2020-03

READING FROM THE SAME MAP: TOWARDS A NEW SITUATIONAL AWARENESS MODEL FOR EMERGENCY MANAGEMENT

Rau, Erik

Monterey, CA; Naval Postgraduate School

https://hdl.handle.net/10945/64903

NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

READING FROM THE SAME MAP: TOWARDS A NEW SITUATIONAL AWARENESS MODEL FOR EMERGENCY MANAGEMENT

by

Erik Rau

March 2020

Co-Advisors:	Robert L. Simeral Anthony Canan

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REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington, DC 20503.			
1. AGENCY USE ONLY ***(Leave blank)***	**2. REPORT DATE** March 2020	**3. REPORT TYPE AND DATES COVERED** Master's thesis	
4. TITLE AND SUBTITLE READING FROM THE SAME MAP: TOWARDS A NEW SITUATIONAL AWARENESS MODEL FOR EMERGENCY MANAGEMENT			**5. FUNDING NUMBERS**
6. AUTHOR(S) Erik Rau			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			**10. SPONSORING / MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release. Distribution is unlimited.			**12b. DISTRIBUTION CODE** A

13. ABSTRACT (maximum 200 words)

Situational awareness (SA) is a critical issue for public safety disciplines, including emergency management, law enforcement, and the fire service. These fields operate substantially differently from each other, but share a common model for SA, based on John Boyd's OODA loop. Boyd's model, though applied widely, is heavily shaped by artefacts from its origin in the culture of fighter pilots. These artefacts include premises that the practitioner can perceive information directly, has a clear understanding of the nature of events, and is primarily concerned with their own actions. While some disciplines have enough in common with pilots for this SA model to match their activities, emergency management does not. In emergency management, practitioners are separated from the event, events are uncertain in type and duration, and coordination among teams is a primary function. These differences in culture create mismatches between emergency management activities and the SA model, which lead to repeated failures of SA across many organizations. Furthermore, despite a large body of applicable scholarly research on SA specifically and shared cognition in general, little of it has been adopted by practitioners in any discipline. This thesis will examine the SA model to identify mismatches with emergency management, consider research on shared cognition to identify useful elements, and summarize those elements to present options for consideration and further investigation.

14. SUBJECT TERMS situational awareness, SA model, distributed teams, shared SA, emergency management			**15. NUMBER OF PAGES** 81
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UU

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

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READING FROM THE SAME MAP: TOWARDS A NEW SITUATIONAL AWARENESS MODEL FOR EMERGENCY MANAGEMENT

Erik Rau
Emergency Management Planner, Oregon Office of Emergency Management
BA, University of Hawaii at Hilo, 2005

Submitted in partial fulfillment of the
requirements for the degree of

**MASTER OF ARTS IN SECURITY STUDIES
(HOMELAND SECURITY AND DEFENSE)**

from the

**NAVAL POSTGRADUATE SCHOOL
March 2020**

Approved by: Robert L. Simeral
Co-Advisor

Anthony Canan
Co-Advisor

Erik J. Dahl
Associate Professor, Department of National Security Affairs

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ABSTRACT

Situational awareness (SA) is a critical issue for public safety disciplines, including emergency management, law enforcement, and the fire service. These fields operate substantially differently from each other, but share a common model for SA, based on John Boyd's OODA loop. Boyd's model, though applied widely, is heavily shaped by artefacts from its origin in the culture of fighter pilots. These artefacts include premises that the practitioner can perceive information directly, has a clear understanding of the nature of events, and is primarily concerned with their own actions. While some disciplines have enough in common with pilots for this SA model to match their activities, emergency management does not. In emergency management, practitioners are separated from the event, events are uncertain in type and duration, and coordination among teams is a primary function. These differences in culture create mismatches between emergency management activities and the SA model, which lead to repeated failures of SA across many organizations. Furthermore, despite a large body of applicable scholarly research on SA specifically and shared cognition in general, little of it has been adopted by practitioners in any discipline. This thesis will examine the SA model to identify mismatches with emergency management, consider research on shared cognition to identify useful elements, and summarize those elements to present options for consideration and further investigation.

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EXECUTIVE SUMMARY

Situational awareness (SA) is a critical issue for public safety disciplines, including emergency management, law enforcement, and the fire service. These fields operate substantially differently from each other, but share a common model for SA, based on John Boyd's OODA loop. Boyd's model, though applied widely, is heavily shaped by artefacts from its origin in the culture of fighter pilots.[1] These artefacts include premises that the practitioner can perceive information directly, they have a clear understanding of the nature of events, and they are primarily concerned with their own actions. While some disciplines have enough in common with pilots for this SA model to match their activities, emergency management does not. Differences in culture create mismatches between emergency management activities and the SA model, which in turn lead to repeated failures of SA across many organizations. Thus, this thesis asks the question: How can models of situational awareness be adapted to describe shared SA among distributed teams in emergency management?

One of the common elements that make up the central activity of emergency management is situational awareness (SA): the aggregated activities by which practitioners develop, understand, and share an understanding where individual actions fit within the context of the collective response to an event.[2] Because SA is a central issue in emergency management and public safety, one of the greatest challenges facing practitioners is that breakdowns in it affect the entire response.[3] Even when SA processes are working properly, however, practitioners can achieve incompatible results if different models are

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[1] Ron Azuma, Mike Daily, and Chris Furmanski, "A Review of Time Critical Decision Making Models and Human Cognitive Processes" (2006 IEEE Aerospace Conference, Big Sky, MT: IEEE, 2006), 1–9, https://doi.org/10.1109/AERO.2006.1656041.

[2] Amy K. Donahue and Robert V. Tuohy, "Lessons We Don't Learn: A Study of the Lessons of Disasters, Why We Repeat Them, and How We Can Learn Them," *Homeland Security Affairs* 2 (July 2006): 28.

[3] Mica R. Endsley, "Situation Awareness: Operationally Necessary and Scientifically Grounded," *Cognition, Technology & Work* 17, no. 2 (May 2015): 163–67, http://dx.doi.org/10.1007/s10111-015-0323-5; and Michael E. Russas Sr., "Correcting Blindness in the Nerve Center: How to Improve Situational Awareness" (master's thesis, Naval Postgraduate School, 2015), https://doi.org/10.21236/AD1009217.

used. These deficiencies and mismatches need to be addressed in order for the discipline to develop a model of SA that better matches practitioners' activities.

It is not surprising that practitioners are just beginning to develop ideas and epistemologies in emergency management, nor that the discipline's models still require adjustment. In a departure from other public safety fields, the natural state of the work is not at the individual level but rather in teams, often spread across large spans of time, distance, and organization.[4] Furthermore, the primary job of emergency management practitioners is to coordinate information effectively rather than to act instantaneously, another major difference from other public safety disciplines. Though these are challenging activities, applied to sometimes difficult circumstances, they provide extraordinarily rewarding opportunities for growth and learning, and can therefore be, as Rebecca Solnit says, the avenue by which gifts arrive.[5]

Being able to analyze SA models according to principles that reflect practitioners' actual use would allow not only basic improvements through deliberate design but also better improvements after failures noted during exercises or events. Such analysis would require additional effort, but it would address many failures that are currently noted but not classified. The ability of these theories to incorporate complexity beyond the immediate elements of an activity is also valuable—there are several elements that affect SA that have not yet been identified because they exist outside the SA processes themselves.

As challenging as the problems intrinsic to SA are, factors outside the SA process itself nonetheless exert very strong influences over that process and the SA models that underlie it. These factors include goals set by organizational leaders, definitions of the environment and activities that SA is applied to, and even the types of knowledge used to build those definitions. The relative importance of these factors may vary from one event to the next, or even from one team to the next, but they are all germane to the overall SA model, and none of them is accounted for in existing descriptions of that model.

---

[4] Federal Emergency Management Agency, *National Response Framework*, 4th ed. (Washington D.C.: US Department of Homeland Security, 2019), 48.

[5] Rebecca Solnit, *A Paradise Built in Hell* (New York: Viking, 2009), 6.

Emergency management and public safety as disciplines require a commitment to iterative change, a constant desire for improvement, and a recognition that there are no universal solutions. These qualities have rarely been stated so bluntly as by the authors of the *Final Report of the Interagency Management Review Team* from the fatal South Canyon Fire:

> The reader will find no dramatic changes in the form of new equipment or technology, new training, new policy, or new procedures. Rather, there are numerous modifications and improvements in those areas, representing a process of constant and ongoing progress toward the goal of reduced risks to wildland firefighters.[6]

In short, we do not, or perhaps cannot, know the totality of what we need to know in our operating environment, but we can and must continue to push forward in some areas based on past experience and available knowledge.

Compounding the problem, the tremendous variety in organizational structures makes it difficult to supply specific recommendations, as emergency management is conducted in widely disparate ways. Processes are profoundly shaped by factors external to the processes themselves, so any specific solutions must be founded in an understanding of a particular set of processes as well as those external factors relevant to their operation. This thesis provides insight into the SA model, but any organizational improvement will require a great deal of internal analysis to realize the benefits described herein.

In order to seek improvements in SA models and reduce some of the failures articulated throughout this discussion of emergency management, there are two important areas of action. First, we must admit that the problem exists and set higher standards than we have had for solving it. While no organization will ever achieve perfect communications under ordinary circumstances, it is possible for practitioners to imagine a functional SA process that does not suffer from frequent and expected breakdowns. Second, we must recognize some of the conditions that make the causes of failures so damaging and adjust organizations to make them less susceptible by mitigating those

[6] *Final Report of the Interagency Management Review Team: South Canyon Fire* (Washington D.C.: US Department of the Interior, 1995), 7.

conditions. One area of research that demonstrates this approach separates SA into three levels with consistent groupings (Figure 1).

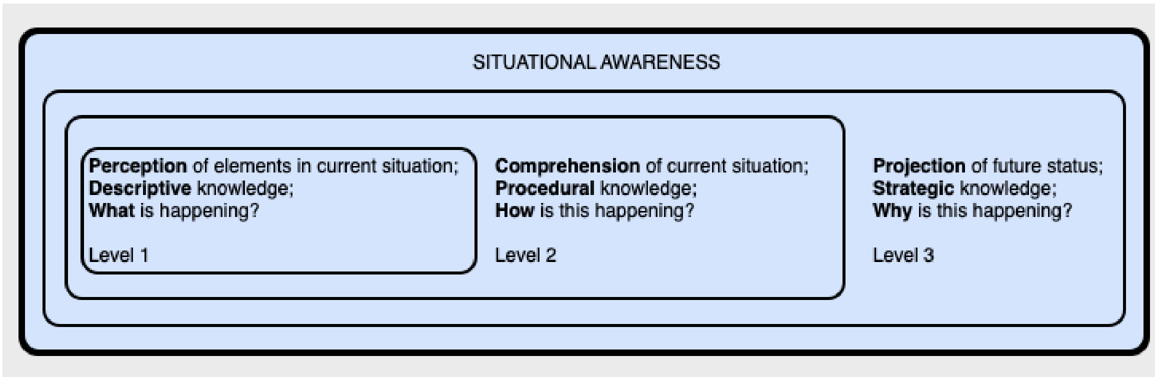

Figure 1. Comparing Three Descriptions of SA Levels[7]

The nuances of the three levels reflects the activities of emergency management better than the existing SA model and allow for a better analysis of how to improve SA overall. It is precisely these two remedies—imagination of a higher standard and the improvement of indirect conditions—that require the qualitative methods described in this thesis.

Converging pragmatism and exploration is precisely the kind of novel thinking required to develop a new SA model. Such a model will not emerge from an endless succession of after-action reviews conducted under the current model any more than one person observing one star while another person observes another can form an idea of where their ship is sailing to. The scholarly research provides many potential remedies, but pragmatism is needed to measure, compare, and apply those remedies to the actual challenges. This thesis examines the SA model to identify mismatches with emergency

[7] Adapted from Mica R. Endsley, "Toward a Theory of Situation Awareness in Dynamic Systems," *Human Factors: Journal of the Human Factors and Ergonomics Society* 37, no. 1 (March 1995): 32–64, https://doi.org/10.1518/001872095779049543; W.B. Rouse, J.A. Cannon-Bowers, and E. Salas, "The Role of Mental Models in Team Performance in Complex Systems," *IEEE Transactions on Systems, Man, and Cybernetics* 22, no. 6 (December 1992): 1296–1308, https://doi.org/10.1109/21.199457; Susan Mohammed, Lori Ferzandi, and Katherine Hamilton, "Metaphor No More: A 15-Year Review of the Team Mental Model Construct," *Journal of Management* 36, no. 4 (July 2010): 876–910, https://doi.org/10.1177/0149206309356804.

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References

Allen, Tom, Tom Zimmerman, Jim Douglas, Michael Benscoter, Robert Joslin, Mike Edrington, Jose Cruz, Edy Petrick, Mike Barry, and Rick Ochoa. *Final Report of the Interagency Management Review Team: South Canyon Fire*. Washington, DC: U.S. Department of the Interior, 1995.

Azuma, Ron, Mike Daily, and Chris Furmanski. “A Review of Time Critical Decision Making Models and Human Cognitive Processes,” 1–9. Big Sky, MT: IEEE, 2006. https://doi.org/10.1109/AERO.2006.1656041.

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Endsley, Mica R. “Situation Awareness: Operationally Necessary and Scientifically Grounded.” *Cognition, Technology & Work* 17, no. 2 (May 2015): 163–67. http://dx.doi.org/10.1007/s10111-015-0323-5.

Endsley, Mica R. “Toward a Theory of Situation Awareness in Dynamic Systems.” *Human Factors: Journal of the Human Factors and Ergonomics Society* 37, no. 1 (March 1995): 32–64. https://doi.org/10.1518/001872095779049543.

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Russas Sr., Michael E. “Correcting Blindness in the Nerve Center: How to Improve Situational Awareness.” Master’s thesis, Naval Postgraduate School, 2015. https://doi.org/10.21236/AD1009217.

Solnit, Rebecca. *A Paradise Built in Hell*. New York: Viking, 2009.

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ACKNOWLEDGMENTS

If I have learned anything, it is that life must be both intellectual and practical, and that neither approach is complete without the other. My parents, Dan and Linda, were the first to teach me this, and still do so often.

As a consequence of my peregrinations over the years, many former (and some current) supervisors have taught, encouraged, and tolerated me in the course of my education. They deserve a large part of the thanks, and include: Edie Curry, Jerry Phillips, and Phil Rounds at the University of Alaska Fire Department; David Byrne at the Mauna Kea Visitor Information Station; Peter Michaud at Gemini Observatory; Mary King, Clay Stephens, and Diana Simpson at the Benton County Sheriff's Office; Douglas Baily at the Corvallis Fire Department; and Sonya McCormick, Matt Marheine, and Andrew Phelps at the Oregon Office of Emergency Management.

