CANADA-U.S. ENHANCED RESILIENCY EXPERIMENT SERIES (CAUSE V) AFTER ACTION REPORT

Homeland Security
Science and Technology

Canada

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Canada-U.S Enhanced Resiliency Experiment (CAUSE V)

Binational After Action Report

Prepared for
Department of Homeland Security
Science and Technology Directorate,
First Responders Group

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Executive Summary

The Beyond the Border (BTB) Action Plan, released in 2011, outlined joint priorities and specific initiatives for cross-border collaboration between Canada and the United States (U.S.). This partnership is focused on enhancing the coordination of multi-agency emergency management (EM) responses during binational disasters. In order to enhance cross-border Emergency Manager (EM) capabilities, interoperability and situational awareness (SA), Defence Research and Development Canada (DRDC) Centre for Security Science (CSS), Public Safety (PS) Canada and the Department of Homeland Security (DHS) Science and Technology Directorate (S&T) have collaborated to design the Canada-U.S. Enhanced (CAUSE) Resiliency experiment series. This series used a scenario-based approach to simulate the use of interoperable and emerging technologies during cross-border emergencies.

In November 2017, the fifth experiment in the series, CAUSE V, took place in British Columbia (BC), Canada and the state of Washington (WA), U.S. This experiment provided an opportunity to test and explore a suite of emerging technologies and applications to support an interoperable cross-border response to simulated flooding and lahar flows. The objectives of this experiment were to test emerging technologies and the use of digital volunteers in supporting interoperable communications and information sharing between cross-border EM organizations.

Qualitative and quantitative data were collected during the experiment to measure the impact of the emerging technology on EM operations. Overall, the analyses suggested the technologies and applications supported the planning, response and recovery of a simulated emergency. The results of the evaluation process indicated the technology enhanced the reach, range and quality of information exchanged among cross-border partners during emergency operations.

CAUSE V technology supported geographically distributed organizations in their efforts to share information in a common forum and in multiple formats. The digital volunteers successfully supported EM decision makers through the collection and sharing of relevant information. The technology also successfully supported the incorporation of real-time resource tracking and information exchange with field resources and the inclusion of data acquired by environmental sensors and robots. Use of prioritized wireless networks ensured communications and data transfer between the field and EM organizations on both sides of the border continued, despite network congestion or failure.

This experiment investigated the use of new and emerging technologies to support and enhance current response processes and protocols. Official mutual aid activation and inter-agency notification procedures will require additional investigation and awareness. The use of unmanned aerial and submersible robots to support reconnaissance and search and rescue (SAR) operations yielded vast amounts of data, and exposed challenges related to sharing that data over the wireless networks. These challenges may be addressed by new data processing techniques. As well, processes involving information exchange with digital volunteers and their integration into cross-border EM operations require further development and adoption.

The evaluation of the experiment data considered the potential for modifications and identified strengths and areas for improvement. A set of recommendations was generated to guide the future implementation and use of these technologies during daily and emergency operations. In addition, the implementation must be supported by more frequent and focused training opportunities to ensure the technologies can be used effectively during large-scale cross-border emergencies.

Acknowledgements

The success of the CAUSE Experiment series, including the CAUSE V event, is due the commitment of many organizations, and the contributions of time and effort towards a common goal. A special thanks to the following groups:

- Abbotsford Fire Rescue Services
- Blaine Washington School District
- Canada Border Services Agency (CBSA)
- CANARIE Network
- Cascadia Virtual Operation Support Team (VOST)
- Communications Research Centre (CRC) Canada - Innovation, Science and Economic Development
- Defence Research and Development Canada's Centre for Security Science (DRDC CSS)
- Emergency Management British Columbia
- E-Comm 911
- FirstNet
- Internet2
- Langley Emergency Program
- New Westminster Fire Rescue Services
- National Information Sharing Consortium (NISC)
- Nooksack Valley Washington School District
- Public Safety (PS) Canada
- Semiahmoo First Nation Emergency Preparedness Team
- Texas A&M University Center for Robot-Assisted Search and Rescue (CRASAR)
- Texas A&M University Internet 2 Technology Evaluation Center (ITEC)
- University of Washington
- U.S. Geological Survey's (USGS) Cascade Volcano Observatory
- U.S. Department of Homeland Security (DHS) Office of Emergency Communications (OEC)
- U.S. DHS Science and Technology Directorate (S&T) First Responder Group (FRG)
- U.S DHS, U.S Customs and Border Protection
- Victoria Fire Department
- Washington State Emergency Management Division (EMD)
- Whatcom County Division of Emergency Management
- Williams

Abbotsford Fire Rescue Service

Langley Emergency Program

New Westminster Fire Rescue

Victoria Fire Dept

Whatcom County Sheriff, Division of Emergency Management, Washington

NV Nooksack Valley School District

E-Comm 9-1-1

Semiahmoo First Nation

British Columbia Emergency Management BC

Emergency Management Division Washington

VOST

University of Washington 1861

FirstNet™

NISC National Information Sharing Consortium

A|M Internet 2 Technology Evaluation Center Texas A&M University

USGS science for a changing world

U.S. Customs and Border Protection

CBSA ASFC

Homeland Security Science and Technology

CRC

DRDC RDDC

Public Safety Canada Sécurité publique Canada

Introduction

CAUSE Series

In 2011, then Prime Minister Steven Harper and the President Barack Obama established the Canada – United States (U.S.) Beyond the Border (BTB) Action Plan [1] [2]. The plan supports endeavours that lead to security enhancements along the shared border while aiming to improve the effective crossing of secure and legitimate people, goods and services. Further, this partnership helps to ensure binational coordination is not geographically limited to the border crossing, but rather it is extended to public safety issues that simultaneously affect both nations, regardless of where incidents occur. Measures in the BTB Action Plan cover a range of security-focused objectives, including improving binational responses to large-scale disasters through improved communications interoperability.

To address these objectives, several cross-border working groups were established, including the Canada-United States (CANUS) Communications Interoperability Working Group (CIWG). In 2012, the CANUS CIWG developed a five-year work plan with specific goals and activities, several of which are addressed through the development of the Canada-United States Enhanced (CAUSE) Resiliency Experiment series.

The CAUSE experiment series has been built upon a strong collaboration between Defence Research and Development Canada (DRDC) Centre for Security Science (CSS), Public Safety (PS) Canada and the U.S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T). The CAUSE experiment series supports the BTB Action Plan by demonstrating that emerging technologies for shared situational awareness (SA) and interoperable communications during emergency events can lead to enhanced community resilience. The events carried out as part of the CAUSE experiment series have confirmed that disasters occurring along the CANUS shared border requires close cooperation between officials in both countries. The shared goal within this partnership is centered on enhancing the coordination of emergency responses during disasters affecting both countries.

Figure 1. *Map of CAUSE Experiment Locations.*

CAUSE V is the fifth experiment in this series. The series began with CAUSE I, which took place on the west coast in June 2011 [3]. The second experiment, CAUSE II [4], took place on the east coast in March 2013, while the third experiment, CAUSE III, took place in both eastern [5] and western border communities [6] in 2014 and focused on different response and recovery aspects in each region. CAUSE IV was conducted in Southern Ontario and the state of Michigan in 2016 [7]. The most recent experiment, CAUSE V, was held in 2017 and returned to the west coast to focus on border communities within the Sumas, Washington (WA) and Abbotsford, British Columbia (BC) regions (Figure 1).

While each of the experiments were guided by the overarching objectives of the CAUSE experiment series, each individual experiment focused on key capability areas and technological solutions relevant to the particular geographical regions where they were held (*Table 1*). Information sharing and shared situational awareness using emerging technologies has been an underlying theme across each experiment. Alert and warning activities, including integration of the U.S. Integrated Alert and Warning System (IPAWS), Canadian Multi-Agency Situational Awareness System (MASAS) and the National Alert Aggregation & Dissemination System (NAADS) were included in CAUSE I-IV. Risk planning factored into CAUSE I, IV and V, involving evaluating and predicting the impact of natural and man-made hazards using technology such as HAZUS and other GIS-based tools. Mutual Aid and resource planning were key components of CAUSE II-IV, where participants tested systems, including the Mutual Aid Support System (MASS) and Mutual Aid Resource Planner (MARP) for managing and tracking mutual aid resources and requests for resources. Communications interoperability involving land mobile radio (LMR) and broadband was foundational to all of the CAUSE experiments other than CAUSE II. And, the use of digital volunteers to augment emergency operations by monitoring social media were part of CAUSE III-V.

Table 1. *Overview of Capabilities and Key Technologies Demonstrated During CAUSE Experiment Series*

Capability	CAUSE I	CAUSE II	CAUSE III	CAUSE IV	CAUSE V
Information Sharing; Shared Situational Awareness	◉	◉	◉	◉	◉
Alert & Warning	◉	◉	◉	◉	
Risk Planning	◉			◉	◉
Mutual Aid, Resource Planning		◉	◉	◉	
Comms: Land Mobile Radio (LMR)	◉		◉		
Comms: Long-Term Evolution (LTE) wireless networks			◉	◉	◉
Digital Volunteers			◉	◉	◉

CAUSE V Experiment

The latest experiment in the series was CAUSE V, held in November 2017 between lower mainland BC and Whatcom County in Northern WA. The scenario for this experiment was a Mt. Baker eruption and the resulting lahar flow that affected the river valleys below.

The purpose of the CAUSE V experiment was to use a hazard-based scenario along the CANUS border to evaluate the impact of enhanced interoperable communications, information sharing technologies, mutual aid planning and response technologies on multi-agency planning, response, and recovery. Enhanced SA for first responders in emergencies was a key way to evaluate the success of these emerging technologies. The CAUSE V experiment objectives were developed to test emerging technologies. The inclusion of digital volunteers as a means to support interoperable communications and information sharing between cross-border EM organizations during a large-scale disaster was also investigated.

The specific objectives developed for the CAUSE V experiment were:

1. Leverage long-term evolution (LTE) networks to create a common operating picture (COP) to enhance decision making and increase the ability of various emergency operation centres (EOC) and other agencies to receive information from multiple responding agencies;
2. Provide live, or near real-time data and imagery from the field leveraging robots and participants in the field to COP applications in EOCs via LTE network;
3. Explore the use of digital volunteers to support emergency operations;
4. Test the Pacific Northwest Emergency Management Arrangement (PNEMA) for state-to-provincial mutual aid requests leveraging the Emergency Management Assistance Compact (EMAC) Operating System; and
5. Test the process for moving specialized resources and personnel across the CANUS border.

Due to real-life constraints, the inclusion of the EMAC Operating System to leverage PNEMA was omitted from the experiment.

The experiment was developed based on the findings and lessons identified from previous CAUSE experiments. As well, input and guidance was gathered from local participants, including members of existing cross-border working groups (*Table 2*), to ensure the issues investigated were relevant to the local geographical region. As with previous experiments, the intent was to use CAUSE as a catalyst to advance the goals of the BTB Action Plan by expanding cross border coordination among response agencies, thereby enhancing resilience to cross-border disasters.

Table 2. *Descriptions of Existing Cross-border Working Groups.*

Working Group Name	Purpose
Mutual Aid Group	Focuses on planning for cross border mutual aid requests within lower mainland British Columbia (BC) and northwest WA This includes planning for equipment needs, expedited border crossing, cross training in U.S and Canadian courses, and policy for cross border MOU's.
Law Enforcement Group	Facilitates planning for cross border law enforcement activities along the border.
Communications Group	Discusses issues and solutions for cross border communications for first responders and receivers. It was mentioned that CBSA and CBP have been excellent for organizing and hosting meetings of this group.

In CAUSE II, III and IV, a single scenario with two separate vignettes was used to meet the objectives of the experiment. One vignette focused primarily on broadband wireless communications and information sharing whereas another focused on various capabilities that included alerts and warnings systems, digital volunteers, social media and information sharing that provided enhanced SA to EOCs, emergency managers, and first responders. Both vignettes were indirectly tied together by a common scenario and inter-related experiment injects. In the case of CAUSE V, a key goal and major achievement was to tie all components of the experiment together in a manner that would further enhance the SA of emergency managers at EOCs as well as all wireless participants [8].

Experiment Design and Methodology

CAUSE V was held November 15-16, 2017. Multiple training sessions were held prior to the experiment on November 14, and a half-day After Action Review (AAR) was held upon completion of the experiment, on November 17. A full experiment schedule can be found in Appendix 1. The timing for each phase of the experiment (i.e., planning, response, recovery) were general guidelines and accommodated pauses in the experiment to address any unforeseen delays or issues.

While CAUSE V was carried out over a two day period, the scenario timeline spanned many months as participants reacted to the threat of an eruption, responded to both the eruption and the resulting lahar flow, and finally began recovery operations. In addition to the fixed EOCs and emergency managers, the list of wireless users in the experiment included first responders, Canada and the U.S. border agencies and First Nations. In addition, the experiment supported the use of drones, robots, sensors and commercial users [8].

Although not carried out as a traditional exercise, the experiment was designed and executed based on exercise design best practices, including the development of a master scenario events list (MSEL) and experiment control procedures. Where necessary, these procedures were modified to suit the specific requirements of the experiment objectives. An evaluation process, involving pre-experiment interviews, observations gathered during the two-day event and data gathered via the administration of post-experiment surveys, was used to measure the impact of the emerging technologies tested during the experiment.

Participating Organizations

More than 60 individuals from approximately 24 local, provincial / state, federal and private sector agencies actively participated or observed the experiment, with nearly twenty using broadband wireless networks. Federal departments from both Canada and the U.S. provided oversight to the development, delivery and evaluation of this experiment. The lead federal departments were:

- U.S. DHS S&T;
- DRDC CSS; and
- PS Canada.

Technology Support

Numerous organizations were involved with the configuration of the technology used during the experiment, offering on-site and virtual training to participants, and providing technological support to participants on the use of the emerging technologies and applications during the experiment. These organizations included:

- DRDC CSS;
- Communications Research Centre (CRC) Canada;
- Roboticists Without Borders;
- Texas A&M Internet 2 Technology Evaluation Center (ITEC);
- International Safety Research (ISR) (under contract of DRDC CSS); and
- G&H International (under contract of DHS S&T).

Experiment Design Team

The Experiment Design Team (EDT) was primarily responsible for developing the experiment scenario, experiment plan and MSEL. This group was comprised of representatives from the primary participating agencies and representatives from each federal lead department. Organizations involved within this group included:

- ISR (under contract of DRDC CSS);
- G&H International (under contract of DHS S&T);
- DRDC CSS;
- DHS S&T FRG; and
- Members of selected organizations as identified in *Table 3* below.

Controllers

Controllers were responsible for managing overall experiment conduct, including control of the pace of the experiment and delivering injects to participants. Controllers for the experiment were a group of trusted agents from the following organizations:

- DHS Customs and Border Protection (CBP);
- Canada Border Services Agency (CBSA);
- Langley Emergency Program;
- ISR (under contract of DRDC CSS); and
- G&H International (under contract of DHS S&T).

Evaluators

The Evaluators managed the data collection for CAUSE V, including gathering observational data (quantitative and qualitative) and supporting the acquisition of participant data before and after the experiment. Controllers for the experiment were a group of trusted agents from the following organizations:

- ISR (under contract of DRDC CSS);
- G&H International (under contract of DHS S&T);
- DHS Office of Emergency Communications (OEC); and
- Members of selected organizations as identified in *Table 3* below.

