Situational Awareness During a Catastrophic Incident: Insights from the Cascadia Rising Exercise of June 2016

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Abstract

In a catastrophic incident gaining situational awareness (SA) is the foremost prerequisite that enables responders to save and sustain lives, stabilize the incident, and protect the environment and property from further damage. However, catastrophes severely damage and disrupt critical infrastructures including response assets. Initially and for days and even weeks, essential information remains incomplete, unverified, and is changing as the catastrophic incident unfolds, all of which leads to a distorted common operating picture (COP). The lack of clear and comprehensive SA/COP prevents incident commanders from efficiently directing the response effort. This study reports on the challenges emergency responders faced with regard to situational awareness in a recent large-scale exercise under the name of Cascadia Rising 2016 (CR16) conducted in the Pacific Northwest of the United States. The exercise involved a total of 23,000 active participants. Over four days in June of 2016, CR16 simulated the coordinated response to a rupture of the 800-mile Cascadia Subduction Zone resulting in a magnitude-9 earthquake and tsunami similar to the catastrophic incident in Eastern Japan in 2011. Responders at all levels were severely challenged, and the exercise revealed major vulnerabilities in critical infrastructures. Situational awareness was very difficult to establish.

1. Introduction

Around the late 1980s and early 1990s geological researchers increasingly discovered indicators and evidence for the potential occurrence of magnitude 8 to 9.5 earthquakes in the Pacific Northwest of the North American continent [5, 13, 26, 46]. In the course of these studies, it became clear that such megathrusts had reoccurred with relative regularity every 350 years over the past 8,000 years, the latest of which could be exactly dated to January 26, 1700 at about 2100 hours local time [24, 29].

After the scientific evidence had emerged, professional responders in the area had begun planning and preparing for responding to the "big one" fairly early, whereas the general public in the potentially affected areas did not take much notice of the likely threat until the devastating Tōhoku earthquake and tsunami had

happened in Eastern Japan in March of 2011 [16, 17, 32]. The US Department of Homeland Security and its Homeland Infrastructure Threat and Risk Analysis Center commissioned a simulation study (the so-called HITRAC study) the same year, which estimated in great detail the potential impact of a magnitude-9 earthquake and tsunami on the Pacific Northwest as a result of a complete rupture in the Cascadia subduction zone [1]. With the results of the HITRAC study in hand, the need for a major effort in planning and preparedness had become painfully clear to officials and professional responders alike. A year after the catastrophe in Japan, the local newspaper *Seattle Times* then alerted the public that for the "Puget Sound and the Pacific Coast, the basic earthquake question is when, not if" [2]. The Cascadia Rising 2016 Exercise, which involved a total of 23,000 participants from responder agencies of all levels in three Federal States (Oregon, Washington, and Idaho), the FEMA Region X, as well as the Military, was the acknowledgement of both the urgency of the need to prepare and the severity of the threat [3].

As stated in a previous study, "[r]esponse efforts on this scale are extremely complex undertakings, and they require enormous managerial, operational, and tactical skills on part of the responders" [30, p 2498] A catastrophic incident of the scale, scope, and duration of a complete Cascadia Subduction Zone rupture has not been recorded in recent history. The zipper-like rupture from one end of the subduction line to the other is expected to occur along the 800-mile-long subduction line resulting in five to six minutes of violent shaking impacting areas up to 100 miles away. A 30 to 40-foot high tsunami would reach the coastline about 20 to 30 minutes after the rupture. Several aftershocks of significant magnitude would be expected to follow the initial rupture inflicting more damage on the already heavily compromised and impacted infrastructure. According to the aforementioned HITRAC study, once this particular incident unfolded, it would likely inflict a major toll in terms of human lives lost and humans severely injured; it would also destroy critical and non-critical infrastructure alike. The impact on human lives and infrastructure would be the greater the closer the location to the coastline in the West ranging from severe damage throughout the so-called Interstate-5 corridor to almost total annihilation along the Western

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shorelines. Power outages would be widespread and lasting up to a year, or even longer. The impacted areas West of the Cascadian Mountain range would be inaccessible by ground transport or sea transport for extended periods of time leaving the engulfed populations and the local responders to mainly their own means of support and response for up to two to three weeks. Relief would first come predominantly by air transport. Responders would find themselves stripped from using most modern information and communication technologies for the lack of power and intact communication infrastructures. Sustained communication infrastructures such as satellite phones or HAM (amateur) radio would provide only relatively low bandwidths, particularly, in data communications. Low-tech technologies such as T cards and other paper-based methods would be the tools of necessity for an extended period of time. Responders' "situational awareness" as the basis of a shared "common operating picture" would be hard to establish for at least the first couple of weeks after the incident.

