrieval, and amalgamation of critical information that otherwise may be either ignored as irrelevant, accidentally bypassed, or misdirected in the stressful and chaotic crisis environment (Orr, 1983; Cooper and Block, 2006; von Lubitz, 2006). DSS may be also of assistance in emphasizing the relevance of disaster-associated *secondary* elements that may attain primary operational importance (S. Dietrich, personal). Altogether, network-centricity augments situational awareness, and vastly expands command and control functions. In practical terms, despite lesser capability compared to the US military counterpart, NEC has the potential to serve as a "mega-decision support system," providing the matrix embedding and linking previously isolated local responder organizations into an interconnected "shooter" network with uninterrupted access to all data/information/knowledge resources, and to the

regional/national (and, if need be, international) command and control networks (Beakley et al., 2007).

It may be argued that the functionalities offered by NEC are of either no- or very limited consequence during small, well contained adverse events (e.g., local flood.) However, increase in event complexity results in the correspondingly elevated demand for resources of correspondingly increasing magnitude (Rosenthal et al, 2001; Boin et al., 2005). The mobilizing process is invariably associated with its own intricacies that, particularly at the level of national and international environments, add further disarray and confusion (Rosenthal et al., 2001). Eventually, as many incidents have shown, *local* response to a disaster becomes a part of a larger, *national* effort. At that stage, coordination takes place simultaneously at the local and national command centers. Subsequent confusion fuelled by interagency frictions, political power plays, and bureaucratic timidity or public relations "spin" provides one of the primary causes of ineptitude and mismanagement that invariable emerge (Boin et al., 2005; Cooper and Block, 2006).

In similarity to military operations, unity of command, agency and mission coordination, and control of mission execution are the essential elements of disaster/crisis response. Yet, their preservation becomes an insurmountable task related, in part, to the traditionally fierce independence of local responder units and agencies (Boin et al., 2005; Cooper and Block, 2006) but also due to political considerations and inter-agency "turf wars" that combine with stagnant, non-responsive, and frequently irrelevant bureaucracies (Lagadec, 1993). Yet, despite frequent irrelevance to the overall effort, many of these bureaucracies insist on participation in the overall effort (Cooper and Block, 2006.) The significance of NEC in such environments appears to be indisputable: it eliminates the existing barriers, promotes interoperability and collaboration among the local units, and, while preserving their operational independence, facilitates execution of complex multi-unit tasks by offering higher level command a precise, real time overview of both operational and tactical "ground reality."

Full, unfettered access to knowledge and information by all actors in the action space curtails rigid vertical control of operations, which during complex disasters may rapidly transform into another layer of chaos (Cooper and Block, 2006, see also Wiese, 2006; World Disaster Report, 2005). In such context, NEC becomes an instrument of adaptive management (Wiese, 2006) facilitating planning and preparation at the prodromic stage, promoting operational supervision and coordination at the executive level during the disaster itself, and assisting subsequent recovery. The existing military experience also indicates that implementation of NEC enhances the ability of the ground responder forces to focus on flexible, local situation-relevant execution of the tasked missions (executing the "commander's intent", e.g., Gilman, 2006; Luddy, 2005; Wallace, 2005.) Unquestionably, implementation of NEC supported by the efficient, reliable, timely and

relevant outputs of I/KM nodes will guarantee a resounding success each time the system is used. It will, however, serve as a major support element assisting the responders in shortening the Observation-Action interval of Boyd's OODA Loop, and, by facilitating increased speed of Loop's revolutions, promoting the likelihood of such success.

DISCUSSION

Our discussion of the significance of information and knowledge management in crisis and disaster mitigation does not open a new territory. Several authors stressed the need for I/KM development and operational use (Ferguson et al., 1995; Quarantelli, 1997; Uitto, 1998; Christoplos et al., 2001; Comfort, 2005; Michaels and Headley; 2004). However, most authors viewed the need in its static, prodromic relation to disasters, i.e., as a tool for developing preparedness based on "lessons learned" from the preceding events. We believe the present paper is the first in which the importance of information and knowledge management *during* and *immediately following* the disaster are considered. Also for the first time the paper incorporates concepts of network-centricity and Boyd's OODA Loop as the cardinal constituents of effective management and leadership during crises and disasters.