Participating Organizations

Participants from 30 agencies participated in, and / or observed the experiment (*Table 3*).

Table 3: *List of U.S. and Canadian agencies that participated in CAUSE V.*

United States	Canada
• Cascade Gas • Cascadia Virtual Operations Support Team (VOST) • City of Bellingham • CBP[EDT Eval] • FirstNet • National Institute of Standards and Technology (NIST) • Puget Sound Energy • Roboticists Without Borders • Seattle City Light • U.S DHS Office of Emergency Communications (OEC)[Eval] • U.S DHS S&T Directorate[EDT] • U.S Geological Survey's Cascade Volcano Observatory [EDT] • Washington State Emergency Management Division (EMD) • Western Washington University • Whatcom County Division of Emergency Management [EDT] • Williams • Texas A&M University	• Abbotsford Fire Rescue Service[EDT] • CBSA[EDT Eval] • CRC Canada • DRDC CSS[EDT] • E-Comm 911[EDT] • Emergency Management B.C. (EMBC)[Eval] • Fraser Valley Regional District[Eval] • Langley Emergency Program[EDT Eval] • New Westminster Fire & Rescue Services[Eval] • PS Canada[EDT] • Semiahmoo First Nation Emergency Preparedness Team • Surrey RCMP • Victoria Fire Department[Eval]

Wireless Users

In CAUSE V, a large number of the participants used wireless networks to access a wide variety of applications to communicate and share information with each other as well as with the two EOCs. Some users were in fixed locations while others were mobile. Furthermore, while most wireless users were humans, the sensors, drones and robots also used wireless networks.
Appendix 2 lists the users directly involved with the use of wireless equipment.

Wireless devices allowed users to view and upload information to the COP while within range of the wireless networks. Four vehicles in the experiment were equipped with modems and laptops as were the CBSA border sites at Surrey and Abbotsford and the U.S CBP border sites at Blaine and Sumas. Each laptop was set up with a suite of applications that was used to support participants' involvement in the experiment. The EOC laptops were connected via Ethernet and had all applications the wireless users had, thus allowing them to fully communicate and share information with all CAUSE V participants and as required, the outside world. Two sensor platforms with vibration, water level and temperature monitoring used Band 14 modems, as did the drone / robot platform provided by Texas A&M University. Eight smartphones were provided to participants where six had simulated public safety roles and two

[EDT] Member of the Experiment Design Team
[Eval] Member of the Evaluation Team

had simulated commercial roles. The devices were equipped with a suite of applications that were similar to those used on the laptops [8].

Location

Participants and observers were stationed at various locations across Whatcom County and lower mainland BC during the experiment. All locations are listed below, with the primary EOCs and border crossings indicated on the map in *Figure 2*:

- Abbotsford EOC;
- Whatcom Unified Emergency Coordination Center (WUECC);
- Langley EOC;
- E-Comm BC Dispatch Center;
- Bellingham Cascade Gas office;
- Williams site office;
- Seattle City Light - Skagit facility;
- Washington EMD office;
- Port of Entry (POE) Blaine / Douglas;
- POE Sumas / Abbotsford; and
- Field deployments (Blaine, Sumas, Abbotsford, Mt. Baker).

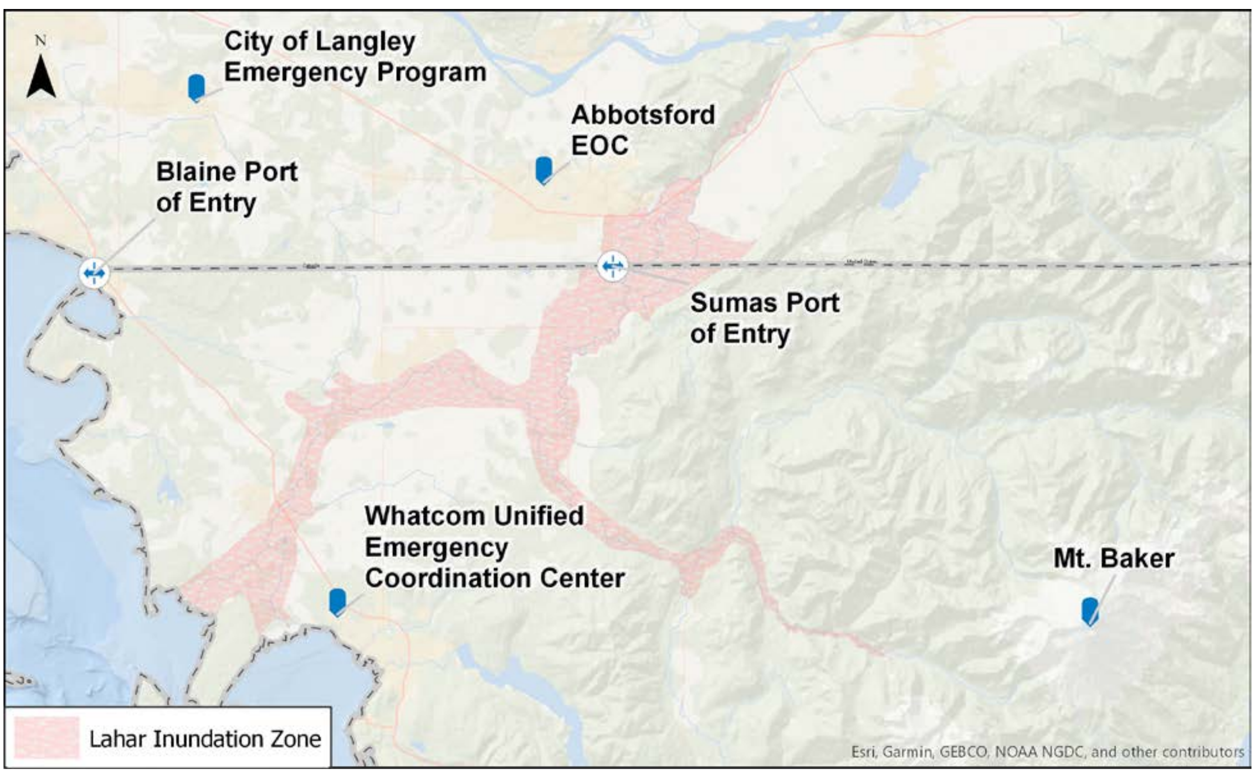

Figure 2. *Map of physical locations involved with CAUSE V.*

Experiment Planning

The experiment objectives and scenario were developed and refined over the course of three face-to-face planning meetings between February and September 2017. These meetings were hosted by Whatcom County Sheriff's Office Division of Emergency Management in Bellingham, WA. In addition to these three planning conferences, other face-to-face and virtual meetings were conducted under the guidance of four primary working groups including: the Exercise Design Team, Information Sharing and Situational Awareness Group, Mutual Aid and Planning Group and the Digital Volunteer Group. These working groups were established to focus on specific topics following the Initial Planning Conference. The working groups collaborated to develop the scenario, injects and supporting logistical considerations to meet the objectives for the experiment and CAUSE series.

The full list of planning meetings and training sessions held as part of the experiment development and conduct under these working groups is included in *Table 4*.

Table 4. *Schedule of planning meetings, virtual and hands-on training and dry runs (all dates in 2017).*

Date	Type	Training
Feb 7-8	Planning Conference	Initial Planning Conference
May 24	Planning Conference	Main Planning Conference
Jul 8	Training Webinar	Digital Volunteer Training 1
Aug 3	Training Webinar	Info Sharing Apps - Session 1
Aug 17	Training Webinar	Info Sharing Apps - Session 2
Aug 30	Training – On Site	Digital Volunteer Training 2
Sep 6	Training Webinar	Digital Volunteer Training 3
Sep 26	Training – On Site	Digital Volunteer Training 4
Sep 27	Planning Meeting	Final Planning Conference
Sep 28	Training Webinar	ExCon Instructional Training
Oct 18	Training Webinar	Info Sharing/Situational Awareness Tools Dry Run
Oct 23	Training – On Site	Social Media for Disaster Response and Recovery (PER 304)*
Oct 24	Training – On Site	Social Media Tools and Techniques (PER 344)*
Oct 25-26	Training – On Site	Volcano Crisis Awareness (AWR 233)*
Oct 25	Training – On Site	Digital Volunteer Training 5
Oct 25	Training – On Site	Unmanned Aerial Systems in Disaster (AWR 345)*
Nov 9	Training Webinar	Controller / Evaluator Training
Nov 13	Training – On Site	Digital Volunteer Training 6
Nov 14	Training – On Site	Just-In-Time training for CAUSE V

**Class provided by the National Disaster Preparedness Training Center (NDPTC) on site at the WUECC.*

Experiment Design Process

The EDT held meetings every two weeks between August 31 and November 7, 2017 to ensure coordination between all design team members, a common level of SA regarding the current status of experiment-related documentation and content and to progress the experiment design tasks such as the detailed scenario and inject development.

Information Sharing and Situational Awareness Group

The Information Sharing / Situational Awareness group was open to all CAUSE V participants. This working group's objective was to gather input on current processes and operational gaps related to information sharing and SA within the affected cross-border communities. This group also provided training on the information sharing tools leveraged during the experiment, including the CAUSE V COP, reporting tools and dashboards.

Planning and Mutual Aid Group

The magnitude of the Mt. Baker scenario used in this experiment would require extensive cross-border collaboration and coordination for planning, response and recovery. The Mutual Aid and Planning working group included representatives from the local, state and provincial levels, as well as a mutual aid subject matter expert from DRDC CSS who worked with the EDT to review the Mt. Baker coordination plan prior to the development of the detailed experiment scenario and injects. This review of the coordination plan, in conjunction with a review of the roles and responsibilities of PNEMA helped determine the expected actions and outcomes for this type of scenario. The nature of this type of event (i.e., high impact, relatively slow onset) would offer the opportunity for a thorough assessment of risks associated with the hazard. Based on the risk assessment conducted for this event, the working group decided to focus development of the planning phase of the experiment around three core response capabilities: debris management, damage assessment and mass care.

Prior to the experiment, interns with the Whatcom County Division of Emergency Management conducted an initial risk assessment for Whatcom County. They evaluated the potential impact of a lahar on the primary economic sectors in the area including: agriculture, business and industry, critical infrastructure (e.g., dams, utilities and transportation), public infrastructure (e.g., roads, bridges and schools), private property, natural resources and recreation / tourism [9].

The intent of this working group was to develop pre-scripted mission plans (PSMPs) for the communities that would be notionally impacted directly by the scenario, taking into consideration the impact estimates from the Whatcom County interns. During the experiment, these PSMPs would be tracked using the Mutual Aid Resource Planner (MARP) application, which represented the key capabilities, required resources and the mutual aid partnerships that would provide the resources. The MARP was developed by DHS S&T and hosted by the NISC. The MARP was then used in the experiment, which allowed for testing of the processes associated with requesting, deploying and demobilizing resources to assist during the response to and recovery from the volcanic eruption on Mt. Baker and the resulting lahar. The group planned to develop the required PSMPs based on these capabilities to support response and recovery operations; however, activity was suspended due to the wildfires in BC.

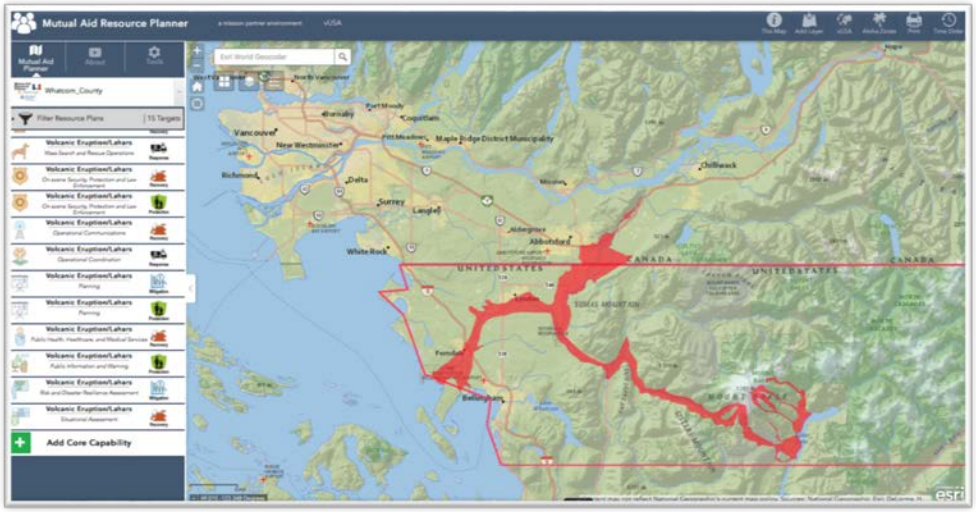

Figure 3. *The Mutual Aid Resource Planner (MARP) application with the Core Capabilities for the Volcanic Hazard.*

Digital Volunteer Working Group

A comprehensive training program, involving both virtual and hands-on classes, was prepared to provide the digital volunteers from Whatcom County and the City / Township of Langley with a base level of proficiency in social media monitoring during an emergency. As part of this plan, DHS S&T FRG partnered with FEMA Region X and the National Disaster Preparedness Training Center (NDPTC) to conduct a week of onsite training at the WUECC for disaster response and recovery (*Table 4*), which focused on leveraging social media. The NDPTC training complemented, and built upon the digital volunteer training provided by the DHS S&T FRG. The training provided participants with background information and methods for monitoring social media and working with online tools to assist in the digital volunteers' activation during an emergency. The Cascadia VOST was established as an outcome of this training and planning campaign.

In addition to the continued research on expanding the role and capabilities of digital volunteers through the Cascadia VOST during CAUSE V, training specifically focused on addressing fake news and intentional misinformation was conducted as another means to support local public safety practitioners and communications officers. To support this, the University of Washington's Emergent Capacities of Mass Participation (emCOMP) Lab provided training on identifying and mitigating misinformation, shared relevant research on the phenomena of false news and countermeasures and offered assistance in developing the experiment scenario and injects related to digital volunteers [10] [11].

Specifically, the research provided by the emCOMP Lab identified the following five strategies for local public safety teams (including VOST), which should be considered when being confronted by conspiracy theorists, or individuals promoting potentially harmful misinformation [11]. These five strategies include:

1. Watch for trending signs of influence. For example, posts containing photos from past events that can incite confusion, fear and / or mistrust;
2. Establish a clear concept of operations (COP) that identifies when it is appropriate to respond and when it is best not to;

3. Provide awareness that the lingering effects of social media may go beyond the timeframe of the initial incident;
4. Train community liaisons to be vigilant for how fake news affects the community. Specifically, identifying those who could be harmed by false information and individuals who are responsible for amplifying the reach of untrue messaging; and
5. Create a knowledge pool of these conspiracy / misinformation actors and consider some base level of monitoring of their posts.

The planning group developed a general workflow diagram representing the digital volunteer / VOST processes used during the experiment based on the training provided and monitored products that were expected to be used during the experiment (*Figure 4*). Note the fifth step, Direct Engagement, was not tested during CAUSE V because the VOST was only directed to perform monitoring and reporting support for the experiment.

The process in the workflow described in *Figure 4* includes of the following steps:

Step 1. Following an event, the VOST is activated by the public information officer (PIO) or other operations staff:
   a. A VOST workbook is created by the VOST for the event. The workbook is a Google Sheet template, which is used to coordinate VOST activities and track incident information [12];
   b. Mission Assignments are provided to the VOST by the PIO;
   c. Key words and hashtags are identified for the mission, based on the specific event and location and tracked in the VOST workbook; and
   d. Essential Elements of Information (EEIs) are established and recorded in the VOST workbook.