All of the faculty and staff at NPS-CHDS were helpful and friendly, and put in tremendous effort to help us succeed. My fellow students also taught me a great deal, and their influence consistently inspired me to work harder and do better. Three people deserve additional thanks for most of what is good in this work, however. Noel Yucuis improved my writing considerably, often by insisting that I take away words. Robert Simeral and Mustafa Canan were model co-advisors: willing, patient, and relentless in their critiques.

Last, but certainly not least, my family has supported and encouraged me in many ways over this part of the journey. My children have, at various times, either offered to write my thesis for me, or loudly wished that it was done, sometimes during the same, interminable wait for me to finish One More Thing. Alicia has done an immense amount to make this whole life work—more than anyone, including I, will ever see. Even so, I know that she has, and I am grateful.

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I. THE MAP AND THE TERRITORY—INTRODUCTION

> The map is not the territory.
>
> —Alfred Korzybski, *Science and Sanity*

> If you have exact Greenwich time aboard—if you carry it with you—you can fix your longitude exactly by accurate observation of local noon, to say nothing of occultations and the finer points. [...] In these waters that would tell you where you were, east or west, to within three miles or so.
>
> —Patrick O'Brian, *The Surgeon's Mate*

> Though the year was 1969, we were, in fact, reliving the Polynesian past. Down in a locker below were the compass, the sextant, charts, and our watches; the 120-mile round trip voyage between the remote Santa Cruz Reef Islands and the even more desolate Taumako was being navigated solely by Tevake's unaided senses.
>
> —David Lewis, *The Voyaging Stars*

A. PROBLEM STATEMENT

As a professional discipline, emergency management is young. Counting its creation in the middle of the 20th century and its sudden jump in prominence following several traumatic events of the early 21st, practitioners are still finding their way towards common definitions and understanding. Even so, there are certain common elements that make up the central activity of emergency management, as well as its functional epistemology, a catch-all term for the philosophy, knowledge, and modes of understanding. One of these common elements is situational awareness (SA): the aggregated activities by which practitioners develop, understand, and share an understanding where individual actions fit within the context of the collective response to an event.[1] Though SA is a central issue in emergency management and public safety, it also presents one of the greatest

[1] Donahue and Tuohy, "Lessons We Don't Learn: A Study of the Lessons of Disasters, Why We Repeat Them, and How We Can Learn Them."

challenges facing practitioners of these allied disciplines when the processes they use to develop it fail.[2] The centrality of SA in emergency management means that breakdowns there affect the entire response. Even when SA processes are working properly, practitioners can achieve incompatible results if different models are used, just as neither of the navigators would recognize the map the other uses.

Establishing SA among responders is the primary purpose of government emergency management organizations, but this activity is poorly modeled, which leads to repeated misunderstandings and failures. To take one common misunderstanding, a lack of SA does not always arise from a lack of information. In analyses of events ranging from a single small plane crash in the Montana wilderness to the massive Deepwater Horizon oil spill in the Gulf of Mexico, failures of SA were identified as direct causes of poor decision-making during the response as responders were unable to share, analyze, or integrate information.[3] In those examples, some responders had information available; but lacked the ability to develop it into effective SA either within their own team or across the multiple teams of the entire incident response. Until the model is recognized as a problem, the challenge of establishing SA remains much more difficult than it needs to be, and these failures will happen more frequently than they should.

The presence of multiple participants in the discussion introduces another important element of its study: the need to move beyond individual SA and toward a concept of shared SA. Teams of public safety and emergency management practitioners, often drawn from disparate organizations, work under separations of distance or time that prevent immediate, face-to-face communications.[4] Building, sharing, and maintaining SA in these widely

[2] Mica R. Endsley, “Situation Awareness: Operationally Necessary and Scientifically Grounded,” *Cognition, Technology & Work* 17, no. 2 (May 2015): 163–67, http://dx.doi.org/10.1007/s10111-015-0323-5; and Michael E. Russas Sr., “Correcting Blindness in the Nerve Center: How to Improve Situational Awareness” (master’s thesis, Naval Postgraduate School, 2015), https://doi.org/10.21236/AD1009217.

[3] Wendy S. Becker, “Missed Opportunities: The Great Bear Wilderness Disaster,” *Organizational Dynamics* 36, no. 4 (January 2007): 363–76, https://doi.org/10.1016/j.orgdyn.2007.06.003; and Erich Telfer, “Unlimited Impossibilities: Intelligence Support to the Deepwater Horizon Response” (master’s thesis, National Intelligence University, 2014).

[4] Federal Emergency Management Agency, *National Response Framework*, 15.

distributed teams are critical processes to examine in the context of emergency management.

Given the challenges presented in the above examples, it is clear that the existing SA model is not sufficient as a foundation for SA in emergency management. The orientation of the research question is drawn directly from that need.

B. RESEARCH QUESTION

How can models of situational awareness be adapted to describe shared SA among distributed teams in emergency management?

C. LITERATURE REVIEW

This thesis addresses SA in emergency management as a shared feature of distributed teams. Scholars in fields from combat operations to network utilities have identified elements that can improve existing models, but this research is underutilized by emergency management practitioners. In fact, the breadth of research available indicates that a model can more easily be created on premises aligned with the environment and activity of emergency management than on the narrow basis of SA models currently in use.

The current understanding of SA in emergency management is derived from studies in military aviation, and discussions about the subject are often confined to a small number of ideas and sources from that discipline.[5] The most prevalent of these ideas is the OODA loop, developed by John Boyd of the U.S. Air Force.[6] Boyd's model separates the steps of observation, orientation, and decision and culminates in action, thus presenting a useful if simplistic model of SA. The OODA loop's simplicity has been the secret of its success: even curricula designed for broader applications (for instance, FEMA's course E/L0948:

[5] Alfred Nofi, *Defining and Measuring Shared Situation Awareness* (Arlington, VA: Center for Naval Analyses, 2000); Endsley, "Toward a Theory of Situation Awareness in Dynamic Systems."

[6] Azuma, Daily, and Furmanski, "A Review of Time Critical Decision Making Models and Human Cognitive Processes."

Situational Awareness and Common Operating Picture) tend to start with Boyd's concise model and add only a small measure of research.[7]

The balance of the small measure of research beyond Boyd is made up by Mica Endsley's influential 1995 article, "Toward a Theory of Situation Awareness in Dynamic Systems."[8] This paper establishes a model of SA widely used in the academic community, if not by practitioners. Endsley defines SA as follows: "The perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future." Because of its specificity, Endsley's research is more applicable than Boyd's, since she carries the description even further and addresses factors external to SA that nevertheless affect it, including "goals and goal-directed processing, automaticity, mental models, and pattern matching to schemata of known situations, and expectations."[9] Unfortunately, none of this increased specificity is reflected in the SA model used in emergency management.

Another major limitation of the current SA model is the focus on individual SA. A new approach is required in order to move beyond this and consider the reality, which is that SA must be established for teams of practitioners. In one example of underutilized but pertinent research, Endsley and Jones in their 2012 book anticipate this large problem:

> In many other systems, it is necessary to design to support the situation awareness of not just individual team members, but also to support the situation awareness of the team as a whole. Understanding how to best accomplish this requires that we understand a few key factors underlying the nature of teams, and also how SA is affected by the presence of team operations.[10]

In other words, we need not only consider each person's SA but also consider what the team is doing, which is greater than the sum of its parts, the team's SA. Endlsey's work on

[7] Emergency Management Institute, "Situational Awareness and Common Operating Picture" (class notes, E/L0948: Emergency Management Institute, 2019).

[8] Endsley, "Toward a Theory of Situation Awareness in Dynamic Systems."

[9] Mica R. Endsley and Debra G. Jones, *Designing for Situation Awareness*, 2nd ed. (New York: CRC Press, 2012), 28.

[10] Endsley and Jones, 193.

SA contains much that could improve the existing models of individual SA by examining this larger sphere.

Examining groups as a unit allows a variety of approaches that address these group interactions in several ways. One approach, described by Verlin Hinsz as information processing activity, provides both generalized definitions and more specific components of group problem-solving.[11] Hinsz describes an information processing model comprising four steps: acquiring information, constructing a mental representation, processing the information into a useful form, and responding based on the information. This model aligns with Endsley's levels of generalized SA: perception, comprehension, and projection. A comparison of these works can be used to adapt parts into a more comprehensive model.

The information-processing model that Hinsz resembles the intelligence cycle, a process that describes a particular process closely related to SA.[12] Though a detailed study of the intelligence cycle is beyond the scope of this thesis, it has a strong relationship to civilian emergency management. This relationship is best illustrated by a quote from Mark Lowenthal, whose textbook provides considerable detail of that rarefied discipline: Intelligence is "the process by which specific types of information . . . are requested, collected, analyzed, and provided to policy makers."[13] This description matches the description of SA with allowances for the inference that intelligence is taking place within a national government. In providing several ways to think about intelligence, Lowenthal creates another point of congruence with SA: he lists intelligence as something that can be both a process and a product. The focus on the processes of the intelligence cycle allows a comparison with the processes of SA, rather than focusing on the products of either. This is useful because the disciplines overlap on numerous occasions.

---

[11] Vernor Hinsz, "A Groups-as-Information-Processors Perspective for Technological Support of Intellectual Teamwork," in *New Perspectives in Cooperative Activities: Understanding System Dynamics in Complex Environments* (Santa Monica, CA: Human Factors and Ergonomics Society, 2001).

[12] Mark Lowenthal, *Intelligence: From Secrets to Policy*, 7th ed. (Thousand Oaks, CA: CQ Press, 2017), 86.

[13] Lowenthal, 4.

In one such overlap between the disciplines of intelligence and emergency management, Erich Telfer's work on the failures of intelligence during the Deepwater Horizon oil spill response speaks directly to the challenges of SA in both. Telfer's work is an exhaustive examination of the integration (or failure thereof) of Department of Defense intelligence agencies into the Deepwater Horizon oil spill response. As such, it unites Lowenthal's purely national intelligence discussion with the principles of SA in a domestic emergency management environment. Taken together with analysis such as that found in Lowenthal's book, Telfer's presence as an intermediary helps to address issues raised by other researchers such as Hinsz. For example, Hinsz includes two environmental factors in his model: requirements for and feedback from information processing. It would be difficult to find a more thorough examination of those factors than has been done in developing the intelligence cycle, as Telfer and Lowenthal explain it.

A closely allied body of research that does not refer to the term SA but nonetheless addresses the issues and challenges is found in public safety case studies. Wendy Becker's analysis of a plane crash in the Great Bear Wilderness Disaster includes enumeration of latent conditions, which she describes as "weaknesses in organizations that exist prior to the onset of the accident."[14] In Becker's description, these latent conditions include poor work design and inadequate staffing, among other factors. She contrasts them with proximate causes that are often cited as the reason accidents happen: triggering events, such as using the wrong radio channel to communicate critical safety information. While latent conditions are far removed from the incident itself, they are the pathway that proximate causes travel to cause the accident in question. As diffuse but related factors for SA failures, latent conditions have not thus far formed part of SA models.

Other scholars provide relevant perspectives in this field from very different directions, such as by applying activity theory. Judith Brown, Steven Greenspan, and Robert Biddle conducted a survey of complex activities in a utility operations center with the stated goal of studying "attention allocation and distributed decision-making through team coordination[,] . . . two of ten top human supervisory control issues in network-centric

[14] Becker, "Missed Opportunities," 364.

operations."[15] In work centered on a commercial data operations center, the objects of study were attention allocation, pattern matching, decision making, and "the essential elements of activities as they have been structured by individuals or groups over time."[16] Turner and Turner take a more general approach to describing activity theory, but still provide a number of very useful touchpoints with SA models, such as their description of its function within "domains with complex, dynamic environmental constraints, typical examples including nuclear plants and operating theatres."[17] The use of activity theory provides an interesting possibility for a method of study, as those elements of focus listed above are very similar to the factors used to address the development of SA models.

Both Endsley and Brown, Greenspan, and Biddle consider the team, not the individual, as the basic unit and suggest that activity among members of the team is worthy of study in its own right. As described by Brown, Greenspan, and Biddle,

> Activity theory provides a framework that allows for the identification of the distinct activities occurring in a complex environment. […] Within this framework, activities are seen as systems of interrelated parts that adapt and change in response to any one of its elements changing. The concepts of individual and group activity are well integrated; in this research both are important because many of the activities of the center are accomplished by groups of people working together.[18]

The "systems of interrelated parts" that make up activities are a good comparison with Endsley's descriptions of team SA as more than the sum of individual SA from the various team members.[19] This departure from Boyd's model and approaches founded on his work introduces work that is useful for emergency management.

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[15] Judith M. Brown, Steven L. Greenspan, and Robert L. Biddle, "Complex Activities in an Operations Center: A Case Study and Model for Engineering Interaction," in *Proceedings of the 5th Annual Symposium on Engineering Interactive Computing Systems* (London: Association for Computing Machinery, 2013), 266.

[16] Brown, Greenspan, and Biddle, 266.

[17] P. Turner and S. Turner, "Describing Team Work with Activity Theory," *Cognition, Technology & Work* 3, no. 3 (August 2001): 128, https://doi.org/10.1007/PL00011528.

[18] Brown, Greenspan, and Biddle, "Complex Activities in an Operations Center: A Case Study and Model for Engineering Interaction," 266.

[19] Endsley and Jones, *Designing for Situation Awareness*, 201.

Endsley; Brown, Greenspan, and Biddle; and Hinsz have expanded the scope of SA from individuals to teams. The next step, then, is to consider activity performed in a group by default, such as the description and measurement of team SA by Nancy Cooke, Renée Stout, and Eduardo Salas.[20] Their model includes the environment, knowledge, and mental models as precursors to SA, each of which either directly correlates or is closely related to factors identified by Endsley, Hinsz, and others. These factors that are influential but external to SA deserve considerable scrutiny, even though they are by definition part of the process.

Research conducted with the aim of exploring shared SA among distributed teams abounds, it has simply been ignored. This research is well-matched with the environment and practices of emergency management, and can provide practitioners with a much-needed improvement in SA models.

D. RESEARCH DESIGN

This thesis considers how shared SA is developed among distributed teams in public safety and emergency management. The research will be conducted through multiple modes, including the exploration of existing research, comparison and categorization of concepts, and finally sense-making or synthesis to integrate all previous modes.

First, an exploration of the issue: the discipline of emergency management, the SA model, and its constituent parts; these things establish a position fix, drawn from the existing research in use by practitioners. Next, of the considerable body of work in these known research communities, only a small amount has been applied, making it a fruitful source for new material. In this and subsequent research areas, the major sources of data are books and journal articles.

[20] Nancy Cooke, Renee Stout, and Eduardo Salas, "A Knowledge Elicitation Approach to the Measurement of Team Situational Awareness," in *New Perspectives in Cooperative Activities: Understanding System Dynamics in Complex Environments* (Santa Monica, CA: Human Factors and Ergonomics Society, 2001).

