RescueCASTR: Exploring Photos and Live Streaming to Support Contextual Awareness in the Wilderness Search and Rescue Command Post

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Wilderness search and rescue (WSAR) is a command-and-control activity, where a Command team manages field teams scattered across a large area looking for a lost person. The challenge is that it can be difficult for Command to maintain awareness of field teams and the conditions of the field. We designed RescueCASTR, an interface that explores the idea of deploying field teams with wearable cameras that stream live video or sequential photos periodically to Command that aid contextual awareness. We ran a remote user study with WSAR managers to get an understanding of the opportunities and challenges of such a system. We found that the awareness provided by the camera footage could give additional confidence and comfort to Command, as well as reduce the need for explicit communications. However, it could also impact workers' traditional roles and responsibilities, shifting the burden of responsibility toward Command. We conclude that, while wearable-camera footage could be beneficial to Command, they need to have the tools and means to narrow their focus within the abundance of information provided. Furthermore, camera streams should not be thought of as a replacement for more direct communications, but rather as another tool available to help Command supplement their understanding of events in the field and help them narrow their focus.

CCS CONCEPTS • Human-centered computing ~ Collaborative and social computing ~ Collaborative and social computing systems and tools • Human-centered computing ~ Collaborative and social computing ~ Empirical studies in collaborative and social computing

Additional Keywords and Phrases: Search and rescue, outdoors, distributed collaboration, awareness, live streaming, video communication

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1 INTRODUCTION

Wilderness search and rescue (WSAR) is the search for and extraction of one or more lost people from a wilderness environment, such as a forested or mountainous region. WSAR is a time-critical disaster-response activity requiring careful communication and collaboration between multiple responders scattered and moving around different locations in a large geographic environment. WSAR is a command-and-control activity (Figure 1), where several teams of field workers (called *field teams*), searching different parts of the wider search area, are instructed by a WSAR management team working at a command post. The management team (called *Command*) tracks and coordinates constantly-changing information, including which teams are deployed, what teams are doing, where they are searching, which areas have been searched, what clues have been found, what equipment is available and in use, who is on each team, what are the unique skills of team members, and so forth [32].

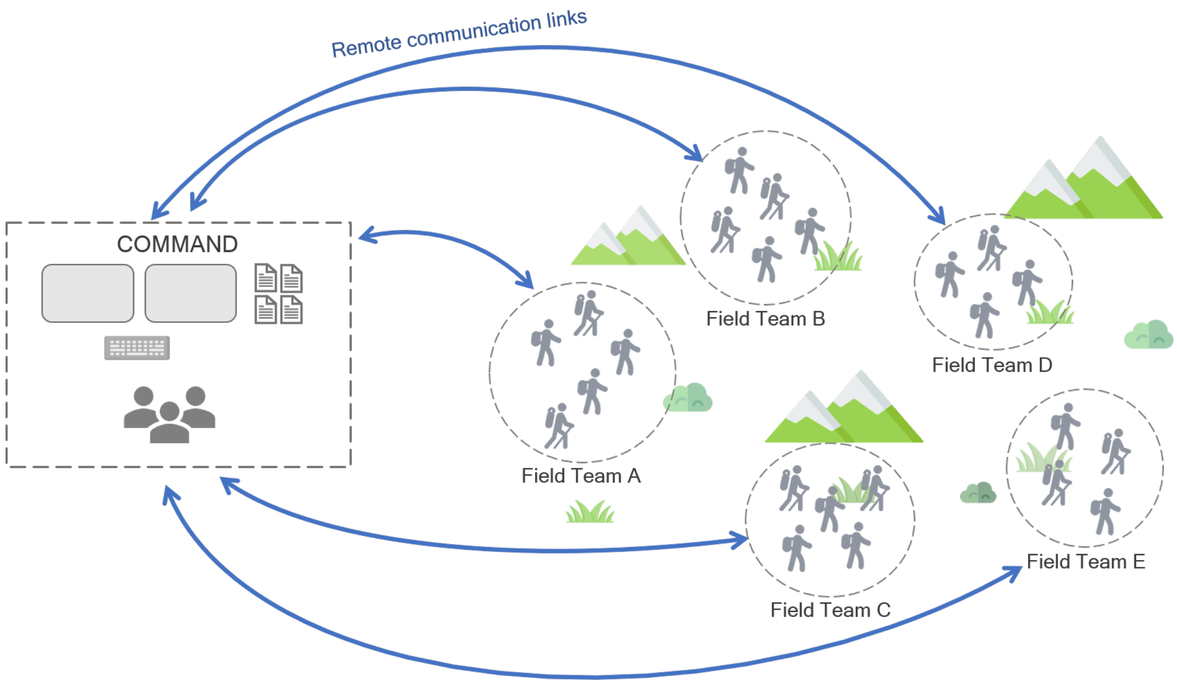

Figure 1: An illustration of WSAR remote collaboration. Numerous field teams (right) search a large wilderness area for the lost person, while the Command team (left) oversees the operation and manages the field teams and resources. All remote communication goes to/from Command, and field teams do not communicate directly with each other. Remote communication takes place mainly using two-way radios (walkie talkies), and sometimes via text and photo messaging.

WSAR is a distributed problem-solving task. From the Command side, activities fall into the buckets of *operations* and *planning*. Operations is about *running* the response in the present moment, and dealing with current demands, while planning is about deciding what course of action to take next. Both activities rely on working with already-collected information (i.e., *past* information) in the form of records such as completed and ongoing team task assignments, areas covered on the map, clues found, and past communications/messages between field teams and Command. Operations work involves a lot of back-and-forth communication and information sharing between Command and field teams [32]. WSAR organizations use multiple tools to build and maintain a shared mental model, or shared understanding, awareness, and agreement on key aspects of the search response [32]. For example, they use the radio, in-person briefings, text/photo messaging, task sheets, and Incident Command System (ICS) [8,27,70] paper forms. However, implicit awareness—awareness through seeing activities rather than through explicit verbal communications—is lacking in WSAR between the command post and teams deployed in the field [32]. Furthermore, the typical challenges that Command and field teams experience in maintaining a shared mental model are exacerbated because Command and field teams experience events from different perspectives [32] (e.g., see Figure 2). For instance, Command operates on maps, whereas a field team can see, for example, that an entire section of a mountain has been washed out by a flood.

Figure 2: The WSAR command post (left) in contrast with the field (right). Command workers (left) work inside a mobile office trailer and view the operation from a higher-level perspective based on maps, incoming radio updates, and teams' GPS coordinates. Field teams (right) have a more narrowed perspective and experience the conditions of the field firsthand.

We designed ***RescueCASTR***, or *Search and **Rescue** **C**ontextual **A**wareness **Str**eaming Platform*: an interface for the command post designed to help Command keep track of field teams' progresses, actions, and communications in a large WSAR operation. Our goal is to explore ways to bridge the perspectives of Command and the field through new technologies and information streams. For this current work, we focus on the Command side; more specifically, on exploring ways to provide Command with more implicit awareness of events and conditions in the field and the experiences of the field teams, so their decision making can be better reflective of and empathetic toward the experiences and needs of the field teams. RescueCASTR does this by exploring the idea of sending teams out to the field with at least one of their members wearing a body camera that streams live video or sequential photos periodically (e.g., once every five seconds) to Command, allowing Command to see the footage live and explore past footage.

We ran a remote user study with WSAR workers in Canada to understand the potential opportunities that a system like RescueCASTR could provide to WSAR commanders, including the potential for WSAR managers to use the system as part of their workflow in building and maintaining a mental model of the operation, as well as in projecting ahead and planning future decisions. Participants completed a series of simulated WSAR scenarios, where they viewed simulated live camera-footage from simulated WSAR field teams moving around a search area looking for a lost person. Participants played the role of SAR manager and imagined they were using the interface in the command post. They were asked to check on the teams, make sure they were on track, message them (using a simple text-messaging interface), and respond to their messages as needed.

We found that WSAR managers see video/picture streaming from wearable cameras as something that could be useful for them to provide contextual awareness of a team's progress and status. This awareness could provide additional confidence and comfort, as well as reduce the amount of explicit communication requests (e.g., radio checks) from Command to the teams, which could help teams focus more on their in-the-moment duties, as well as save time on Command's part, allowing them to put their focus toward other activities. SAR managers also pointed out that the camera footage could be useful for planning and reviewing activities, both during and after a response. However, the new capabilities afforded by body-camera streaming could also impact WSAR workers' traditional roles and responsibilities, shifting the burden of responsibility further away from field teams and more toward Command. For example, Command could be encouraged to micromanage the teams, and responsible for acting on the knowledge contained in the camera footage, even if they are not watching all the time and even though field teams still have a better view of the situation.

From these findings, we conclude that an interface design like RescueCASTR can provide rich and actionable contextual information about a field team's activities, status, and surroundings, all while requiring little effort from field teams. Body camera footage can be a bridge between the 'focus and context' [3] of other data channels. For example, it can add *context* to radio updates, text messages, and clue photos, while providing more *focused* detail and depth to information sources such as maps and satellite imagery. However, camera streams should not be thought of as a tool to replace more direct (explicit) communications or even as a means of providing super-detailed shots. Rather, the implicit information source should be treated as a tool to augment existing explicit communications to help Command build and expand their understanding of events in the field and help them narrow down what to focus on next.

2 BACKGROUND

2.1 Wilderness Search and Rescue through the Lens of CSCW Theory

Communication is often cited as one of the biggest challenges in WSAR collaboration [32]. While communication is easy within the command vehicle, it is difficult between Command and deployed field teams. Numerous challenges contribute to this, including technical issues such as unpredictable radio and cellular coverage in wilderness areas, but also usability issues such as the challenges of using audio as a communication medium (e.g., [21]), the lack of ability to express things non-verbally or implicitly (e.g., via deictic gestures or visual information) between field teams and Command, reduced ability to prioritize messages based on importance when communicating via the radio, time and effort needed to send a message (e.g., a field team needs to stop what they are doing and use their hands to interact with the radio), and effort needed to describe complex features in the field [32]. These challenges can easily lead to misunderstandings as well as gaps in teammates' mental models and awareness. Jones et al. [32,33] have suggested that there are opportunities for new WSAR remote collaboration technologies to bridge the Command and field perspectives, utilize asynchronous communication, and utilize communication channels beyond just audio and text. However, they have also recommended anticipating for network sparseness, bringing together new and existing communication channels and data streams, and being careful as to not burden or distract workers.