Step 2. The VOST tracks information about the event from official sources, for example the USGS and National Weather Service.

Step 3. The VOST tracks official alerts / warnings made to the public and may function as amplifiers for these official alert messages and press releases.

Step 4. During the response and recovery phase, the VOST team will:
   a. Identify social media that may require some follow-up action and share these directly with the PIO / relevant emergency response sections.
   b. Monitor traditional and social media to ensure that the message is being effectively communicated, produce ‘listening reports’ (which summarize trending topics, public sentiment and other relevant information) and share them with the PIO and relevant emergency response sections.

Step 5. In certain situations, VOST members may be authorized to directly engage with disinformation threads or posters.

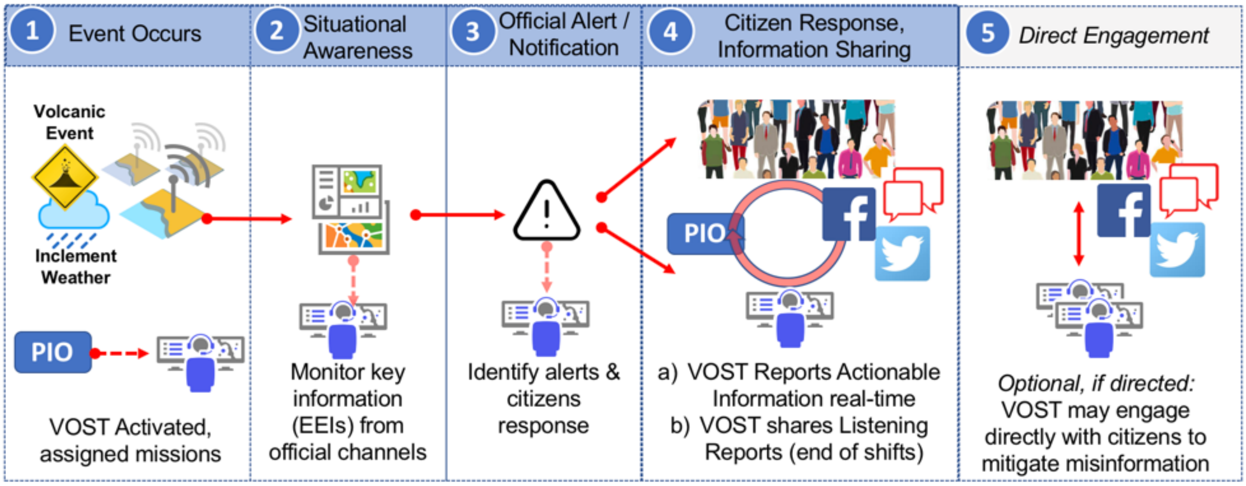

Figure 4. *Social Media Workflows tested during CAUSE V.*

The social media injects created for CAUSE V were developed with input from the emCOMP Lab. Experiment designers developed simulated user accounts to post in a similar manner as those of the previously identified proponents of disinformation on real-world social media platforms. For example, certain simulated ("puppet") accounts posted consistently controversial conspiracy theories and facilitated the amplification of fake news while others represented well-meaning citizens unintentionally spreading rumors.

Scenario Design and Experiment Conduct

After considering a variety of hazard types relevant to emergency managers in the Pacific Northwest, the decision was made to use a volcanic eruption and flood (atmospheric river and volcanic lahar) event as the scenario for CAUSE V [13]. Due to the magnitude of this type of an event and proximity of Mt. Baker to the border, the proposed scenario would require a cross-border, multi-agency planning, response and recovery operation. The scenario was developed with significant input from the USGS Cascades Volcano Observatory, which developed physical attributes for the emergency (e.g. lahar depth, volume of debris, series of events) and was based on the last large eruption of Mt. Baker approximately 6,600 years ago [14] (*Figure 5*). That event included destructive lahars, a mixture of water and rock fragments that flow down the slope of a volcano and generally enters a river valley [13].

A coalition of federal, state, provincial and local agencies concerned about a Mt. Baker eruption have formed the Mt. Baker-Glacier Peak Facilitating Committee and subsequently drafted a Mt. Baker Coordination Plan [15]. This plan, while not formally tested during CAUSE V, provided a framework to address some of the inter-agency coordination and communication requirements, primarily during the initial planning phase of the experiment.

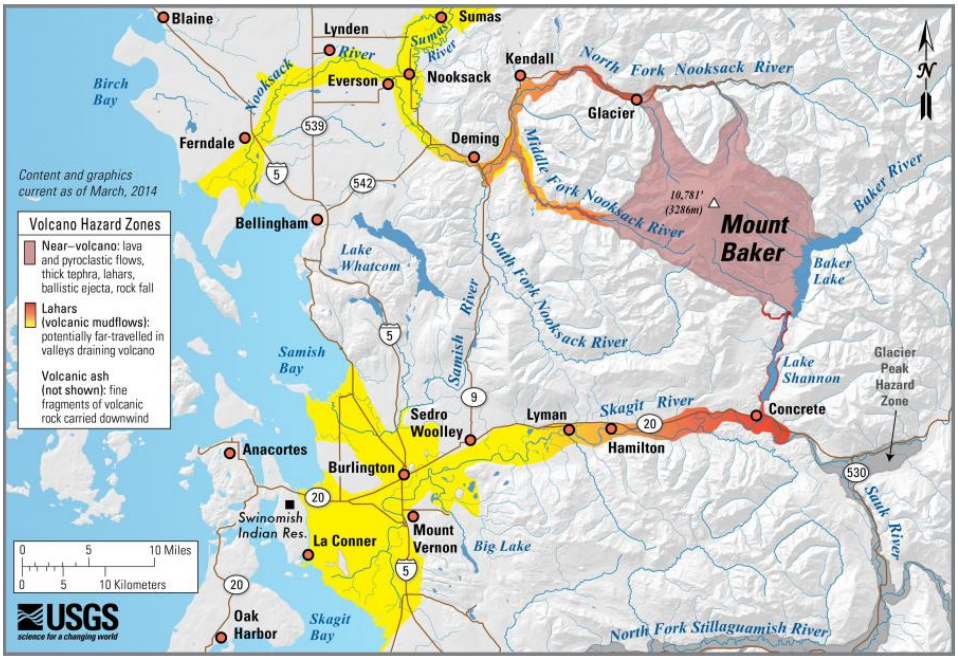

Figure 5. *USGS Volcanic Hazard Map for Mt. Baker.*

The experiment design comprised three emergency operational phases: planning, response, and recovery (Figure 6). During each phase of the experiment, the scenario and injects, maintenance of consistent interoperable communications, and coordination between the participating organizations through the use of the interoperable and emerging technology were considered.

As part of the experiment design process, a series of documents for both the participants and control team were produced. These were used as reference guides for both groups during the experiment. Prior to the experiment, all participants were provided with a player guide containing important logistical details concerning the experiment. This guide provided players with a detailed experiment schedule, location of the various experiment related events, and an overview of the key technologies and equipment that were being tested within the experiment [16]. Additional documentation for wireless technical demonstrations and for evaluation was developed and provided prior to the experiment.

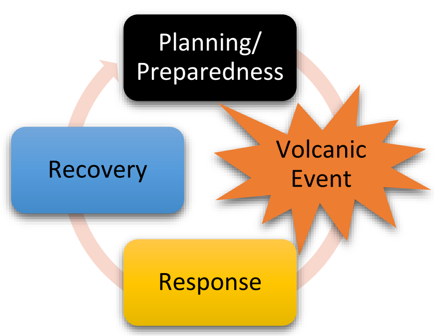

Figure 6. Experiment phases.

Throughout each of the three operational phases, participants used emergent technologies, primarily by leveraging wireless public safety networks, applications to support information sharing and SA and social media. Participants, in particular digital volunteers, identified trends in the information being posted through the simulated social media. The social media content was developed to contain common hashtags that could be searched in the social media monitoring tool. This provided the digital volunteers with criteria to reduce background "noise" on the social media platforms, leaving only the actionable posts relevant to their geographic area, or accounts of interest.

Planning Phase

The planning phase simulated the events of a timeframe that was approximately three months in duration. The phase began with the USGS Cascades Volcano Observatory issuing several Volcano Activity Notices, and periodic updates to inform the participants of the volcanic and seismic activity starting to occur on Mt. Baker. Starting at this phase of the experiment, participants leveraged the use of information sharing applications to develop a COP and identify available resources to support mutual aid planning. Participants were provided with updates in the form of official alerts, traditional media articles, and social media posts. Two groups of digital volunteers were activated and provided with mission assignments, including identification of misinformation and other potentially actionable posts from the public.

During this phase of the experiment, the experiment control team guided participants through a facilitated discussion concerning the events of the scenario. This session prompted key EM stakeholders in both Canada and the U.S. to discuss any information known about the hazard, potential cross-border resource management, information sharing mechanisms, contingency planning and determination of the command structure that would be used in the event of an eruption.

Response Phase

The response phase began with a large atmospheric river event resulting in significant flooding along the Nooksack River. This event was introduced into the experiment during a 'lull' period following the observations of initial volcanic activity in the planning phase. During the response phase, a large, 20-minute steam and ash emission was released from Mt. Baker in conjunction with increased seismic activity around the volcano. In addition, six smaller steam and ash emissions were released from the volcano. Following this, the western and southern portions of the Sherman crater failed, sending a large lahar down the Middle Fork Nooksack River. The flooding that previously occurred as a result of the atmospheric river had clogged the rivers with debris, forcing the movement of the lahar north into the Sumas Valley. Almost immediately after the collapse of the crater, a three-hour eruption occurred sending a narrow plume of tephra west towards the Ross and Diablo dams.

Throughout the response phase, scenario injects prompted the movement of emergency response vehicles and personnel across the CANUS border in support of emergency response operations. Participants were provided with simulated weather advisories, social media and traditional media articles that all discussed the flood and lahar events, providing additional context to inform response activities. Personnel located in the EOCs and field locations were able to observe the response activities in real-time through cross-border COPs and other dashboards. The wireless capability set up for the experiment enabled field personnel to communicate with border agencies, facilitating the movement of emergency resources across the border. Ongoing communications between the EOCs and emergency resources, through the applications and wireless capability, enabled consistent situational updates as response vehicles crossed the border and a tracking system allowed participants to view the exact location of the vehicles as they crossed. Ground and water-based robots were dispatched at various locations to conduct both aerial surveillance and search and rescue (SAR) operations.

Social media messages were provided via a simulated social media environment. This environment contained observational reports about the events that were developing, both intentional and unintentional misinformation, as well as social media posts that are unrelated to any one topic and do not contain actionable information (background noise). Digital volunteers helped identify this

misinformation as well as other actionable information and produced reports for their PIO or other applicable members of their EOC.

Recovery

Based on the information provided by USGS and research performed by interns from Western Washington State University in support of the Whatcom County Division of Emergency Management [9], the scenario considered the recovery process for a Mt. Baker lahar event as a long and difficult process. It is anticipated that the area inundated by the lahar would contain up to 12 feet of concrete-like sediment. This impact would convert a large percentage of land in the affected area into unusable space for many decades after the event. Further to this, sedimentation in the river channel would alter the river profile, resulting in increased flood risk along the banks and the potential for deviations in the path of the river. Long term impacts would include destroyed or damaged critical infrastructure including roads, bridges, and natural gas pipelines; and changes in continued use of affected land for agriculture, commercial, and residential use. The lahar would also shut off access to the Mt. Baker ski resort via current transportation networks, diminishing local tourism. In addition to this, the lahar would result in detrimental effects on natural resources, including local salmon fisheries in the Nooksack River and commercial forestry operations in the Mt. Baker-Snoqualmie National Forest.

The recovery phase of the experiment involved planning and preparation for short-term recovery activities, which supported the immediate needs of residents and long-term recovery activities that consisted of complex matters including economic recovery, re-settlement activities, land use decisions and claims to property. Similar to the planning phase, a guided discussion was conducted to examine some of the existing mutual aid arrangements and both short and long-term recovery challenges. The recovery phase focused on exploring and discussing some of the current mutual aid agreements between various levels of government and how these are affected by the cross-border nature of the scenario.

Technology use

Wireless

All information on the wireless component of CAUSE V contained within in this report is extracted from a forthcoming detailed technical report [17].

Third Generation Partnership Project (3GPP) LTE broadband wireless networks were designed, planned and installed in both Canada and the U.S. LTE is the technology that underpins 4G cellular networks and is composed of two major components including: the core network (centralized hub) and the radio access network (RAN), which by means of evolved node base stations (eNodeB) cellular sites, delivers the over-the-air wireless coverage to users. In the case of CAUSE V, the RAN network is local to the experiment whereas the core networks were located in Ottawa, Canada [17]. These networks supported the use of the various information sharing applications, allowing the wireless exchange of voice, video and data. Participants at the EOCs, POEs, and in the field were able to make voice and video calls over the wireless networks to discuss upcoming actions or plans and were able to exchange data through the ArcGIS Online and COP tools. Information from the field including video, photos, voice calls, damage assessment forms and maps were transferred from simulated First Responders and unmanned vehicles to the EOCs via the wireless networks. The experiment also supported numerous tests for transferring data, demonstrating how Public Safety users would have priority access over commercial users on a

Public Safety Broadband Network (PSBN) during an emergency. The use of the wireless devices showcased access class barring, prioritization, pre-emption, session persistence and congestion-based session persistence.

The main design considerations that were made regarding the wireless networks included the geographical experiment locations, site permissions and access, wireless user requirements, coverage at the experiment locations, support for technical demonstrations and the availability of backhaul connectivity. The latter of these is often very challenging in that most information technology (IT) departments within organizations are often reluctant to provide access to their network infrastructure, particularly for a short duration with no contractual vehicle in place.

For a highly complex experiment such as CAUSE V, the design phase typically starts one year prior to the conduct of the experiment. Work in these early stages included the identification of potential geographical sites, collaborators and the conduct of sophisticated coverage analyses. These investigations were supported by several site visits that were needed to validate the suitability of the selected sites. Several potential options for geographical locations were assessed. Once the appropriate sites were confirmed, a detailed network design was created for each network site, including the core networks. *Figure 6* depicts the broadband wireless sites selected for the CAUSE V experiment.