Developing additional references based on existing research into shared SA is also likely to prove fruitful. This expansion draws on the disciplines of human factors analysis, organizational dynamics, and complex systems research. Starting from methods of constant comparison as described by Dye et al., in which pieces of theory are combined and compared several times as though they are the colorful bits in a kaleidoscope, theories can be compared with each other in various arrangements that allow new patters to emerge. This is complemented by thematic analysis as described by Nowell et al., which fosters the development of themes through repeated, varied analyses of underlying data. Using these techniques, new concepts will augment (and re-categorize) the existing elements of SA models in combination with other applicable research.[21]

Finally, a brief voyage into sense-making will synthesize ideas developed in earlier sections. Weick describes methods to first ascertain which questions are necessary to better understand the problem, before undertaking more detailed research. Much like the systems of navigation described in the quotes at the head of the chapter, there is more than one method to find the way to the destination. These varied methods allow us to chart courses for future exploration, sketched onto a blank area that previously read only "hic sunt dragones" (here be dragons).[22] Following these courses will lead to a new understanding of shared SA among distributed teams, which will remain a critical subject in homeland security and emergency management for as long as we practice them.

[21] Jane Dye et al., "Constant Comparison Method: A Kaleidoscope of Data," *Qualitative Report* 4, no. 1/2 (January 2000): 10, https://nsuworks.nova.edu/tqr/vol4/iss1/8/; and Lorelli S. Nowell et al., "Thematic Analysis: Striving to Meet the Trustworthiness Criteria," *International Journal of Qualitative Methods* 16, no. 1 (December 2017), https://doi.org/10.1177/1609406917733847.

[22] Karl Weick, *Sensemaking in Organizations* (Thousand Oaks, CA: Sage Publications, 1995).

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II. ONE AVENUE THROUGH WHICH GIFTS ARRIVE—EMERGENCY MANAGEMENT, TEAMS, AND SITUATIONAL AWARENESS

> Disasters are, most basically, terrible, tragic, grievous, and no matter what positive side effects and possibilities they produce, they are not to be desired. But by the same measure, those side effects should not be ignored because they arise amid devastation. The desires and possibilities awakened are so powerful they shine even from wreckage, carnage, and ashes. What happens here is relevant elsewhere. And the point is not to welcome disasters. They do not create these gifts, but they are one avenue through which the gifts arrive. Disasters provide an extraordinary window into social desire and possibility, and what manifests there matters elsewhere, in ordinary times and in other extraordinary times.
>
> —Rebecca Solnit, A Paradise Built in Hell

A. AN INTRODUCTION TO EMERGENCY MANAGEMENT

In contrast to other public safety disciplines, emergency management developed fairly recently, in the mid-20th century. Unlike police and fire departments, whose history dates back to the ancient Roman *vigiles*, the oldest stand-alone emergency management agencies emerged during the civil defense era of the 1940s and 1950s, and FEMA itself was not created until 1979. That recency is not the only difference, though; the practice of emergency management is distinct from those older, allied disciplines in several ways. One major distinction among disciplines is the criteria each uses for engaging with an incident. Emergency management agencies operate under the principle of tiered response such that "most incidents start at the local or tribal level, and as needs exceed resources and capabilities, additional local, state, tribal, territorial, insular area, or federal assets may be required."[23] One practical consequence of this principle is that a team of responders from other disciplines is nearly always in place by the time emergency management practitioners become engaged in an event. Because these larger events happen less frequently, there are fewer chances to iterate than in other public safety professions; thus, the majority of

[23] *National Response Framework*, 48.

professional evolution occurs after genuine disasters. While these events are certainly not welcome, they are more than just tragic—they are also transformative.

The actual work of emergency management usually takes place in one or more of a panoply of distinct facilities and organizations. The types of facilities vary from one organization to another but include agency operations centers, department operations centers, emergency coordination centers, emergency operations centers, joint information centers, joint operations centers, and multi-agency coordination centers. Some of these names represent differences of function while others are simply institutional habits, but of them all, the title emergency operations center (EOC) is the most common.

In every case, however, the practitioners that make up these organizations fill different roles each time, based on the particularities of events that do not match any single, pre-existing structure. In that, they typify many modern teams in that their members work under separations of organization, distance, and time.[24] The Department of Defense captures this complexity well in Joint Publication 3-27, *Homeland Defense*, with the following summary of civilian–military relationships: "Regardless of the size and scope of the particular operations, inevitably they will involve multiple jurisdictions (such as cities, counties, regions, tribes, and states)."[25] Because the events in question defy typical authorities and boundaries, and because relationships necessary for response depend on sustained collective understanding, emergency management is clearly not a solitary activity.

There is thus divergence between permanent, legally autonomous organizations that respond to the most frequent events like car crashes, and the infrequent coordination of numerous agencies across large geographic regions for responses to catastrophic events like earthquakes. This tension between autonomy and coordination is addressed in part through the National Incident Management System (NIMS), which provides "a common,

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[24] Eduardo Salas, Nancy J. Cooke, and Michael A. Rosen, "On Teams, Teamwork, and Team Performance: Discoveries and Developments," *Human Factors: The Journal of the Human Factors and Ergonomics Society* 50, no. 3 (June 2008): 541, https://doi.org/10.1518/001872008X288457.

[25] Joint Chiefs of Staff, *Joint Publication 3-27 Homeland Defense* (Washington D.C.: Department of Defense, 2018), xi.

interoperable approach to sharing resources, coordinating and managing incidents, and communicating information."[26] While practitioners can and do use the methods specified in NIMS to improve responses to events, it "will never be a sufficient tool for governing an entire incident," and cannot address all response failures even in this single area.[27] While NIMS identifies the problem of infrequent and imperfect coordination, it cannot fully resolve that problem.

One reason that the problem of imperfect coordination cannot be fully resolved is that emergency management has a broad, rather than specific, purpose. This is encapsulated by the mandate to address "all threats, hazards, and events" for the relevant government or organization.[28] The type of work may vary depending on the nature of the incident because a direct response agency may exist for particular threats or hazards (e.g., a fire department for a structural fire) but not exist for others (e.g., landslides). Nevertheless, the general approach is to manage the consequences, regardless of the type of precipitating event. This all-hazards mandate requires emergency managers to generalize rather than specialize by maintaining familiarity with public health practices, adverse weather conditions, law enforcement operations, transportation system maintenance, utility infrastructure design, and many other areas. Subject-matter experts in these and other disciplines are critical members of the response, but the core emergency management practitioners organize, prioritize, and facilitate operations among all of them.

B. TEAMS, COORDINATION, AND COMPLEXITY

As described above, emergency management work is performed in teams almost without exception. Rouse, Cannon-Bowers, and Salas present three characteristics of decision making in complex systems that speak directly to emergency management:

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[26] Federal Emergency Management Agency, *National Incident Management System* (Washington D.C.: US Department of Homeland Security, 2017), 1.

[27] Branda Nowell and Toddi Steelman, "Beyond ICS: How Should We Govern Complex Disasters in the United States?," *Journal of Homeland Security and Emergency Management* 16, no. 2 (May 27, 2019): 4, https://doi.org/10.1515/jhsem-2018-0067.

[28] *National Incident Management System*, 2.

- Typically, multi-person teams are involved; thus, overall performance depends on more than just individual performance. . .
- Members of teams have differing roles and responsibilities; consequently communication and coordination are central issues. . .
- Decision making is embedded in an organizational context; therefore, team performance must be consistent with objectives and constraints external to the team.[29]

Based on these characteristics, how those members are organized, how they coordinate, and how they make decisions about their work matter as much as the composition of the team.

Coordination is arguably the most important factor in this environment, but one that has failed to garner much direct attention. For example, though there is no central definition, FEMA repeatedly emphasizes the word "coordination" as either a positive value or a desirable goal in doctrinal documents such as the National Incident Management System (NIMS).[30] Communication is used with similar frequency as coordination in NIMS, but while communicating effectively presents a number of technical challenges, they can be separated. Su's article analyzing coordination during a large emergency management exercise puts the relationship in perspective by assuming that "communication is an adequate proxy for coordination efficacy," such that communication is the channel by which coordination happens.[31] This paradoxical state, wherein coordination is deemed critical but not carefully defined, leaves practitioners without consistent, tested ways to remedy problems that arise. Instead practitioners must (and do) individually solve similar problems over and over and over again, depleting time and attention that could be better used elsewhere.

That paradox becomes more calamity than curiosity when practitioners encounter the difficulty of coordinating among teams as increasing in direct proportion to the

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[29] Rouse, Cannon-Bowers, and Salas, "The Role of Mental Models in Team Performance in Complex Systems," 1296.

[30] "Coordination," is mentioned 102 times on 45 pages, in the 133 page document. Federal Emergency Management Agency, *National Incident Management System*.

[31] Yee San Su, "Application of Social Network Analysis Methods to Quantitatively Assess Exercise Coordination," *Homeland Security Affairs* 7, no. 18 (December 2011): 4.

complexity of event in question. Practitioners and scholars alike have observed the difficulty in achieving coordination even during "routine emergencies," and rarer, larger crisis events exacerbate those challenges.[32] This is borne out in the detailed analyses of events, from the multi-state, multi-phase response to Hurricane Katrina, a simulated "dirty bomb," attack in the national exercise TOPOFF 4, and the Deepwater Horizon response, where in each case agencies that ostensibly shared common objectives could not apply their respective resources with the unity of effort described in NIMS.[33] This, despite the frequent and successful use of communication technologies and even personnel working in the same physical location. Successful coordination is so elusive that achieving it is something of a white hart, the mythical creature that flees from hunters, always remaining just barely in view, for emergency management practitioners, particularly against the background of increased difficulty that is a consequence of more rare, complex events.[34] Coordination is, therefore, an ever-present issue and one that becomes exponentially more difficult as the complexity of the event increases.

While complexity by its very nature is difficult to define, communications networks offer a useful example. Network theory lists the members of a system as nodes, and counts the connections among them, which then allows description of the system as a whole through various metrics.[35] Even small increases in the density of connections among members or the connectedness among nodes themselves, for example, which is analogous to the organization of individuals into teams, causes the network to rapidly increase in complexity.[36] By way of analogy, then, communication and coordination are a challenge for individuals working within an organization, but things are even more difficult at the

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[32] Arnold M Howitt and Herman B. "Dutch" Leonard, "The Novelty of Crises: How to Prepare for the Unexpected," in *The LA Earthquake Sourcebook* (Pasadena, CA: Art Center College of Design, 2009), 212.

[33] Su, "Application of Social Network Analysis Methods to Quantitatively Assess Exercise Coordination," 2; Telfer, "Unlimited Impossibilities: Intelligence Support to the Deepwater Horizon Response," 64.

[34] Nowell and Steelman, "Beyond ICS," 1.

[35] Ted G. Lewis, *Bak's Sand Pile* (Williams, CA: Agile Press, 2011), 79.

[36] Lewis, 113.

scale of teams working with other teams.[37] Complexity is an inescapable effect of this change in scale, but it is one that can be mitigated through a variety of methods, once identified.[38] The increase in complexity and the corresponding need to mitigate it demonstrate the central nature of communication and coordination to team performance in emergency management.

C. SITUATIONAL AWARENESS IS CENTRAL

The first requirement for effectively coordinating among teams of practitioners in emergency management is to understand the incident or event that is the reason for the response in the first place. In order to coordinate actions, emergency management practitioners obtain and disseminate accurate, timely, and relevant information in a constant flow during the incident.[39] The collected processes performed to achieve these results is situational awareness (SA), which Endsley simply defines as "being aware of what is happening around you and understanding what that information means to you now and in the future."[40] The importance of SA in emergency management is more than inferred—it is direct. Both relevant national doctrines make explicit references to the criticality of SA: it is a "principal goal" in NIMS and "critical to . . . interorganizational cooperation" in Joint Publication 3-27.[41] Thus, SA emerges as the primary factor in the success or failure of coordination in emergency management.

The basis of SA in emergency management and public safety is derived from studies in military aviation, and discussions about the subject are often confined to a small number of ideas and sources from that discipline.[42] The most prevalent of these ideas is the

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[37] Eduardo Salas et al., "Situation Awareness in Team Performance: Implications for Measurement and Training," *Human Factors* 37, no. 1 (January 1995): 125.

[38] Federal Emergency Management Agency, *National Incident Management System*, 54; Lewis, *Bak's Sand Pile*, 326.

[39] Federal Emergency Management Agency, *National Incident Management System*, 50.

[40] Endsley and Jones, *Designing for Situation Awareness*, 13.

[41] Federal Emergency Management Agency, *National Incident Management System*, 50; Joint Chiefs of Staff, *Joint Publication 3-27 Homeland Defense*, II–17.

[42] Nofi, *Defining and Measuring Shared Situation Awareness*; Endsley, "Toward a Theory of Situation Awareness in Dynamic Systems."

observe-orient-decide-act (OODA) loop, developed by John Boyd of the U.S. Air Force.[43] Boyd's model is clearly influential—it has been widely applied to fields well beyond the original realm—but it was built to explain how one pilot can defeat another in air-to-air combat.[44] The separation of the steps of observe, orient, and decide, and the loop's culmination in the injunction to act establish a useful—if simplistic—model of SA. That simplicity is one secret of the OODA loop's success, though: even curricula designed for broader applications tend to start with Boyd's concise model and add only a small measure of research.[45] It is certainly true that, for a pilot, surviving a dogfight represents a profound achievement of SA, so Boyd's success with pilots lends weight to the validity of this SA model.

Communication and coordination are important for individual SA, as in Boyd's model, but those become primary activities rather than ancillary ones in a model of team SA.[46] There are a myriad of other desirable characteristics of coordination and communication during an incident—from common terminology to management by objectives—but SA is rooted in "gathering and analyzing operational information" to share it across the organization.[47] While individual responders on a day-to-day emergency tend to gather and analyze for themselves, teams and larger organizations must centralize this activity. This centralization, however, results in one of the classic dilemmas of SA in emergency management. The practitioners gathering the information—and applying the finished products—are separated from those who are analyzing and sharing it. All of the team members must therefore understand SA in the same way for their shared efforts to be effective.

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[43] Azuma, Daily, and Furmanski, "A Review of Time Critical Decision Making Models and Human Cognitive Processes."

[44] Frans P B Osinga, *Science, Strategy and War* (London: Routledge, 2007), 20.

[45] Emergency Management Institute, "Situational Awareness and Common Operating Picture."

[46] Salas, Cooke, and Rosen, "On Teams, Teamwork, and Team Performance," 541.

[47] Federal Emergency Management Agency, *National Incident Management System*, 30.