A shared mental model [7] is a shared and consistent understanding that collaborators maintain as they go about their work. It comes from people talking to one another and looking around to see what others are doing. In WSAR, Command wants to maintain control, consistency, and shared agreement amongst members of the responding agency [32]. In other words, they are invested in maintaining some degree of a shared mental model [7] amongst the responding organization. Early research in CSCW has promoted the idea that a shared mental model is important for large collaborative activities involving many people and resources, in particular because it helps maintain strong team cognition [5,7,46,47]. However, more recent research has argued that organizations do not necessarily need to have a complete shared mental model, especially if collaborators' tasks are decoupled [55]; rather, each worker may only need to have a subset of the organization's total knowledge in order to complete their own unique duties [9]. In WSAR, while not all members have to have complete knowledge of what is going on, the SAR manager does want to maintain consistent agreement on key things such as workers' roles, duties, assignments, and basic higher-level information about the subject, in addition to more scoped or focused knowledge depending on one's current roles and context [32]. Command workers try to maintain this through consistent communications and radio updates, as well as through documentation such as Incident Command System (ICS) [8,27,70] forms indicating workers' roles and responsibilities, task-assignment sheets indicating the makeup of field teams (e.g., the list of members as well as the tools and resources they carry with them), radio logs, constantly-updating paper and digital maps, and so on [32].

Team cognition, which is closely related to the concept of shared mental models, is the team's shared understanding of its members, work processes, duties, and the workspace or artifact of collaboration, as well as the team's collective ability to act on that knowledge and effectively collaborate based on it [18,29]. *Awareness* is important for maintaining team cognition [25] and thus for maintaining a shared mental model. In WSAR, Command wants to maintain awareness of each field team's actions, status, progress, and location, but getting this information from remote teams requires explicit radio communication [32]. In addition to managing personnel and resources and overseeing the operation, SAR managers' other key job is to ensure that teams and workers in the field are safe. Establishing and maintaining this awareness, though, is challenging across distances [9,15,16,26], and this leads to reduced team cognition [25] and an inconsistent shared mental model [7].

In order to support team cognition and awareness, WSAR members transfer knowledge amongst each other via a mix of explicit and implicit communications and by containing bits and pieces of the agency's knowledge in artifacts distributed across the Command vehicle, and/or their placements within the vehicle [32]—a phenomenon known as *distributed cognition* [29,30,54]. Much of Command's work involves documentation and record keeping, in service of distributed cognition. Records are kept for use during the incident to manage roles, share information, and maintain consistency, in service of creating and maintaining a shared mental model [32]. They are also used after an incident for archiving as evidence [32] similar to how multi-centre control rooms use record keeping for archiving and managing collaboration in the present moment [43]. Command is responsible for receiving communications about crucial events from the field, such as a team finding a significant clue, and they are also responsible for updating the agency's shared mental model with this crucial information. When it is between the field and Command, maintaining a consistent mental model is challenging, as each side is experiencing events from different perspectives. For example, Command has their higher-level picture, and is seeing things through constantly updating maps, forms, and radio/message logs; while the field teams experience the elements and see things firsthand, although with a more narrowed perspective. Our goal is to bring a more complete picture of the field teams' perspectives to Command, to aid in their decision making.

2.2 Technologies for Emergency and Disaster Response

SAR has been extensively studied by researchers in HCI and CSCW in various contexts (e.g., urban, wilderness). Desjardins et al. [13] studied co-located collaboration around beacons during avalanche rescues and found that control should be simplified, and information should be presented in relation to the spatial layout of the location. Alharthi et al. [1] revealed that much of SAR planning and discussion is centred around maps, as they provide an effective means to record key information about the search and communicate it with team members. Thus, we designed the RescueCASTR interface to display information mainly centred around a map, while showing the geographic and temporal relationships between pieces of information available to Command.

Both implicit (e.g., non-verbal) [65] and explicit (e.g., verbal) [21] communications occur in team-based emergency-response activities such as firefighting. In co-located settings such as command centres, collaborators benefit from being able to constantly observe [28], hear [52], and read the intentions of [28] their colleagues. Yet, this constant stream of implicit communication and awareness does not yet exist in present-day WSAR [32], at least between the command post and the field. Even with new communication mediums, maintaining an 'always-on' stream through which live up-to-date information keeps piping is difficult considering the lack of radio and cellular reception in the wilderness. As a result, field teams are often disconnected from each other, and Command is effectively more disconnected from field teams than the members of the Command team are with each other. This results in challenges in maintaining shared awareness, agreement, and consistency.

2.3 Video Calling, Streaming, and Sharing

Video and picture streaming and sharing is used to support a variety of work-based activities, and has been studied and explored in emergency domains. Some SAR agencies have used live streaming and body cameras for enhancing situation awareness [62,69]. The main benefit of this approach is that it can provide members with peace of mind, knowing that other team mates are aware of their actions and situations [62]. We are interested in understanding how body cameras can be used in wilderness operations, in conjunction with other communication and data channels, and how they can be adopted within the workflow of WSAR teams and agencies.

Previous work has revealed value in emergency dispatchers and coordinators receiving information in the form of photos and videos from the ground and using them to aid in coordination and building a mental model [4,42,67]. Previous work has also investigated the use of CCTV camera footage to aid coordinators in control centres (e.g., [43,44]). We are interested in examining the potential utility for multiple camera views moving around a large geographic space over a long period of time to aid WSAR commanders, and the potential for them to use both the live and pre-recorded data from those views. While video and pictures can provide useful information, there are difficulties in making sure that they contain useful and *actionable* [68] information. The difficulties usually centre around the challenge of camera work [34,50,53], which involves making sure the right visual information is communicated in the frame. Poor camera work can result in reduced awareness and thus reduced ability to take action [34]. Effective camera work is even more difficult to attain when the camera is mobile (i.e., the viewpoint is moving) [34]. This problem has also come up in other emergency response domains such as 9-1-1 video calling [48,49] and firefighting [38]. To address the challenge of providing 'good' camera views, researchers and designers have created prototypes involving the use of 360° cameras (e.g., [36,37,63]), drones (e.g., [31,39,56]), wearable movable cameras (e.g., [40,41]), and those that provide users with a means to gesture and deictically reference in the space (e.g., [17,20,22,23,35]).

Privacy concerns also arise when using cameras to capture footage in public [6,34,53,59]. Such concerns have arisen in studies involving 9-1-1 video calling [48,58] and firefighters [49]. This issue usually centres around capturing bystanders on video inadvertently; though in such emergency domains, there are also concerns around capturing video of deceased people. In addition, there is also the issue of liability, and potentially capturing a worker making mistakes on camera. These same issues could certainly occur in WSAR as well. We are interested in how WSAR workers might approach such issues, and how they should be addressed within the context of WSAR work practices.

3 SYSTEM CONCEPT: RESCUECASTR

The overarching challenge we tackle through the design of RescueCASTR is the challenge of building and maintaining a shared mental model. In tackling this challenge, we pursue the following design goals:

1. Begin to bridge the perspectives of the field teams and Command through bringing more of the field perspective to the command post.
2. Introduce additional communication modalities and information channels beyond just audio and text.
3. Introduce additional opportunities for asynchronous communication and information sharing between the field teams and Command.

These three design goals were also highlighted as design opportunities for WSAR remote collaboration technologies in previous work [32,33]. The same research also highlighted the following recommendations, which we follow:

1. Anticipate network sparseness, and design communication modalities and information channels that take these into account.
2. New technologies should not burden or distract workers.
3. Communication modalities and information channels should be aggregated, to allow for easy viewing, searching, sorting, and comparisons.

Alharthi et al. [1,2] found that much of SAR planning and discussion is centred around maps, as they provide an effective means to record key information about the search and communicate it with team members. Given this, we designed the RescueCASTR interface to focus on displaying information in relation to a map of the search area, with the map as the central focus. In addition, other interfaces designed for similar emergency-response situations focus on a large central map for discussion (e.g., [19,66]) and place details such as team/collaborator information and timelines (e.g., [66]) beside and below the central map. We thus took inspiration from these interfaces in the design of RescueCASTR.

The goal of RescueCASTR is to explore how information aggregation and body cameras can be used to give Command better awareness of events and conditions in the field. Field teams carry with them a wearable camera that the team leader or one of the team's members wears on their jacket, helmet, or backpack strap. This camera takes sequential photos, once every few seconds, showing a forward-facing visual picture of the team's surrounding environment, the path ahead, and the team's actions if the team member wearing the camera is at the back of the group. The camera is connected to a computing device such as a smartphone or tablet connected to a cellular network and/or a digital radio system (e.g., a mesh-networked system such as goTenna Pro [71]), and whenever there is a connection with Command, the device sends the photos to Command immediately after they are shot. If the team does not have a connection with Command (e.g., the team is in a radio or cellular dead zone), the photos are cached locally on the field team's device and sent to Command immediately after the team regains a connection with Command. The camera footage is meant to provide Command with extra contextual information of teams' activities to reduce explicit communication requests (e.g., requesting the field teams to respond on the radio or to a text message).

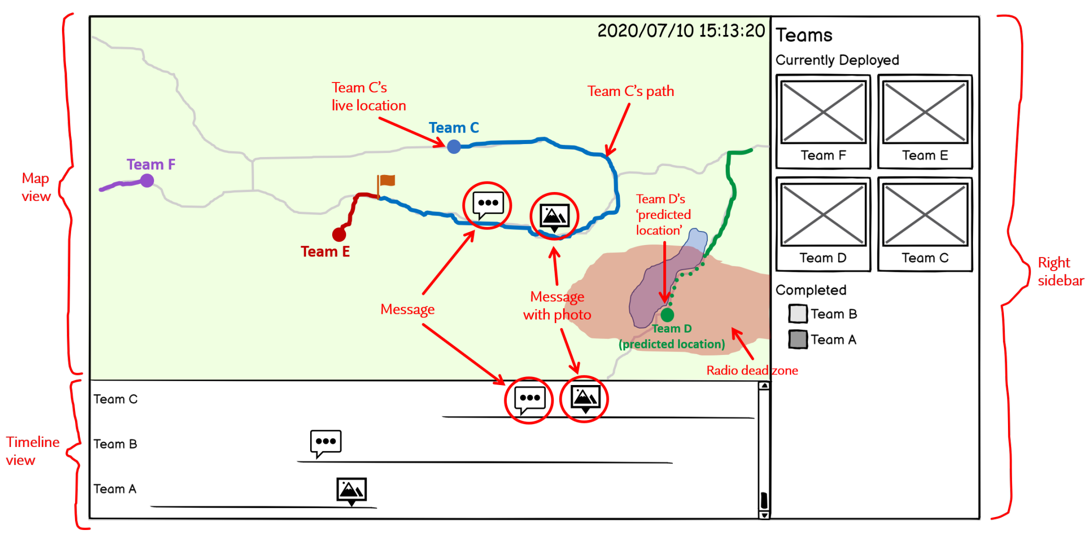

Figure 3: A schematic of the RescueCASTR Command interface.