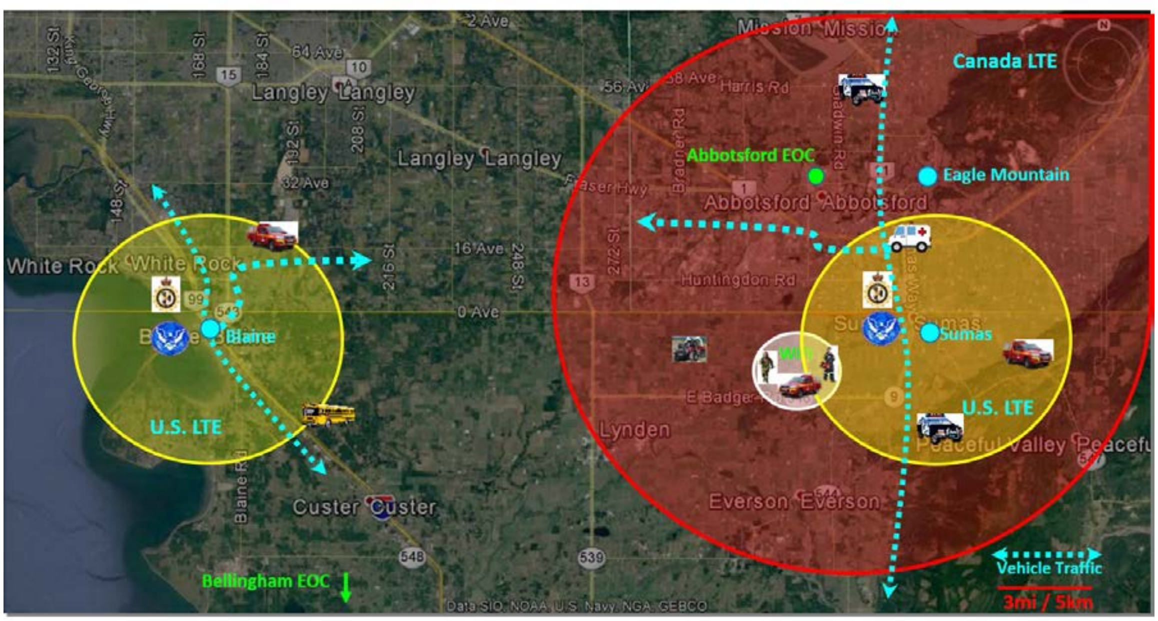

Figure 7: *CAUSE V Wireless Deployment.*

CAUSE V had a U.S. EOC in Bellingham, WA and a Canadian EOC in Abbotsford, BC with full communication channels between the two organizations. Additionally, a number of wireless users were in proximity to the CBSA Abbotsford and CBP Sumas POEs as well as the CBSA Douglas and CBP Peace Arch ports of entry. Finally, three wireless eNodeBs were designed and installed to provide the wireless coverage.

Wireless network coverage simulations were produced using sophisticated radio frequency (RF) coverage analysis tools and three-dimensional digital terrain elevation data. The simulation tool used was InfoVista Planet and the elevation data sources were Geobase 0.75 Arc-Second for Canada and SRTM V3 1 Arc-Second for the U.S. The coverage simulations are based on having no co-channel interference [17].

Site Descriptions

Three LTE RAN sites were used to provide wireless coverage during the CAUSE V experiment. These suites are described below.

The Eagle Mountain site was the only wireless LTE eNodeB (base station) on the Canadian network for the experiment and provided very good coverage throughout the eastern part of the Fraser Valley, both in Canada and the U.S. E-Comm 911 made their emergency mobile unit (EMU) available for the experiment at this location. The EMU unit is used to provide a rapid instantiation of wireless communications for emergencies or planned events.

The Sumas Elementary School was one of two eNodeB sites on the U.S. wireless network for the experiment. This site provided additional coverage at the Abbotsford – Sumas border crossing area and was required to support key technological demonstrations for emergency responders from both Canada and the U.S. Blaine Middle School was the only site to provide wireless connectivity in the White Rock - Linden area of the experiment. Therefore, Blaine provided coverage in this area in both Canada and the U.S. throughout the experiment.

Figure 7 illustrates an estimate of the predicted coverage from Eagle Mountain, Sumas Elementary School and Blaine Middle School.

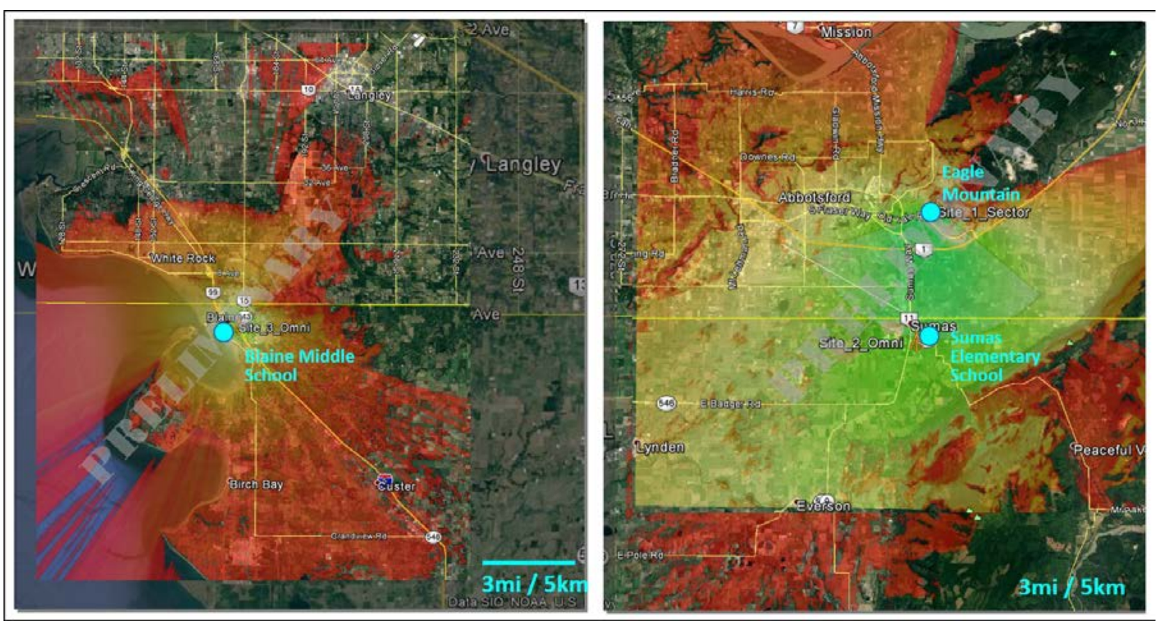

Figure 8: *Predicated Wireless Coverage.*

Vehicles were provided by Semiahmoo First Nation, Whatcom County, the Langley Emergency Program and Abbotsford Fire and Rescue Services. All vehicles were equipped with LTE Band 14 modems and Windows laptops [17].

Overall Wireless Design

In consideration of the CAUSE V experiment scenario and design including locations, site selection, user requirements and technology demonstration needs, Figure 8 describes the overall wireless design of the CAUSE V experiment and shows the various components associated with the wireless network.

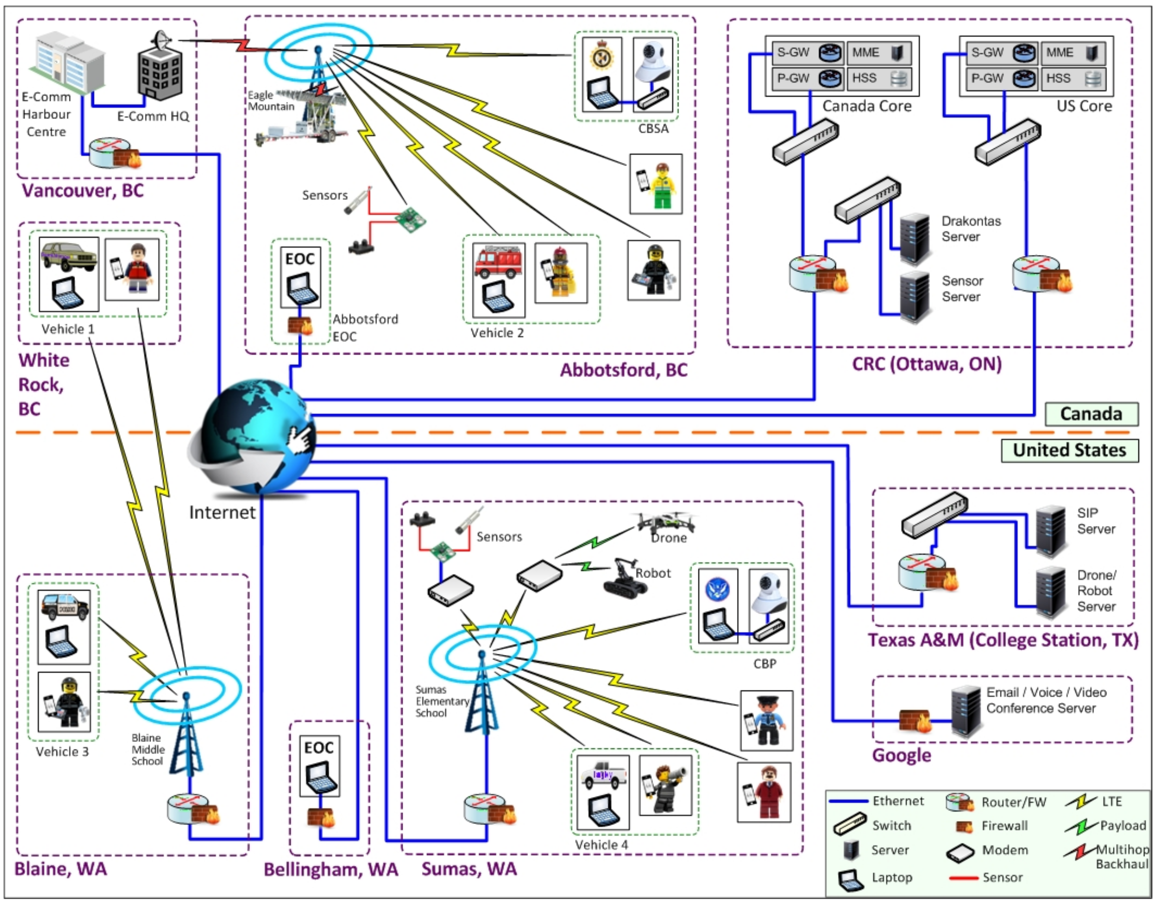

Figure 9: *CAUSE V – System Level Diagram.*

The eNodeB at Eagle Mountain was connected to the Canada core network by means of E-Comm 911 and the CANARIE network. The Sumas eNodeB site in the U.S. was connected to the U.S. core network over a series of connections between the Nooksack School District Network, the Washington K-20 network and finally, Internet 2. Similarly, the Blaine eNodeB site was connected to the U.S. core network over a series of connections between the Blaine School District, the Washington K-20 network and Internet 2. The use of the Research and Education (R&E) networks such as Internet2 in the U.S. and CANARIE in Canada, allowed for the establishment of a high quality, reliable transport network to the LTE cores. As such, the backhaul network was able to be removed from the list of experiment design variables.

In order to get wireless connectivity to the networks, participants were provided with handheld smartphones and modems for vehicles, drones, robots and sensors. These smartphones and modems allowed participants to use the complete range of experiment applications. While most applications were hosted over the Internet, some were either hosted remotely on private networks or hosted locally [17].

Technical Demonstrations

A key objective of the CAUSE experiment series was to test, evaluate and demonstrate emerging technologies that improve the operational capabilities of emergency responders. CAUSE V investigated the impact of several emerging wireless technology demonstrations that could benefit current initiatives within the public safety broadband wireless domain. These included quality of service demonstrations on prioritization, pre-emption, seamless wireless communications over multiple networks when moving from one country to another, congestion-based session persistence, and the use of drones and robots providing live feeds during a simulated volcanic event. Each of these types of service demonstrations are discussed in detail below. Each type of service demonstration was successfully demonstrated on multiple occasions during the experiment. Participants who supported these technical demonstrations were provided with documentation, including a detailed schedule, to track the demonstrations and coordinate with all involved members.

Prioritization

If enabled on a network, prioritization is invoked when both public safety and commercial users are connected in the same cell of a network. As more and more users of any type enter the cell, the capacity eventually becomes congested. In such conditions, if the prioritization function is enabled on the network, commercial users will begin to notice an impact to the quality of their communication session. These impacts could include broken audio, video pixilation or unusually slow web browsing. This approach is taken to increase the amount of capacity that is made available to the public safety users within the congested cell.

Pre-emption

Pre-emption is a prioritization of access to the network. If enabled, it is invoked when both public safety and commercial users are connected in the same cell of a network. As more and more users of any type enter the cell, the capacity eventually becomes congested. In such conditions, commercial users will begin to become fully disconnected from the network. This approach is taken to increase the amount of capacity available to the public safety users within the congested cell.

Session Persistence (Service Continuity)

Roaming in wireless networks is the ability to connect to a visited network when the user is not in coverage of its home network. To do so, the visiting user needs to be authenticated by the visited networkand a connection to the network is then established. Session persistence is an advanced form of roaming that allows a user to automatically and seamlessly maintain network and communication sessions while moving from one network to another. In this case, session persistence was enabled as users moved between cross-border networks.

Congestion-based Session Persistence

Congestion-based session persistence is similar to session persistence, but where the level of network congestion determines where the user is connected as opposed to the strength of coverage of the two networks. If enabled, it is invoked when public safety users located in areas covered by both the Canada and the U.S networks experience significant congestion on one of the networks. When this occurs, public safety users whose network becomes congested will automatically and seamlessly be connected to the network that is not as congested. This approach is taken in order to maintain a high quality communication session for those users that need to move to the uncongested network. Furthermore, in doing so, traffic is reduced on the congested network, which then increases the amount of capacity available to the public safety users that remain within the congested cell.

Access Class Barring

When access class barring is enabled, commercial users are not able to connect to the network under any conditions [17].

Robots and Sensors

Increasingly, the ability to integrate information from the scene of an incident using sensors and ground, air, and water-based robots is being recognized as an important, if not necessary, component of effective emergency response. Sensors that monitor the environment, including seismicity, flooding, and other parameters, are being deployed more widely, and the data collected can be shared widely when these are connected to a wireless network to enable near or real-time data upload. Unmanned robots, which include unmanned aerial systems (UASs) and unmanned marine vehicles (UMVs), can provide important tactical applications during emergencies, including mapping a scene, transmitting still imagery or video to the EOC, and supporting SAR operations. The sensors and robots tested during CAUSE V are listed in *Table 5*.

Table 5. *List of environmental sensors and robot technology tested during CAUSE V.*

Sensors
• Vibration sensors (ServerCheck) • Water sensors (ServerCheck)
Robot Equipment
• RESPOND-R: 20-foot box truck mobile laboratory / command vehicle for data collection, post-processing of imagery, recharging assets, etc. • Small Unmanned Aerial Systems for surveying and mapping: o 2 DJI M600 o 6 DJI Mavic Pro o 2 DJI Phantom 3 o 1 Insitu ScanEagle o 5 PrecisionHawk Lancaster v5 o 1 Parrot Disco • Unmanned Marine Vehicles for underwater mapping and using streams for access to difficult to reach places: o 2 Hydronalix EMILY o 1 iSENSYS Mako

A primary objective of the CAUSE V experiment was to leverage the PSBN to support data integration from robots deployed in the field, and other sensors making it feasible to share information from the field back to the EOC to support overall SA and decision making. Two sets of sensors, each with a vibration and a flood sensor were deployed during the experiment. Although located with the experiment control team, the locations of these sensors were simulated to be at the base of Mt. Baker near Welcome, WA and on the outskirts of Everson, WA. Additionally, operators from the Center for Robot-Assisted Search and Rescue at Texas A&M University, and Roboticists without Borders group deployed to locations in Whatcom County to carry out pre-defined mission assignments.

Applications

Participants used a variety of applications to carry out specific tasks during the experiment to promote cross-border communication, increased SA and information sharing to support decision-making, in particular to support the list of target capabilities established during the experiment design process (Appendix 3 - Experiment Capability Needs).