D. CONCLUSION

It is not surprising that practitioners are just beginning to develop ideas and epistemologies—common philosophies and bodies of knowledge—in emergency management, nor that the discipline's models still require adjustment. In a departure from other public safety fields, the natural state of the work is not at the individual level but rather in teams, often spread across large spans of time, distance, and organization. Furthermore, the primary job of emergency management practitioners is to coordinate information effectively rather than to act instantaneously, another major difference from other public safety disciplines. Though these are challenging activities, applied to sometimes difficult circumstances, they provide extraordinarily rewarding opportunities for growth and learning, and can therefore be, as Solnit says, the avenue by which gifts arrive.

III. THE CURIOUS INCIDENT OF THE DOG IN THE NIGHT-TIME—MISMATCHES BETWEEN MODELS AND ACTIVITIES

> Gregory: Is there any other point to which you would wish to draw my attention?
>
> Holmes: To the curious incident of the dog in the night-time.
>
> Gregory: The dog did nothing in the night-time.
>
> Holmes: That was the curious incident.
>
> —Arthur Conan Doyle, *The Memoirs of Sherlock Holmes*

As shown in the previous chapter, SA is central to the discipline of emergency management. Despite that centrality, however, failures of SA in emergency management and public safety like those noted in Chapters I and II are pervasive and profound. These failures are customarily addressed through a series of (generally valid) individual remedies proposed in after-action reviews and improvement plans. However, one commonality among the series of failures has gone unexamined—the SA model itself. The existing model of SA is entirely silent on how and why these failures occur, limiting remedies to after-the-fact reactions. Thus, a new approach is needed to escape the fog of ignorance.

In order to stop reacting to separate losses of SA as each event occurs, practitioners must first understand how they became disoriented. Bowker and Star provide the first hint of a way out of this fog, with the idea that systems of classification carry forward the cultural artefacts of their creators.[48] These artefacts affect processes built by members of a culture. Because of the underlying differences, those processes will not necessarily match activities of another culture, even if they seem superficially connected. In terms of the way models and theories carry the marks of their origin, Turner and Turner identify the imprints

[48] Geoffrey C. Bowker and Susan Leigh Star, *Sorting Things Out: Classification and Its Consequences* (Cambridge, MA: The MIT Press, 2000), 82.

placed on activities by "cultural context and history (of their development)."[49] Tenney et al. drive home the influence of mental models on SA by drawing an explicit link between those models and the kinds of information incorporated into SA processes.[50] In other words, how a practitioner thinks about a process affects where they direct their attention. In even more concise terms, Martin describes the same phenomenon: "The imagery you employ guides you to ask certain questions and not ask others."[51] Emergency management practitioners can improve response to disaster events with a closer look, not at individual SA failures but at the models and cultural artefacts underneath.

This chapter first describes the most prevalent model of SA used by emergency management practitioners and then contrasts that model (and the environment it grew from) with some contemporary research on the subject. This contemporary research comes from a number of different disciplines, but can be compared with the expanded features of SA models developed here. One reason that practitioners have not already addressed these mismatches (and the problems that result from them) is that the mismatches are only revealed by a notoriously difficult phenomenon to detect: *things that do not happen*.

A. SITUATIONAL AWARENESS MODEL MISMATCHES WITH EMERGENCY MANAGEMENT

Systems carry the cultural artefacts of their origins. Since common SA models are derived from the culture of fighter pilots, those models carry many artefacts from that culture, including a focus on an individual acting alone. As demonstrated in Chapter II, however, most emergency management work involves coordination among teams. This mismatch between the cultural artefacts of the model and the activities they are applied to represents one of the biggest—but far from the only—reasons to examine SA models and identify likely improvements for emergency management.

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[49] Turner and Turner, "Describing Team Work with Activity Theory," 132.

[50] Yvette Tenney et al., *A Principled Approach to the Measurement of Situation Awareness in Commercial Aviation* (Langley, VA: National Aeronautics and Space Administration, 1992), 3.

[51] David Freedman, "New Theory on How the Aggressive Egg Attracts Sperm," *Discover Magazine* (blog), June 1, 1992, http://discovermagazine.com/1992/jun/theaggressiveegg55.

One critical concept is that the partial overlap among members' individual SA, which represents the ideal balance of team SA, is frequently represented by a Venn diagram. Endsley uses a figure like this but follows it by noting that using such a concept does not mean that there is an actual repository of team SA.[52] Klimoski and Mohammed as well as Salas et al. emphasize a similar idea: team SA is a real and distinct concept, but it does not exist except as a result of the interactions of team members' individual SA.[53] In other words, Venn diagrams of individual SA can represent team SA as the overlap among the components, but that overlap does not exist without the individual circles, making team SA both an important concept and an elusive one to study.

One such mismatch is when models developed for individuals do not adequately address many of the challenges of teams. For example, as Klimoski and Mohammed describe, the group can be said to be aware of a problem only when multiple group members know that others are aware of it—not merely when individual members are aware on their own.[54] Carrying this idea further, an individual does not need to worry about the internal consistency of their own SA, but with team SA, it is likely that a single event can produce divergent SA for several team members.[55] This is illustrated in Wendy Becker's case study for the Great Bear Wilderness plane crash, when searchers flying in a helicopter developed interpretations of a flyover that were diametrically opposed from those of search subjects on the ground.[56] Such coordination errors lead to large differences between critical elements of team SA that are not possible for the individual variety and, thus, not accounted for by models based on it.

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[52] Endsley and Jones, *Designing for Situation Awareness*, 197.

[53] Salas et al., "Situation Awareness in Team Performance: Implications for Measurement and Training," 131; Richard Klimoski and Susan Mohammed, "Team Mental Model: Construct or Metaphor?" *Journal of Management* 20, no. 2 (1994): 426.

[54] Richard Klimoski and Susan Mohammed, "Team Mental Model: Construct or Metaphor?" *Journal of Management* 20, no. 2 (1994): 422.

[55] Mustafa Canan and Andres Sousa-Poza, "Pragmatic Idealism: Towards a Probabilistic Framework of Shared Awareness in Complex Situations," in *2019 IEEE Conference on Cognitive and Computational Aspects of Situation Management (CogSIMA)*, Las Vegas, NV, USA: IEEE, 2019), 1, https://doi.org/10.1109/COGSIMA.2019.8724208.

[56] Becker, "Missed Opportunities," 369.

Another cultural artefact of the current SA model is an emphasis on information used by pilots, which is available through direct observation by sight, hearing, and proprioception. These sources of information stand in contrast to those used in emergency management, which are obtained through proxies such as remote instrumentation or communication with team members. This mismatch leads directly to a series of superficial remedies found in after-action reviews, because the two types of information are received and understood very differently.

In total, the solutions that work for an individual immersed in an environment are very different from the solutions that work for teams of emergency management practitioners cloistered in EOCs. Endsley notes that attempts to cure the multiplying number of contexts through conventional solutions may be worse than the disease: "Our response to this has been more procedures and more systems, but I'm afraid we only add to the complexity of the system in the process."[57] When practitioners obtain information by proxy, removed from its original setting, using that information to develop SA requires placing it within the necessary context for others who are similarly removed; this is quite distinct from an individual practitioner working directly to gain all the information that they require for themselves.

The final mismatch from a cultural artefact presumes a clear understanding of the nature of the situation when ambiguity often clouds the nature and pace of events. For a pilot sitting in the cockpit of a plane, there is one activity that clearly requires their attention, and the information required to develop SA about it is well-articulated. As challenging as flying a plane is, and as much as the presence of enemy aircraft may complicate that flying, the necessary actions are clear and the desired outcomes even more so. None of that applies to emergency management, as the complete nature of the event is only discernable after the event itself has concluded. For example, whether an earthquake that just happened was the main shock or the foreshock of an even larger quake is apparent only in retrospect. The determination comes either after the larger quake occurred, or after

[57] Mica R Endsley, "The Challenge of the Information Age: Designing for Situation Awareness in Complex Systems" (Second International Workshop on Symbiosis of Humans, Artifacts, and Environment, Kyoto, Japan, 2001), 3.

a long period of uncertainty (several days, in some cases) has elapsed.[58] Those two cases represent vastly different environments for emergency management practitioners to operate in, with correspondingly vast differences in SA requirements, but the existing SA model does not account for the problem at all.

These mismatches, resulting from cultural artefacts, represent a few facets of the problem with the existing SA model. As they are only dimly observed, however, more work will be needed to identify how to remedy them. Much of that work already exists in scholarly research even if not in practical application, but it needs to be analyzed for themes, then compared with similar elements of SA models in order to deliver improvement.

B. REFINING SITUATIONAL AWARENESS MODELS—FIRST STEPS

Improvements to SA models need not be baroque—some are effective but simple. In a key insight, Mica Endsley describes three levels of SA—perception, comprehension, and projection. These levels lend more precision to the model, which allows closer analysis of its elements, building on the generally cyclical OODA loop without contradicting it. Mohammed, Ferzandi, and Hamilton's presentation reinforces this description: they summarize the levels as "descriptive," "procedural," and "strategic."[59] Rouse, Cannon-Bowers, and Salas further reinforce that description through their use of "what," "how," and "why" questions to denote SA levels.[60] In fact, they are even similar to Boyd's steps of "observe," "orient," and "decide," but that similarity goes unmentioned in any application of SA. The prevalence of these three levels across different researchers indicates that further analysis of them is likely to be fruitful—unfortunately the levels are absent from emergency management doctrine and training, and go unmentioned in case

[58] United States Geological Survey, "What Is the Probability That an Earthquake Is a Foreshock to a Larger Earthquake?" USGS Natural Hazard FAQ, accessed February 9, 2020, https://www.usgs.gov/faqs/what-probability-earthquake-a-foreshock-a-larger-earthquake?qt-news_science_products=0#qt-news_science_products.

[59] Mohammed, Ferzandi, and Hamilton, "Metaphor No More," 880.

[60] Rouse, Cannon-Bowers, and Salas, "The Role of Mental Models in Team Performance in Complex Systems," 1300.

studies and after-action reports. Figure 1 summarizes the levels as described by each of these authors.

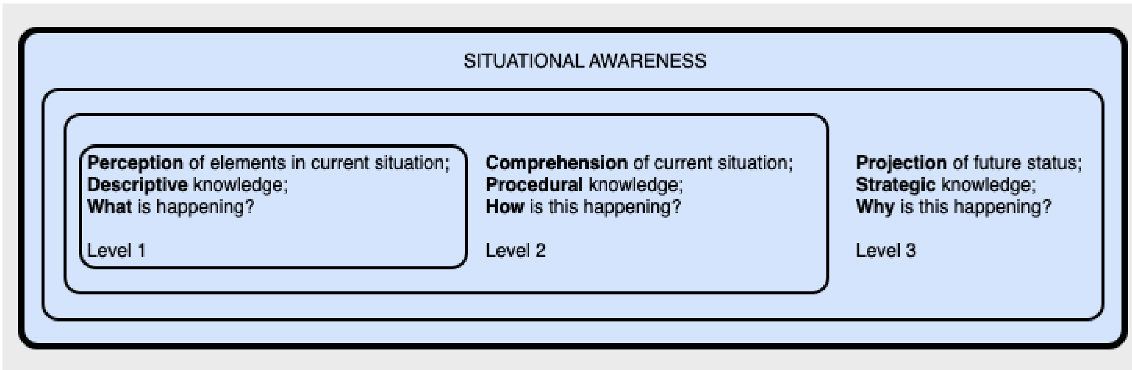

Figure 1. Comparing Three Descriptions of SA Levels[61]

These levels afford an opportunity to examine SA for a variety of settings. Pilots immersed in their environment may rely on direct observation of the view from their canopy and instruments in the cockpit, leading to an emphasis on the first level of SA (perception, descriptive knowledge, "what is happening," or observing). In the case of Boyd's pilot and direct response professions such as firefighting, the objects requiring attention are obvious conceptually and visually.[62] In the environment of emergency management teams, however, members perceive little first-hand information, instead processing nearly everything through indirect observation. Only a few members of the team observe the event directly from the scene, far more work at incident command posts and emergency operations centers, removed—by design—from the affected area.

Meanwhile, the analogous environment for emergency management is the EOC—generally a carefully controlled space far from the event. This environment requires that

[61] Adapted from Endsley, "Toward a Theory of Situation Awareness in Dynamic Systems"; Rouse, Cannon-Bowers, and Salas, "The Role of Mental Models in Team Performance in Complex Systems"; Mohammed, Ferzandi, and Hamilton, "Metaphor No More."

[62] "S-130 Firefighter Training Module 4: Potential Hazards and Human Factors on the Fireline" (Boise, ID: National Wildfire Coordinating Group, 2008), 4; Jonathan Anderson, "Focus on Training: Developing Situational Awareness as a Community-Engagement Initiative," *FBI: Law Enforcement Bulletin* (blog), July 12, 2018, https://leb.fbi.gov/articles/focus/focus-on-training-developing-situational-awareness-as-a-community-engagement-initiative.

all information accessed by practitioners be accessed remotely. For example, during a volcanic eruption, remote sensing is critical, including seismometers, satellites, and remote cameras; direct observation of the event is extremely hazardous and does not provide a complete picture. None of the most familiar physical gestures, cognitive strategies, or intuitions are applicable to distant sensors and their information. The number of sensors practitioners need to monitor is not limited by physical space, the most important ones are not placed preferentially, and no criteria besides the sensor value itself may attract the practitioner's attention. Developing SA while separated by indirect perception requires different processes from those of direct observation.

This proliferation of processes carries additional consequences, however, because to understand which data sources to devote attention to first requires the application of a mental model. In other words, the separation necessary for the work to take place introduces ambiguity into the mental models of the workers. Rather than calling attention to a single object or event that everyone can see, the indirect nature of the information creates a number of possible interpretations.[63] This ambiguity is different from ignorance and reflects another disadvantage of the existing SA model: it cannot resolve differences in conflicting ideas of SA, either for an individual or among members of a team.

Monitoring events at a distance requires a comparison to specific ideas about the sequence and mechanisms of those events. Continuing with a previous example, there are several different types of volcanoes, and each is capable of producing a wide variety of eruptions. It is critical to responses to know that shield volcanoes, such as those in Hawai'i, rarely produce large explosions, but stratovolcanoes, such as those in Italy, frequently do. Even for a single individual, the level of orientation, comprehension, or procedural information, or the answer to "how is this happening," will depend on the particular interpretation selected. This process is complicated enough for a single individual, but as previously discussed, most emergency management practitioners work in teams, which increases the complexity of the problem of achieving consistent schemas.

[63] Weick, *Sensemaking in Organizations*, 27.