Today, every new critical event introduces a plethora of previously un-encountered elements which need to be analyzed, disregarded, or incorporated into appropriate actions.. The often derided statement of the former US Secretary of Defense, Donald Rumsfeld, "we now know what we don't know" has an ominous significance: the events surrounding Hurricane Katrina have made all aware of how well we know now how much we *do not know*. And it is because of the lack of knowledge, recognized or not, that, in the words of de Saxe, "we do what we know, instead of knowing what we should be doing" are particularly true.

The latter statement may be viewed unjust and almost derisive when seen in the context of extraordinary feats of professionalism and personal bravery of responders observed during disaster containment operations. Our intention is not to offend, but to emphasize that, in many ways, the entire territory of disaster and crisis management, despite its rapidly growing social, economical, and political importance, is still a poor relative compared to almost everything else. It is, for example, more than surprising that nearly ten years after its inception, a senior official of the US Department of Defense conceded that the military network-centric platform may have dual use in the management of large scale disasters (Ackerman, 2006). One would have expected that such elementary concept would be entertained from the moment network-centricity became an integral aspect of real-life operations.

The development of broad-based, universal concepts common to the area of crisis and disaster management is affected by two major issues. The first relates to the intense

preoccupation of governments' funding authorities on issues of terrorism. Unquestionably essential, exclusive concentration on terrorism resulted in the almost astounding disregard of the fact that practically *every* act of terrorism is accompanied by a physical disaster where first responders representing healthcare, firefighting, law enforcement, civil defence, and even military *must* work in a coordinated, mutually supportive fashion. Often this does occur: the wide variety and incompatibility of physical resources, discrepancies in organizational culture and patterns of training, and interagency competition or institutional obstinacy (at times bordering on sheer stupidity) reduce the efficiency of effort. Whatever measure of success is achieved is thus not due to the consciously developed policies, but the result of personal perseverance and dedication of the "shooters" on the ground, their personal flexibility, and their ability to improvise.

The second issue is similar to that observed in healthcare: regional concentration of personnel, material, and intellectual resources in the metropolitan areas. Both in healthcare (particularly at the pre-hospital and emergency care levels, e.g., von Lubitz et al., 2005) and in the disaster management arena, the level of available resources, the quality of continuous education and training, and the availability of specialized personnel decreases drastically while workloads increase correspondingly in proportion to the distance from the metropolitan centers.. Since many of the disaster response units are financed by often small, local municipalities, it is unsurprising that the resources available for training, personnel expansion, or even refits and upgrades of material (not to mention acquisition of the new one) are small and strictly prioritized. The responders even in the immediate periphery of metropolitan areas, but particularly in the distant rural regions, continue to remain the equally distant and persistently poor relatives largely ignored by the national funding institutions.

We have no illusion that the concepts introduced in this paper solve all problems that the recent crises and disasters revealed with unprecedented ferocity. A much greater political will and vision are needed. There is also the need for the responders, "knowing what they don't know" (and don't have) to exercise much greater pressure at the federal/national agencies to approach disaster management with the same intensity of purpose as they approach other socially relevant and essential fields. Nonetheless, we believe that I/KM and K-BPO managed in a network-centric setting of Disaster Action Information Organization (DAIO) nodes offers very significant operational advantages in prodromic planning, education, training, and the development of preparedness. The same concepts, particularly when enhanced by OODA Loop-based decision-making and leadership will undoubtedly improve the efficiency of readiness and the actual disaster management operations. Most importantly, we are convinced (in concordance with the creators of the military concept of network-centricity) that NEC will help to dispel the erroneous and potentially dangerous philosophy of offering different levels of information and knowledge to different levels of operators working within the same

"battlespace" (*c.f.* Dr. Carthy, DHS, lecture on weapons of mass destruction given during the Homeland Security Symposium at the Association for Intelligence Officers and transmitted by C-SPAN2 on the 6th November 2002).

The final issue that needs to be addressed is the reality of concepts presented in this paper. Do we propose a practical approach that can be implemented within foreseeable future, or is it the proverbial "pie in the sky"? The complexities of practical introduction of NEC are, unquestionably, immense and span the vast range of relevant technologies. The integration of the existing legacy systems with the forthcoming, vastly more capable ones, absence of common standards, deeply rooted organizational traditions and culture preferences, political realities, and the pervasive dislike of substituting the old and somehow working with the new and largely unproven represent but few of the most obvious obstacles. Yet, the energetic development of network-centric principles by the military establishments of the world (i.e., not only the EU and US), and the already demonstrated success of their practical implementation also in civilian operations, indicate that our ideas are not unrealistic. The process will be a difficult, and, most likely, not a straightforward one. On the other hand, the complexities of the modern world result in vastly more complex crises and disasters than the one that took place in Sunda Strait on the 27th July 1883. On that day, nearly 40.000 people died. On the 26th of December 2004, in the aftermath of a tsunami of a largely similar size, nearly 230.000 people perished in the same region of the world. We may never be able to avert crises and disasters. But we may be much better prepared to reduce their consequences.