During the lead up to CAUSE V, an inventory of existing applications used by local agencies was developed to determine possible points of integration. Two participating agencies were in the early stages of adopting Esri's ArcGIS Online, establishing this platform as a common denominator among the agencies involved. A 'system-of-systems' approach was applied by integrating ArcGIS Online and the Drakontas DragonForce app to share information using the open ArcGIS Representational State Transfer (REST)-based application programming interface (API) [18]. DragonForce was used for tactical vehicle location tracking and field-based SA, and was configured to consume map layers from, and share responder locations and field reports with the ArcGIS Online platform.

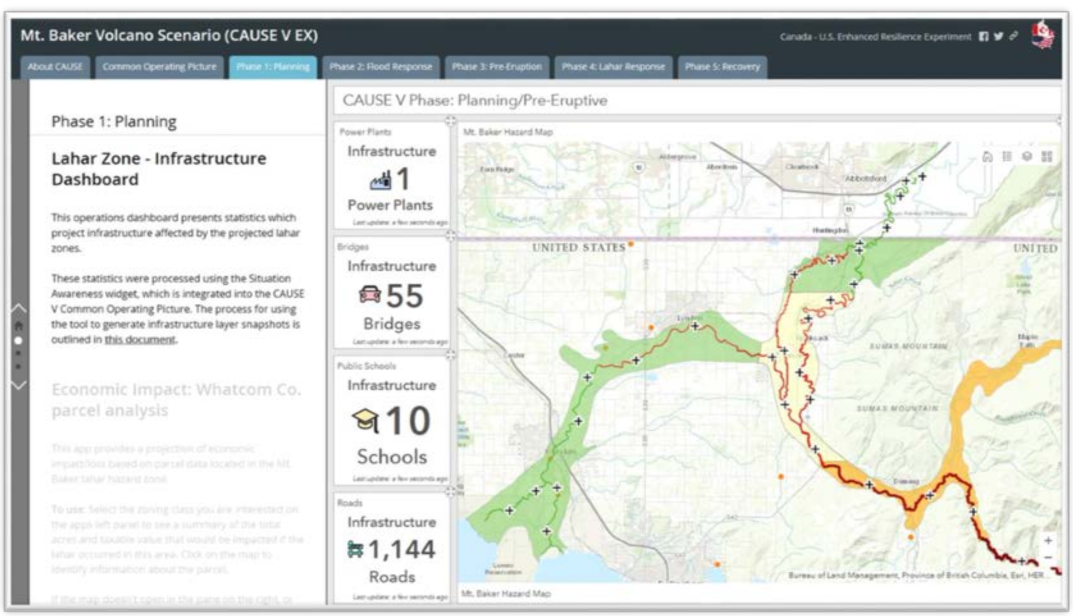

Figure 10. *The CAUSE V Home App with embedded COP and Operations Dashboards.*

Other applications were configured using this platform to address specific capability requirements. These included field reporting tools based on Esri's Survey123 for ArcGIS and a GeoForm for digital volunteers to submit actionable social media reports to the EOC. The Operations Dashboard and COP

were configured to support visualization and were also configured to display information from field reports, vehicle locations, and other layers relevant to the lahar hazard. Whatcom County used the Incident Action Plan (IAP), a NIMS-compliant application, to track incident event logs.

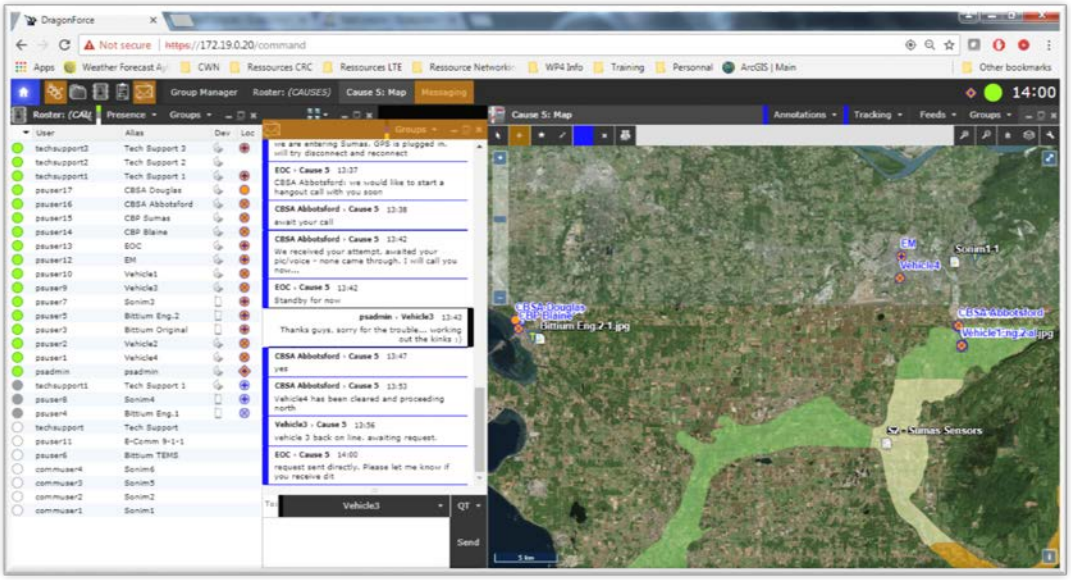

Figure 11. *Drakontas DragonForce application, showing the chat widget and map view containing information shared from the ArcGIS Online platform.*

VOST members collaborated through Slack [19], a team collaboration tool for internal messaging, and the VOST workbook based on Google Sheets to track work shifts, mission-tasks, and mission-specific results. Complementing the use of the VOST workbook was the use of the ESRI Survey 123 application for recording actionable social media posts that they observed. Participants also used email and voice / video sharing clients to exchange information during the experiment. These applications leveraged the wireless network to provide communication and data capabilities to responders in the field and allowed them to share updates with the EOC (Figure 11). Finally, a system called ResponseReady was utilized for this experiment to deliver simulated traditional and social media injects to the participants and allowed for VOST members to interact with the simulated public throughout the experiment.

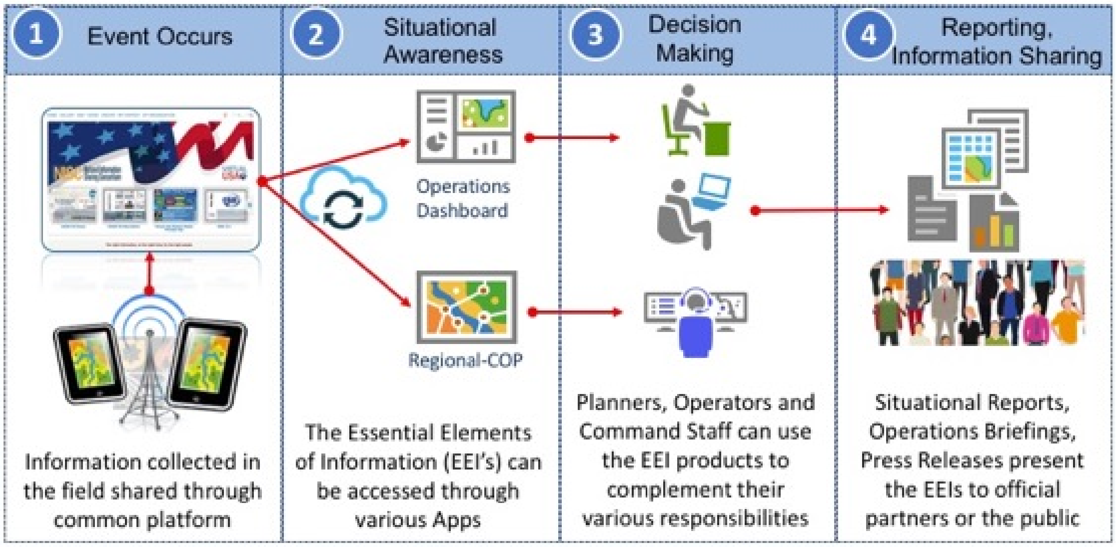

Figure 12. *Overview for the information sharing processes tested during CAUSE V.*

A complete list of applications tested during the experiment is included in Appendix 4 - Technology Used During Experiment.

Evaluation Process

Evaluation framework

A three-phase evaluation framework was developed by the evaluation team with input from the country leads. The evaluation framework produced for CAUSE V was used to identify and guide the development of data collection tools needed to measure the impact of the interoperable technologies on the emergency organizations' capability to plan for, respond to, and recover from a cross-border disaster. These tools were also designed to identify gaps or challenges related to the implementation and / or use of the technology. As well, data collection tools were developed to capture data from third-party evaluators and from the participants. A summary of the evaluation framework and the data captured during CAUSE V is presented in this report. A detailed record that includes the data collection tools and CAUSE V metrics is presented in the CAUSE V Evaluation Framework [20].

Phase 1 – Pre-experiment

Prior to the experiment, the evaluation team conducted interviews with key participants via teleconference. The intent of these interviews was to identify the current governance structures, resources and technology that are already in place to respond to a binational emergency. As well, these interviews identified the current organizational roles and processes (e.g., policies and standard operating procedures (SOP)) used during cross-border emergency operations to exchange information via voice and data communications. The results of these interviews provided the foundation used by the evaluation team to investigate how the current EM processes within the EM organizations were impacted by the technology introduced during the experiment.

Phase 2 – During the experiment

Members of the evaluation team were positioned at various experiment sites to observe the activity of each participating organization. Evaluators collected quantitative data at each of the three phases of the

experiment (i.e., planning, response, recovery) by using a separate set of data collection tools. These evaluator tools were developed to record information related to the CAUSE V evidence-based metrics. The metrics were based on indicators of resiliency that were identified through previoU.S literature reviews within the EM domain and on the findings from previous CAUSE experiments. They addressed enhanced resiliency in terms of people, governance, technology and their implementation into current processes. Quantitative ratings corresponding to each applicable metric, were provided by the evaluators, along with qualitative observations.

Phase 3 – After the experiment

At the end of each experiment day, players participated in a guided debrief at their respective location. They were also requested to complete a short online survey. The focus of the daily debrief sessions was to gather feedback about the participants' experiences with the CAUSE V technology and how it affected SA, information sharing and the development of a cross-border concept of operations. The survey was based on the CAUSE V metrics and supported the feedback provided via the evaluator ratings.

Upon conclusion of the experiment, a guided After Action Review (AAR) was held and a brief participant feedback questionnaire was administered. Similar to the daily debriefs, the qualitative observations and data gathered during the final AAR were used to support the results from the various other data collection tools. The participant feedback questionnaire was provided to all participants at the end of the experiment. This tool gathered quantitative and qualitative feedback concerning the preparation and conduct of the CAUSE V experiment.

Data analysis

As a basis for the evaluation of the CAUSE experiment series, the impact of interoperable technology on emergency operations and community resiliency has been characterized through the use of a multi-dimensional model known as the SAFECOM Interoperability Continuum (Figure 12) [21] (Figure 12) as well as a similar model adopted by Canada referred to as the Canadian Communications Interoperability Continuum (CCIC) Model [22]. This model is defined by five dimensions including governance, SOPs, technology, training / exercises and usage. The CAUSE V metrics were developed and refined based on these dimensions. Throughout the experiment, evaluators assigned a rating to each of the CAUSE V metrics based on the events of the experiment. During the pre-experiment evaluator training sessions, the evaluators were asked to consider the following 5-point rating scale when applying a score to each metric:

1 = Strongly disagree;
2 = Somewhat disagree;
3 = Neutral;
4 = Somewhat agree;
5 = Strongly agree; or
N/A = Not Applicable / Not tested.

The collected data set was analyzed to determine the impact of exchanging cross-border information and SA, enabled by the use of the wireless networks and interoperable applications, on emergency operations.

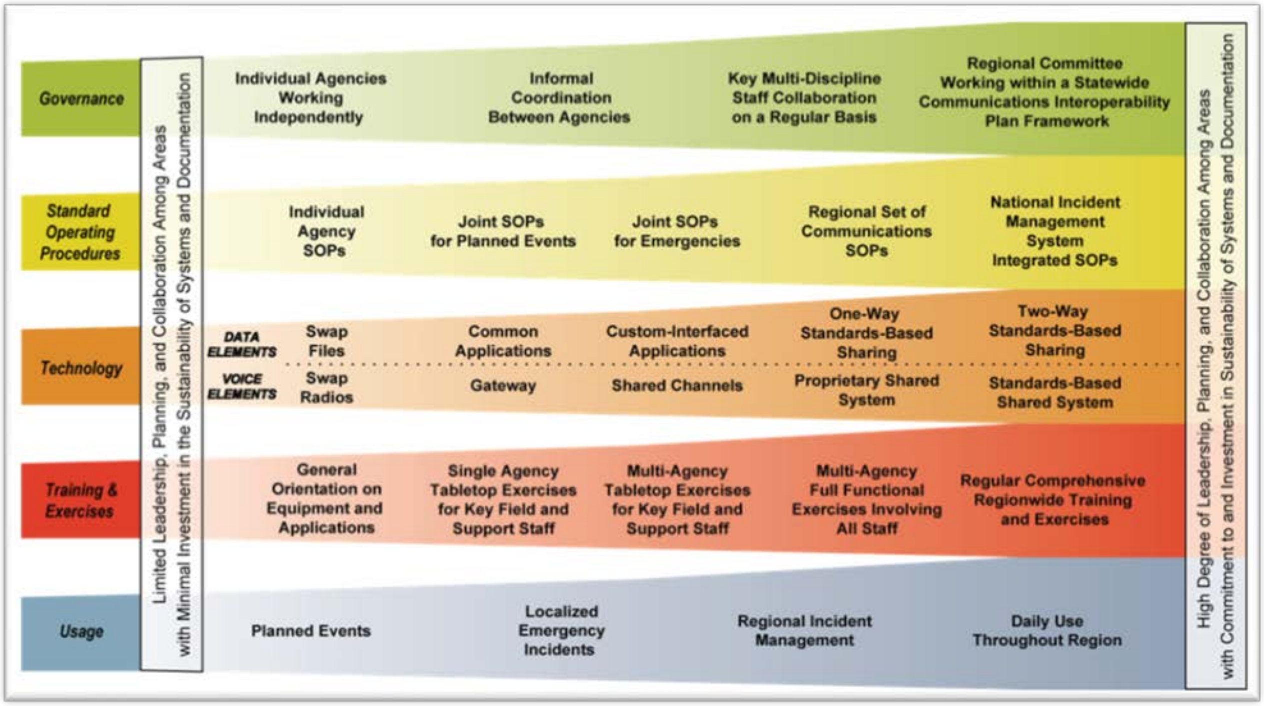

Figure 13. *The SAFECOM Interoperability Continuum.*

To measure the impact of including digital volunteers and social media monitoring in EM operations, a theoretical model referred to as the Social Media Emergency Management (SMEM) Maturity Model (*Figure 13*) was developed during CAUSE III [23]. This model includes the four main dimensions that contribute to the development of a mature emergency operations capability including people, governance, technology and implementation [24].