For the third level of SA, the sharpest distinction exists between Boyd's process and that described by other researchers: his injunction to "decide" differs markedly from the language used by other scholars. The bias toward action contrasts the other descriptions of this level, each of which emphasizes knowledge and context (comprehension, strategic knowledge, and the question "why is this happening?"). While it is true that "natural decision environments can be turbulent, with time-varying goals and requirements," this description from Rouse, Canon-Bowers, and Salas continues to say that "such environments often require the coordinated effort of a team of individuals operating within an organizational context."[64] Emergency management is an environment where the relevance and significance of information depends on relationships among various pieces of information. Salas, Cooke, and Rosen assess that practitioners "must integrate, synthesize, and share information; and they need to coordinate and cooperate as task demands shift throughout a performance episode to accomplish their mission."[65] Placing emphasis on these disparate areas requires a much different model for SA.

The sheer variety of potential eruptions means that different volcanoes require different interpretations of data. For example, an episode where seismographs show bursts of activity followed by longer quiet periods is unlikely to require immediate action on the part of the emergency management practitioner. It does require them to place that information in context, recognize its importance (or lack thereof), contact various stakeholders, and establish shared and individual responsibilities as needed. This complexity is obscured by the existing model of SA, which implies that the response should be decisive.

While the inclusion of these levels is a relatively minor adjustment to the SA model, it is possible to see how even that introduces the possibility of a model that fits better with emergency management. This is not to say that the OODA loop is wrong or outmoded, but rather that it should be the beginning of the conversation rather than the end. There is a

[64] Rouse, Cannon-Bowers, and Salas, "The Role of Mental Models in Team Performance in Complex Systems," 1296.

[65] Tenney et al., *A Principled Approach to the Measurement of Situation Awareness in Commercial Aviation*, 6; Salas, Cooke, and Rosen, "On Teams, Teamwork, and Team Performance," 541.

great deal more research, and a number of other concepts that can bring even more benefits to such a critical area of public safety.

C. INFORMATION PROCESSING THEORY AND ACTIVITY THEORY

Two theories that afford structures similar to those seen in SA are information processing theory and activity theory, and they both provide a level of analysis that may be useful in studying the activities of emergency management. Each of these theories is also designed to study communication and coordination as specific activities and, thus, may be relevant to a detailed examination of emergency management.[66] This section summarizes these theories briefly and provides points of comparison with elements of the SA model that have emerged thus far.

Information processing theory comes from a different background from the study of SA but arrives at some similar descriptions of processes. Though it is a model that is "a collection of different perspectives," information processing theory has a clear similarity to SA when described as "a metatheoretical foundation for understanding how individuals perform intellectual tasks…"[67] Information processing theory and SA activities both encompass, in Hinsz's words, "higher-order cognitive processes based on complex, emergent, dynamic, and profuse information."[68] Hinsz also notes congruence between individual and group activity in that "the same set of processes that may occur for individuals are *conceptually* involved in the information processing by group," an approach that is similar to SA. Information processing theory thus provides another way to examine group processes of emergency management practitioners to improve them.

The three levels of SA demonstrated in Chapter II align neatly with information processing theory. The first step of information processing theory, acquisition, fits with the first level of SA, perception, as both deal with "information [that] comes to the group from

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[66] Turner and Turner, "Describing Team Work with Activity Theory," 130.

[67] Hinsz, "A Groups-as-Information-Processors Perspective for Technological Support of Intellectual Teamwork," 25; Endsley and Jones, *Designing for Situation Awareness*, 28.

[68] Hinsz, "A Groups-as-Information-Processors Perspective for Technological Support of Intellectual Teamwork," 23.

the environment."[69] The second level of information processing, attention and encoding, correlates with the second level of SA, comprehension. The second-level information-processing concepts involve "how the information is structured, interpreted, and given meaning in the group."[70] Because levels are very close in function between information processing theory and SA, the former is likely to be useful to emergency management practitioners in assessing their own activities.

Moving into the deeper steps of information processing theory, one difference—albeit a minor one—emerges between it and SA. Information processing theory does not explicitly address the SA level of projection, involving "the ability to predict what … elements will do in the future."[71] This omission is notable even though information processing theory as a whole is clearly situated in a progression through time.

Information processing theory and SA once again converge with the next step, however. Hinsz's description is separated into constituent activities that may not correlate exactly with the SA model, but still shares common features with it.[72] Though Endsley's detailed model of SA departs from the three levels described earlier in the chapter, it does include direct references to "information processing." Hinsz's next step is "memory," which he then subdivides into "storage" and "retrieval," indicating that this includes technological storage as well as biological memory.[73] Though Endsley uses only a single designation for "long-term memory stores," she also identifies a technological component closely related to Hinsz's description. Ultimately, the processes described by information processing theory differs slightly from studies of SA, but the similarities are numerous and relevant. Information processing theory is, therefore, valuable in developing a new model of SA.

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[69] Hinsz, 28.

[70] Hinsz, 30.

[71] Endsley and Jones, *Designing for Situation Awareness*, 18.

[72] Endsley and Jones, 25.

[73] Hinsz, "A Groups-as-Information-Processors Perspective for Technological Support of Intellectual Teamwork," 31.

Another candidate, activity theory, provides a rough but useful method for analyzing team cognition. General descriptions of activity theory also show similarities with SA. For example, Brown, Greenspan, and Biddle describe their research as an "approach to improving attention allocation and collaboration in operations and command centers."[74] Similarly, Turner and Turner describe "tasks involv[ing] the coordination of representational states, both internal and external, whereby multiple representations are combined, compared, derived from each other or made to correspond."[75] These descriptions closely match those of SA activities provided by Endsley and others.

Activity theory allows analysis at a variety of levels of detail, but the most applicable to SA models is the examination of a single activity. Brown, Greenspan, and Biddle define activities as "systems of interrelated parts that adapt and change in response to any one of its elements changing."[76] Specifically, Turner and Turner describe an activity as interactions among three points of a triangle: the subject (which can be either an individual or a group), the object (the purpose—analogous to goals or objectives in descriptions of SA), and artefacts (any tools or representations used in the activity). Other points can be added, expanding the size and complexity of the analysis (and of the triangle), but those additional points would only be relevant with a careful application of activity theory to a case study of SA activity.

This theory provides a flexibility and a depth that match SA models well. To continue describing the general framework, the connecting lines of the triangle are "individual actions… each directed at achieving a particular goal mediated by the use of an artefact."[77] These individual actions are also potential sites for disturbances or contradictions, which inhibit the performance of the activity. Disturbances, according to

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[74] Brown, Greenspan, and Biddle, "Complex Activities in an Operations Center: A Case Study and Model for Engineering Interaction," 266.

[75] Turner and Turner, "Describing Team Work with Activity Theory," 128.

[76] Brown, Greenspan, and Biddle, "Complex Activities in an Operations Center: A Case Study and Model for Engineering Interaction," 266.

[77] Turner and Turner, "Describing Team Work with Activity Theory," 129.

Brown, Greenspan, and Biddle, are "disruptions to the free flow of an activity."[78] Contradictions, a similar concept used by Turner and Turner "can be understood in terms of breakdowns between actions or sets of actions which realise the activity."[79] The generality in a theory with such flexible definitions is central to its usefulness—the structure and work of emergency management teams is very similar to those described by these authors in their case studies.

D. CONCLUSIONS

This chapter has demonstrated the mismatches between SA models and emergency management activity and the nature of team SA as distinct from individual SA. The chapter also provided an overview of scholarly research—including information processing theory and activity theory—that could be useful if systematically applied to the study of SA in emergency management. Each of these theories provides a method for identifying specific malfunctions in the development of SA.

Being able to analyze SA activities according to some of these principles would allow not only basic improvements through deliberate design but also better improvements after failures noted during exercises or events. Such analysis would require additional effort, but it would address many failures that are currently noted but not classified. The ability of these theories to incorporate complexity beyond the immediate elements of an activity is also valuable—there are several elements that affect SA that have not yet been identified because they exist outside the SA processes themselves.

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[78] Brown, Greenspan, and Biddle, "Complex Activities in an Operations Center: A Case Study and Model for Engineering Interaction," 267.

[79] Turner and Turner, "Describing Team Work with Activity Theory," 130.

IV. SPECULUM MUNDI—SITUATIONAL AWARENESS AS A MIRROR OF THE WORLD

> In order for there to be a mirror of the world, it is necessary that the world have a form.
>
> —Umberto Eco, *The Name of the Rose*

If a hiker is reported missing in Crater Lake National Park, search and rescue mission coordinators use topographical maps, physical evidence, and behavioral statistics to establish a list of potential search segments where the subject might be found. The coordinator then rates each segment with a probability that the subject is there to assign teams efficiently and track the search methodically. Because the subject might not be in any of the search areas at all, but instead located somewhere entirely unexpected, the search coordinator can assign a probability to that option as well. The term used to identify that probability is the "rest of the world." In the Crater Lake example, the subject may not be there at all, but may be visiting a cousin in Cleveland. Though events in the rest of the world are outside the search segments, they certainly affect the outcome of how those segments are drawn and what happens inside them.

The concept that things external to the process affect the outcome of the process itself appears in much of the SA research but is rarely if ever described by practitioners. This chapter examines such rest-of-the-world factors to reveal their influences on the SA model and its applications. Even if we cannot understand the form of the world, we can still identify the parts of it that affect us.

A. GOALS AND REQUIREMENTS

The axiom that "no two disasters are alike" is no less accurate for being common: a town can suffer spring floods two years in a row, but the impacts of the flood will be different each time. In a similar fashion, goals during responses to these events vary from one to another. In general, most emergency management and public safety organizations use the same three overall incident priorities, regardless of the event. Those priorities are customarily listed as life safety, property and environmental conservation, and incident stabilization, in that order. While the overall priorities may remain consistent, more specific goals will be different not only from a flood to a fire, but from one fire to the next, and conditions evolve even within operational periods (e.g., day shift to night shift) of a single event. Though these priorities have been parceled out among different organizational schemes at various times, they have remained well-established for many years—the fundamentals things apply.

Generally, in emergency management, elected or appointed officials exert influence by setting strategic goals, such as "establish mass care shelters for the flooded town," within those three overall priorities. The officials' primary involvement in SA for emergency management is this strategic goal setting, since practitioners near the scene of an event typically make operational and tactical choices that drive the SA process at those levels. Those operational and tactical choices develop into incident objectives, which are specific and measurable goals, usually set to be accomplished within a narrow timeframe.[80] Incident objectives occur within the framework set by the elected and appointed officials' strategic decisions, however, so the influence generally flows in only one direction.

Even though those goals exist outside the process, they drive a great deal of what happens within it. Endsley defines goals as "higher-order objectives essential to successful job performance."[81] While Endsley expands on goals at some length, it suffices to say that goals "help determine which environmental elements to pay attention to" in top-down (goal-driven) information processing.[82] Endsley's description of goals aligns with the emergency management definition of incident objectives, even though those objectives consist of more specific parameters than her examples. However, both emergency management objectives and Endsley's goals influence the SA processes. In that way, goals drive the organizational response to the event and affect the behavior of all of the members of that organization, including their SA activities.

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[80] Federal Emergency Management Agency, *National Incident Management System*, 21.

[81] Endsley and Jones, *Designing for Situation Awareness*, 68.

[82] Endsley and Jones, 68.

Goals and objectives, no matter how specific, cannot provide the only direction for emergency management, given the dynamic and uncertain nature of the events themselves. Often, practitioners in the field detect information that changes the course of the response, necessitating a modification of previous incident objectives—this is a form of bottom-up (data-driven) processing. For example, if wildland firefighters are conducting a survey by airplane to determine the extent of a fire and they observe a car crash on the road below, they will act in response to the car crash even though it was unrelated to their original goal. Endlsey contrasts top-down (goal-driven) information processing to bottom-up (data-driven) processing that occurs when "information 'catches' a person's attention," based on cues that indicate something important to the practitioner.[83] In fact, most activity involves switching between goal-driven and data-driven processing, and emergency management is no exception.

The tension between goal-driven and data-driven processes is part of the challenge in setting goals for SA processes. Too much regard for goals will cause emerging conditions to be overlooked while too little regard for them leads to a lack of coordination—and SA—across the agency. Since emergency management teams are separated by so many factors (e.g., time, distance, and organization), as described in earlier chapters, goals for each event are one of a small number of unifying factors.

Sharing goals across an organization is no mean task, as team SA is contingent on so many subjective individual SA states. Thus, while officials may feel that they have clearly articulated their priorities to the entire organization, that clarity cannot be taken for granted. Using examples from military and intelligence organizations working in civilian emergency management, Jennifer Sovada demonstrates that a lack of clarity and unity around goals and objectives can hinder all efforts and lead to resources being underutilized and opportunities lost.[84] Mark Lowenthal also explores this problem at some length in discussing the balance between priorities set by policymakers and information gathered by

[83] Endsley and Jones, 25.

[84] Lowenthal, *Intelligence: From Secrets to Policy*, 75; Jennifer P. Sovada, "Intelligence, Surveillance, and Reconnaissance Support to Humanitarian Relief Operations within the United States: Where Everyone Is in Charge:" (Fort Belvoir, VA, Defense Technical Information Center, 2008), 5, https://doi.org/10.21236/ADA484333.

intelligence agencies.[85] Though Lowenthal's terms are slightly different from Endsley's, the problems are analogous to the tension between goal-driven and data-driven activities. These problems arise from multiple sources: the first is a failure to develop SA from the beginning, owing to a lack of understanding of what goals to focus on. The second source is an inability to propagate SA across the organization because of leaders' inability or unwillingness to share information and coordinate activity that could affect the goals that they have set. But since goals are not included in the existing SA model at all, those hindrances are not examined as a part of that process.

Requirements, as a subunit of goals, are the manifestation of data-driven information processing but are rarely if ever examined in the current SA model. Endsley defines requirements as she describes how to enumerate them when interviewing practitioners: "tak[ing] each decision in turn and identify[ing] all the information the operator needs to make that decision."[86] Requirements are more closely tied to SA because practitioners, not officials, set them. Because practitioners derive requirements based on goals and because there is so much variability among events, ensuring that all team members understand requirements consistently is critical to team SA. The parameters of a requirement can turn on nuances: for example, during a flood, the actual numerical value of a river gauge may be less important than the change in that value over 24 hours. Therefore, some effort is necessary to determine exactly what information is needed and in what form, but again, requirements are rarely if ever examined as general features of the SA model, as opposed to specific values recorded accurately or inaccurately.

B. DEFINITIONS, BOUNDARIES, AND NORMALCY

Sometimes, the most influential aspects of a thing are the conditions that define it in the first place: the very useful and detailed documents known as Natural Hazard Mitigation Plans, which represent a compendious knowledge of natural hazards, completely omit human-caused hazards by design, and thus are very far from a complete picture of risk. Unfortunately, those conditions and the resulting definitions are rarely

[85] Lowenthal, *Intelligence: From Secrets to Policy*, 76.

[86] Endsley and Jones, *Designing for Situation Awareness*, 72.

examined once the thing has been built. These definitions are, however, a part of the world that influences SA processes from the outside. Definitions of various elements—such as how a tornado differs from a derecho—affect SA models when they are created or adopted but are not themselves identified or examined.