REFERENCES

911 Commission Report at http://www.9-11commission.gov/report/911Report.pdf

Ackerman R, 2006, Unclassified information: new key to network centricity, Signal 11, at http://www.imakenews.com/signal/e_article000633561.cfm?x=b11,0,w

Alberthal, Les. Remarks to the Financial Executives Institute, October 23, 1995, Dallas, TX

Alberts DS, Garstka JJ, Hayes RE, and Signori DA, 2001, Understanding Information Age Warfare CCRP Press, 2001. at http://%20www.dodccrp.org/publications/pdf/Alberts_UIAW.pdf

Asghar S, Alahakoon D, Churilov L, I.J. Simulation on Line 10/11 at http://ducati.doc.ntu.ac.uk/uksim/journal/Vol-6/No.10-11/Paper8.pdf

Assilzadeh H and Mansor SB, 2004, Natural disaster data and information management system, Proc.Intl. Soc. Photogrammetry and Remote Sensing (ISPRS) Conference, Istanbul, at http://www.isprs.org/istanbul2004/comm7/papers/146.pdf

Au G, Goss S, Heinze C, Pearce AR, 2001, RescueModel: a multi-agent simulaton of bushfire disaster management, Lecture Notes Comp. Sci. 2019, 285-290

Auf der Heide, E, 2006, The importance of evidence-based disaster planning, Annals Emerg. Med. 1, 34-49

Award, E.Ghaziri, H. 2004. Knowledge Management, Prentice Hall, Upper Saddle River pp. 3-240.
Bell V, 2003, A different battlefield, the same strategy, The Fabricator. March 27, at http://www.thefabricator.com/ShopManagement/ShopManagement_Article.cfm?ID=540
Blackler, F. 1995, Knowledge, Knowledge Work and Organizations: An overview and Interpretation. Organization Studies 16, 1021—1046
Boccardelli P, Magnusson MG, 2006, Dynamic capabilities in early-phase entrepreneurship, Knowledge and Process Management 3, 162-174
Boin A, ‘t Hart P, Stern E, Sundelius B, 2005, The Politics of Crisis Management: Public Leadership Under Pressure, Cambridge University Press Cambridge, UK), pp. 1-182
Boyd JR, COL USAF, 1976, Destruction and Creation, essay in R. Coram “Boyd”, Little Brown & Co (New York) 2002, pp. 451-462
Boyd JR, COL USAF, 1987. in Patterns of Conflict, unpubl Briefing (accessible as “Essence of Winning and Losing”, http://www.d-n-i.net)
Boyd JR, COL USAF, 1987. in Patterns of Conflict, unpubl Briefing (accessible as “Essence of Winning and Losing”, http://www.d-n-i.net)
Brinkley D, 2006, The Great Deluge: Hurricane Katrina, New Orleans, and the Mississippi Gulf Coast, W. Morrow (N.Y.), pp. 1-716
Broughton E, 2005, The Bhoppal disaster and its aftermath: a review, Environmental Health 6, at http://www.ehjournal.net/content/4/1/6
Brown JS, Duguid P. 1991. Organizational learning and communities of practice: Toward a unified view of working, learning, and innovation. Organization Science 2, 40-57
Cebrowski AK and Garstka JJ, 1998, Network-Centric Warfare: Its Origin and Future, Proc. US Naval Inst. 1, at http://www.usni.org/Proceedings/Articles98/PROcebrowski.htmt
Christoplos I, Mitchell J, Liljelund A, 2001, Re-framing risk the changing context of disaster mitigation and preparedness, Disasters 30, 377-379
Comfort LK, 2005, Risk, security, and disaster management, Ann. Rev. Political Science 8, 335-356
Cooper C and Block R, 2006, Disaster: Hurricane Katrina and the Failure of Homeland Security, Times Books/Henry Holt and Company, New York, pp. 3-333
Corram R, 2002, “Boyd”, Little Brown & Co (New York) 2002, pp. 1-462
Courtney, J. 2001 Decision Making and Knowledge Management in Inquiring Organizations: Toward a New Decision-Making Paradigm for DSS, Decision Support Systems Special Issue on Knowledge Management 31, 17-38
Drucker, P. 1993. Post-Capitalist Society. New York, Harper Collins pp. 6-352.
Elash D, 2006, Realizing untapped potential, Leader Values, November 2006, at http://www.leader-values.com/Content/detail.asp?ContentDetailID=230
FEMA, at http://www.training.fema.gov/EMIWeb/downloads/is288_unit2.pdf