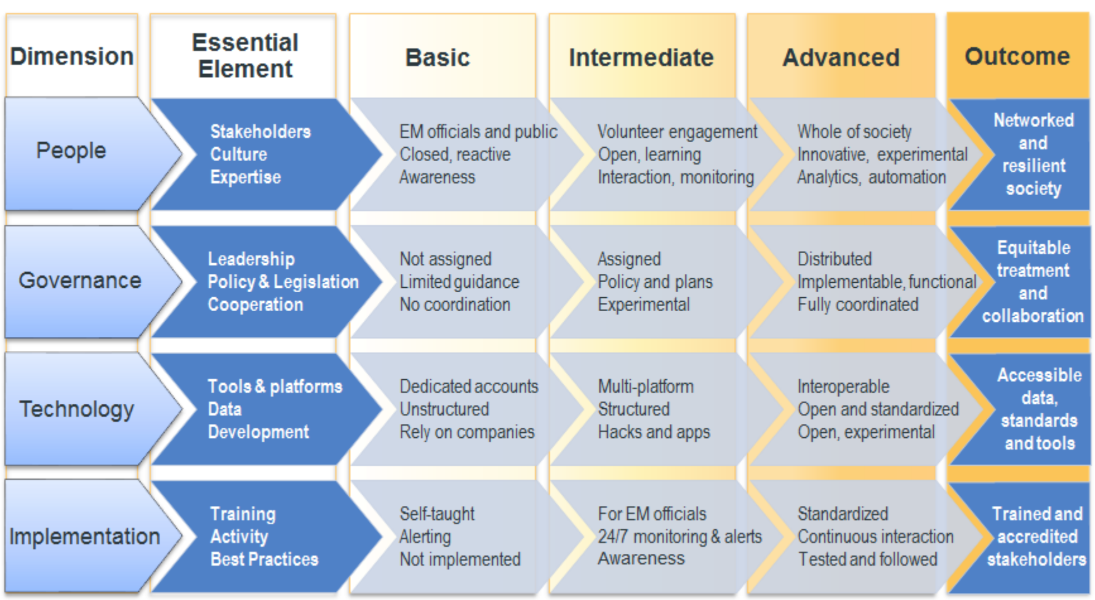

Figure 14. *Social Media in Emergency Management Maturity Model.*

This model, in conjunction with the SAFECOM / CCIC Model, was used to develop the metrics for CAUSE V. The data collected from these metrics were analysed to evaluate the impact on the inclusion of digital volunteers in EM operations during large scale cross-border emergencies.

Following the conclusion of the experiment, the evaluation team collected the results of the data collection tools, including the metric ratings provided by the evaluators. All metric data was subjected to a descriptive analysis to determine overall responses (e.g., mean, mode, range, and sample standard deviation). Metrics not addressed or considered during experiment conduct were removed from the analysis. All qualitative data collected was subjected to a theme-based analysis to identify the primary themes associated with the responses. The results of the qualitative analysis were used to support the findings from the descriptive analysis.

The ratings provided by the evaluators were used to generate an overall mean rating for each metric within five key dimensions: people, governance, technology, implementation and usage, within each of the three phases of the experiment: planning, response and recovery.

The results of the quantitative and qualitative analyses were used to identify areas of strength and areas of improvement in the implementation of technology. This can, if addressed, improve cross-border information sharing and SA during large scale emergencies. These results also guided the development of recommendations to address challenges of the technology and related processes, and their integration into emergency operations.

In addition to evaluating the specific objectives of CAUSE V, the overarching CAUSE objectives and the relevant metrics in relation to the CAUSE V experiment were also assessed [20]. To evaluate the CAUSE series objectives, the evaluation team assigned a rating to each metric based on observations gathered during the experiment, quantitative results from both the evaluator and player data sets and feedback and discussions during daily debriefs and the AAR. Ratings were assigned using the below 5-point rating scale:

- 1 = Little knowledge about information exchange or how SA is generated or enhanced within any organization;
- 2 = Information is monitored and shared within an organization;
- 3 = Information is gathered from other organizations and used to determine actions;
- 4 = Organizations inform others about their plans for action; or
- 5 = Multiple organizations plan a coordinated response.

The results of this analysis supported the identification of potential recommendations to the CAUSE series as a whole, specifically regarding the implementation of emerging technology in EM operations.

Finally, data collected through the use of the Participant Feedback Questionnaire was subjected to a descriptive analysis of the quantitative data and a theme based analysis of the qualitative data. The results of this analysis were used when developing recommendations for developing future experiments and to gain awareness on the overall effectiveness of CAUSE V.

Findings

Information Sharing and Decision Making

The results of the pre-experiment interviews indicated that there is a strong level of commitment to maintain cross-border communications among the participating EOCs, in both large-scale emergencies and less significant events that affect the communities on both sides of the border. Current procedures include alerting the foreign EOC (Whatcom County, WA or Abbotsford, BC) on the status of the emergency and providing ongoing situational reports (SitReps) as the emergency progresses. These communication protocols are based primarily on pre-established relationships within the community and are facilitated by traditional modes of information sharing (e.g., phone calls, emails, physical liaison). Information sharing with other key partners, including provincial and state EM organizations and local partners such as the school boards, critical infrastructure (CI) owners and operators, and border officials, was also identified. While sharing information with these partners was identified as part of the current processes, it was indicated that these communications were again based on pre-existing and informal relationships and leveraged traditional methods of communication. Unofficial channels between organizations are difficult to maintain as personnel positions and contact information frequently change.

It was also identified that the Canada and U.S. border agencies have processes in place to communicate the status of a border (e.g., open, restricted, etc.) and any temporary disruptions in service between the relevant POEs. However, there is currently no information exchanged between the border agency and the foreign EOC, and they rely heavily on communications with other agencies (e.g., PS) that become their connection with local authorities and relevant federal departments. This mechanism of using a central agency to communicate and distribute information with other involved partners also applies to local CI owners and operators. To facilitate information sharing during an emergency, more informal methods for sharing information directly with first responders are being sought.

The pre-experiment interviews also identified that there is a limited amount of data that is transferred during an emergency to share actionable information. While most current communications are limited to traditional methods of communication, it was identified that some organizations can share maps, operation plans and pictures but very few organizations have the ability to receive this type of data transfer in a useful format.

CAUSE V aimed to minimize some of these gaps identified during the pre-experiment interviews by introducing effective and interoperable data sharing methods. Applications that could support the development of a COP, plot and track resources in real-time and share the current status of response activities intended to improve the existing information exchange and data sharing processes were investigated. The use of the ArcGIS Online platform and related applications provided a formal method to simultaneously share a wide range of information and data during an emergency with numerous organizations. Additional tools and applications allowed for the development and active sharing of maps, collaborative whiteboards, damage assessments, SitReps, photos and videos. Exploring the activation processes associated with PNEMA also sought to assist in exploring requirements needed to formalize some of the existing informal communication channels.

After the experiment, participants evaluated the impact of the CAUSE V technologies on information sharing and decision making. using a 5-point rating scale, where a score of '1' referred to 'Strongly

disagree' and a score of '5' referred to 'Strongly agree,' participants indicated the extent they agreed with several statements concerned with information sharing and decision making (*Figure 14*). In general, the participants reported that the technologies implemented during CAUSE V were effective in supporting timely, effective and pre-conceived decision making. These findings indicate that the technology supported requests for assistance by cross-border partners and sharing of critical information between stakeholders across the border. The findings also indicated that the technology supported the reach and range of information being shared, suggesting that it could be implemented in real-world events to support cross-border communications among multiple organizations.

Participants provided qualitative feedback indicating that information received from the field through both the sensors (water level and seismic) and the robots (UASs and UMVs) successfully supported emergency operations. To a lesser extent, the participants indicated the technology tested during CAUSE V could be useful for identifying the economic impact of the emergency. However, qualitative observations suggested that more training and experience with the technology would be necessary to fully leverage these capabilities [25].

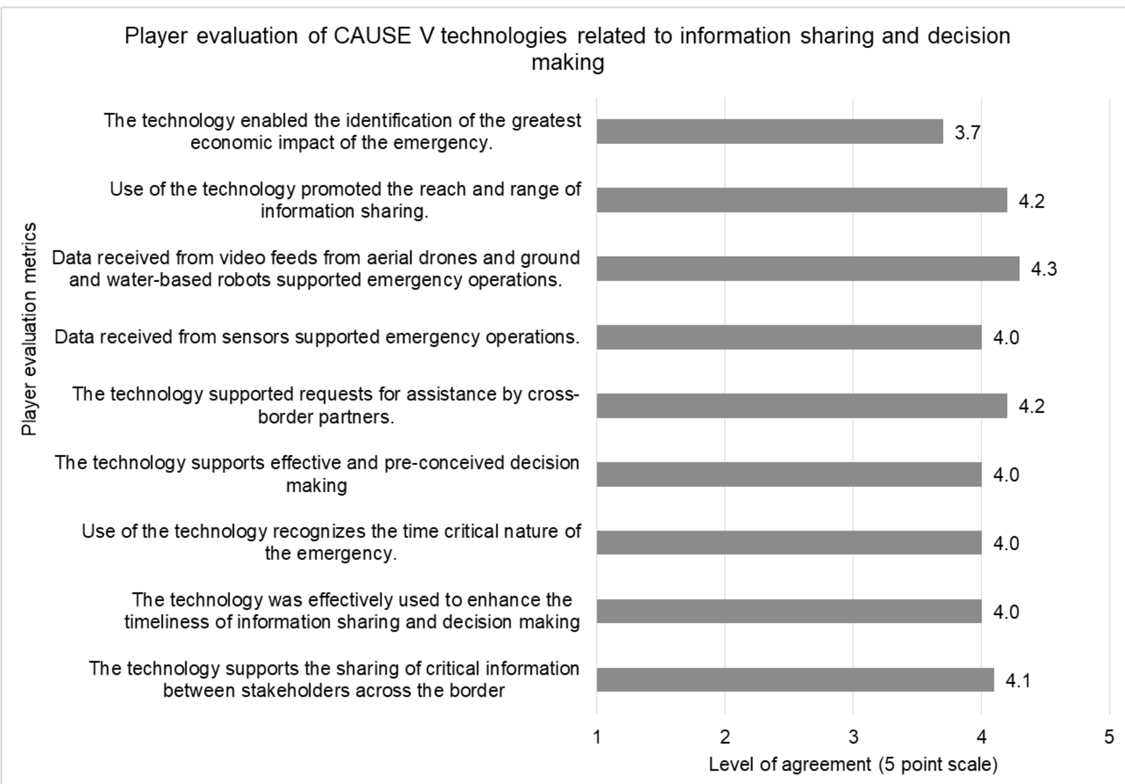

Figure 15. *Player assessment of CAUSE V technology.*

There are no formal processes in place for cross-border information sharing or establishing SA through a shared COP. All current communications and partnerships are based on informal channels and pre-existing relationships. At the time of the experiment however, the adoption of suitable technology to address this gap was underway by several key participants on both sides of the border. CAUSE V provided an opportunity for participants to use ArcGIS Online as a common platform for information sharing. It was facilitated through the use of a private group, which was accessible only to individuals

who were invited to join the group. This platform supported field reporting capabilities and the Use of both a COP and Operations Dashboards.

The information sharing platform was leveraged in a variety of ways during the planning stage of the experiment to help forecast potential damages as a result of the lahar and inform the planning process. The USGS lahar hazard zones were combined with local parcel / land Use data to identify risks to individual property owners and businesses. The lahar travel times were developed using elevation and hydrography data from the USGS and were then presented in an animated time-enabled application during the experiment (*Figure 15*) [26]. This spatiotemporal-enabled (i.e., time and geography) data supported the development of an emergency plan by Williams, a CI / gas utility company, which addressed a potential emergency shut-down and applicable lead-times following a crater collapse and before the lahar event.

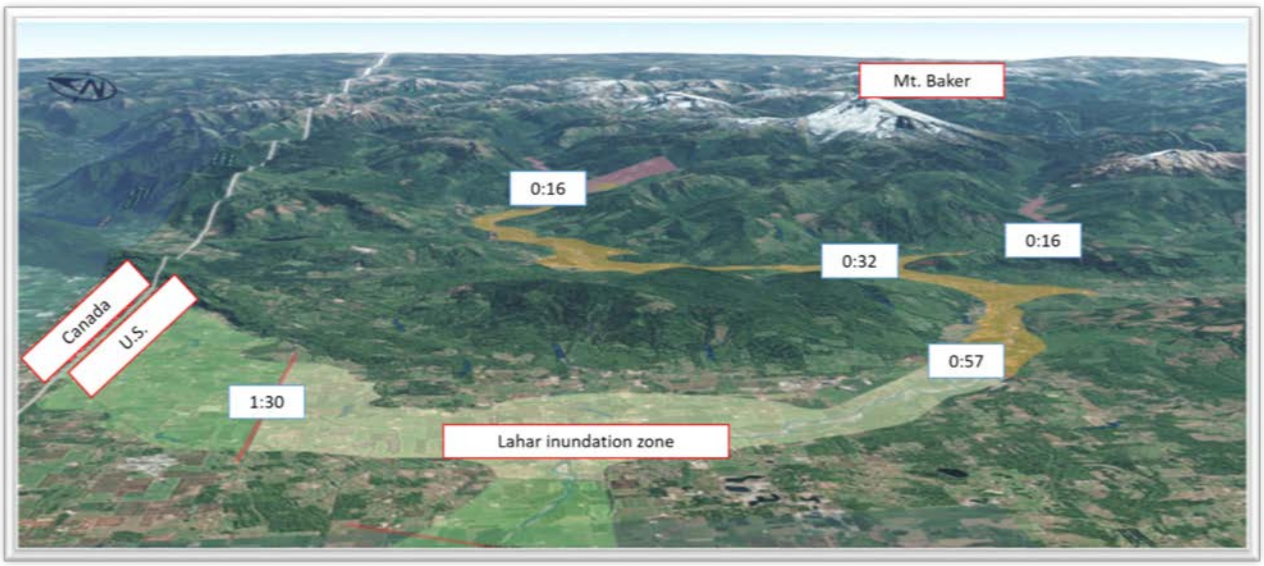

Figure 16. *An example of the time-based lahar inundation model, showing time points (in hours / minutes) for the lahar to reach different locations.*

During the response phase Abbotsford Fire Rescue Services were requested to support Whatcom County near the Sumas border. First responders were deployed in the field and began sharing their locations in real-time using Drakontas DragonForce. While deployed in the field, these teams sent reports back to the EOC using Esri-based digital reporting tools (i.e., Survey123 and GeoForm). This data was integrated in the EOC along with other (simulated) emergency vehicle movements provided by E-COMM 911. The field reports were also spatially-enabled, allowing their output to be displayed on the map in near real-time.

Participants continued to test the reporting process during the recovery phase, with damage assessments obtained from responders, along with crowdsource reports from citizens indicating the extent of flooding and damage to owner-occupied dwellings. The GIS staff in Whatcom County successfully performed an ad-hoc analysis during the recovery process, assessing the number of properties that would be affected by the lahar but would not be covered by the National Flood Insurance Program (NFIP).

Best Practices in Cloud-based Situation Awareness Solutions

Use of the cloud-based ArcGIS Online platform, including it's component of feature layers, web maps, and applications, stimulated discussion among participants, particularly in Whatcom County. The platform is based on an open API [18], enabling integration with other systems, as was demonstrated during this experiment through the two-way integration of Drakontas DragonForce and ArcGIS Online. Easily configurable online applications, such as those that can do a quick analysis of infrastructure within USGS-provided lahar inundation zones were of interest to participants that managed critical infrastructure within the impacted area. In particular, participants highlighted the the ability to use the time-aware applications to visually identify how soon the lahar impact would take to reach different locations along it's path was useful for planning purposes. There was also a practical discussion about how to synchronize offline and online GIS resources as a means to maximize their benefits and accessibility for the EOC members and first responders [20].