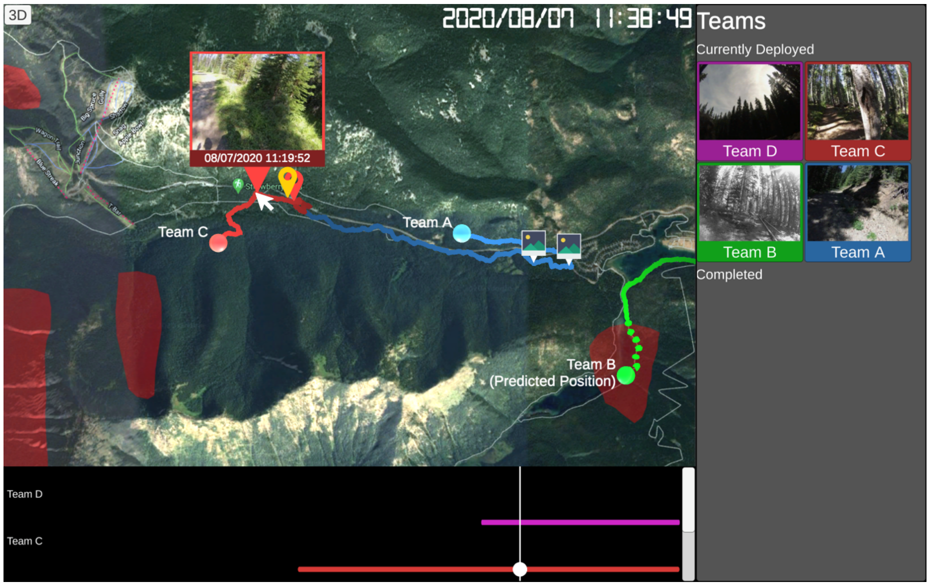

Figure 4: The RescueCASTR Command interface, default view.

This footage is then displayed on Command's interface, shown in Figure 3 as a schematic for simplicity and easier understanding, and Figure 4 as a screenshot of the actual system. This interface runs on a desktop or laptop computer inside the Command vehicle, displays a map of the search terrain, and presents information about the current status of the search as well as the data collected and recorded via field teams' actions throughout the search operation. The following data are presented:

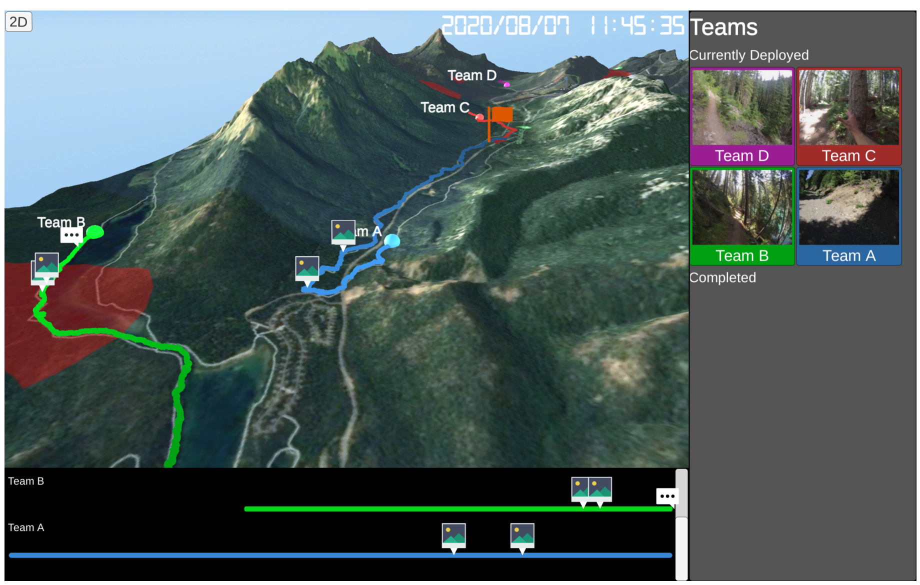

Figure 5: The map of the search terrain displayed in '3D mode'.

- **Map View:** Displays a map of the search area, overlaid with a satellite image. The user can pan the map via clicking and dragging with the mouse, and zoom in and out using the mouse wheel. The user can also toggle the map to ‘3D mode’ to get a 3D perspective of the area, see the terrain height, and rotate to view from different perspectives (see Figure 5). The map displays teams’ paths, current locations, messages, locations of radio dead zones, and features such as trails and bodies of water. For example, Figure 4 shows four teams presently deployed in the field (Team A, B, C, and D as shown in the figure), three of which are visible on the map along with traces of their paths, and one that is presently off-screen on the map.

Figure 6: Displaying a full-screen view of a team’s body-camera footage.

- **Team Paths:** Teams’ routes of travel are shown on the map as coloured paths. As an example, Figure 4 shows Team A’s path with a blue line, Team B’s path with a green line, and Team C’s path with a red line. These paths come from teams’ GPS locations, which are captured every few seconds. When a team is in a radio dead zone, their predicted route in the dead zone is represented as a dotted path (e.g., Team B’s path inside a radio dead zone in Figure 4). Hovering the cursor over the team’s path reveals what their body camera was capturing at that location (e.g., Figure 4), as well as a needle on the timeline view (bottom) indicating what point in time they were at that location. Clicking on the path at that location displays the image in full screen (e.g., Figure 6).
- **Teams’ Live Locations:** A dot on the team’s path indicates their current location. If a team is in a radio dead zone (i.e., out of telecommunications contact with Command), this dot indicates their ‘predicted location’, calculated using dead reckoning from their assigned path, average speed of movement, and last known location. While dead reckoning is used in this iteration of the prototype, we recognize that this method might present some weaknesses, particularly if teams do not travel in straight lines.
- **Radio Dead Zones:** Shown as red shaded areas on the map, these indicate areas where field teams are likely to not have telecommunications contact with Command. When a team is in a dead zone, their predicted location

is displayed. Once a team exits a dead zone, all of their camera footage and messages sent from inside the dead zone become visible on the interface. For example, Figure 4 illustrates that Teams A and C currently have live contact with Command, but Team B is in a dead zone, and thus their location presented on the map is a predicted location. This design choice is motivated by the principle of *seamful design* [10,11], which proposes showing users the 'seams' or limitations of their capabilities.

- **Timeline:** On the bottom of the screen, the timeline displays a temporal representation of the same data that are displayed on the map. Messages are displayed on the timeline using the same icons as on the map. Hovering the cursor over a team's timeline on the timeline view reveals what their body camera was capturing at that point in time, as well as a dot on the map indicating what their location was at that time. Clicking on the timeline reveals a full-screen view of the image (e.g., Figure 6), similar to clicking on a team's path on the map.

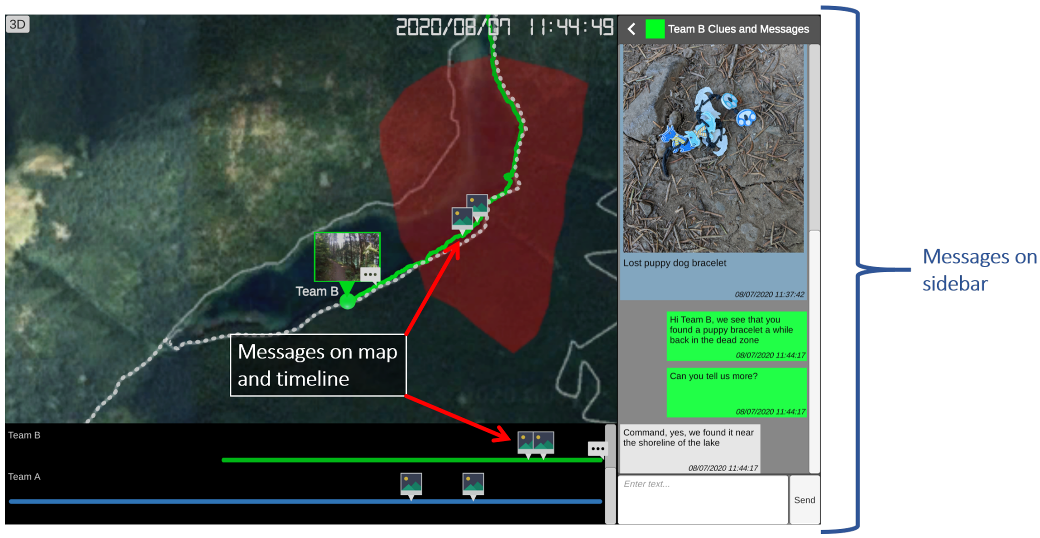

Figure 7: The messages thread (right sidebar) for Team B, showing a messaging thread between Team B and Command. Messages are also indicated on the map and timeline as icons.

- **Messages:** In addition to implicit information sharing (body camera footage, GPS positions, etc.), RescueCASTR also provides the ability for field teams to explicitly communicate with Command via text messages. Messages are displayed on the map and timeline views (indicating the locations and times they were sent), as well as in the team's messages thread (Figure 7). A message can also contain an attached photo (e.g., a clue photo), and messages with photos are indicated as image icons on the map and timeline views. When a team send a message inside a radio dead zone, it is cached on their device and sent to Command as soon as they regain connection.
- **Right Sidebar:** Reveals details about the field teams, including which ones are currently deployed and which ones have finished their assignments. For the deployed teams, their most recent body-camera images are shown. Clicking on a field team's icon reveals more details about them (Figure 8), including a list of the team's members (not implemented in the current iteration of the prototype), a larger view of their most recent body-camera image, their assigned path of travel (revealed on the map as a white dotted line; e.g., Figures 7 and 8) and an option to pull up a messages thread (Figure 7) in which the Command user can view the team's previous messages, as well as send them new messages.