Ferguson EW, Villasenor A, Cunnion S, De Ville de Goyet C, Young FE, Laporte RE, 1995, A global health disaster network is needed (Letter to the editor), BMJ 310, 1412

GAO, 2006, Hurricane Katrina: GAO's Preliminary Observations Regarding Preparedness, Response, and Recovery, US Government Accountability Office (GAO) Report 06-442T, Washington, DC

Garstka JJ, 2004, Implementation of network centric warfare, Force Transformation Trends, 28th January 2004, http://www.oft.osd.mil

Gilman MAJ BL, USA, 2006, Distributed Operations: translating tactical capabilities into operational effects, naval War College, Newport, RI, 1-30

Grant, R. 1991 "The Resource-Based Theory of Competitive Advantage: Implications for Strategy Formulation" California Management Review, vol. 33, no. 3 Spring pp. 114-135

Grobmyer JE Jr., Lum T, Morris RE, Hard SJ, Pratt, Florence T, Peddycoart E, Airborne ladar man-in-the-loop operations in tactical environments, Proceedings of SPIE -- Volume 5412, Laser Radar Technology and Applications IX, Gary W. Kamerman, (Ed), September 2004, pp. 137-148

Harris AS and Kononczuk P, 2005, 3 years on: is Prague flood-proof? The Prague Post, August 10, at http://www.praguepost.com/P03/2005/Art/0811/news2.php

Hodgson J, 2006, The headache of knowledge management, Nature Biotechnology 19, BE44 - BE46

Howells J, Andrew J, Khaleel M, 2003,The sourcing of technological knowledge: distributed innovation processes and dynamic change, R&D Management 4, 395-409

Hutchinson JF, 2000, Disasters and the inernational order: earthquakes, humanitarians , and the Ciraolo Project Intl. History Rev. 21, 1–36

Hutchinson JF, 2001, Disasters and the International Order – II: The International Relief Union Intl. History Rev. 23, 253–98

IBM, 2006, Network-centric operations centre launches crisis management program, IBM Global Services, June 26, at http://www935.ibm.com/services/us/index.wss/summary/imc/ a1024842?cntxt=a1000452

Inglesby TV, Grossman R, O'Toole T, 2000, A plague on your city: observations from TOPOFF, Clin. Inf. Diseases 32, 436-45

Jashapara A, 2005, The emerging discourse of knowledge management: a new dawn for information science research, J. Info. Sci. 31, 136-148

Jonas KW, 2005, Network-centric operations: European capabilities, Report A1899, Assembly of WEU, Inter-parliamentary European Security and Defense Assembly

Kershaw J.P and Mason B, 2005, The Indian Ocean tsunami Disaster: Implications for US and Global Disaster reduction and Preparedness; Summary of the June 21, 2005 Workshop of the Disasters Roundtable, National Research Council of the National Academies, The National Academies Press (Washington, DC), downloadable at http://www.nap.edu/catalog/11619 html

Kotnour T and Hjelm M, 2002, Leadership mechanisms for enabling learning within project teams, Proc. III European Conf. on Organizational Knowledge, Learning, and

Capabilities (OKLC 2002), Athens, at http://www.alba.edu.gr/OKLC2002/Proceedings/pdf_files/ID340.pdf

Lagadec P, 1993, Preventing Chaos in Crisis: Strategies for Prevention, Control and Damage Limitation, McGraw-Hill (New York), pp. XXIII-XXXVI, 1-360

Luddy J, 2005, The challenge and promise of network-centric warfare, Lexington Institute, Arlington, VA, at http://www.lexingtoninstitute.org/docs/521.pdf

Mandelbrot B(with Hudson, RL), 2004, The (Mis-)Behavior of Markets: A Practical View of Risk, Ruin and Reward, Basic Books (New York), pp. 3-328

Michaels S, Headley W, 2004, Actively searching for hazards information, Natural Hazards Rev. 1, 10-17

Molka-Danielsen J, Beke T, 2007, Rumours interplay in disaster management, In Int. J. Risk Assessment and Management, in press

Nature.com, 2006, Preparing for disaster: earth scientists should find better mechanisms to disseminate facts about the risks for natural disasters, to help populations make the necessary preparations, Nature: news@nature.com (Dec. 14) at http://www.nature.com/news/2005/051212/pf/438889a_pf.html

Newell, S., Robertson, M. H. Scarbrough, H. Swan, J.. 2002. Managing Knowledge Work Palgrave, New York pp. 2-261.