Interoperability and Coordination

The results of the pre-experiment interviews indicated the EOCs involved in the response operations were committed to work collaboratively to deliver a response for an emergency affecting the cross-border communities. Emergency response personnel and contractors could be deployed across the CANUS border to support the response efforts in the neighbouring country. Liaisons in the EOCs have a fundamental role in coordinating the overall response and they are able to identify where support is required, including identifying materials and personnel to aid in the response. However, in an emergency, there may be challenges to providing a liaison. Delays at the border or road closures may affect the personnel's ability to travel. Additionally, infrastructure damage, network congestion or lack of active monitoring may result in the inability for the liaison to report back to their EOC through traditional means of communication.

During an emergency, EOCs work with the border agencies to develop plans for evacuation and mass movement of personnel across the border. Since the emergency explored during CAUSE V could impede a crossing or result in the development of significant backlog at a specific border crossing, it is recognized that the EOCs may need to send resources and help manage the affected border crossings in collaboration with the border agencies. It was identified that although the relevant EOCs are aware of the formal processes required to support the cross-border movement of resources and personnel during an emergency, including submission of requests for assistance (RFA) to the relevant state / provincial or federal agency, this would currently be performed through unofficial channels and pre-established relationships. This is due to the associated challenges of time constraints, costs and committing resources.

Some of the tools explored in CAUSE V were aimed at minimizing the challenges associated with identifying available resources who could support an emergency response in neighbouring jurisdictions or across the border. The MARP application was used to identify partner agencies that have the available personnel or materials that could be used to support response operations. Additionally, CAUSE V introduced applications that leveraged wireless networks to track resources as they were deployed in the field.

After the experiment, participants evaluated the impact of the CAUSE V technologies on interoperability and coordination. Using a 5-point rating scale, where a score of '1' referred to 'Strongly disagree' and a

score of ‘5’ referred to ‘Strongly agree,’ participants indicated the extent they agreed with several statements concerned with interoperability and coordination during emergency operations (*Figure 16*).

In general, the participants agreed the CAUSE V technologies supported the cross-border coordination of emergency operations. The players were very confident that the CAUSE technologies were interoperable with the existing technologies that are used within their organizations. The technologies supported the development of a COP for all stakeholders, which was used to share information and support a consistent and coordinated emergency response among multiple organizations on each side of the border. However, it was identified that the COP was used primarily for collecting and sharing planning information, rather than indicating how the response was progressing in real-time.

The participants indicated the technology could also be used to readily compare SitReps between stakeholders in order to coordinate a response. In addition to receiving shared information, participants indicated that their own SA was improved and enhanced through the use of real-time map-based information. Although information sharing to support cross-border responses was performed well, participants’ feedback did suggest that the activation of mutual aid agreements was supported to a lesser degree. This may be due to an experiment constraint as not all organizations that would be required for arranging mutual aid requests actively participated in the experiment. Although discussions regarding using the technology to support mutual aid took place, technology was not formally used during the experiment in this way.

Response operations were enhanced through the use of video conferences with partner organizations and the ability to perform real-time location tracking on resources associated with the emergency operations. However, some of the technology introduced to support communications and interoperability during an emergency are not used or required during daily operations. This makes it difficult to maintain availability, functionality and training for any emergency-specific system. There are also privacy and security concerns regarding the sharing of information outside of a specific organization on these types of tools [20].

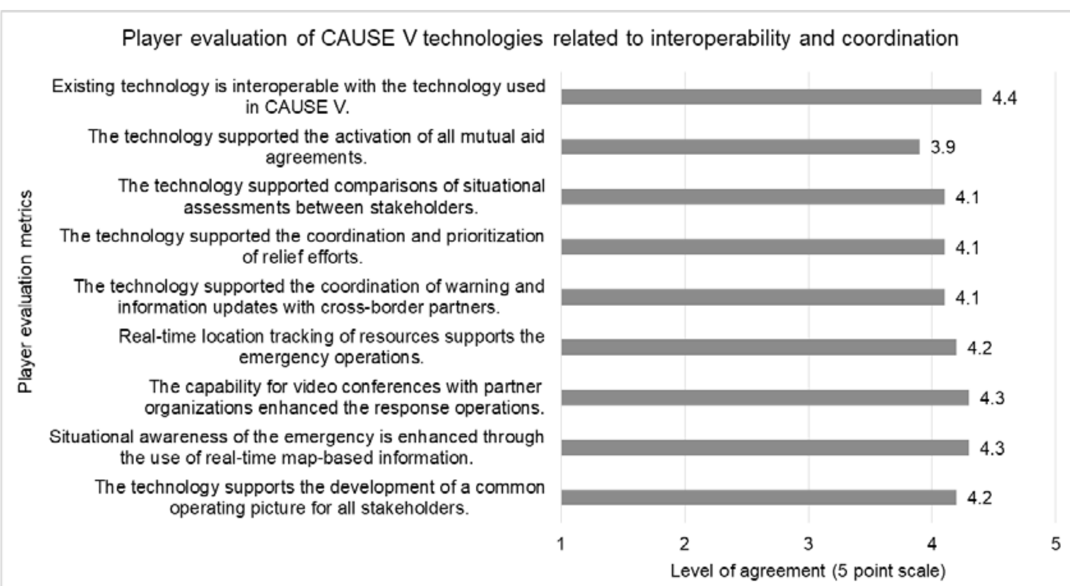

Figure 17. *Player evaluation related to interoperability and coordination.*

Emergency Operations Technology

Based on the results reported above, it is evident that the technology and applications introduced during CAUSE V were effective in minimizing some of the gaps and challenges associated with information sharing and response coordination during real-world emergencies. Following the experiment, participants evaluated the impact of the CAUSE V technologies with respect to the efficiency and effectiveness of the technology leveraged during the experiment (*Figure 17*). Using a 5-point rating scale, where a score of '1' referred to 'Strongly disagree' and a score of '5' referred to 'Strongly agree,' participants indicated the extent they agreed with several statements concerned with the efficiency and effectiveness of the CAUSE V technology. In general, the participants agreed that although several aspects of the CAUSE V technologies support cross-border emergency operations, additional effort is required to maximize the efficacy of the use of the technology.

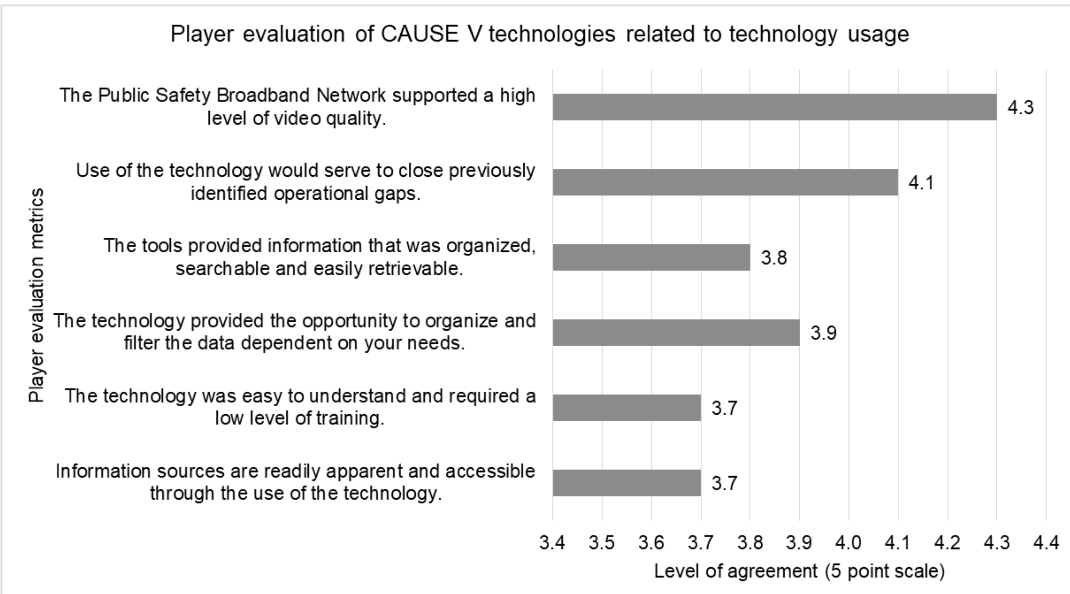

Figure 18. *Player evaluation related to technology usage.*

The players identified that the wireless networks were quite effective in supporting video calls from the field or supporting teleconferences between participating organizations. To a lesser extent, the players indicated that the technology required a low level of training and information sources were readily accessible through the use of the technology. This finding is aligned with qualitative observations gathered by the evaluation team, which suggest that although users had the knowledge to use the technology for the purposes of the experiment, users needed more training and experience in order to fully benefit from its capabilities. Participants also identified that the technology was being used more effectively on the second day of the experiment, following more experience with using the relevant tools.

Similarly, players did not believe the technology provided information that was effectively organized, searchable and easily retrievable. Although the technology had filters and search tools that could be leveraged during the experiment, additional training was required to maximize their use in order to meet the information sharing and decision support requirements for each individual organization. Players identified that some of the legends and labels were missing or were not readily accessible within

the mapping tools, making it difficult to gain all relevant information. It was also suggested that organizing the different data sets by incident management / command functions would help participants to access the information pertinent to their role more readily.

Additionally, the participants observed several technical issues throughout the course of the experiment. Participants indicated that support personnel would not be available to fix technical issues during a real-world emergency. However, it is anticipated that these technical problems were due to experiment constraints and would not actually occur when the technology was implemented and used during a real-world response [20].

Social Media / Digital Volunteers

Two trained teams of digital volunteers from the City / Township of Langley, BC and the Whatcom County, WA Community Emergency Response Team (CERT) operated as a single Cascadia VOST during the experiment. Volunteers participated based on specific missions, including identifying rumors and harmful misinformation.

The VOST utilized the provided VOST Workbook to coordinate mission-focused activities, track relevant hashtags and trending topics. The VOSTs prepared more than 70 records based on these mission requirements out of over 700 simulated social media messages broadcast during the experiment. Approximately 40 messages were identified as actionable, meaning that they were important and were flagged for follow-up action within the EOC. This information was shared in real-time with the EOC and were immediately observable in the EOC via the COP.

In addition to the actionable messages, the digital volunteers tracked other information in the VOST Workbook that was used as a reference when building the Social Media Listening Reports. These reports were shared with the PIO in Whatcom County and Langley at the end of each shift, resulting in a total of four Listening Reports generated over the two day experiment. The VOST also identified misinformation and other relevant information from the noise observed in social media through the development of the Listening Reports and the information shared using the Survey123 forms. Although the information flow between digital volunteers and their relevant EOC was well understood, ad hoc information transfer was less readily incorporated into the experiment. Since the Langley EOC did not participate in the experiment, the reports from Langley digital volunteers was shared with the Abbotsford EOC. This experiment design artificiality caused a breakdown, at times, in information exchange between the VOST and decision makers.

Although digital volunteers operating as the Cascadia VOST operated out of two physical sites (Langley and Whatcom County), there were challenges with coordination between these two teams. The two teams largely operated independently, rather than as a single group. One explanation for this is that, during the lead up to the experiment, they primarily trained as a single group and did not leverage tools such as Slack for coordinating from different locations. Additionally, the two groups used separate VOST Workbooks to track activities, leading to some duplication of effort.

After the experiment, participants evaluated the impact of the digital volunteers and social media monitoring during the experiment. using a 5-point rating scale, where a score of '1' referred to 'Strongly disagree' and a score of '5' referred to 'Strongly agree,' participants indicated the extent they agreed with several statements concerned with the use of digital volunteers and social media monitoring during

the experiment (*Figure 18*). In general, the participants agreed that the inclusion of the digital volunteers and the use of social media during CAUSE V was positive. The digital volunteers supported the EOCs' ability to provide notifications to the public with regard to relief efforts. As well, the digital volunteers identified misleading information to support the distribution of corrective messaging. This suggests the digital volunteers had several positive impacts including summarizing trending topics and other EEIs, identifying social media that requires follow-up and identifying misinformation, all in order to support SA for decision makers within the EOCs.

The digital volunteers also supported the effective verification of social media data by gathering additional information to enrich the understanding of the social media posts (e.g., relevant hashtags, geographic location related to posts) and provide the information in a useful format to the EOCs. The delivery of regular status reports and text-based press releases (i.e., Social Media Listening Reports) also supported the EOCs' efforts and operations.

Participants provided several examples for how social media could be used to support operations in real-world events. The lack of geotagged social media posts and the inability to receive information back from the PIO, or similar, were experiment constraints that were not fully exercised but could have supported these operations [20].

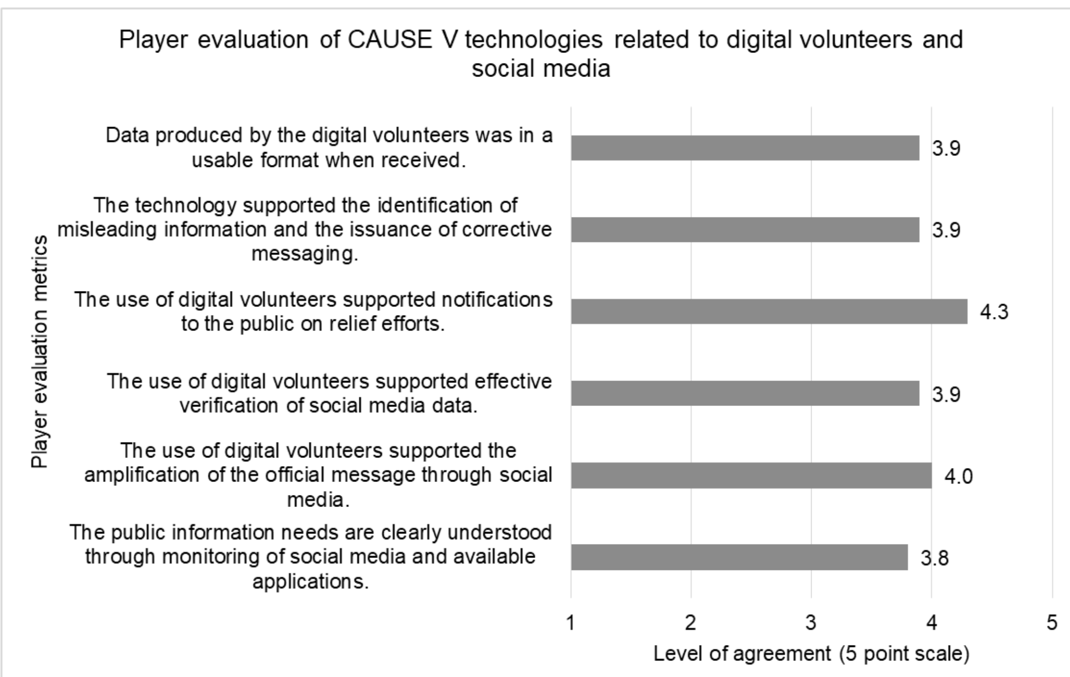

Figure 19. *Player evaluation related to digital volunteers and social media.*

CAUSE V Metrics

An analysis of the metrics ratings, assigned by the CAUSE V evaluation team, was performed to evaluate the overall impact of technology in accordance with the four dimensions of the SMEM Maturity model (i.e., governance, implementation, people and technology) along with basic usability of the technology (*Figure 19*). The results associated with each dimension indicate that participants were generally able to leverage the emerging technology, applications, tools and processes implemented during CAUSE V and

these had a positive impact on the emergency operations that were executed during the experiment. The introduction of the technology capabilities had the most significant positive impact on the emergency operations during the experiment.