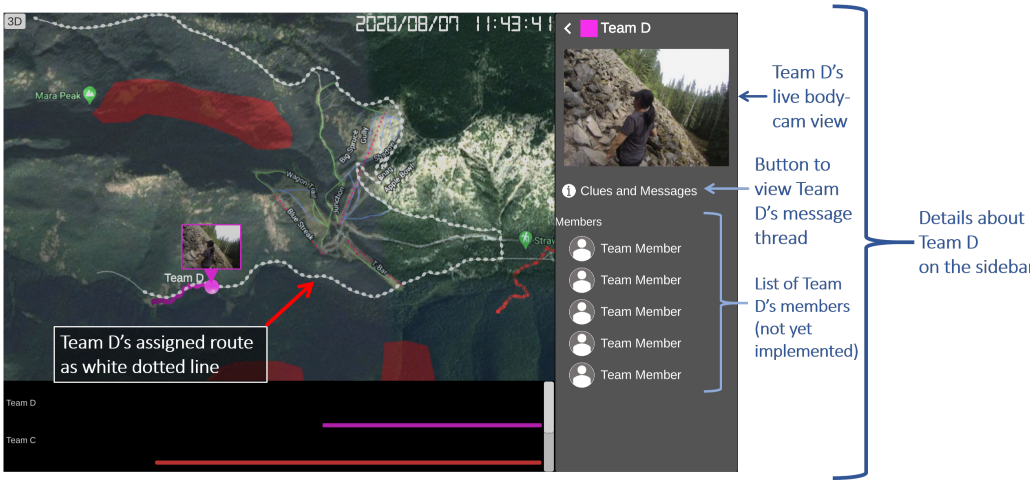

Figure 8: Selecting a team displays (a) more details and options for the team on the right sidebar, and (b) their assigned search path as a white dotted line on the map.

This system concept operates best when the field team has a relatively stable connection (e.g., cellular, radio) with Command. However, it would still operate under spotty conditions. For example, it would allow the Command user to make use of the data on the interface both synchronously, as it is coming in live, and asynchronously, after it had already come in. Even if a field team's body camera could not transmit photos at all while deployed, Command could still upload the photos to the interface and make use of them after the team returns to the command post. This idea to provide both synchronous and asynchronous features was motivated by the challenge of network sparseness.

4 STUDY METHOD: REMOTE STUDY WITH WSAR WORKERS

We conducted a remote user study with WSAR managers from across Canada. The goal of our study was to get an understanding of the potential opportunities and challenges of live wearable-camera streaming from field teams to the command post. This study was approved by our university's research ethics board. We focused this study around the following research questions:

1. To what extent would WSAR managers be able to understand the information presented on the interface?
2. How would WSAR managers use RescueCASTR to build a mental model of field teams' statuses and actions?
3. How might a system like RescueCASTR impact WSAR workers' existing roles and responsibilities?

4.1 Participants and Recruitment

We recruited 11 WSAR workers, including 10 WSAR managers and one field team leader, from volunteer SAR agencies in Canada. Ten of our participants were from agencies in Western Canada and one was from an agency in Eastern Canada. We recruited WSAR workers by contacting SAR agencies and provincial organizations representing SAR agencies, as well as through social media and our existing contacts working in WSAR. Participants were aged 27-63 (M=46.9, SD=11.6), had between one and 20 years (M=9.2, SD=5.3) of experience working in WSAR, and responded to between nine and 43 callouts (M=22.2, SD=11.7) on average per year. The ten WSAR managers had between one and 15 years (M=4.9, SD=4.2) of experience working in the WSAR command post.

4.2 Protocol: Simulated WSAR Scenarios

The study took place over a video call due to research restrictions on in-person studies as a result of the COVID-19 pandemic. The study was conducted in the fall of 2020, during a time when restrictions on travel and in-person indoor and outdoor gatherings were in place across most of Canada (where we and our participants were located), and university research facilities and other workplaces were either closed or restricted access. A prototype of the RescueCASTR Command interface was deployed to a web page that ran on a web browser on the participant's computer while they shared their screen to the study investigator via a Zoom call. The prototype displayed three simulated WSAR scenarios, where each simulated live footage and location feeds from field teams deployed in a search area. Participants were asked to imagine as if the data on the interface was live data from a real WSAR incident, and to imagine themselves in the Command post using this interface on a desktop machine as they explored the simulated live camera feeds and streaming information coming from the field teams. We developed the three scenarios based on real incidents that WSAR workers shared in a previous research study [32]. Prior to this study, we sent the scenarios to two WSAR managers to get feedback on their realism, and iterated on them a few times before arriving at these final scenario designs. One of the two WSAR managers who gave feedback on the study scenarios was involved in the study as a participant (as P11).

- ***Scenario 1: Checking the Statuses of Teams.*** In this scenario, the participant was asked to do a routine check of the field teams' statuses, by checking the live camera footage. Participants were asked to make sure that all teams were safe (e.g., that nobody was injured), that they were on track to completing their assignments. There were four teams deployed in the field, one of which was in a radio dead zone at the start of the simulation. About 3.5 minutes in, this team stepped out of the radio dead zone and regained contact with Command.
- ***Scenario 2: New Information from the Lost Person's Family.*** In this scenario, a lost child's father comes to the Command post with new information about his kid, and the participant has to explore the past footage and messages from teams on the interface to see if there is anything relevant to the new information given by the lost child's father. There are three teams deployed in the field, all of whom have radio contact with Command.
- ***Scenario 3: Understanding Where a Team Landed.*** In this scenario, there is one team deployed via helicopter to the base of a mountain. However, the team leader messages Command telling them that they might not be where they should be, as poor weather conditions may have made it impossible for the helicopter to land near the mountain. The participant is to (a) check if the team is at (or near) the mountain, and (b) if they are not, give them instructions on how to get there.

Each scenario lasted between five and 20 minutes. During these scenarios, we asked participants to 'think aloud', or to describe what they were doing and why, so we could understand their thought processes while using the interface. During moments when they were silent, we used prompts to gauge their thoughts.

Rather than simulating a complete search response from start to finish, each scenario placed the participant in the middle of an ongoing response, and had them complete some of the smaller routine tasks that they would perform as a SAR manager or other member working in the Command post. We took this 'in the middle of the search' approach in order to assess the efficacy of the tool in allowing SAR managers to perform these tasks while also having them explore a variety of use cases within a limited time period.

Simulated WSAR Data. To seed the system with data, 12 hours of hiking timelapse footage (i.e., a photo once every two or five seconds), across 35-40 kilometres of travel, was pre-recorded by the lead author using a GoPro camera attached to his backpack strap. This footage was captured in two mountainous provincial parks and one large forested urban park where each contained a network of hiking trails. This footage was used as the simulated 'live' footage from the field teams in the study scenarios. Footage was recorded for eight moving teams in total, with each team's footage lasting between 30 minutes to two hours and covering a path of between one and five kilometres. Even though participants spent only five to 20 minutes per scenario, the longer footage ensured that there was a lot of 'past data' for them to explore on the interface via hovering their cursor over teams' paths and timelines.

'Wizard of Oz' Message Responses. During each scenario, when the participant used the interface to send text messages to the field teams, the study investigator played 'Wizard of Oz' to fulfill message responses from the teams in order to add additional interactivity. The study investigator used his own interface to type up responses to the participant's messages, which would then show up as a message from the field team on the RescueCASTR interface. The researcher who was the wizard (the first author of this paper) had no direct experience in WSAR, but had experience observing WSAR workers in their training and work practices, and the Wizard-of-Oz responses were based on these direct observations.

4.3 Interviews

After completing the three scenarios, we conducted 15-30-minute post-scenario semi-structured interviews with each participant to get an understanding of their work in the Command post, challenges they face in communicating with and maintaining awareness of field teams, and their interactions with and perceptions of the RescueCASTR interface. We started each interview by first asking them broad questions related to their work as SAR managers; e.g., *"Please describe a real incident you responded to as a SAR worker in the Command post in which maintaining communication with and awareness of field teams was particularly challenging. What made it challenging?"* We then narrowed the scope, focusing more on the RescueCASTR system concept and Command interface; e.g., *"If you had a fully-functional version of the RescueCASTR interface to use during that incident, how do you imagine it might have played out?"*

4.4 Data Analysis

The data were analyzed using an approach taken from Grounded Theory [12], through open, axial, then selective coding. When analyzing and coding the data, we were particularly interested in understanding the following:

- How did participants use the camera footage and other data on the interface to establish and maintain *workspace awareness* (WA) [24,26]? How did certain elements of the interface design or the information-sharing modalities in the interface support or hinder this? We were interested in understanding how participants used the interface to answer the *who/what/where/when/how* questions of WA—questions such as "*who* is deployed?", "*what* are they doing?", "*what* have they found?", "*what* are they seeing?", "*what* have they seen?", "*where* are they?", "*where* have they been?", "*when* have they been there?", "*when* will a team reach a certain area?", and "*how* did they perform certain actions?"
- How did participants use the camera footage and other data on the interface to establish and maintain *situation awareness* (SA) [14–16]? How did certain elements of the interface design or the information-sharing modalities in the interface support or hinder this? We were interested in understanding how participants used the interface to attain SA across all three levels (*perception*, *comprehension*, and *projection*). For example, were they able to *perceive* the contents of the body-camera footage or the contents of teams' messages? Were they able to *comprehend* their meaning, and infer understanding of the current situation or status of the response from them? Lastly, were they able to use that understanding to *project* ahead and plan future actions in the response?
- What are the potential challenges and opportunities, within the context of WSAR, of aggregating multiple data sources into a single location and presenting relationships between various representations of the data (e.g.,

relating data on a map to the same data on a timeline)? Could such an approach support participants in establishing WA and SA? What challenges might such an approach introduce?