An earlier empirical study had shown in detail how accurate and reliable information was the "most important and most scarce resource in early disaster response" [30, p. 2498]. The study's focus was the March 2014 SR530/Oso landslide in Washington State, which was declared a national disaster. Many, if not most, responders and agencies involved in the real response of 2014 participated in the CR16 exercise two years later. Quite a few responders who had been interviewed for the SR530/Oso landslide study were willing to be interviewed again after the CR16 exercise providing an excellent frame of reference. Other responders and exercise planners from several levels of government were also interviewed. Furthermore, along with the interview transcripts the study analyzed the after-action reports from 23 responder agencies. The overall methodology, the theoretical framework, the interview instrument, and the ex-ante codebook, and other tools used for this study were largely similar to those used in the earlier study.

This paper is one of two publications from a study dedicated to situational awareness during a simulated catastrophic incident response; while the other paper covers the communication- and technology-related challenges in the context, this paper focuses on challenges of information sharing and of practically attaining situational awareness among responders regardless of the technological underpinnings. Unlike the previous study, which studied the inter-responder information sharing challenges and related SA/SSA challenges of a local disaster of limited scope, scale, and duration, this study attempts to understand, how these challenges change under the impact of a catastrophic disaster, which engulfs a large geographic area with large scope and scale and long duration.

The paper is organized as follows: First, the academic literature on situational awareness during incident responses is reviewed followed by a presentation of the resulting research questions and the methodology section. Subsequently, the study findings are detailed leading to the discussion of insights from the findings. At last, conclusions are drawn, and the directions for future research on the subject are sketched out.

2. Literature Review

The academic literature has highlighted the indispensable role of actionable and integrated information in disaster response [9, 23, 34]. Based on this particular type of information, (individual) situational awareness (SA) leading to shared (group or team) situational awareness (SSA) can effectively be developed among responders, which then serves as a prerequisite for generating and maintaining a shared common operating picture (COP) [8, 9, 15, 34],). Both SA/SSA and a shared COP are foundational to any mission and any well-directed and effective response [14]. However, despite their extraordinary importance to the success of disaster response and early recovery, systematic study of SA and SSA advanced in other academic fields such as Behavioral Science, Human Factors Research, and Safety Sciences, particularly, in the context of the military, far earlier and much faster than in Disaster Science. As an example, Endsley presented a comprehensive SA framework, in which she distinguished (1) perception, (2) comprehension, and (3) projection as three intertwined levels of SA [8]. The Endsley framework, which was first developed in the context of military combat aviation, has been found the most influential theoretical contribution to the understanding of SA and SSA [27]. The framework, however, despite its popularity and wide acceptance has been criticized for its alleged linearity, its lack of accounting for inter-level feedback relationships as well as for an unclear distinction between SA product(s) and SA process(es) [27, 38, 39, 43]. In a detailed rejoinder Endsley refuted these criticisms as mainly misunderstandings and misconceptions [9]. Critics of Endsley's approach to SA and SSA have proposed the concept of "Distributed Situation Awareness" (DSA) as an alternative [39, 40], which claimed to employ a system-theoretical perspective. "DSA is considered to be activated knowledge for a specific task within a system at a specific time by specific agents, that is, the human and nonhuman actors in a system" [39, p. 47]. The inclusion of technology or information artifacts into the DSA framework as nonhuman "actors" has drawn serious criticism itself [9]. In DSA, nonhuman "actors" have been portrayed as triggering and informing each other, thus along with human actors representing the activated knowledge within the network; however, as Endsley pointed out, it would still always need a human actor to notice, interpret, and comprehend the technology alert or

the interaction to make it an instance of SA. In terms of DSA it has also remained unclear, what exactly the "system" is, and what its identifiable system boundaries might be. In other words, no clear system definition has been found regarding what is considered part of or element inside the system, and what is not.

As pointed out before, in Disaster Sciences the notion of and discussion about SA/SSA was informed and influenced by advances in other disciplines, which over time have mainly adopted the Endsley framework [15, 22, 28, 35-37]. However, upon reviewing government documents on the subject as to when professional responders had gained "full" SSA in the early stages of a response to a major incident, the point in time when SSA was fully established appears to be somewhat in the eye of the beholder. For example, an official commission report on the response to a recent landslide disaster in Washington State claimed that SA was established after "several hours" [21], while other documentation on the same incident stated that, in fact, SA was not fully established for "several days" [30]. This substantial discrepancy in views ("hours" versus "days") demonstrates that what establishes, or what "is," situation awareness is still not well enough articulated. While the commission report might correctly refer to the SSA level of "perception," which was assumed after "hours," the other official documentation undoubtedly refers to the SSA level of "comprehension," also indicated by readjustments in the response mentioned in the document, which indeed took several days.