News@Cisco, 2006, Boeing, Cisco business alliance accelerates network-centric technology development and deployment, at http://newsroom.cisco.com/dlls/partners/news/2005/pr_prod_06-08.html

Nonaka, I 1994. A dynamic theory of organizational knowledge creation Organizational Science 5:14-37

Nonaka, I, Takeuchi H, Umemto K, 1996, A theory of organizational knowledge creation, International Journal of Technology Management 1, 833—854

Orr, Major GE, USAF, 1983, Combat operations C^3I: fundamentals and interactions, Airpower Research Institute, Research Report AU-ARI-82-5 available at http://aupress.au.af.mil/ Books/Orr/Orr.pdf

Phatic Communion, 26th June 2006, accessible at http://www.phaticcommunion.com/archives/2006/06/rethinking_the.php

Quarantelli EL, 1997, Ten criteria for evaluating the management of community disasters, Disasters 1, 39-56

Radon K, Rosenberger A, Ehrenstein V, Hoopmann M, Basting I, Tödt H, Reichert J, Dressel H, Schmidt M, Suchenwirth R, Nowak D, 2006, Geographical distribution of acute symptoms after a train collision involving epichlorohydrin exposure, Environ. Res. 1, 46-51

Rand Corporation, Intelligence Preparation of the Battlefield: An Overview, at http://www.rand.org/pubs/monograph_reports/MR1287/MR1287.ch2.pdf

Richards C, 2004, Certain to Win: the Strategy of John Boyd Applied to Business, Xlibris, St. Paul (MI), pp. 1-187

Ricks T, 2006, Fiasco: the American Military Adventure in Iraq, The Penguin Pres (N.Y.), pp. 3-482

Rosenthal U, Boin AR, Comfort LK, 2001, Managing Crises: Threats, Dilemmas, Opportunities, Charles C. Thomas (Springfield, IL), pp. 5-354

Satterly MT, Stubbs KD, Gilbert GD, Iler CL, Glenn KB, 1999, Intelligence Preparation of the Battlespace – and airman's introduction, Air & Space Power Journal, at http://www.airpower.maxwell.af.mil/airchronicles/cc/Satterly.html

Schipper L and Pelling M, 2006, Disaster risk, climate change and international development: scope for, and challenges to, integration, Disasters 1, 19-38

Schultz, U., Leidner D., 2002 Studying Knowledge Management In Information Systems Research: Discourses And Theoretical assumptions, MIS Quarterly vol 26 No. 3 pp. 212-242

Sensky T, 2002, Knowledge management, Adv. Psych. Treatment 8, 387-395

Spender JC, 1996, Making knowledge the basis of a dynamic theory of the firm, Strategic Management Journal 17,45-62

Sullivan JP, 2000, Integrated Threat and Net Assessment: the L.A. Terrorism Early Warning (TEW) Group model, in Proceedings Bioterrorism: Homeland Defence: The Next Steps Conference, Section II, Pre-Attack Panel: Prevention and Deterrence, Santa Monica (CA), February 2000

Sullivan JP., 2005, Terrorism Early Warning and Co-Production of Counterterrorism Intelligence, Canadian Association for Security and Intelligence Studies, Montreal, Quebec, Canada

Thierauf RJ, Hoctor X, 2006, Optimal Knowledge Management, IGI Idea Group (Hershey, PA), pp 1-300

Thompson F, 1995, Business Strategy and the Boyd Cycle, J. Contingencies Crisis Management 2

Torres JA, 2005, Disaster in the Indian Ocean: Tsunami, 2004, Mitchell Lane Publishers (Hockessin, DE), pp. 1-48

Tucker T, 2006, The future of supply chain management: network-centric operations and the supply chain, Supply & demand Chain Executive, November 8, at http://72.14.209.104/search?q=cache:nLCl-YWdbx8J:www.sdcexec.com/article.arch.asp%3Farticle_id%3D7285+Network-centric+operations+in+business&hl=en&gl=us&ct=clnk&cd=28