Geographic administrative boundaries may be the most influential group of definitions in emergency management, and they illustrate the effect that such elements have on SA processes after they are drawn. Emergency management is often organized based on these definitions such that a government may have a mandate to respond only to events that occur within its administrative boundaries (e.g., national borders). One difficulty presented by this organizational principle is that, as Chapter III has shown, no classification system is without biases and artefacts. Indeed, the dominant group (e.g., the U.S. government) draws definitions—most certainly including national boundaries—for some specific purpose, but those boundaries may have secondary effects on other involved communities (e.g., tribal nations).[87] In this case, what are barely perceptible secondary effects to the dominant culture cause tremendous impacts on involved communities, such as the Akwesasne Mohawk whose territory includes portions of the state of New York and the Canadian provinces of Quebec and Ontario.[88] With community members, facilities, and licensed healthcare providers in three different states and provinces of two separate countries, the Akwesasne Mohawk must be aware of the border in a way that non-natives need not. These impacts show the complicated nature of definitions and how, even when they seem straightforward to their designers, they can profoundly affect emergency management, which by its very nature deals only in exceptions.

In a further complicating circumstance, situational awareness may depend on information gained from outside the administrative boundaries, however carefully they are defined. For example, a volcano may be hundreds of kilometers away from a city, but an eruption from that volcano is still capable of directly affecting the city. Those direct effects

[87] Rachel Rose Starks, Jen McCormack, and Stephen Cornell, *Native Nations and U.S. Borders: Challenges to Indigenous Culture, Citizenship, and Security* (Tuscon, AZ: Native Nations Institute for Leadership, Management, and Policy, 2014), 26, http://www.tandfonline.com/doi/full/10.1080/14649365.2013.806759.

[88] Starks, McCormack, and Cornell, 15.

necessitate that emergency management practitioners include the distant volcano as a part of their SA process. Perhaps the most famous example of this need to maintain SA outside the usual boundaries was the 2010 eruption of Eyjafjallajökull.[89] Though the volcano is located in Iceland, the ash plume it produced over ten days, coupled with the complex nature of the world air traffic control system, caused the cancellation of more than 100,000 flights with millions of passengers from dozens of countries across Europe and Asia.[90] This event demonstrates that relevant SA for emergency management practitioners does not depend solely on information gathered from within the geographic boundaries of a city or a nation but, instead, requires examining the definition to improve the SA model. Military practitioners at least identify this disparity, although they do not completely address it, by differentiating between the concepts of operational area and area of interest. Even this distinction does not reveal much about how to draw the boundaries of the two, nor would it have accounted for the volcano prior to its eruption. [91] The dangers of treating definitions as exact and complete are very real, particularly in work that requires coordination within complex systems.

Defining other natural hazards is also challenging in a variety of ways, given the wide variation in environmental conditions from one climate region to another and throughout a year. Basing definitions of events on quantitative data is more precise than relying on anecdotal descriptions. To illustrate, weather forecasters consistently issue forecasts for flooding and storm surges like those New York City suffered during Superstorm Sandy in 2012 when they can measure precipitation precisely and compare it with multi-decade averages. This precise comparison frees emergency management practitioners to engage only their resource-intensive SA process for events that are likely to damage the human environment. Practitioners in a coastal city such as New York can

[89] “Iceland’s Volcanic Eruption And Its Aftermath,” NPR.org, April 22, 2010, https://www.npr.org/series/126106506/iceland-s-volcanic-eruption-and-its-aftermath.

[90] Bente Lilja Bye, “Volcanic Eruptions: Science And Risk Management,” Science 2.0, May 27, 2011, https://www.science20.com/planetbye/volcanic_eruptions_science_and_risk_management-79456.

[91] Joint Chiefs of Staff, *Joint Publication 5-0 Joint Planning* (Washington D.C.: Department of Defense, 2017), A-2.

then establish the requirements for each particular point on the coastline for what water levels represent dangerous flooding from storm surge events.

This challenge of establishing a precise value amongst so much noisy variation is only part of the story, however. The very multi-decade techniques that forecasters have used to improve precision also confine them to the range of events they have observed in that period. Using those long-baseline averages provides some relief from this confinement, but that relief is proving to be short-lived as climate change challenges many of the previously settled definitions. Forecasters now predict that events that were previously classified as “1 percent” floods for New York City, for example, now have more than a 5 percent chance of occurring any year.[92] Terminology is at fault here, too: the better-known term “hundred-year floods” has never been accurate and is rapidly becoming less so. But the problem is not just one of language: while the actual numbers are small, the change from 1 to 5 percent represents a tremendous increase in the frequency of flooding. Emergency management practitioners must also change the definition of which events they choose to engage the SA process for. The definition of a single type of emergency requires modification, but practitioners need to evaluate the models of entire classes of natural hazards as a result of this dramatic change in a short period.

Part of the models for these classes of hazards involves not just monitoring for when things become abnormal but defining “normal” in the first place. Emergency management practitioners depend on shared definitions of normal for the actual elements that comprise an event to develop SA. To return to volcanoes, for example, whether or not a volcano is erupting depends a great deal on which volcano is under discussion. Kilauea on Hawai`i Island erupted continuously from 1983 to 2018; with the exception of a few short periods when lava flows destroyed several dozen homes, most of these eruptions had little impact on the communities nearby. Residents and emergency management practitioners alike accepted them as part of the normal environment. By contrast, Mount Hood in Oregon is a volcano that has not erupted since the late 18th century and may indeed be better known

[92] Ning Lin et al., “Physically Based Assessment of Hurricane Surge Threat under Climate Change,” *Nature Climate Change* 2, no. 6 (June 2012): 466, https://doi.org/10.1038/nclimate1389.

for snow than for lava. In the intervening two hundred years, communities (and emergency management practitioners) have not experienced anything but quiet around Mount Hood, so even small indications of activity provoke a great deal of fear and uncertainty. Thus, even though the general class of hazard is the same, there is tremendous variation in the definition of a given level of activity, such as "quiet," and what that definition means to emergency management practitioners in the context of SA processes.

Whether emergency management practitioners pay attention to a particular event (or choose not to) varies widely depending on the definitions surrounding the event. These choices about definitions align most closely with Level 1 of the emerging SA model—perceptive, descriptive, "what is" knowledge. Definitions have a profound effect on SA not only at that level but throughout the entire model.

C. MENTAL MODELS AND SCHEMATA

In the multi-hazard world of emergency management, knowledge across many disciplines is necessary, and practitioners require accurate descriptions of events to effectively develop SA processes around them. These descriptions are more than just definitions that provide the bare bones of an idea; rather, they are "a systematic understanding of how something works."[93] These understandings form essential pieces of the SA process, but even with clarity of definitions, there is still uncertainty around the type of event and the progress of the particular event as compared with others of its type. Even in the fairly simple case of volcanoes, striking differences between shield volcanoes, stratovolcanoes, or any of the several other types exist. An understanding about a variety of types of one element of the SA model—in this case, the particular hazard of volcanoes—is yet another factor that exists outside the model.

Distinguishing among the members of this topic becomes challenging because many of them are very similar in their qualities. Definitions, as described in the previous section, are single elements that combine to make up mental models and schemata. They may be descriptive or quantitative, but they are relatively simple, individual elements.

[93] Endsley and Jones, *Designing for Situation Awareness*, 22.

Mental models, as used here, mean an understanding of how an object or system works. Mental models cover a single topic such as "how volcanoes erupt." Since they operate at a systematic level, one model may contain more detail than another, but they are general rather than event-specific. In contrast, schemata represent a practitioners' specific understanding of how a particular object or system is working at a given moment. Because they are situation-specific, they may be more detailed than the relevant mental model—in other words, a schema would cover a topic such as "how Kilauea erupted in summer 2018." Various scholars apply the terms mental model and schema in slightly different ways, some of them overlapping, but the conceptual distinctions between those elements are well-established in each case.

Endsley uses the extended metaphor of an auto mechanic to illustrate the function of (and difference between) mental models and schemata:

> An auto mechanic listens to a car and makes various observations or tests when it is brought in for service. He uses his mental model of how the car (based on the year, make, model, etc.) should sound, feel, and behave to interpret what he hears and sees and to direct what he should examine. When he hears something amiss (perhaps a whine, or a clinking), the schema (linked to the mental model) that best matches that cue is activated. This schema provides a classification for the situation that allows him to correctly understand why the car is making that particular noise, its origin, and its impact on the proper functioning and safety of the vehicle (Level 2 SA) and what is likely to happen if the car continues to be driven (Level 3 SA).[94]

Both of these concepts are important in SA in emergency management because their distinct functions affect the overall process in different ways.

As Endsley notes above, mental models and schemata intermingle in their definition and in their application, so drawing distinctions between them is challenging. Emergency management practitioners from Hawai`i and Oregon can share a common mental model of volcanoes, but they may have very different schemata for how an active volcano behaves. This disparity is all the more important because mental models and schemata affect two levels of SA: level 2 (comprehension, procedural, "how is"

[94] Endsley and Jones, 23.

knowledge) and level 3 (projection, strategic, "why is" knowledge). Furthermore, with the multifarious challenges of measuring SA, differences in mental models and schemata can make it even more difficult to distinguish among practitioners with widely varying SA at those levels.

Mental models and schemata are also important in the context of team SA. As shown in Chapter III, team SA is a complicated subject in its own right. Moreover, as Mohammed, Ferzandi, and Hamilton note, there is a difference between similarity the of mental models and the accuracy of them. In fact, those scholars were even more specific about the possibility of a range of mental models: "Rather than assume that there is a single, correct model, ... the concept of equifinality... suggest[s] that there may be 'multiple equally good yet different mental models.'"[95] This topic relates not only to the discussions of team SA in Chapter III but also to the navigational quotes at the beginning of chapter I. Thus, as with other aspects of SA models, mental models and schemata are important to add to a discussion of individuals but absolutely necessary for teams in emergency management.

D. INFORMATION AND KNOWLEDGE

Creating definitions requires knowledge about the subject, and knowledge itself is composed of many separate types. Types of knowledge thus propagate throughout any system from its inception. In the case of SA models, the types of knowledge involved include tacit and explicit knowledge. Explicit knowledge is a plain, factual domain, characterized as "what is" knowledge; tacit knowledge, meanwhile, is a more obscure realm generally learned through practice, characterized as "how to" knowledge.[96] Within the context of SA models, there is a strong connection between those two types of knowledge and SA.[97] Both types are deeply involved, despite explicit knowledge (and

[95] Mohammed, Ferzandi, and Hamilton, "Metaphor No More," 889.

[96] Richard Adler, "Knowledge Engines for Critical Decision Support," in *Gaming and Simulations: Concepts, Methodologies, Tools and Applications* (Hershey, PA, USA: Information Resources Management Association, 2010), 1935, https://doi.org/10.4018/978-1-60960-195-9.ch803.

[97] Julia C. Lo et al., "Explicit or Implicit Situation Awareness? Measuring the Situation Awareness of Train Traffic Controllers," *Transportation Research Part F: Traffic Psychology and Behaviour* 43 (November 2016): 326, https://doi.org/10.1016/j.trf.2016.09.006.

other elements derived from it) being much easier to measure.[98] As with other emerging elements of SA models, these types of knowledge are omnipresent but rarely, if ever, acknowledged by practitioners.

One example of a potential improvement to SA models is a recognition that the proportion of the two types of knowledge varies widely from one individual to another, depending on training and experience. The highly individual nature of these kinds of knowledge can prove fertile soil for confusion.[99] Two team members, for example, may read a report of evacuations in the Oregon towns of "Bend" and "North Bend," but only one of those team members realizes that the towns in question are located more than a hundred miles apart and are not, as the names might imply, adjacent to each other. For one team member, that knowledge is tacit and internalized, but for another, it is explicit and available only if sought. The resulting difference in SA is dramatic, however.

When considering the varied nature of mental models, knowledge becomes even more complex. There are many correct ways to achieve SA, and one of the ways that they differ is in the knowledge required. For example, in European celestial navigation, the elements of knowledge include complex writing systems and trigonometric calculations, a precise measurement of clock time, and detailed numerical descriptions of the position of the sun. In traditional Polynesian navigation, however, none of those are relevant: instead, the types and behaviors of birds, the feel of waves under the ship, and the taste of the seawater are critical. Thus, while the types of knowledge involved can shape the SA model, the reverse is also true: the SA model can shape the type of knowledge involved. This problem of reciprocal influence can make a comparison between different models and different knowledge types extremely difficult, but it remains necessary to establish SA across the team.

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[98] Iris Reychav and Jacob Weisberg, "Good for Workers, Good for Companies: How Knowledge Sharing Benefits Individual Employees," *Knowledge and Process Management* 16, no. 4 (October 2009): 187, https://doi.org/10.1002/kpm.335.

[99] Lo et al., "Explicit or Implicit Situation Awareness?" 326.

E. CONCLUSIONS

As challenging as the problems intrinsic to SA are, factors outside the SA process itself—in the rest-of-the-world, as it were—nonetheless exert very strong influences over that process and the SA models that underlie it. These factors include goals set by organizational leaders, definitions of the environment and activities that SA is applied to, and even the types of knowledge used to build those definitions. The relative importance of these factors may vary from one event to the next, or even from one team to the next, but they are all germane to the overall SA model, and none of them is accounted for in existing descriptions of that model. Though the form of the world remains obscure, we can still make some sense of our circumstances by improving that model.

V. THE WAR AGAINST THE IMAGINATION—CONCLUSIONS AND FURTHER RESEARCH

> The only war is the war against the imagination. All other wars are subsumed in it.
>
> —Diane di Prima

> E lauhoe mai na wa'a; i ke ka, i ka hoe; i ka hoe, i ke ka; pae aku i ka 'aina (327)
>
> "Everybody paddle the canoes together; bail and paddle, paddle and bail, and the shore will be reached."
>
> (If everybody pitches in, the work is quickly done.)
>
> —Mary Kawena Pukui, *'Olelo No'eau*

Emergency management and public safety as disciplines require a commitment to iterative change, a constant desire for improvement, and a recognition that there are no universal solutions. These qualities themselves are hardly novel, having been expressed repeatedly in case studies and after-action reviews. Rarely have they been stated so bluntly as by the authors of the *Final Report of the Interagency Management Review Team* from the fatal South Canyon Fire:

> The reader will find no dramatic changes in the form of new equipment or technology, new training, new policy, or new procedures. Rather, there are numerous modifications and improvements in those areas, representing a process of constant and ongoing progress toward the goal of reduced risks to wildland firefighters.[100]

In short, we do not, or perhaps cannot, know the totality of what we need to know in our operating environment, but we can and must continue to push forward in some areas based on past experience and available knowledge.

[100] *Final Report of the Interagency Management Review Team: South Canyon Fire,* 7.