In other words, research needs to address in more detail, which level of SSA is investigated, and how the three levels of SSA transition from one another (including feedback), which may, for example, include granular computational approaches [20]. A recent experimental study found evidence that "enriched" information, that is, summarized information rather than providing raw data enhanced responders' SSA, and hence, would improve the effectiveness of a response [45].

In contrast, strong hindrances to attaining even the entry level of SSA (perception) were also identified in the absence of planning and preconfiguring so-called "Essential Elements of Information" (EEIs), which are itemized lists of assets and critical infrastructure that help guide responders systematically through the collection of detailed and hazard-specific information [30, 36]. Furthermore, a lack of standardization of information sharing procedures and protocols impeded all levels of SSA and prevented the necessary integration of information from different sources, which it was argued could be overcome by a unified disaster information architecture and a unified system platform shared by responders at all levels [30, 35, 36]. Information infrastructures, which cater professional responders' specific information needs, support their information behavior, and facilitate the vertical and horizontal information flows between and among them, have been characterized as prerequisites for developing and maintaining SA/SSA and a shared COP, which in turn makes possible an effective response [30, 32-34].

In summary, while emergencies and non-catastrophic disasters present a number of known and not so known challenges, the challenges to inter-responder information sharing along the three dimensions of specific information needs, information seeking behaviors, and information flows under the impact of a catastrophe and severely compromised information infrastructures are not clearly understood. Likewise, it is little known what specific challenges ensue for responders from the impact of a catastrophe and severely compromised information infrastructures with regard to the three levels of SA/SSA (perception, comprehension, and projection).

3. Research Questions

This then leads to the following two research questions, which address the identified gap in understanding of information-sharing and SA/SSA challenges:

Research Question #1 (RQ#1):
What are specific *information-sharing challenges* for professional responders in a catastrophic incident response?

Research Question #2 (RQ#2):
What are specific SA/SSA-related *challenges* for professional responders in a catastrophic incident response?

4. Method Section

Theoretical Lens. This study implements the so-called "information perspective." At its core this perspective is human actor and human action-centric, and it views information and communication technologies (ICTs) as facilitators of human information needs, information behaviors, and information flows. Human actors' (here: responders') information behavior and the information flows between them depend on so-called information infrastructures, which encompass formal and informal, organizational, technological, and social elements among others [32, 34]. In disaster management, when looking at the technological elements, ICTs as part of the information infrastructures have assumed important roles [7, 18] by providing high-quality, mission-critical, timely, and actionable information to responders in typically fast and dynamically changing environments [18, 19, 42]). On the downside, ICTs have also been found contributing to information overload, work overload, and other stressors to responders in disaster responses [9]. The information perspective allows a detailed investigation of actions and interactions of responders as they are mediated via the

existing and emerging information infrastructures and their various elements.

Instrument and Coding Scheme. Based on the theoretical lens, that is, the conceptual framework of resilient information infrastructures (RIIs) [34] a semi-structured interview protocol was devised upfront, which covered five topical areas of (1) management and organization, (2) technology, (3) information, (4) information infrastructure, and (5) RIIs/resiliency. The instrument administered was a shortened and adjusted version of the instrument used in a previous study [30, 31]. A total of twenty-five interview questions plus respective probes were incorporated.

Sample. The sample was purposive [25] and included responders from eight different groups: the (1) City Emergency Operations Centers, (2) County Emergency Operations Centers, (3) Washington State Emergency Management Division, (4) WA State Agencies, (5) Health Districts, (6) Regional Aviation, (7) Washington State National Guard, and (8) Federal Emergency Management Agency (FEMA), region X. A total of 17 individuals were interviewed. Furthermore, after-action reports (AARs) from 23 agencies from all eight responder groups were collected.

Data collection: Whereas the CR16 exercise was undertaken in June of 2016, the interviews were conducted in person between September 2016 and March 2017 and lasted between 33 to 107 minutes. Two interviews were conducted via Skype video conferencing. All interviews were audio taped, transcribed, and coded by at least two coders for analysis. During the interviews also notes were taken and participant interaction was observed and recorded. Moreover, besides after-action reports other documents such as press interviews were collected, reviewed, and coded as appropriate.

Data analysis and coding: The initial codebook by following the aforementioned conceptual RII framework [34] contained six category codes (one for each topical area) and 141 sub-category codes. Additional codes were inductively introduced during data collection, in individual coding sessions, and inter-coder sessions [11, 12, 41, 44]. Since in a hybrid approach of deductive and inductive analyses [10] a codebook is designed to be open to extension, it ultimately encompassed 176 sub-category codes in the aforementioned six main categories.

At least two researchers coded each transcript and document by means of a cloud-based software tool for qualitative and mixed-method data analyses (Dedoose main versions 7 and 8, dedoose.com). The coded data were compared one by one and demonstrated high inter-coder reliability.