Open codes included categories such as 'footage providing awareness of features in the field', 'footage providing awareness of a team's progress', 'reviewing past data to plan future actions', and 'micromanaging the field teams' actions'. Our axial codes included categories such as 'footage enhancing awareness', 'use of live footage', 'use of past footage', and 'decision making'. During the selective-coding phase, we saw themes emerge around the footage enhancing Command's awareness and mental model, the impact of camera footage on workers' roles and responsibilities, and Command's need to narrow their focus in an abundance of camera footage. The first author completed most of the coding, but the codes were reviewed collectively and iteratively by the other two authors, as well as in a group session with other research colleagues.

We now describe our findings. Participants' interview quotes and vignettes illustrating their interactions with the RescueCASTR interface are listed with *'P#'* indicating the participant ID.

5 FINDINGS

The findings are split into five subsections. First, we report on the use of body-camera footage to aid Command in planning and maintaining awareness. We then report on how commanders used the footage in combination with other data sources such as GPS tracks, messages, and mapping data (trail maps, satellite imagery, terrain data) to triangulate it in attempt to infer a complete story. Next, we report insights on how new implicit information sources such as body-camera footage could impact WSAR workers existing roles, responsibilities, and work practices. We then report on how participants made asynchronous use of past data (i.e., as opposed to synchronous use of live incoming data). Finally, we touch on privacy, pragmatic, and usability concerns raised by participants.

5.1 Camera Footage could Enhance Command's Awareness and Aid in Planning

Participants found utility in the camera views within RescueCASTR and stated that the views could provide extra awareness of field teams' situations and activities to Command. The camera views could boost the agency's shared mental model, as they provide Command with a visual awareness similar to that of the field teams.

> *"I definitely see a lot of value in in having that real time data in being able to see through their eyes." – P8*

Awareness of Conditions in the Field. In particular, participants found utility in the additional awareness of features in the field, such as tree and vegetation cover, the nature of the path (e.g., wide, narrow, steep, flat, bumpy, smooth, etc.), the steepness of the terrain, and the proximity of geographic features such as lakes and rivers. They said this awareness could help them in understanding what a team is facing, and in addition help them with future decision-making and planning activities.

> *"It probably would have been extremely helpful because of the weather challenges we had and [in] getting up-to-date overhead imaging of the area we were in. [RescueCASTR] would have helped in some of the areas to identify what kind of coverage we had, like vegetation coverage." – P4 (when asked about how RescueCASTR might have affected a past incident he was involved in)*

Seeing the features of the field via the body-camera views could also help in that they allow Command to make their own determination about field conditions, rather than having to rely on radio-based verbal reports from field teams. In turn, these are tedious to give, as they are plainly obvious to field teams (akin to reporting on the nature of the weather).

"I can make my own interpretations. I mean, there's a certain degree of cost we have with team members [in] how they would describe their environment and all the rest of it, [and] it's just kind of nice to see for my own eyes. You know what kind of environment that they are truly in." – P6

In some cases, Command being able to interpret the situation on their own could save time. It may not always be the case that a member of a field team has the knowledge or skills to make some of these judgement calls themselves; but someone at the Command post might have the expertise to make a better judgement.

"Some people will underplay or overplay the difficulty of the terrain that they're in. And [they say] 'oh yeah, you can easily get a quad up here', when in fact it's not easy to get a quad up [there], that kinda stuff." – P6

Awareness of features in the field could also potentially help SAR managers guide teams in their assignments when they are currently deployed. For example, participants mentioned that if they are able to observe the current weather and ground conditions that teams are facing, they might be able to suggest to the team to traverse an easier or safer area, or an area where they might be more likely to find the lost person.

"Being able to have eyes up on just how bad the conditions were that the teams were working in, the manager at that time may have sent extra resources or maybe changed the way of following the terrain. When I said 'okay, well, you know, go up higher, you know, stay down low, keep following the creek'. It [would] make me want to make some different choices. Just because you have more information to make decisions on." – P5 (when describing how RescueCASTR might have affected a past incident he was involved in)

During Scenario 1, we witnessed P9 scanning the footage to remain aware of the current safety and situation of a team traversing through a steep mountainside, and to plan ahead for how to keep them safe in case the situation changes. For example, as he was scanning the imagery, he said *"looking at these pictures here, I wouldn't have sent these people up into the field, they're wearing improper footwear."* While pointing at a particularly steep section of the team's path containing large smooth boulders, he said *"this area right here, going back there, would be something that I would make sure the team [is] doing a good recon [assessment of their own safety], especially if rain came in [...] this could be very slippery."* This is information that he, as a manager, would be able to make use of, for instructing or guiding the field teams in making better decisions in the current moment, for deciding what clothing and resources future teams being deployed to the same area should take with them, and for planning ahead for what to do in case the situation changes at that particular location (e.g., the temperature drops, rain falls, someone is injured, etc.). When we asked about these actions later during the interview phase, P9 said that he found value in being able to think about these decisions in realtime, with a visual picture of the team's situation coming in in realtime.

In the same scenario, we also witnessed P4 scanning his cursor over a team's path along a lake to scan the team's camera footage taken along that path, in order to determine what the water was like along the path. P4 determined that the water was calm and still. Given this and the fact that the team found a puppy-dog bracelet along the water, which was a relevant clue to the lost child in the scenario, P4 determined that the lost child may have gone for a swim in the water. He then stated that his next step as a SAR manager in this case would be to deploy a team with diving gear to that location.

While Command has access to maps and satellite images of the search terrain, like in other emergency domains such as disaster response [51], we found that these are not always up to date in WSAR. For example, our participants pointed out that there could be paths that are non-existent on Command's map, or conversely, paths that show up on Command's map that are non-existent in the field. Additionally, the satellite images only show an aerial snapshot of the terrain taken at a point in the past. They also do not show details of what the terrain looks like close-up, in the present moment, in current circumstances (e.g., weather, snow, mud, and/or water buildup, etc.) and from the perspective of the field teams. Participants pointed out that the body-camera footage allows Command to see a snapshot of this information, albeit lower fidelity than what the teams actually experience with their own eyes. This information can give the SAR agency a more consistent shared mental model, as it could enhance Command's understanding of what the field teams are experiencing.

> *"I think it's going to help me with planning considerations like this team here... Knowing there's a trail that's not on our map means [there are] probably a number of trails not on our map." – P8*

Participants also mentioned that awareness of features in the field could help managers plan for the future. This planning could occur both live (when teams are deployed) and at the end of an operational period, when the teams sent out to the field finish their assignments. The SAR management team could review past footage in certain parts of the search area to determine what strategies to take when they deploy teams to those areas in the next operational period.

> *"Being able to get that live view of what the terrain was like would really help with planning the second or third or fourth operational periods [the next stages of the operation]." – P8*

For some of this planning, they may need to make a judgement that relies on knowledge of the present ground or weather conditions of a certain area. For example, they may need to know if they can deploy a field team to a location via an all-terrain vehicle (ATV), whether a team needs to take snowshoes with them, if an area is safe to land a helicopter at, or if a rescue team can carry a stretcher with a wheel to an area if they find the lost person there. Some SAR managers mentioned that they could explore the camera footage on the map to help them determine these things.

In addition, SAR managers pointed out that some situations could benefit from a second look by someone with specialized expertise, such as a medical doctor or avalanche technician. For example, one SAR manager pointed out that an avalanche technician could examine body-camera footage of a scene to assess the risk level of an avalanche occurring, as well as to provide necessary advice to the field team.

> *"We're doing training around avalanche, but [...] we have to get boots on the ground, and then you're either waiting there for an avalanche technician to fly in, or you know, you might try [to go in]. But if we've got a video camera that can take pictures, then [the avalanche technician at Command] can make some assumptions based on what he's seeing because he already will have a lot of forecast data. And we [Command] can provide info: 'here we see crowns, we can see fresh snow', and we can show the path of the avalanche, what classification it is... and we can say 'no, you can't go in, we'll have to do something in the area to make it safe'." – P9*

He also pointed out that a paramedic on scene at the command post could use a team's body-camera footage to perform an early assessment of the subject, to give advice to the team on first-aid interventions, or to assess the subject's health and situation in advance of their arrival at the ambulance.

Awareness of a Team's Progress. In addition to awareness of features in the field, our participants pointed out that the camera footage could also provide Command awareness of a field team's progress—or simply, it could provide awareness *that* a team is making progress.

"On an immediate day to day operation, I think the utility's in the fact that there's movement [that I can see movement]. I really like that. I can see the teams are moving." – P1

With today's technology, SAR managers are usually aware of a team making progress only when they do a radio check with Command [32]. However, with body-camera footage, as long as a team has a stable connection with Command, our participants said that Command could see a team making progress through changes to their live camera footage. At minimal, this could serve as sort of a 'heartbeat' for the team, providing basic awareness that the team is still okay. Our participants mentioned that seeing the contents of the camera footage change live could give Command additional confidence that a team is safe.

"There's a strong safety aspect here of being able to see what the teams are up to. And what the environments are like and things like that, and just [to] have that realtime position data. It makes us very nervous when we don't hear from teams in quite a while and don't know exactly where they are. So there's a strong safety argument for this kind of technology as well." – P8

SAR managers mentioned that the heightened awareness of field teams' surroundings, their activities, and their progresses provided by the camera footage can provide Command with additional comfort, confidence, and trust of their field teams.

"It would be nice just to sort of have the body camera, you know, just to sort of peek in and see what they're up to. And I guess I would then pester them less frequently with requests of how things are going and what their ETA was if I could actually see what they're doing." – P6 (when asked about how RescueCASTR might have affected a past incident he was involved in)

Our participants mentioned that this could potentially help serve SAR managers in moments when a field team does not update Command on their progress frequently. Participants mentioned that these moments could occur when, for example, the team is preoccupied with activities that require a high degree of attention, such as listening for the lost person or driving an ATV or snowmobile, or activities that require use of one's hands, such as scrambling over steep terrain or operating skis. During such moments, field team members might not be able to stop what they are doing to respond to Command's requests over the radio or via text messaging, or they might be in a situation where stopping to respond is cumbersome or frustrating. For example:

"It was the heaviest rain I've probably ever been in. [...] We were soaked, and it was because it was raining so hard that our radios weren't working. [...] As we were heading up, I mean, we were already pretty miserable. And Command kept asking us for our UTM [location] coordinates, which is a real pain to transmit over the radio, especially when your radios barely work. And I mean, we were, like, 100 metres away from Command. So I told them 'I'm 100 metres to your east, like literally'. And they're like 'no, we want to see your location'. So that was a real pain. [...] And we're right in the middle of rescuing this guy..." – P10 (when describing a past incident)

The visual updates are useful if field teams are not disciplined enough to regularly radio Command, or simply do not have good communication skills.