Uitto JI, 1998, The geography of disaster vulnerability in megacities, Applied Geography 1, 7-16

US Navy Office of Naval Research, 2003, Taxonomy of Technology Limitations to Support the Five Enabling Functions Required for Navy Network Centric Operations, http://www.onr.navy.mil/02/baa/expired/2003/03_007/docs/tax_tech.doc

Van Bommel P, 2005, Transformation of Knowledge, Information and Data: Theory and Applications, IGI Idea Group (Hershey, PA), pp. 1-338

von Lubitz DKJE, 2003a, OODA, Proceedings, Intl. IT Conference IPSI 2003, Montenegro, October 2003 von Lubitz DKJE, 2003b, Bioterrorism: Field Guide to Disease Identification and Initial Patient Management, CRC Press, Boca Raton (Fl)

von Lubitz DKJE, Carrasco B, Levine H, Richir S, 2004. "Medical Readiness in the Context of Operations Other Than War: Development of First Responder Readiness Using OODA–Loop Thinking and Advanced Distributed Interactive Simulation Technology" Proceedings EMISPHERE 2004 Symposium, Istanbul, Turkey September 2004. For on-line version at the Defence and National Intelligence Network, see http://www.d-n-i.net/fcs/pdf/von_lubitz_1rp_ooda.pdf

von Lubitz DKJE, Carrasco B, Fausone CA, Gabbrielli F, Kirk J, Lary MJ, Levine H, Lary MJ, 2005, Bioterrorism, medical readiness, and distributed simulation training of first responders. In Community and Response to Terrorism (Vol. II): A Community of Organizations: Responsibilities and Collaboration Among All Sectors of Society (J. Johnson, M. Cwiek, G. Ludlow, EDS), Praeger (Greenwood Publ. Group) Westport, CT, pp. 267-312

von Lubitz DKJE, 2007, Medical readiness for operations other than war: Boyd's OODA Loop and training using advanced distributed simulation technology, Intl J. Risk Assessment and Management, in press

von Lubitz DKJE, Wickramasinghe N, 2006a, Healthcare and technology: the doctrine of network-centric healthcare, Intl. J. Electronic Healthcare 4, 322-344

von Lubitz DKJE, Wickramasinghe N., 2006b, Key Challenges and Policy Implications for Governments and Regulators in a Network-centric Healthcare Environment, Intl. J. Electronic Government. 2, 204 – 224

von Lubitz, DKJE, Wickramasinghe N, 2006c, Dynamic Leadership In Unstable And Unpredictable Environments, Intl. J. Innovation Learning 4, 339-350

von Lubitz DKJE, Wickramasinghe N, 2006d, Networkcentric healthcare and bioinformatics: unified operations within three domains of knowledge, Expert Systems With Applications 30, 11-23

von Lubitz DKJE, Patricelli F., 2006, Network-centric Healthcare Operations; Data Warehousing and the Associated Telecommunication Platforms, Intl. J. Services and Standards, in press

von Lubitz DKJE, Wickramasinghe N, Yanovsky G, 2007, Newtork-centric healthcare operations: the telecommunications structure, Int. J. Networking and Virtual Operations 1, 60-83

Wallace GEN WG, USA, 2005, Network-enabled battle command, Military Review, May-June 2005, at http://usacac.leavenworth.army.mil/CAC/milreview/download/English/MayJun05/wallace.pdf

Wallace WA and De Balogh F, 1985, Decision Support Systems for Disaster Management, Publ. Admin Rev. (Spec. Issue: Emergency Management: a challenge for public administration) 45, 134-146

Wickramasinghe N, von Lubitz DKJE, 2007, Knowledge Enterprises: Theory and Fundamentals, IDEA Publishing Group (Hershey, PA), pp. 1-300

Wiese CR, 2006, Organizing Homeland Security after Katrina: is adaptive management what's missing, Publ. Adm. Rev. May-June 2006, 302-318

Winchester S, 2003, Krakatoa; The Day the World Exploded: August 27, 2883, Harper Collins (New York), pp. 1-416

World Disasters Report 2005: Focus on information in disasters, Intl. Federation of Red Cross and Red Crescent Societies (J. Walter Ed.), Kumarian Press (Bloomfield, CT), 1-251

Wyle MD, Lind WS, Trainor BE, 1981, Maneuver/Fluid Warfare, Marine Corps Gazette 65 (April), 49-54