When analyzing the code frequency table, the highest counts of code applications were found in the areas of "management and organization" (2,763), "information" (1,705), and "technology" (1,111). For the purpose of the specific analysis on situational awareness-related information needs, information behaviors, and information flows the code intersection represented by the sub-codes of "situational awareness," "address challenges of information sharing," and "use of information and communication technologies for information sharing" was selected, which produced 1,558 excerpts.

For the most part, these excerpts were between two and three paragraphs in length. They were clustered by responder teams and then analyzed for emerging concepts in a grounded fashion. Recurring concepts and main themes were identified and labeled through keywords and key phrases. All excerpt clusters were concept-analyzed by at least two analysts, in most cases by three analysts, as well as by the principal investigator. The coded concepts were checked for inter-analyst validity and a convergence of interpretation was found. Converging concepts were identified and transferred to the "canvas" of a cloud-based mapping tool (CMAP, version 6.03).

After reconciling the remaining inter-analyst discrepancies in interpretation as much as appropriate, the reconciled concepts were also transferred to the canvas. The concept clusters were inspected and sorted into topical "bins" or "buckets," in which chronological, logical, and other non-causal relationships were identified.
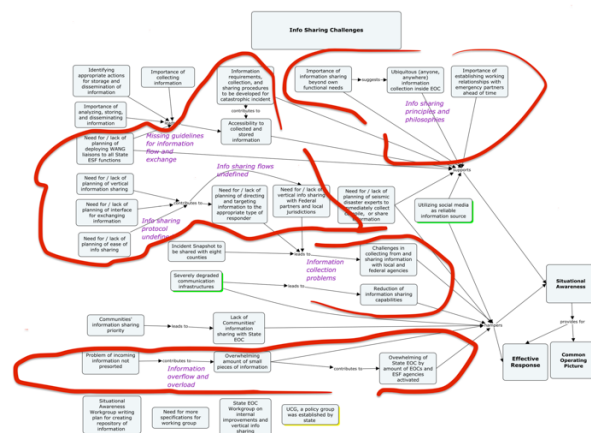

Figure 1 Sample CMAP (Concept Mapping for Information Sharing at the EMD Responder Group) including researchers' concept cluster markings

Whenever evidence from the data supported it, relationship links between concepts were established, which were not interpreted as causal links.

Research team and processes. The research team consisted of the principal investigator (PI) and more than forty research assistants (RAs) who participated in the

project both for-credit and voluntary. The PI and RAs worked individually and in small teams to transcribe, code, conceptually/contextually analyze, and finally map the concepts. The research team met weekly in person or online and communicated via the research project site and the project listserv as well as via individual face-to-face and group meetings. All weekly meetings were streamed and recorded, which kept the whole research team in sync over extended periods of time.

5. Findings

5.1 Ad research question #1 (What are specific *information-sharing challenges* for professional responders in a catastrophic incident response?):

As mentioned before, this publication is the one of two from a single study on the various challenges to responders' situational awareness. The other paper presents technology and communication-related aspects of the subject under investigation. Therefore, in this paper the focus lies on to the non-technological aspects of information-sharing challenges. As shown there, in the real-case response to this particular simulated catastrophic incident modern technologies will for the most part be unavailable due the complete loss of electrical power for an extended period of time, which will gravely affect the response. Along these lines, a technology-nescient analysis of responders' information-sharing challenges is necessary and justified. Even if electrical power, and with it modern information and communication technologies (ICTs), had remained at responders' disposal, the systemic problems reported in the following would have persisted.

Lack of Standardized Information Flows, Protocols, and Flow Frequencies. Responders on all levels bewailed the absence of clear-cut definitions and prescriptions of what information had to go where, when, in what frequency, in what format, and at what level of detail. The information needs of horizontally and vertically working response units were unclear, or, at least, not clearly known. There was no standardized push mechanism nor any standardized pull mechanism for sharing information between responder units, even within the same jurisdictions. As a City after-action report (AAR) laconically states,

> *"Neither the TCC* <Transportation Coordination Center, insertion by authors> *or* <sic!> *EOC* <Emergency Operations Center, insertion by authors> *has* <sic!> *guidelines on how and when to share information."* (quote #01),

And a County AAR adds,

> "*The establishment of regional situational awareness/common operating picture (SA/ COP) was not achieved due to inconsistent protocols and incomplete processes, as well as the lack of an effective and established common mechanism for sharing SA/COP information."* (quote #02)

Just using the standard ICS213 message form (https://www.fema.gov/media-library/assets/documents/33548, retrieved May 31, 2018) would not meet this particular need, since it only specifies the elements of basic messaging, but it does not specify any (vertical/horizontal) procedures, pathways nor protocols about processes, frequencies, nor reception notifications of point-to-point message exchanges and distribution among a number of other issues. In addition, message exchanges with the military are in need of specification, the latter of which, however, appears to be working between FEMA and other federal agencies.