Compounding the problem, the tremendous variety in organizational structures makes it difficult to supply specific recommendations, as emergency management is conducted in widely disparate ways by cities, counties, states, tribes, and federal agencies. As demonstrated in Chapter IV, SA processes are profoundly shaped by factors external to the processes themselves, so any specific solutions must be founded in an understanding of a particular set of processes as well as those external factors relevant to their operation. This thesis provides insight into the SA model, but any organizational improvement will require a great deal of internal analysis to realize the benefits described herein.

In order to seek improvements in SA models and reduce some of the failures articulated throughout this discussion of emergency management, there are two important areas of action. First, we must recognize that the problem exists and set higher standards than we have had for solving it. While no organization will ever achieve perfect communications in the chaotic and famously difficult landscape of emergency management, in order to develop improvements it is necessary for practitioners to first imagine a functional SA process that does not suffer from frequent and expected breakdowns. Second, we must recognize some of the latent conditions that make the proximate causes of failures so damaging and adjust organizations to make them less susceptible by mitigating those latent conditions. It is precisely these two remedies—imagination of a higher standard and the improvement of indirect conditions—that require the qualitative methods of sensemaking and comparison described in this thesis.

Having said that, there are a few areas of further research that are strongly indicated from the analysis of the SA model. This chapter lays out several of those areas for consideration while indicating their connection to issues raised in earlier chapters. In this way, the sensemaking and comparison lay out the next leg of the journey.

A. EMERGENCY MANAGEMENT, TEAMS, AND SITUATIONAL AWARENESS

In the discipline of emergency management, a number of salient elements emerge for a consideration of SA models. First and foremost, its relatively short tenure as a distinct discipline compared to its public safety counterparts (decades as compared with centuries for others) is a partial explanation for reliance on those disciplines for ideas, even though in many cases they are ill-suited to the work. Second, since emergency management practitioners deal primarily with unusual types or scales of events, they are implicitly part of a complicated organizational structure. Those two factors, the lack of intrinsic ideas and the complex organizations, when combined with the necessity of maintaining an "all-hazards" approach, make emergency management a discipline with models that sometimes fail to match their applications, particularly with regard to SA and related ideas.

The complex organizational structures mentioned above, which often involves multiple governments as well as other members of other involved groups, defines the natural unit of emergency management work not as individuals but as teams of practitioners. Further complicating matters, these teams are formed from a wide variety of organizations, and members are assigned to unique groups for each event. Some unifying elements from doctrine, such as the National Incident Management System, do bring order to these complicated organizational structures. But even with those unifying elements, practitioners fail to include communication and coordination in their models, despite those activities being the focal point of emergency management. In total, then, this mismatch between model (individuals) and reality (teams) causes a continued gap between theory and practice in emergency management SA models.

The nature of emergency management organizations as the coordinating body during responses to events places strong emphasis on activities to develop and share information about the event itself, as well as the resources and activities responding to it. This information gathering and sharing activity of SA is critical but not well-understood. This lack of understanding is demonstrated by the adoption of a SA model originally developed for individual fighter pilots, and with many of that discipline's cultural artefacts, by emergency management practitioners. In emergency management, by contrast, SA processes include teams separated by time, distance, and organization from the event.

B. MISMATCHES BETWEEN MODELS AND ACTIVITIES

As noted in the previous section, there are several ways that SA models adopted in emergency management do not match the practices of that discipline. Not only do emergency management practitioners work in teams whereas the SA model is founded on individual activity, but the concept of interaction among team members with varied SA is not addressed at all. This is particularly important as, again unlike descriptions in the existing SA model, many emergency management practitioners are not immersed in the events for which they are trying to gain SA. Instead, they are far from the scene of the response by design. Another mismatched cultural artefact from the SA model of fighter pilots is the assumption of a well-defined problem. Rather than the clear-cut environment of aerial combat—with a small number of scenarios likely to occur, however tactically complex they may be—emergency management practitioners face continual ambiguity and uncertainty in the nature of events. Thus, the SA model most commonly used by emergency management practitioners is ill-suited to their activity.

Researchers have produced a considerable amount of insight that might provide a path toward SA models that better match emergency management, and highlighting a few findings that can illustrate what a better fit would look like. One major area of research has been to separate SA into three levels. Different researchers categorize these levels in a variety of ways, but the separations are consistent. Three closely related descriptions establish those levels as follows: level 1 as perception, descriptive knowledge, or "what is happening"; level 2 as comprehension, procedural knowledge, or "how is this happening"; and level 3 as projection, strategic knowledge, or "why is this happening." The various descriptions are again summarized in Figure 2 (repeated from Figure 1 in Chapter III for the reader's convenience).

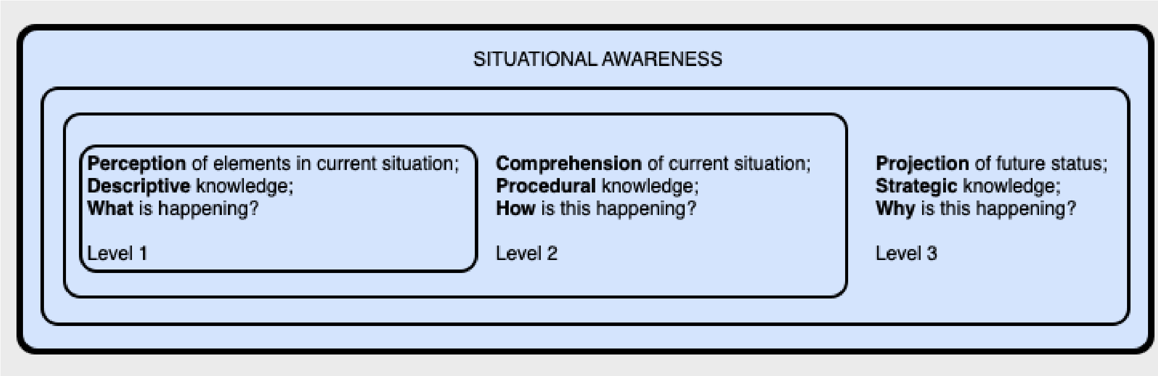

Figure 2. Comparing Three Descriptions of SA Levels (repeated from Figure 1 in Chapter III)[101]

The nuances of the three levels reflects the activities of emergency management better than the existing SA model and allow for a better analysis of how to improve SA overall.

Other bodies of research approach the problem of shared cognition from different angles, leading to useful methods, which have not thus far been applied to SA models in emergency management. One of these bodies of research is information processing theory, which takes a more general view of the problem by examining processes among groups in general. In Hinsz's description of the theory, it applies to "higher-order cognitive processes based on complex, emergent, dynamic, and profuse information."[102] This theory also aligns with the levels of SA presented above, lending further weight to its applicability. The other body of research is activity theory, which takes a similarly general view of group interaction and cognition. Activity theory is relatively simple in its components but provides a framework to analyze the process with any desired level of specificity. The framework also explicitly includes the potential for disruptions in the activity, rather than

[101] Adapted from Endsley, "Toward a Theory of Situation Awareness in Dynamic Systems"; Rouse, Cannon-Bowers, and Salas, "The Role of Mental Models in Team Performance in Complex Systems"; Mohammed, Ferzandi, and Hamilton, "Metaphor No More." Adapted from Endsley, "Toward a Theory of Situation Awareness in Dynamic Systems"; Rouse, Cannon-Bowers, and Salas, "The Role of Mental Models in Team Performance in Complex Systems"; Mohammed, Ferzandi, and Hamilton, "Metaphor No More."

[102] Hinsz, "A Groups-as-Information-Processors Perspective for Technological Support of Intellectual Teamwork," 23.

considering everything in an ideal format—this is a feature that could prove useful in the often-imperfect world of emergency management. Thus, though these theories come from entirely different backgrounds from most emergency management and public safety work, they afford useful analysis all the same.

C. SITUATIONAL AWARENESS AS A MIRROR OF THE WORLD

Many factors that operate outside the SA model nonetheless affect its workings. One is related to the hierarchy of decision making, as it occurs within emergency management. The other factor that emerged from the constant comparison methods of this research is the construction of knowledge used to develop SA: both the pieces of information that practitioners use to construct definitions, and the mental models that they then build with the definitions themselves.

Goal setting by elected and appointed leaders of an organization exerts profound influence over the SA process—within standing priorities—for emergency management practitioners during the response to an event. Those leaders' goals constrain the practitioners' own, more specific objectives, and those objectives provide the real drivers for SA. Regardless, the influence of the leaders' goals persists throughout. There is tension, however, between the practitioners' activity being driven by goals and data that develop during the response; this tension is an integral part of the SA process but one not represented in the existing SA model. Furthermore, sharing goals across an organization is part of establishing SA in the first place, yet again, the existing SA model does not include that aspect, thus preventing analysis of it. Lastly, goals may be defined in terms of precise concepts developed by practitioners, and ensuring consistency across the organization presents a challenge, which the current SA model fails to articulate. Thus, goals represent an influential feature of SA that is completely outside current models of SA and must be incorporated to develop an improved model.

Definitions, boundaries, and the values that constitute an idea of normal make up another area outside SA models that strongly affect those models. For example, geographic boundaries such as those used by emergency management organizations are often regarded as precise and absolute, but they may not represent the real area of concern or activity, or they may cause different and unintended effects depending on the nature of events. Definitions of environmental conditions can also be complex, and measuring them with enough precision while still capturing the range of possibilities is an ongoing challenge. Closely related to this problem is the difficulty of setting values of normal, as opposed to abnormal, events. These can vary widely based on location, culture, experience, and other factors, yet again, these kinds of definitions are not examined as a part of the existing SA model. Altogether, then, definitions constitute another major influence on SA models and processes that are not captured in current iterations.

Definitions comprise the larger concepts of mental models and schemata. Scholars use the two terms somewhat differently—mental models are general ideas of how systems work while schemata are specific ideas of what is happening with a system at a particular time. Mental models and schemata also cut across multiple levels of SA, as well as add complexity to concepts of team SA. Nevertheless, they are not described at all in current SA models.

Types of knowledge are another factor that affect SA models and processes as they form the constituent parts of definitions. One salient way to classify types of knowledge is to consider them as either tacit, which is to say internalized through experience, or explicit, which is available only externally via a reference. These two types of knowledge have a strong effect on individual SA. The complexity of team SA is even more affected by types of knowledge, especially considering the possibility of multiple SA models operating simultaneously—as illustrated in the cases of European and Polynesian navigation. As with the other rest-of-the-world factors, nothing about types of knowledge manifests in existing SA models.

D. RECOMMENDATIONS

In emergency management, as in many disciplines, doctrine leads to standards, and standards to procedures, and—accounting for variations among organizations—the results from each step can be validated against a known reference. In contrast, no established mechanism measures the fit of activities to the models that underlie them, though they are critical to an understanding of how groups coordinate their work.[103] Instead, failures documented in case studies and after-action reports reveal the ill-fitting model indirectly—outlines emerge from the aggregation of events.

This is where we must remember that, to turn again to the *Final Report of the Interagency Management Review Team*, “no number of procedures, no number of training courses, and no amount of sophisticated equipment and technology can replace personal and institutional values,” and those institutional values are not yet present with the current SA model.[104] The values are not so far outside the institutions, however, and they can be brought within by work on the issues described in this thesis. Thus, there are recommended methods to begin development of both the values and the systems that are derived from them, by examining the descriptions provided in Chapter II, the mismatches described in Chapter III, and the factors described in Chapter IV to extend sensemaking to more specific areas. These recommendations follow.

1. Measurement

In order to make any specific recommendations to change SA processes, practitioners must approach the challenge of measuring SA to compare a variety of recommendations and identify which are most suitable. Despite the presence of a large body of academic literature on exactly this topic, including work by Endsley, Lo et al., and Cooke, Stout, and Salas, the current practices in emergency management do not address the issue of measurement at all.[105] A thorough discussion of how to measure SA among emergency management practitioners would be a considerable task in its own right, let alone undertaking that measurement in various experimental or professional settings.

Developing methods for measuring SA in experimental or professional settings in emergency management first requires several refinements to the existing SA model.

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[103] Richard Klimoski And Susan Mohammed, “Team Mental Model: Construct Or Metaphor?” *Journal of Management* 20, no. 2 (1994): 405.

[104] Allen et al., 7.

[105] Endsley and Jones, *Designing for Situation Awareness*, 63; Lo et al., “Explicit or Implicit Situation Awareness?” 328; Cooke, Stout, and Salas, “A Knowledge Elicitation Approach to the Measurement of Team Situational Awareness,” 114.

Refinements to the levels of SA, as described in Chapter III, would begin with a detailed effort to document the multitude of tasks that organizations and individual practitioners perform during SA processes. Also, the areas of ambiguity and indeterminacy around definitions and knowledge, as described in Chapter IV, require additional clarity before measurement is possible. In short, many of the concepts identified in this thesis need to be developed into fully fledged analyses before measurement can be undertaken.

Several of the scholars quoted in this thesis provide ready-made techniques for measuring SA in settings closely matched to emergency management. While refining those techniques would require some effort by knowledgeable practitioners, greater engagement with the academic research in this area would yield better results than empirical development of unique methods.

2. Teams, Rather than Individuals

It is imperative to develop methods for identifying team SA models and processes within emergency management to reflect the actual practice of the discipline. Chapter II showed the ubiquity of teams throughout emergency management, Chapter III demonstrated that team SA is distinct from individual SA and provided some techniques for describing and documenting it. Given the prevalence of teams among emergency management practitioners, numerous empirical methods have emerged to address this problem, but absent improvements to the model itself, those methods cannot be generalized.

In addition, with teams as the natural unit of the SA model, and coordination among members of various teams as a primary activity, systems can be developed to intentionally provoke comparisons of information, and resolve conflicting interpretations of that information by team members. Such a system might display information like the number and location of earthquakes from a volcano, as well as whether the volcanic activity is increasing, decreasing, or constant. These changes can be reflected in each of the subsequent areas: though much work will be required, it starts with changing the model.

The adoption of teams as the standard unit for consideration of SA, together with the aforementioned development of measurement techniques, will enable more detailed recommendations in the next areas of this section.

3. Training and Education

Until the issue of measurement has been developed further, improvements in training and education are likely to be uneven at best and counterproductive at worst. A successful program of training and education implies that instructors will bring students' performance closer to a predetermined measure of success, so it will be difficult to develop these programs absent that measurement.

Furthermore, there are a number of other refinements without which no improvement program of training or education is likely to be effective. For example, as identified in Chapter IV, mental models and schemata are distinct concepts that function in different areas of SA. The kind of training and information required to develop a better mental model could include classroom instruction by subject-matter experts. That kind of education would not necessarily produce improved schemata, however, which are more likely to be developed through exposure to scenarios in controlled settings or in actual experience. Nevertheless, the fact that many emergency management and public safety disciplines currently provide both types of training does not indicate comprehension of the underlying systems, as evidenced by the failure to name them distinctly in plans, training documents, or after-action reviews. Thus, again, specific work is needed for efforts to deliver the desired outcomes.