"If their discipline is poor and they're not checking in every half hour like [they're] supposed to, or if they're not giving me, you know, clear messages on the radio, then I become more frustrated. You know, if it's a team that has really excellent radio etiquette, [and they] describe things well [and] radio in with their safety checks every 30

minutes, then I have more trust in that team. But if their discipline is poor with regard to those aspects, then that's where I would really wish I could be having a camera on their on their body and see for myself what they're doing." – P6

Participants also mentioned that, even when a team appears not to be moving on the map or not making progress, they could see potential in using the body camera to confirm whether they are moving, and if not, why. In such an instance, Command seeing a live image of the actions of the team and the conditions they are experiencing would discourage Command from interrupting the team unnecessarily, while at the same time gaining useful status information.

5.2 Using Camera Footage to Infer a Complete Story

While having a visual picture of the conditions in the field could provide important details and awareness information to Command, our participants were quick to point out that this footage may not tell the whole story about what is happening on the ground.

"Command would be convinced, based on what they're seeing in the video, that a certain thing is happening, but they don't have the full picture. They don't have the continuity. That comes up all the time, even with radio comms." – P11

Even though this is the case, participants found that the combination of data sources provided by RescueCASTR beyond the camera images helped them make deeper inferences about a team's situation. In addition to the body-camera footage, RescueCASTR also provides SAR managers with message threads, field teams' live locations and paths (historical location data), satellite imagery, terrain data, and a map showing trails and landmarks. There were a few instances in our study when participants compared the body-camera footage to this other data on the interface to make an inference about the current state of something in the field.

For example, in Scenario 1, P2 found a section of Team A's path, along a trail in a long flat valley, that appeared to go off the trail. The team's path on the map reflecting their actual path (based on their recorded GPS positions) did not reflect the trail's path on the map for about 200 metres, thus making it appear as though they deviated from their assigned path for about 200 metres. To see what was going on, P2 scanned the past body-camera footage along this area:

[Looks at the footage on the exact spot on the map where the team's path appears to branch out from the trail path on the map.]

P2: Again, I'm trying to see if there was a crossroad.

[Sees the team's body-camera footage looking toward the bushes beside the trail.]

P2: Oh, potentially here. So they might be looking at the initial trail here.

[Scans cursor forward along the team's path]

P2: But they continue on the easiest one. So that's something I'm going to ask the field team leader afterward. Cause now it's too late.

His interpretation from scanning the body-camera footage in this area and comparing it to the trail map and the team's assigned path was that there was a fork in the trail that the team saw, and they were required to take the more difficult path as part of their search assignment, but they purposely decided to take the easier path, thus deviating from their assigned path for a short distance. Though he admitted that he could be wrong and said that he would note it down and ask the field team later, when they return to Command after they complete their assignment.

Participants mentioned that the camera footage could sometimes confirm things that appear in other sources of data. For example, P4 mentioned:

"I kind of like [the body-camera footage] because it lets me know other than if I didn't have the map, I wouldn't know how close the water was to that team." – P4

Participants also mentioned that they could compare the body-camera footage in a location to the satellite imagery and map data from the same area too see how much they match or are 'consistent' with each other, then use that comparison make a 'projection' or 'prediction' about what the conditions would be like in another location:

"Combining those body camera images with the map and I can see that it may be that the trail is quite good where they're at. But it won't be very long [until] the trail is going to deteriorate into, you know, just a single track as it gets to the steeper slopes." – P6

5.3 Footage could Impact Workers' Roles and Responsibilities

While introducing body cameras to WSAR has the potential to enhance the agency's shared mental model and provide an abundance of information that could be useful for planning and decision making, the new capabilities afforded by such a system setup could also impact WSAR workers' traditional roles and responsibilities, shifting the burden of responsibility further away from field teams and more toward Command. While the WSAR command post today often suffers from a lack of information [32], the abundance of information made available to Command by a system like RescueCASTR could easily bring with it an abundance of responsibility.

For instance, SAR managers pointed out that the sheer amount of information provided in the camera footage, especially when combined with other information such as GPS location and GPS history, could encourage micromanagement on the part of Command. The way teamwork is structured in WSAR today, the field teams are generally trusted to perform their search assignments correctly and without error. Their work is largely decoupled from that of Command.

"In theory the SAR teams in the field are the eyes and the ears of Command." – P1

However, SAR managers pointed out that when Command starts being able to see things from the same perspective of the field teams, through the body-camera footage, there could come with that an increased desire to take action based on that abundance of information. Participants mentioned that if a SAR manager is not properly trained to trust their field teams, they could be tempted to make judgements for field teams and ask them to change their behaviours prematurely or unnecessarily based on the narrow-window view they have into the field team leader's perspective.

"You're kind of looking at the [interface] and [thinking] 'Oh did they see that? Did they see that? Did they see that?' And [...] there's three people on a team or four people on team: 'Yeah, we've got [...] four sets of eyeballs!'" – P1

This information could encourage some SAR managers to steer away from their traditional role of being the overseer, and overreach into the bounds of the field teams' roles, making the work more coupled. This could be potentially detrimental to field teams if they suddenly have to respond to more of Command's requests.

"There's some search managers that I know, I would never let them have this kind of thing because they'd be pestering [the teams]." – P4

"I mean, to a certain point, like, you want to allow the independence of your team. And [...] like the body camera could allow [the] search manager to really micromanage their teams in the field. And sometimes you kind of just have to, like, trust that you train those people and they can make the right operational decisions, and they're going to have more information than just a little body camera." – P7

While the extra information could increase the desire to take action based on it, it also has the potential to reduce Command's responsibility and desire to check in with field teams via direct radio or text-message requests.

"It takes a lot of pressure off the team leader. It almost offloads, I mean potentially, it could offload responsibility to the search manager. Which I mean they're already pretty busy. But a lot of [...] why they're busy is because they're trying to get information and in a roundabout kind of way, right? So maybe this could offload some of that responsibility and, you know, make it easier for the search manager. Because you know, they don't need to ask for information as much, and they can direct their attention to where it's needed." – P10

This points to an interesting tension: on the one hand, while extra information can certainly be beneficial to Command, especially considering that the WSAR command post today often suffers from a lack of information from the field, too much information can easily become distracting, introduce too much responsibility, and fundamentally shift the roles and duties of Command. Some of our participants suggested that they might assign a member of the Command team to specifically play the role of attending to and analyzing the incoming camera-footage data. With current work practices, SAR managers typically assign one or two workers at Command to operate the radio, to use it to communicate with field teams, and manually log all communications to and from the field teams [32]. A new system like RescueCASTR could similarly result in having a member of the Command team specifically assigned to operate it and deal with the incoming data it provides.

5.4 Use of Past Data

Given unpredictable radio and cellular coverage in wilderness areas, it cannot be guaranteed that Command will have contact with field teams at all times [32], and in fact some WSAR agencies have almost no stable contact with their teams most of the time in their area of jurisdiction. Given this, unless and until connectivity issues become addressed, this would continue to be the case even when teams are deployed with new technologies such as body cameras. However, as several of our participants pointed out, body-camera footage can still provide utility even when it is not coming in live, but rather being used asynchronously.

"One of the challenges we often have in Command is, we send people out to a map coordinate based on what it looks like on a satellite view. But getting that sense of what it really looks like on the ground would be very valuable. Even after the teams come back, it would still have value when we're planning the next round of assignments." – P8

"I would [have had] a lot more comfort in Command, having more appreciation for what this terrain is like where my [ATV drivers] were at. Because I haven't. I've never been to that location. I have no idea what it looks like. Other than what I can see on the map and satellite imagery." – P6 (when asked about how RescueCASTR might have affected a past incident he was involved in)

Asynchronous use of camera footage can happen either when the team is still deployed in the field (in this case, some of the cached past footage could come in during moments when the team regains some contact with Command), or long after they have returned to Command (at which case any of the footage that Command is missing could then be uploaded to Command's interface). There are several use cases for which use of past data could serve utility.

Reviewing past data while a team is deployed. Participants pointed out that if the connection is stable and Command has access to at least some of a team's past camera footage while they are still deployed, they can make use of it while the team is still out in the field, and even communicate with the team while discussing the footage. For example, Command and the field team might need to discuss discrepancies between the information Command has and what the team is experiencing in the field.

> *"If I could use [the body-camera footage], you know, if I talked to the field team leader and said 'okay, why are you off track here', and he shows me 'this is what your mapping system says, but this is the trail, the actual trail'. So my map was wrong, he was right. That [would be] awesome." – P2*

In such an instance, participants mentioned that the field team could direct Command to a specific location that they passed and a specific place in the camera footage for them to view. In a sense, sending messages or radioing Command, they are already providing Command with some pointers on where to look in the footage.

> *"I don't think anyone's going to review all of the footage of Team D, all like, from start to finish. [...] But being able to have the team flag when there's something worth looking at [...] I think would fix that challenge." – P8*

These kinds of pointers from field teams could help Command narrow their focus in the abundance of information contained in the past body-camera footage.

> *"We've mentioned a couple times the idea of bringing in body-cams into SAR and the pushback has usually been 'well you're going to get hundreds of hours of data and [...] no one's going to sit there and go through it all'. And yeah, there's gonna be a lot of data that you just don't really want. But with the teams sort of flagging where they find clues and things like that, that's going to narrow down where you're interested in seeing." – P8*

In Scenario 1, several participants used the messages sent by the teams to narrow their focus when inspecting the past body-camera footage. For instance, P8 heavily inspected the footage from Team B, particularly around a location where they sent a message containing a photo of a clue that was relevant to the lost person in the scenario. He also spent time looking at Team C's footage because they had been moving in the wrong direction, away from their assigned path of travel. However, he did not spend much time scanning the footage of Teams A or D, because they were moving along at a normal pace, along their assigned path, and did not send Command any messages.