Information Sources, Information Needs, and Information Overload/Overflow. Besides the problem of identifying the adequate lists and paths for distribution of important information to recipients with a need to know, inversely responders found it also difficult to identify the adequate sources of information, when in need. As presented below this problem has been addressed in part via developing checklists known as hazard-specific "Essential Elements of Information" by some jurisdictions. However, to what extent the information has to be pulled from respective recipients, and to what extent it is to be pushed on to recipients, needs further consideration. In particular, quite many responders found themselves overwhelmed by the amount of data shared with them. As a FEMA responder explains,

> "*People at that point are just collecting information, they're coming in, and there is so much of it, it's how do you synthesize what is really important versus not. So that's what I would look at for trying to find out really what is the life-saving issues are about. There's also, what is going to bring, what is the information that we need to know that's going to bring the greatest impact for response and restoration?*" (quote #03)

Information Inconsistencies, Obsolescence, Vetting, and Information Sharing Anxieties. In a turbulent and even chaotic information landscape like in the response to a catastrophic incident, information is incomplete, ambiguous, and even contradictory. The vetting, deconflicting, and verification process, however, can be time consuming. Responders strongly tended to pass on only vetted information, which had the positive effect of preventing ill-guided responses, but it also came at the expense of potentially valuable time lost through the verification process. In quite a number of instances, information was found obsoleted even before the vetting was complete. As a result, some responder groups (even inside EOCs and ECCs) appeared as having developed a reluctance to sharing information beyond their own functional needs, or for other reasons, for example, the police for security reasons, and other responder groups for the lack of trust regarding the

appropriate use of the information, the latter of which extended to not sharing all information with elected officials or external stakeholders. This kind of information siloing has also been observed and described elsewhere [6]. As a City responder illustrates,

> "<Police and Fire, insertion authors> *will have the quickest eye on the street than anybody. So, trying to get that information from them, for example, the police department treats some other information as security-sensitive, and they won't even share it, which is just kind of a problem, and I'm not sure, why it is, especially in the case of disaster. So, the fatality, we were collecting information from the fire department, but they were actually collecting the raw data by themselves.*" (quote #04)

As the quote shows, information siloing leads to a reduplication of information collection efforts requiring further verification and deconflicting.

Impacts of Shift Changes and Physical Separation. In quite a number of cases, shift changes were found a missed opportunity for effective information sharing between responders. Be it for reasons of fatigue, lack of planning or protocol, or other reasons, not every important information including the common operating picture (COP) was relayed from one shift to the next, so that costly double work resulted, and valuable response time was lost. As another State responder describes the shift change,

> "*But, that* <i.e, handing over a chronological log of events, insertion by authors> *in itself is not helpful in sharing information, sharing situational awareness, or sharing a common operating picture, because I do not want to have to read through a thread of 200 events from the previous shift to get an idea of what the current situation is.*" (quote #05)

Some jurisdictions practiced shift overlaps, which significantly helped mitigate the information loss upon shift change. In some other cases, also the physical separation, for example, of the Geographical Information Systems unit and other EOC stations and units led to the loss of information or to a lack of distribution.

Terminology as well as Format and Media Breaks. Information sharing was hampered or slowed down, whenever responders used incompatible terminologies including acronyms. Communication in plainest language omitting any specific lingo elements was found most conducive to effective information sharing. Also, slowdowns occurred when media and document formats differed, or were incompatible. This issue would need attention beyond the use of ICTs. In the real incident, when ICTs are unavailable through the loss of power, it would be a necessity to have standard document formats (such as the twenty-one forms published in FEMA's Incident

Command System forms booklet, https://www.fema.gov/media-library-data/20130726-1922-25045-7047/ics_forms_12_7_10.pdf, retrieved May 31, 2018) available on paper. More importantly, as soon as ICTs in the process of weeks and even months gradually become available again the transition between paper-based response management and ICT-based response management needs to be practiced. According to a responder, at the State level, this particular requirement has been identified,

> "*We've even gone to the extent of that form, this Incident Snapshot, is available as a paper form. It can be filled out in WebEOC providing that the jurisdiction has access to WebEOC, and the other thing, we've also done, we've created this as a template that amateur radio communicators can communicate on behalf of the local jurisdiction via amateur radio.*" (quote #06)

5.2 Ad research question #2 (What are specific SA/SSA-related *challenges* for professional responders in a catastrophic incident response?):

Reliance on Trustworthy Channels, Quickness of Information Collection, and Issues of Verification. As shown in the literature review, the criticality of assuming shared SA and COP quickly is well understood in both academic theory and practice. However, as seen in the previous section on information sharing a standardized process for exchanging information was missing. The same holds true for the information vetting and verification process leading to SSA/COP. During CR16 much information was collected through informal channels, and the trustworthiness of the exchanged information rested on the trust that was pre-established between sender and receiver rather than the message content itself, or other criteria and indicators of veracity (such as verification through own first responders, photographs from independent sources, live video from aircraft, and the involvement of subject matter experts, etc.).