General training and education have begun to proliferate and mature across emergency management and public safety disciplines. Though they are not completely normalized, there are a number of organizations, techniques, and programs that would be well-suited to developing and integrating the research necessary to improve SA in these areas. The first step, as noted above, is the recognition of SA models and processes as requiring improvement—hopefully it is becoming apparent.

4. Procedures, Systems, and Tools

The dependencies described in previous sections are compounded as we move into the area of how specific procedures, systems, and tools can be improved to enhance SA processes: not only are they dependent on measurement and training, but they are where the variation among organizations is fully realized. The goal here, then can be at least to reduce the latent conditions of susceptibility referenced in Chapter I, which Wendy Becker described generally and which Eric Telfer and Jennifer Sovada enumerated in specific forms.[106]

These systems and tools can also enable the flexibility of definitions necessary for effective response to chaotic events, where geographic boundaries and sites of activity are not known ahead of time, and may continue to evolve throughout the event. Features of that system might be that it presents desired information (e.g., volcanic activity, transportation systems, and shelter locations) in a single workspace, rather than separating sources into a number of disconnected silos. These techniques will both benefit from and aid in further sensemaking around SA models.

A few other improvements, that are likewise fairly straightforward, empirically derived changes, can help to address the general mismatches in the SA model based on existing descriptions and understanding. The first of these conditions provides an upper bound to the tendency to add information sources to a single workspace. While it is certainly desirable to combine sources from multiple channels, it is also possible to present too much information in a combined channel. The medical profession has coined the term "alarm overload," such that when patients are suffering from several simultaneous injuries or illnesses, the devices designed to alert their caregivers act as though each system is the only one that requires attention.[107] Likewise, in emergency management, practitioners find this frequent phenomenon demanding their attention, which reduces their ability to focus

[106] Becker, "Missed Opportunities," 365; Telfer, "Unlimited Impossibilities: Intelligence Support to the Deepwater Horizon Response," 50; Sovada, "Intelligence, Surveillance, and Reconnaissance Support to Humanitarian Relief Operations within the United States," 5.

[107] Endsley and Jones, *Designing for Situation Awareness*, 161.

on solving the problems. This is particularly true when multiple urgent situations are, by the nature of the event, likely to arise.

Related to the idea of attention management is the notion of including “pertinent negatives” in event data, in order to definitively state that something did not occur, rather than simply implying that it did not. This phrase represents the difference between “no report received” and “not affected by event” for a practitioner who is tracking airplanes flying near a volcanic eruption, for example. This disparity would require the practitioner to take very different actions, and so is important to establish precisely which condition is accurate. Both alarm overload and pertinent negatives are conditions that procedures, systems, and tools can be designed around as part of the exploratory process of sensemaking, though they are founded in deeply pragmatic experiences.

E. IN SUMMARY

Converging pragmatism and exploration is precisely the kind of novel thinking required to develop a new SA model. The development of a well-articulated SA model that includes the necessary aspects is critical, but it will not emerge from an endless succession of after-action reviews conducted under the current model any more than one person observing one star while another person observes another can form an idea of where their ship is sailing to. The scholarly research provides many potential remedies, but pragmatism is needed to measure, compare, and apply those remedies to the actual challenges.

The challenges of SA in emergency management will remain legion—it is a difficult subject even under ideal conditions—but a better understanding of the environment can lead to fewer of the same problems occurring over and over again. Establishing measurement techniques for SA, embracing teams as the default rather than the exception, adapting training and education to match a more nuanced model, and designing procedures, systems, and tools that take advantage of all of those things will enable practitioners to pull together and develop a much more seaworthy SA model. So that, if we all paddle and sail the canoe together, we will reach the shore and find new knowledge.

LIST OF REFERENCES

Adler, Richard. “Knowledge Engines for Critical Decision Support.” In *Gaming and Simulations : Concepts, Methodologies, Tools and Applications*. Hershey, PA, USA: Information Resources Management Association, 2010. https://doi.org/10.4018/978-1-60960-195-9.ch803.

Allen, Tom, Tom Zimmerman, Jim Douglas, Michael Benscoter, Robert Joslin, Mike Edrington, Jose Cruz, Edy Petrick, Mike Barry, and Rick Ochoa. *Final Report of the Interagency Management Review Team: South Canyon Fire*. Washington, DC: U.S. Department of the Interior, 1995.

Anderson, Jonathan. “Focus on Training: Developing Situational Awareness as a Community-Engagement Initiative.” *FBI: Law Enforcement Bulletin* (blog), July 12, 2018. https://leb.fbi.gov/articles/focus/focus-on-training-developing-situational-awareness-as-a-community-engagement-initiative.

Azuma, Ron, Mike Daily, and Chris Furmanski. “A Review of Time Critical Decision Making Models and Human Cognitive Processes,” 1–9. Big Sky, MT: IEEE, 2006. https://doi.org/10.1109/AERO.2006.1656041.

Becker, Wendy S. “Missed Opportunities: The Great Bear Wilderness Disaster.” *Organizational Dynamics* 36, no. 4 (January 2007): 363–76. https://doi.org/10.1016/j.orgdyn.2007.06.003.

Bowker, Geoffrey C., and Susan Leigh Star. *Sorting Things Out: Classification and Its Consequences*. Cambridge, MA: The MIT Press, 2000.

Brown, Judith M., Steven L. Greenspan, and Robert L. Biddle. “Complex Activities in an Operations Center: A Case Study and Model for Engineering Interaction.” In *Proceedings of the 5th Annual Symposium on Engineering Interactive Computing Systems*, 10. London: Association for Computing Machinery, 2013.

Bye, Bente Lilja. “Volcanic Eruptions: Science And Risk Management.” Science 2.0, May 27, 2011. https://www.science20.com/planetbye/volcanic_eruptions_science_and_risk_management-79456.

Canan, Mustafa, and Andres Sousa-Poza. “Pragmatic Idealism: Towards a Probabilistic Framework of Shared Awareness in Complex Situations.” In *2019 IEEE Conference on Cognitive and Computational Aspects of Situation Management (CogSIMA)*, 114–21. Las Vegas, NV, USA: IEEE, 2019. https://doi.org/10.1109/COGSIMA.2019.8724208.

Cooke, Nancy, Renee Stout, and Eduardo Salas. "A Knowledge Elicitation Approach to the Measurement of Team Situational Awareness." In *New Perspectives in Cooperative Activities: Understanding System Dynamics in Complex Environments*. Santa Monica, CA: Human Factors and Ergonomics Society, 2001.

Donahue, Amy K., and Robert V. Tuohy. "Lessons We Don't Learn: A Study of the Lessons of Disasters, Why We Repeat Them, and How We Can Learn Them." *Homeland Security Affairs* 2 (July 2006): 28.

Dye, Jane, Irene Schatz, Brian Rosenberg, and Susanne Coleman. "Constant Comparison Method: A Kaleidoscope of Data." *Qualitative Report* 4, no. 1/2 (January 2000). https://nsuworks.nova.edu/tqr/vol4/iss1/8/.

Emergency Management Institute. "Situational Awareness and Common Operating Picture." Class notes. E/L0948: Emergency Management Institute, 2019.

Endsley, Mica R. "Situation Awareness: Operationally Necessary and Scientifically Grounded." *Cognition, Technology & Work* 17, no. 2 (May 2015): 163–67. http://dx.doi.org/10.1007/s10111-015-0323-5.

———. "The Challenge of the Information Age: Designing for Situation Awareness in Complex Systems," 14. Kyoto, Japan, 2001.

———. "Toward a Theory of Situation Awareness in Dynamic Systems." *Human Factors: Journal of the Human Factors and Ergonomics Society* 37, no. 1 (March 1995): 32–64. https://doi.org/10.1518/001872095779049543.

Endsley, Mica R., and Debra G. Jones. *Designing for Situation Awareness*. 2nd ed. New York: CRC Press, 2012.

Federal Emergency Management Agency. *National Incident Management System*. Washington, DC: US Department of Homeland Security, 2017.

———. *National Response Framework*. 4th ed. Washington, DC: US Department of Homeland Security, 2019.

Freedman, David. "New Theory on How the Aggressive Egg Attracts Sperm." *Discover Magazine* (blog), June 1, 1992. http://discovermagazine.com/1992/jun/theaggressiveegg55.

Hinsz, Vernor. "A Groups-as-Information-Processors Perspective for Technological Support of Intellectual Teamwork." In *New Perspectives in Cooperative Activities: Understanding System Dynamics in Complex Environments*. Santa Monica, CA: Human Factors and Ergonomics Society, 2001.

Howitt, Arnold M, and Herman B. "Dutch" Leonard. "The Novelty of Crises: How to Prepare for the Unexpected." In *The LA Earthquake Sourcebook*, 4. Pasadena, CA: Art Center College of Design, 2009.

NPR.org. "Iceland's Volcanic Eruption And Its Aftermath," April 22, 2010. https://www.npr.org/series/126106506/iceland-s-volcanic-eruption-and-its-aftermath.

Joint Chiefs of Staff. *Joint Publication 3-27 Homeland Defense*. Washington, DC: Department of Defense, 2018.

———. *Joint Publication 5-0 Joint Planning*. Washington, DC: Department of Defense, 2017.

Klimoski, Richard, and Susan Mohammed. "Team Mental Model: Construct or Metaphor?" *Journal of Management* 20, no. 2 (1994): 35.

Lewis, Ted G. *Bak's Sand Pile*. Williams, CA: Agile Press, 2011.

Lin, Ning, Kerry Emanuel, Michael Oppenheimer, and Erik Vanmarcke. "Physically Based Assessment of Hurricane Surge Threat under Climate Change." *Nature Climate Change* 2, no. 6 (June 2012): 462–67. https://doi.org/10.1038/nclimate1389.

Lo, Julia C., Emdzad Sehic, Karel A. Brookhuis, and Sebastiaan A. Meijer. "Explicit or Implicit Situation Awareness? Measuring the Situation Awareness of Train Traffic Controllers." *Transportation Research Part F: Traffic Psychology and Behaviour* 43 (November 2016): 325–38. https://doi.org/10.1016/j.trf.2016.09.006.

Lowenthal, Mark. *Intelligence: From Secrets to Policy*. 7th ed. Thousand Oaks, CA: CQ Press, 2017.

Mohammed, Susan, Lori Ferzandi, and Katherine Hamilton. "Metaphor No More: A 15-Year Review of the Team Mental Model Construct." *Journal of Management* 36, no. 4 (July 2010): 876–910. https://doi.org/10.1177/0149206309356804.

National Wildfire Coordinating Group. "S-130 Firefighter Training Module 4: Potential Hazards and Human Factors on the Fireline." Boise, ID: National Wildfire Coordinating Group, 2008.

Nofi, Alfred. *Defining and Measuring Shared Situation Awareness*. Arlington, VA: Center for Naval Analyses, 2000.

Nowell, Branda, and Toddi Steelman. "Beyond ICS: How Should We Govern Complex Disasters in the United States?" *Journal of Homeland Security and Emergency Management* 16, no. 2 (May 27, 2019). https://doi.org/10.1515/jhsem-2018-0067.

Nowell, Lorelli S., Jill M. Norris, Deborah E. White, and Nancy J. Moules. "Thematic Analysis: Striving to Meet the Trustworthiness Criteria." *International Journal of Qualitative Methods* 16, no. 1 (December 2017). https://doi.org/10.1177/1609406917733847.

Osinga, Frans P B. *Science, Strategy and War*. London: Routledge, 2007.

Reychav, Iris, and Jacob Weisberg. "Good for Workers, Good for Companies: How Knowledge Sharing Benefits Individual Employees." *Knowledge and Process Management* 16, no. 4 (October 2009): 186–97. https://doi.org/10.1002/kpm.335.

Rouse, W.B., J.A. Cannon-Bowers, and E. Salas. "The Role of Mental Models in Team Performance in Complex Systems." *IEEE Transactions on Systems, Man, and Cybernetics* 22, no. 6 (December 1992): 1296–1308. https://doi.org/10.1109/21.199457.

Russas Sr., Michael E. "Correcting Blindness in the Nerve Center: How to Improve Situational Awareness." Master's thesis, Naval Postgraduate School, 2015. https://doi.org/10.21236/AD1009217.

Salas, Eduardo, Nancy J. Cooke, and Michael A. Rosen. "On Teams, Teamwork, and Team Performance: Discoveries and Developments." *Human Factors: The Journal of the Human Factors and Ergonomics Society* 50, no. 3 (June 2008): 540–47. https://doi.org/10.1518/001872008X288457.

Salas, Eduardo, Carolyn Prince, David P Baker, and Lisa Shrestha. "Situation Awareness in Team Performance: Implications for Measurement and Training." *Human Factors* 37, no. 1 (January 1995): 14.

Solnit, Rebecca. *A Paradise Built in Hell*. New York: Viking, 2009.

Sovada, Jennifer P. "Intelligence, Surveillance, and Reconnaissance Support to Humanitarian Relief Operations within the United States: Where Everyone Is in Charge:" Defense Technical Information Center, 2008. https://doi.org/10.21236/ADA484333.

Starks, Rachel Rose, Jen McCormack, and Stephen Cornell. *Native Nations and U.S. Borders: Challenges to Indigenous Culture, Citizenship, and Security*. Tuscon, AZ: Native Nations Institute for Leadership, Management, and Policy, 2014. http://www.tandfonline.com/doi/full/10.1080/14649365.2013.806759.

Su, Yee San. "Application of Social Network Analysis Methods to Quantitatively Assess Exercise Coordination." *Homeland Security Affairs* 7, no. 18 (December 2011): 16.

Telfer, Erich. "Unlimited Impossibilities: Intelligence Support to the Deepwater Horizon Response." Master's thesis, National Intelligence University, 2014.

Tenney, Yvette, Marilyn Jager Adams, Richard Pew, A.W.F. Huggins, and William Rogers. *A Principled Approach to the Measurement of Situation Awareness in Commercial Aviation*. Langley, VA: National Aeronautics and Space Administration, 1992.

Turner, P., and S. Turner. "Describing Team Work with Activity Theory." *Cognition, Technology & Work* 3, no. 3 (August 2001): 127–39. https://doi.org/10.1007/PL00011528.

United States Geological Survey. "What Is the Probability That an Earthquake Is a Foreshock to a Larger Earthquake?" USGS Natural Hazard FAQ. Accessed February 9, 2020. https://www.usgs.gov/faqs/what-probability-earthquake-a-foreshock-a-larger-earthquake?qt-news_science_products=0#qt-news_science_products.

Weick, Karl. *Sensemaking in Organizations*. Thousand Oaks, CA: Sage Publications, 1995.

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