> *"[Team] D just sort of chugged along, I wasn't too worried about D. They were kind of doing their thing as was A. [Teams] C and B were really where I ended up spending a lot of my attention, but I knew I had to spend attention there because of the real time data, which was nice." – P8*

Reviewing past data when a team returns to Command. With current WSAR work procedures, when a team returns to Command, they perform a debriefing, during which time the team gives a SAR manager a summary of what they did in the field, what they found, and what, if any, issues occurred. Several SAR managers in our study pointed out that reviewing camera footage could be useful as part of this debrief. For instance, it could be useful for a field team leader to guide the SAR manager through the footage and point out noteworthy things in it, as the team is the one that experiences the conditions in the field firsthand, and they have a better idea of what is 'noteworthy' to show Command.

> *"When they're debriefing, they're supposed to, after the fact, let Command know of issues encountered, hazards, terrain, and all that stuff. But if having a picture makes it a lot easier for them to do it, [then] they can say 'okay, refer to footage around this time'." – P3*

This could help save time and effort on the part of field workers, especially if they need to show things that are difficult to describe in words. Given, as pointed out earlier, that Command may not necessarily be paying attention to the live footage at all times, this 'recap' of a field team's search assignment could help bring Command up to speed if, for example, they missed something important in the footage when it was coming in live. It could also, however, put some burden of responsibility on the field team leader to mark noteworthy spots on the map while they are deployed, or to remember them and point them out when they debrief with Command.

Using past data during role changeovers. Some of our participants mentioned that the body-camera footage could be useful during role changeovers, when the SAR manager and others at Command are stepping off duty and others are coming in to take their place.

> *"If the next search manager comes in within two days. I'm back here and I can actually access the other professional peers before me. That would be huge. Five years ago, 10 years ago, [...] we didn't necessarily have the information from other GPS tracks and stuff like that. Now we do and it's very difficult to make good decisions if we don't have what happened before." – P2*

Reviewing past data after an incident. Lastly, participants mentioned that it could be useful to review camera footage after an incident, for training and learning purposes, to review what went right, what did not go as well, what (if any) hazards were in the field, and what the organization could do to improve its performance in future WSAR responses.

> *"If something went wrong with a particular team, you'd be able to... you know what happened or, you know what things went well, what things were bad." – P4*

This would especially be useful for agencies based in smaller towns or more remote areas, that do not get called out as frequently. For these agencies in particular, members' skills could easily deteriorate over time if they are not deployed frequently, and so it could be useful to have tools available to look back at previous incidents and relearn from them. While WSAR agencies already conduct a lot of record keeping of the incidents they take part of [32], which they may make use of occasionally for review purposes, having the opportunity to look through the camera footage more carefully and in greater detail once it has all been collected could be beneficial for doing detailed training reviews.

5.5 Privacy, Pragmatic, and Usability Concerns

Similar to in previous work on introducing video to emergency situations (e.g., [45,48,58]), our participants said introducing body cameras to WSAR could raise privacy concerns, such as the potential to record unconsenting bystanders and the problem of having the live camera footage visible to everyone in the command post at all times, which could be especially problematic in the case that a field team comes across a disturbing scene. Our participants also suggested that WSAR workers should have flexibility in choosing when to stream the video, when to record it, and what to show and present in it.

Participants also reported more pragmatic concerns with using systems like RescueCASTR. This included potential challenges with having to store large volumes of video data. Moreover, while there exists a potential issue around liability and accountability if a WSAR worker does not do something properly and it is captured on video, none of our participants reported such concerns.

6 DISCUSSION AND RECOMMENDATIONS

We now discuss our findings and their implications for how photo and video streaming could impact WSAR remote collaboration. We also discuss design recommendations and opportunities for such a system, as well as recommendations for its usage by WSAR teams.

6.1 Depth of Multiple Information Sources

RescueCASTR brings together information from multiple data channels on a single interface. They all present information at various scopes and varying degrees of breadth, depth, freshness, trust, and intentionality. This is also the case in a real WSAR operation using today's technologies [32], as WSAR command workers have to work with multiple channels of information. In line with the theory of distributed cognition [29], Command's knowledge of the incident response is transmitted through and contained within these data sources. RescueCASTR serves as a means of bringing together these data sources, making it easier for Command workers to view this information in 'focus plus context' [3], while also introducing another data source (body-camera footage) that sits somewhere in between focus and context and is meant to help Command see more from the perspective of field workers. Our explorations revealed that participants interacted with these data sources in different ways and had varying impressions of them.

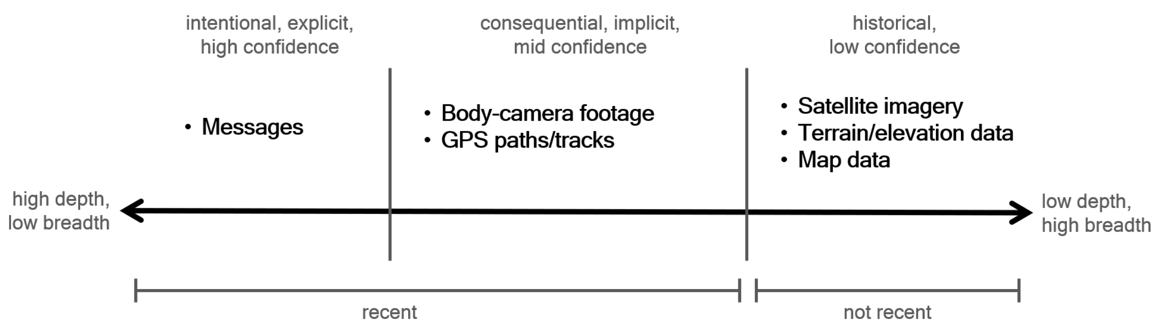

Figure 9: The different sources of information presented to users in the RescueCASTR interface.

Figure 9 summarizes the information sources that were aggregated in the RescueCASTR interface. These fall into three categories, from left to right on Figure 9. First, there were the *intentional/explicit* communications (Figure 9, left), or the messages sent between field teams and Command. Second, there were the *consequential/implicit* communications (Figure 9, middle), or the implicit information that was streaming in as a consequence of teams' actions, such as the body-camera footage and GPS tracks. Finally, there was *historical* information (Figure 9, right), which was information that was already there before the incident began—e.g., existing trail maps, satellite imagery, and terrain data. These categories also vary in the amount of information depth and breadth they provide. For example, the intentional/explicit communications carry a high amount of depth. They contain the highest amount of detail, though the information is more narrowed and focused on a specific event or finding in a particular location or at a specific point in time. For example, a message containing a clue photograph plus a description of the clue carries a lot of detail, but is focused on only one small part of the higher-level story. The consequential communications on the other hand, carry more breadth about the geographic area across the wider timespan of the search operation, as this information is collected automatically across time. On the other hand, they do not carry as much detail as the explicit messages. For example, the body-camera footage provided a high-level view of what teams were up to and what their surroundings were, but these shots often did not provide much detail and were at times blurry. Finally, the historical information covered the whole search area, but the information was not always up to date and did not present much close-up detail.

From our findings, we also noticed a relationship between the category and depth of the data source and participants' confidence in the information contained within it. We noticed that participants tended to have greater confidence in the data sources that provided more depth (i.e., closer to the left side of Figure 9). Our participants mentioned that they had more confidence in the explicit messages that were coming to them directly from field teams, and they generally trusted teams' interpretations of events, findings, and conditions in the field, as they experience these things first-hand. However, participants did not have as much confidence in the body-camera footage, as they said it was sometimes unreliable, distracting, or did not tell the full story. Finally, our participants reflected that the historical information (maps, satellite imagery, etc.) might not always be up to date or reflective of the current conditions in the field, as has also been found in other emergency domains such as disaster response (e.g., [51]).

This was also reflected in our participants' actions. For example, participants tended to start with information sources that were of high breadth (i.e., to the right of Figure 9), and gradually work their way toward greater detail (moving toward the left on Figure 9). There were also numerous instances when our participants tried to make comparisons and contrasts between these data-source categories to build a more-complete picture and tell a more comprehensive story, to get the focus *plus* the context (see [3]). They did this through, for example, looking at the body-camera footage to see what a team was experiencing when they sent a message, or looking at the satellite imagery and terrain elevation data surrounding a body-camera shot to get a sense for how long the terrain will remain the same for a certain team. This illustrates the potential for multiple channels of information with varying breath, depth, and freshness to support sensemaking, situation awareness, and the building of a mental model in the WSAR command post, as long as those information sources ultimately help Command narrow in and focus on the details that matter in the moment, for the specific tasks that the workers in the command post have on hand.

6.2 Facilitating the Narrowing of Focus

RescueCASTR does a good job of providing implicit communication, thereby reducing the number of explicit information requests. However, it does so at a cost: it gives large amounts of information—much of which may not be important or useful. A next iteration of this tool ought to address this by reducing the visual salience of unimportant information to help Command focus on what is important (i.e., to narrow their focus). This falls in line with the recommendation by Jones et al. [32,33] to design WSAR remote collaboration technologies that do not burden or distract workers. While RescueCASTR was designed to do this for field workers by reducing the complexity of communicating and sending information to Command, it is clear that it potentially provides too much information to Command, and thus there needs to be a way for Command to narrow their focus within this abundance of information. This raises the question: can we add automation that interprets the video footage and adds a semantic layer for signalling (e.g. change in environment, change in weather, and so on), to help Command focus their attention on these parts of the footage?

A future iteration of RescueCASTR should be designed to suggest to the commander which spots in the footage might be useful to focus more of their attention. For example, our findings suggest that SAR managers are interested in parts of the footage where the circumstances of a team's situation change, or the team does something unpredictable. We noticed that participants wanted to explore footage around locations and points in time where, for example, the following types of events occurred:

- A change in the team's environment or surroundings
- A pertinent change in the team's speed or direction of movement
- Moments where the team went off track from their assigned path of travel
- A change in the weather or lighting conditions surrounding the team
- A change in the terrain (e.g., an incline or elevation change)
- A change to the team's activities (e.g., changing from a grid search to a hasty search)
- Instances when the frame contains something of note (e.g., a body of water, a person, an animal, or a clue)
- Instances when the camera is pointed downward (e.g., to indicate looking down at a clue on the map)
- At specific locations, manually selected by either Command or the field team
- Near locations where clues were found
- Near locations where the field team messaged Command

Some of these things can be pointed out manually by Command or field teams. Most of these could also be detected automatically by the system itself, through computer vision, artificial intelligence, or other related technologies.