During the exercise collecting information was not quick (as will not be during the real incident), which led to a SSA/COP that was slow in coming. Adding to this, whenever information was acquired through other than internal or trusted external sources, the information was duly scrutinized and vetted before it was compiled into the bigger SSA/COP. As stated before, while time-consuming, this process was followed to prevent undue responses at the expense of delays. However, in quite a few instances, response efforts were carried out even before a better SSA/COP was secured. The exercise clearly demonstrated that SSA/COP would not be established easily nor quickly, which may lead to rethinking the ways information is shared internally and with partners. As a State EMD responders summarizes,

"We have to share that with everyone in the EOC, on the EOC floor, and in the Unified Coordinating Group, but we clearly understand from the exercise that we have to share beyond that. We have to share it with our Federal partners, and we also have to share it with local jurisdictions. We also have to, as we choose the tools that we want to use to collect information, to store information, to share information, we have to work towards everybody being able to access the information, be able to contribute to this situational awareness and to the common operating picture." (quote #07)

When sharing, the sender might need to label the level of confidence and verification of the particular information. This could be helpful in the vetting process, since the recipients might be able to add and piece information elements together, which leads to respective feedback and an improved overall assessment.

Importance of SSA/COP Visualization and Regular Status Updates. As indicated above responders suffered from either not obtaining necessary and sorely sought information or through being flooded by raw data, which were of no immediate use but rather presented an additional obstacle. Pre-incident planning needs to focus on identifying means of how data can be meaningfully filtered without losing essential information in the process. The problem of information overload, however, will occur only as long as modern ICTs and networks are fully functional during the response, whereas in the case of a near-total blackout the problem of not obtaining important information will prevail. Responders repeatedly emphasized the importance of SSA/COP visualization, both low- and high-tech, based on interactive charts, status boards, and otherwise, which provides better at-a-glance situational understanding than lengthy narratives. The situation map tool used by the National Guard was repeatedly mentioned as an excellent example and useful tool for SSA/COP visualization.

Jurisdictions at all levels managed only in part to exchange updated situation reports (SitReps) vertically and horizontally. The horizontal information exchange between neighboring jurisdictions was found as essential as the vertical exchange, since critical infrastructure damage in a neighboring jurisdiction could massively hamper local response efforts, for example, due to road closures and the lack of alternate ground transportation facilities. Some jurisdictions created hourly incident snapshot reports; however, updates were not always complete and at times unobtainable, and discrepancies between incident status boards, on the one hand, and SitReps and snapshots, on the other hand, were observed. Also, SitReps had no standardized formats, and some responders found them hard to read. As long as modern communication capabilities were available,

virtual incident briefings were conducted among various, although not all, responder levels. As a responder from a State Agency puts it,

"The <State, insertion by authors> Emergency Management Division at Camp Murray is sort of the central point for information, for mission request, for damage assessment report, and all other reports. They have typically two briefings a day, one in the morning and one in the evening, and all that information is shared.... and so, all the different partners they have, whether it'd be federal, state, local, have representatives at the State Emergency Operation Center at Camp Murray. Or they can participate either through virtual teleconference or phone in those briefings ensuring information." (quote #08)

However, pre-incident planning needs to anticipate that modern communication capabilities in all likelihood would not be available for some time in the real incident.

Damage Assessment and the Important Role of Essential Elements of Information. Immediately after the simulated catastrophic incident occurred, responders began assessing the damage in terms of critical infrastructures, in particular, also relative to the responders' own capabilities. In so-called windshield surveys Police and Fire provided initial information, as one City responder describes,

"They drive around the community looking initially for columns of smoke and dust, which give you the idea of where's the fire, where's the collapse? The utilities are looking at their (unintelligible) systems for the telemetry of these waters still flowing, are systems still working? Department of Transportation is out inspecting bridges to find out, do we still have critical infrastructure routes?" (quote #09)

And the responder continues,

"If fires are broken out in more places than we can fight, we'd make the decision where will we fight fires, and where will we protect people and how? Where have the most people been trapped or injured and are in need of rescue, etc.?" (quote #10)

The windshield reports fed into the initial and quick assessment of damage, which were amended by incoming 911 calls and other sources of information. More systematic damage surveys were conducted based on checklists under the name of "Essential Elements of Information." These checklists are hazard-specific planning tools, which are used in EOCs for the systematic collection of information and its redistribution. The Seattle City EEIs list, for example, contained a column for the name of "essential element" itself, for example, "roads and bridges," another column for specific information details regarding the essential element, for example, number of bridge inspection teams and the list of bridges already inspected along with the status, another column for the information

provider or owner, for example, Seattle Department of Transportation, and a column for specifying supporting functions and agencies. Other jurisdictions' EEIs included also detailed contact information and information dissemination lists. Particularly, in the chaos of the real incident, the pre-developed EEI checklists may prove invaluable when trying to instill order into the information collection, management, and dissemination process, which would finally lead to establishing a SSA/COP. However, unfortunately, far from all jurisdictions had developed these checklists and standardized processes for information collection and handling. As a State responder admits,

> "*Basically, that is one of the things that we are working on: defining what are the essential elements of information, then defining how are you going about gathering the information? What is the repository going to be of the information, and then what tools are you using to share the information? And writing all of that up in a plan. So right now, we have two work groups: one that has been a direct result of the Cascadia Rising exercise and that is this, what we are referring to as the Situational Awareness Workgroup.*" (quote #11)

6. Discussion

As expected, the Cascadia Rising 2016 uncovered numerous vulnerabilities, planning deficiencies, and process issues with regard to establishing SSA/COP quickly.

Persisting Known Problems. In a previous study on a recent real-world non-catastrophic disaster [30], which involved quite a number of individual responders and jurisdictions who also partook in the simulated catastrophic incident response studied here, already several SSA/COP-related issues had been observed and analyzed, among which the missing standards for information sharing, the need for developing hazard-specific EEI checklists and contact lists, as well as the lack of information integration were identified. The current study re-confirmed exactly the unabated persistence of these key issues. However, this study on the CR16 exercise helped uncovering additional issues and more detail regarding the known problems:

Need for Standardizing Information Collection, Verification, and Dissemination Methods. While standard protocols for information sharing between and among responder units remain a backbone of electronic and paper-based information sharing, the standardization also needs to include mechanisms and methods for collection (push and/or pull), verification methods and levels (for example, confidence levels from unverified, verified in part, or fully verified), and dissemination methods and formats (for example, standardized SitReps). As much

as possible electronic method standards and document formats should be identical to the paper-based ones, which appears as unproblematic with regard to simple forms as in FEMA's ICS forms booklet. Much of any initial SSA/COP revolves around damage assessment. As discussed elsewhere the development of detailed hazard-specific pre-generated checklists on "Essential Elements of Information" present an effective handle, which provides guidance through information collection and dissemination regarding assets of critical infrastructures. However, while the EEI checklists are a much-needed prerequisite, the damage assessment process will not be uniform for each and every asset of critical infrastructure. Consequently, reviewing and defining these various assessment processes and procedures ex-ante will be another necessary investment into preparedness for a catastrophic incident response.

Rethinking the Information Sharing Paradigm. Responders take great pride in vetting and verifying information before they pass it on or use it for informing response efforts. As discussed, this practice effectively prevents suboptimal responses, while the vetting and verifying process can take a long time until completion, which may result in losing valuable time. In life-threatening situations, responders tend to err on the side of caution if information is unverified, that is, rather respond than not. However, too much time might be lost in the vetting process, and as argued before, other response units might have complementing information, which can help draw the bigger and more complete picture, which in turn might also help with identifying information that meanwhile has become obsolete. So, passing on information with a status label, which informs the recipient of the vetting status, might be preferable to hoarding and siloing [6] information. This change of information sharing practice and policy may need some effort to implement including culture change efforts, since many response units have cultivated information sharing anxieties and practice information hoarding for one reason or another. Just to be sure, it is not suggested here that information, which has not been verified, but rather labeled on some lower confidence scale, should ever be shared outside professional response units, and certainly never with the general public.

Information Integration and Visualization. The aforementioned previous study on a recent non-catastrophic disaster had uncovered the lack of integration in disaster information sharing (for example, for reasons of media incompatibilities, document format incompatibilities regarding text/voice/image, among others) [30]. Separate formats basically stayed separate and were not compiled into a single whole. Many voice messages were not transcribed nor was their informational essence captured in text. Video and image-based information was not

associated with text-based reports. As a result, information remained incomplete and distorted. This study, as stated before, strongly confirmed this finding. However, it additionally found that the problem would be most effectively overcome if the information, once properly integrated, was also adequately visualized. Be it on interactive charts (as long as electric power, and with it, ICTs and large screens are available), or on paper/whiteboard-based status boards, the visualization of important information appears as a highly effective means of maintaining SSA/COP inside a response unit such as an EOC or also between response units.