6.3 Balancing the Burden of Responsibility between Command and Field Teams

Designers need to consider WSAR workers' roles and responsibilities, as well as how such a system could impact their traditional roles and responsibilities. Similar to what has been found by Toups et al. [64,66], new technologies and communication modalities could lead to impacts on roles and responsibilities, including new roles emerging, old roles disappearing, and existing roles changing. For example, our findings suggest that while the abundance of information provided by body cameras could reduce the responsibility for field teams to check in with Command and give them status updates, by having status information flow into Command automatically, it could also shift responsibility toward Command. Current work protocols result in WSAR being a largely de-coupled collaborative activity, at least during the search phase. However, the introduction of a new visual channel that helps bridge the perspectives of Command and the field (as per one of the design recommendations of Jones et al. [32,33]), may tend to make the work more coupled. This could be beneficial during instances where Command can be a 'good partner' to field teams, or where they could make use of more information from the field for their own planning duties (e.g., understanding how easy or hard it is to deploy resources to a certain area), without having to burden field teams to collect that information. However, this could be detrimental when the new information is not sufficient for the task at hand (e.g., it does not tell the full story), or the field team has a better perspective (and thus can make a better judgement).

Designers should consider ways to reduce the information burden on SAR managers and allow them to focus more of their attention on the pieces of information that are important. As mentioned above, some of this could be done through automation that interprets the data (e.g., the camera footage) coming in from field teams and determines specific foci of interest for Command to focus on (e.g., a change in environmental or terrain conditions, change in weather, an object of interest appearing in the camera view, or other key events) within the abundance of information. Furthermore, while field workers may not need to give radio updates to Command as frequently, they perhaps could be responsible for helping Command narrow their focus in the body-camera footage, both while they are in the field (by 'pinning' noteworthy locations that they want Command to look at) and after they return, during the debrief phase. SAR managers could also consider assigning one or two people on the Command team to attend to managing the RescueCASTR Command interface, similar to how one or two workers are typically assigned to manage the radio [32].

Issues surrounding privacy should be carefully considered. For example, should field teams be required to turn off their cameras when they come across a bystander who does not consent to being on camera? Should the field team's camera system automatically blur people's faces? What about when the team encounters a deceased person? Should they turn off the camera or point it away from the person? Work protocols and procedures may need to be developed around such privacy concerns, such as how the data should be handled, and who gets to see what parts of the data.

6.4 Designing for Low-Bandwidth and Network-Sparse Situations

While we designed RescueCASTR to work in both 'online' and 'offline' conditions (as recommended by Jones et al. [32,33]), our participants pointed out that radio dead zones in the wilderness can actually be quite more severe than what our scenarios illustrated. If operating in such conditions, body cameras should stream photos less frequently and at lower resolutions, while still trying to provide the 'heartbeat' contextual awareness of teams' visual surroundings and activities that our participants enjoyed and found benefit from in our study.

The same criteria we outlined above for designing to help Command narrow their focus when figuring out what to review in the footage can also be used by the field team's device to prioritize which images are sent first in a low-bandwidth situation. For example, in a low-bandwidth situation, once a field team regains some contact with Command after being in a radio dead zone for two hours, the system on their end could send sections of the footage where they made a turn, where the surroundings (e.g., vegetation) or weather changed, where they went off track, and where clues were found; as well as their most-recent camera image for a view of their present situation. The system could send lower-resolution versions of these photos, to save bandwidth, and Command could gain access to higher-resolution versions of these later when the team returns to Command. In this way, Command has access to the most important information first, and can hopefully receive it within the narrow time window that the team has some contact with them.

6.5 Implications for the Design of Remote-Collaboration Technologies Beyond WSAR

This research has further confirmed the value of implicit communication channels, automatic data collection/aggregation (in the spirit of enhancing distributed cognition), and bridging perspectives in activities involving command and control of several field teams scattered and moving around a large environment. While we conducted this research within the specific context of WSAR, these interventions could also provide value to (and inform the design of technologies for) other collaborative command-and-control situations involving a similar number of sub-teams or individuals moving around a large space. Such examples could include other emergency domains such as police work, firefighting, and disaster response. Indeed, police officers in many parts of the world already use body cameras, though these are primarily for the purpose of recording for archival and evidence purposes [45]. In firefighting, while the environment might not be as large as a wilderness area, firefighters might benefit not only from seeing live footage from their members in different parts of a burning building, but also from reviewing past footage in certain key locations—e.g., reviewing layers of past footage from a single room in the building to get a sense of how the fire has grown in there. In disaster response, there have been many explorations of the use of information from multiple sources (e.g., from social media [60,61,68]) in supporting situation awareness and shared mental models.

With that said though, introducing additional implicit information streams also comes with a cost. For example, it could introduce the potential for information overload and the need to balance workload and adjust team members' responsibilities based on the new information channels being provided. Furthermore, implicit and automatic information channels would likely become more beneficial as the number of collaborators and sub-teams increases (e.g., in the case of large-scale disaster response [60,61,68]). Conversely, in situations involving fewer collaborators, commanders could likely more easily afford to rely on explicit communications if it is proven too difficult to incorporate new implicit modalities into their workflow. For example, in a rescue-only operation involving only a single team deployed to a single location, explicitly messaging a single team and logging their communications over time would not require as much effort as, say, doing the same for a larger number of teams over a longer period of time. Thus, the specific context and scale of the activity (i.e., the number of collaborators or sub-teams, the size of the workspace, and the time span of the activity), as well as the level of urgency should be taken into account when deciding whether or not it would be beneficial to introduce new information-sharing modalities into an organization's workflow, as well as how many new modalities or interventions to introduce.

Lastly, some minimal interventions could likely be introduced without too much impact to an organization's workflow. For example, introducing a system or mechanism that allows incoming radio messages from field teams to be automatically transcribed and recorded (with timestamps and GPS locations) to a database, where they could then be displayed in chronological order, on a timeline, or on a map in relation to other available data on the response, and where they could also be triangulated with the other data to infer focus plus context, could provide notable value to a Command team. Such an intervention could allow them to more easily access, comprehend, and process the data as part of their collective knowledge, thus enhancing distributed cognition and team cognition. At the same time, it would require few technical or infrastructure requirements or adjustments to the organization's existing work practices. Thus, rather than going all in on introducing numerous new technologies or modalities, an in-between approach of introducing some new technologies or minimal interventions could be more beneficial in some contexts.

7 CONCLUSION, LIMITATIONS, AND FUTURE WORK

Overall, our study confirmed previous work in CSCW that suggests that complete shared mental models are not always necessary in collaborative work [9,55], and that the resulting information can sometimes lead to information overload or distraction. We would like to extend this by arguing that, rather than aiming to provide commanders with complete details about all of the field teams' knowledge and experiences, designers should instead aim to provide useful *context* to the details they *can* provide. Furthermore, much of this context can be obtained automatically, or implicitly, as a consequence of field teams' activities.

Our findings illustrate the potential benefits of making use of multiple information sources, some explicit and others implicit, and with varying degrees of depth and breadth, to support team cognition and awareness. Commanders ultimately want to work with a high level of detail, and they put a high degree of trust and confidence in their trained workers on the ground. However, our findings show that it could be beneficial to start off with a high level of breadth and use that to gradually work down and obtain the details necessary to make important decisions. While the details should ultimately come directly from the workers on the ground through explicit communications, it could be helpful to provide more opportunities to obtain breadth first through consequential and implicit information sharing, so that Command does not need to make frequent use of explicit communications to obtain mundane information such as a team's location or a view of their surroundings. This in turn could also help field teams focus more on their duties.

Our study served as an early exploration of the potential opportunities and challenges of equipping field teams with body cameras for streaming photos to Command for contextual awareness information. We revealed potential benefits of this new modality, technological and usability challenges in its use, and sociotechnical insights into how this new information stream could impact WSAR workers' roles and shift responsibilities away from field teams and more toward Command. We further contribute a set of early design considerations and recommendations for adjusting work practices.

We ran this study mainly with SAR managers in a completely simulated context. While the early insights our findings provide can be useful for design and considerations of workers' roles and responsibilities, we have yet to deeply gauge the perspectives of field workers and explore this domain from the perspective of working in the field. While most SAR managers, and indeed all our participants, have experience working as field workers, it would be beneficial to gauge thoughts and perceptions from the perspective of working in the field. Furthermore, out method could have introduced the potential for a power imbalance, as those who are currently SAR managers (and who are no longer doing field work) may have a greater interest in making sure the technology works well for supporting managers, and might not care as much (even subconsciously) about making sure it works well on the field side. For this reason, it is important to highlight the voices of current field workers.

Scenario- and roleplay-based evaluation techniques such as what we employed in this work can be beneficial for evaluating a new user interface [57], as grounding users within a scenario or role helps them use and reflect on the interface based on its intended context of use. With that said though, there are certainly challenges and limitations to this approach, such as on ensuring ecological validity. In our study, participants used the interface in their homes, rather than in an environment that was meant to mimic the hectic, stressful, and crowded surroundings of a WSAR command post. Furthermore, participants were not interacting with other WSAR managers or Command team members, and instead operated individually, only interacting with the study investigator who played 'Wizard of Oz' by sending text-message responses as field team leaders. This led to some limitations in ecological validity. Even with these limitations, this research approach still provided value in terms of insights and knowledge of how WSAR managers would make use of an interface like RescueCASTR within their workflow, to construct a mental model of field teams' situations and use the information provided to support their planning and operations activities. For future studies though, it would be important to investigate interactions between multiple WSAR members, including interactions between members of the Command team as well as interactions between Command and the field teams, in a setting that resembles or mimics the atmosphere and surroundings of a WSAR operation. Through such a study, we could find out more about the nuances of how WSAR workers interact with each other when new technologies and information streams such as body cameras are introduced. It would also be valuable to measure impacts on metrics such as task load and information overload.

Lastly, our participant demographics were limited in that they were all experienced WSAR workers in Canada. We recommend future work include a broader set of participants, including those from other countries, and even non-Western contexts.

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