Shift Overlaps for Maintaining SSA/COP as Low-hanging Fruits. It was surprising to find again the problem of loss of information and degradation of SSA/COP upon shift changes after the previous study. However, the exercise involved many more response units than in the real-world case from a couple of years before. Quite a few units had learned that lesson and conducted shift changes in an overlap fashion of two hours or more, so that the new shift could gradually and smoothly take over without any abruption and loss of essential information. As a result, SSA/COP was fully maintained. Therefore, shift overlaps should become part of the standard procedure.

The Need for Contingency Planning and Paper-based Operations. The simulated response mimicked the real incident only in part, since the loss of power, communication capabilities, networking, and ICTs was only practiced for a few hours at best, and in some jurisdictions was not exercised at all as if the critical information infrastructure was invulnerable. Some interviewees referred to this approach as the "artificiality of the exercise," which did not sincerely represent the real challenge at hand. Unlike the National Guard most jurisdictional exercise participants did not consider that up to 50 percent of their own personnel might be incapacitated by the catastrophic incident in one way or the other, so that the response would be significantly curtailed quantitatively and qualitatively from the get-go. As described before, despite these "artificialities" the challenges to establishing and maintaining a SSA/COP were numerous and grave, and the exercise was very instrumental in uncovering these vulnerabilities and deficiencies despite the aforementioned mock in the exercise. In the real case of the incident, however, such convenience will be absent. Therefore, the response needs to be planned on the basis of a paper-based response for an extended period of time. Moreover, and potentially, more challenging, while modern communication capabilities and ICT capabilities return to operation, the gradual transition from paper to electronic needs to be managed, which might be more challenging than anticipated. It might be conducive to purpose and goals considering the establishments of redundant mirror sites outside the impact areas, which constantly enter and update information collected by first responders on ground zero (even if the paper record arrives and is managed a day later).

However, equally important, as establishing redundant information infrastructures outside the impact and response areas before the catastrophic incident happens, is the development of contingency plans under the assumption that a major number of professional responders and experts would not be available for the response themselves. This particular scenario has not been adequately regarded overall and relative to SSA/COP. It is clear from the Cascadia Rising 2016 exercise that losing a significant number of responders would very gravely exacerbate the situation.

7. Conclusion

This study's object was to contribute to more deeply understanding the SSA/COP-specific challenges during a catastrophic-incident response. The study found and discussed several important new areas, which need attention in the response to such an incident. The response to a catastrophe markedly differs from responses to "regular" emergencies and non-catastrophic disasters. Catastrophe responses require a high degree of procedural flexibility, while maintaining adherence to basic response paradigms and principles. The basis for finding an acceptable balance between the two hinges to a great part upon the quality of the SSA/COP, which makes further study on the subject mandatory.

With regard to the simulated incident response under study, the Washington State CR16 After-Action Report [4] bluntly summarizes,

"The state's current planning framework and approach to disaster response is not suitable to a catastrophic-scale incident" (p. 6)

And further elaborates,

"The state's emergency planning meets the response requirements for a severe winter storm, flooding or wildfire. However, current planning is not adequate for catastrophic disasters at the state and local jurisdiction levels. The state lacks comprehensive catastrophic response plans. Cascadia Rising identified an extreme-response environment demanding state-interagency activities well beyond current operational practice." (p. 5)

Along with the previous study, which had already identified a number of serious problems in attaining SSA/COP in the context of non-catastrophic emergencies and disasters, the results and insights from this study fully confirm the State's assessment and add important detail with regard to establishing and maintaining SSA/COP under the impact of a catastrophic incident. Not only has the need been identified for improving processes, practices,

and procedures for attainting and maintaining SSA/COP in non-catastrophic incidents, but rather increased attention has to be turned towards the particular needs and challenges, when responders have to deal with a catastrophe, which does not simply translate into a linear extension of the identified needs and challenges in non-catastrophic incidents. In particular, paper-based, runner-based, as well as low- or no-technology-based operations need to be redeveloped and practiced along with their gradual transition to more advanced procedures and methods as soon as those become available.

From the perspective of the State AAR and the insights from this study, it is therefore only consequential that FEMA and the Pacific Northwest States (Alaska, Oregon, Idaho, and Washington) plan another large-scale exercise to be conducted in 2022. That exercise should incorporate practicing SSA/COP operations in a blackout information environment as well as under the assumption of massive initial decimation in local response assets and capabilities. Furthermore, adequately mimicking the gradual transition from the aforementioned no/low-tech response management environment back to high-tech and high-speed ICT-supported response operations will remain a challenge to exercise planning, since in the real case this transition will take an extended period of time, which will be difficult to adequately simulate in the relatively short duration of an exercise. Future research will accompany and try to contribute to the design and evaluation of the 2022 exercise, in particular, with regard to addressing the SSA/COP-related challenges.

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