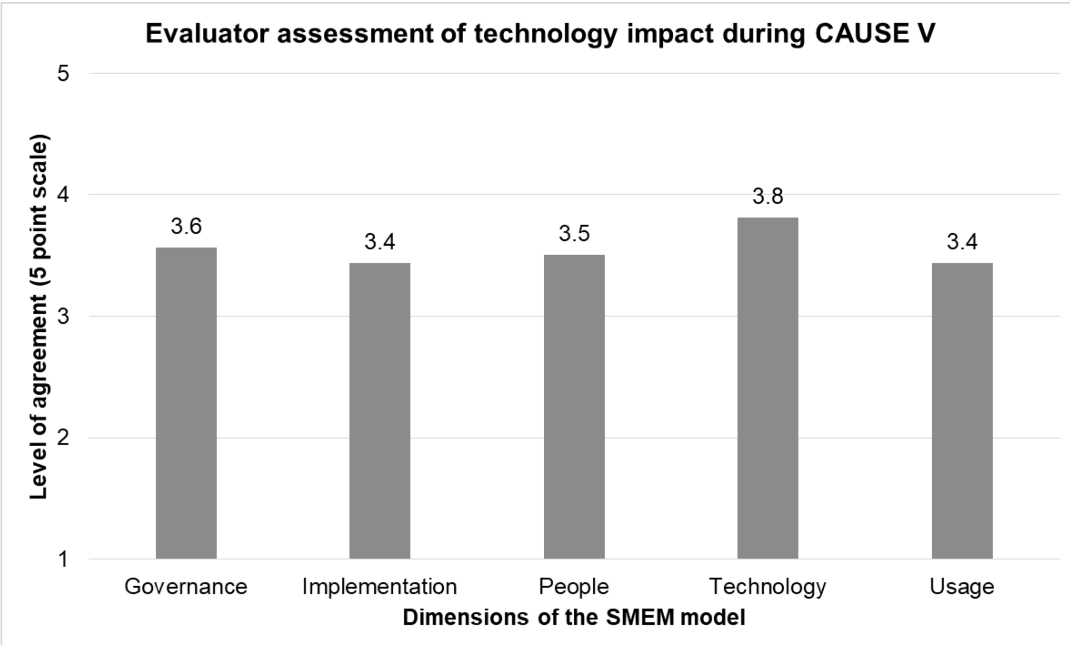

Figure 20. *Evaluator assessment of technology impact during CAUSE V.*

The evaluation team conducted a more detailed analysis to assess the impact of the experiment processes, as they pertained to each dimension, during each of the three phases explored during the experiment (i.e., planning, response, recovery). The results of this analysis revealed similar patterns of positive impact were observed across all three phases (*Figure 20*).

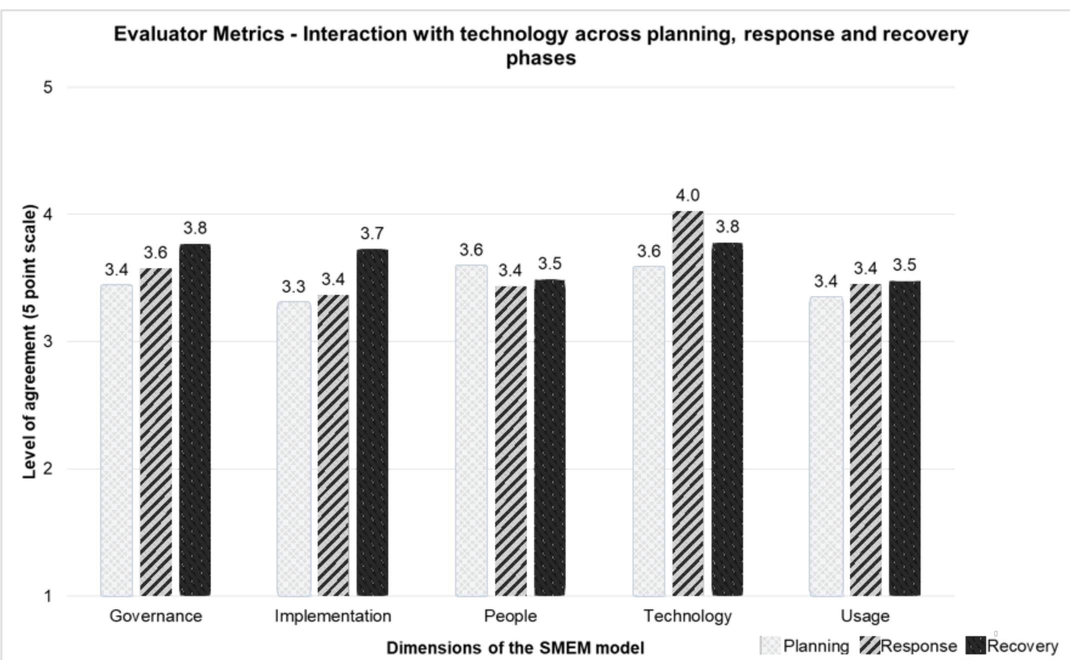

Figure 21. *Evaluator assessment of technology across the phases.*

Planning

Within the planning phase, it was identified that the inclusion of digital volunteers and VOSTs supported the EOCs in their ability to use social media for emergency operations. The participants were aware of the process and responsibilities for monitoring and leveraging social media data in the planning for the emergency. Published press releases and cooperation with industry partners were additional examples of how information was shared with the public within the simulated experiment environment.

Similar to the participant results, it was identified that the technology was not very conducive to allowing officials to verify, organize and filter out excess information to meet their own information requirements. However, the ability for multiple stakeholders to contribute information to status reports was recognized as a strength.

While the technology in CAUSE V was able to increase the reach and range of information sharing, decisions were not always made based on all the available information and information was not consistently shared among partners and stakeholders. A lack of training and insufficient knowledge as to what type of information could be shared may have contributed to this gap within experiment conduct.

Although information was shared cross-border and the main partners were able to work collaboratively towards planning and a response, there was a lack of coordination of the cross-border digital volunteers. The information produced by the Canadian digital volunteers was not being actively used by the U.S EOC or other cross-border organizations. These findings suggest there is a mechanism lacking that would allow participating organizations to obtain information from a cross-border VOST and integrate it into operations by sharing the information with the relevant EOC.

Response

Within the response phase, the use of technology supported the enhancement of SA for responders in the field. Further, using technology to support real-time interoperable voice and data communications was found to be the greatest strength. The ability for responders to send and receive video calls, images and mapping data from the field was proven to be highly effective in the response operations. Once again, it was identified that the technology was not as conducive to organizing and filtering the data to meet their requirements although there appeared to be an improvement over the planning phase. This improvement may be due to operators becoming more familiar with the technology and receiving additional support and training as the experiment progressed. It was identified that the technology was not conducive for extracting or interpreting information and this resulted in players being unable to consistently maintain an accurate COP.

Evaluators identified the need to develop and improve the mechanisms and process by which information was shared among organizations. It is still unclear who, within each organization, has authority and responsibility for monitoring and collecting information from social media by engaging the support of digital volunteers. It was anticipated that the information collected by the digital volunteers would be directed to the PIO; however, there was not an official chain of command or dedicated liaison responsible for working with this group during the experiment. A recent revision of the NIMS indicates incidents involving intelligence gathering can now be assigned within the Planning Section, Operations Section, Command Staff, as a separate General Staff section or some combination therein [27]. During the experiment, however, the steps required to address public safety concerns identified through the monitoring of social media were not successfully implemented within the command structure. This may

be due to an experiment constraint with restricted participation. However, the digital volunteers were successful in notifying key officials, through the experiment channels, of the events of the emergency through the introduced tools and technologies.

The technology allowed information to be shared in a timely manner and did not impede the normal speed of emergency operations and also allowed for multiple organizations and stakeholders to contribute information into a common forum.

Recovery

It should be noted that the experiment play within the recovery phase made use of the technology, but most of the operations were mainly planned and performed on a discussion basis. It was recognized that the technology was very effective in providing feedback and follow-up information among organizations as well as exchanging actionable information between emergency response organizations.

The technology and use of digital volunteers supported the ability of government authorities to detect and analyze trends gathered through monitoring social media. Relief efforts offered by volunteer organizations were effectively coordinated; however, the officials and operators were not always aware of the policy and legislation involved in the use of social media for recovery operations. Concerns of privacy in the release and sharing of information still need to be addressed.

The technology also supported the use of the COP and other information sharing techniques to gather information relevant to recovery operations. However, much of the information shared was ad hoc, without defined mechanisms or processes, but the processes employed by the technology were able to support these actions.

The response operations were effective in considering cross-border partners, including implementing binational infrastructure into their plans. However, although these partners were considered, officials did not readily consider requesting resources from other organizations.

System Interoperability and Technology Findings

This section includes observations related to the technologies that were tested during the experiment and the interoperability of the systems involved.

Wireless networks

Prior to the experiment it was identified that the Whatcom County Sherriff's Office and local CI operators (Williams) currently employ the Government Emergency Telecommunications Service (GETS), a priority service for telecommunications administered by the DHS OEC [28]. These services allow National Security and Emergency Preparedness (NS/EP) responders to maintain a high priority and signal quality when making phone calls during an emergency [29]. CAUSE V leveraged wireless networks that use a dedicated or prioritized LTE Network for First Responders and Public Safety users that ensures communications could continue despite infrastructure damage or increased volume on traditional networks. The experiment demonstrated how the use of these wireless networks ensures information (voice, video, data) can be shared from the field and between EOCs and additional responding organizations in the event of an emergency.

Participants successfully tested the wireless networks and validated that the priority of service was available to public safety users. CAUSE V included numerous technological demonstrations that successfully demonstrated session persistence, prioritization, pre-emption and congestion-based session persistence. Through CAUSE V, the team was able to successfully demonstrate these network achievements over multiple iterations. As well, identifying public safety operational environments where these capabilities would be of benefit is ideal for the continued development of features and their implementation within the public safety broadband networks.

Due to the large number of wireless participants, complex scenario, numerous injects and nature of experimentation of CAUSE V, participants were asked to refrain from making use of their wireless connectivity unless directed to do so by experiment control. This was to control the amount of wireless traffic on the networks at all times so that the technology service demonstrations would function properly. While this request was adhered to at first, the wireless users began using the wireless applications throughout the experiment without direction. This behavior occurred more frequently as the participants became more aware of the potential uses and capabilities of the technology and applications. Further still, this occurred even when they were not part of the ongoing inject. This increased the participants' exposure to the capabilities available via broadband wireless and caused the network traffic to increase significantly. The additional network activity had very little detriment to the experiment itself but injected a significant amount of workload on technical personnel at the network cores.

It is suggested that in future experiments of this nature, participants should be allowed the flexibility and opportunity to make use of the wireless networks in a more flexible and opportunistic manner. In designing future experiments, it is suggested that any regimented testing be restricted to a small subset of the entire experiment. This would allow the opportunity for players to leverage the technology as they would in a real-world response and communicate between the EOC and the field in order to increase SA, simulate a response and exchange information. Additionally, an inject could have been introduced that affected and impeded traditional communications. This would have emphasized the use of the technologies through the wireless networks and would have highlighted the need for non-traditional methods of communication. Logistical barriers, including the provision of additional compatible computers and tablets, would need to be considered before the introduction of this type of inject in any future experiments.

Due to the increased use of the wireless networks during the demonstrations of prioritization, pre-emption, and congestion-based session persistence, wireless users who were not directly involved in the inject were not expecting the increased bandwidth or affected capacity. They experienced a degradation of performance or a full loss of connectivity. Based on the goals of these technical demonstrations, this was not only expected but also served to successfully validate these experiment components. Unfortunately, such users were often not aware of, or expecting these potential consequences. For future experiments, anticipated timings where technical demonstrations are taking place should be more widely communicated and a better understanding of the expected outcomes should be provided.

Due to the large variety of experiment locations and the requirement to move between locations for the technical demonstrations, it proved challenging to keep all participants fully informed throughout the experiment. Interestingly, the participants learned to resolve this issue by using the email application and moreover, the multi-party chat feature in DragonForce to discuss among themselves and clarify involvement and responsibilities throughout the experiment. Wireless users found the most value in the use of the wireless technology through video conferences and applications that provided the location

and status of all users. Live video feeds from drones, robots and Internet Protocol (IP) video cameras, and real-time information from sensors greatly improved participants' SA.

In CAUSE V, Canada and the U.S. worked closely together to develop a single scenario that enabled the interworking of applications. In doing so, participants could monitor the real-time activity of wireless users in DragonForce but could also see the same information simultaneously in the ArcGIS application used to provide a COP throughout the experiment.

The public safety broadband network initiatives in both Canada and the U.S. use the 700 MHz Band 14 spectrum in a fully harmonized manner. While this is highly desirable from interoperability and interworking perspectives, it does create a co-channel interference environment where the coverage of both the Canada and the U.S. networks overlap. This will often be the case at border regions where overlapping coverage is expected to occur. Fortunately, the LTE technology that underpins 4G cellular mobile service in Canada and the U.S. features sophisticated functionality that helps limit the impact of co-channel interference between LTE networks. CAUSE V demonstrated that while network performance is then impacted to some extent depending on the level of co-channel interference, networks in both countries are still capable of co-existing in the vast majority of border regions. This co-existence is also necessary to support session persistence.

Robots and Sensor Technology

Three teams of UAS / UMV operators from the Center for Robot-Assisted Search and Rescue (CRASAR) at Texas A&M University, and affiliated Roboticists without Borders group deployed to locations in Whatcom County [30]. These teams conducted nine missions over two days at seven different locations (*Table 6*); however, the mission schedule and locations deviated slightly from the experiment plan due to inclement weather. The mission assignments included demonstrations of water-based search and rescue (SAR) operations and the collection of aerial imagery and video. The detailed UAS / UMV asset scheduled can be found in Appendix 5 - UAV/UAS Missions.

Table 6. *Missions carried out by the UAS/UMV Robot teams.*

November 15
• North Fork Nooksack (Everson)
• Silver Lake Park (Maple Falls)
• Nooksack River, Williams Pipeline (Bellingham)
• Nooksack River at Everson (Bellingham)
• Nooksack at Deming (Bellingham)
• Williams Pipeline Valve Station (Bellingham)
• Cornell Creek Rd. (Glacier)
November 16
• Silver Lake Park (Maple Falls)
• Nooksack River, Williams Pipeline (Bellingham)

The CRASAR team brought a large vehicle outfitted as a mobile laboratory, RESPOND-R, which was stationed in Sumas, WA inside of the experimental wireless network coverage (*Figure 21*). This vehicle served as a forward operating base for teams to process data and manage the equipment (*Figure 22*). During the experiment, the three UAS / UMV teams deployed outside of the network coverage and returned to the mobile laboratory to share information with the remaining experiment participants.

Figure 22. *RESPOND-R Mobile Lab stationed in Sumas, WA.*

During the response phase, the UAS teams produced a large burst of low-resolution streaming video from multiple sites. This activity is consistent with what responders and incident command typically require during the first 24-48 hours after a disaster occurs to gather initial SA of the scene.

In addition to the low-resolution streaming video, UAS teams captured high resolution imagery and video. Because of the additional detail of the high-resolution products, these can provide valuable information that is unavailable when using low-resolution imagery (e.g., structural damage on bridges caused by the lahar). Rather than streaming directly from the UAS console to the network, this data is typically captured on the device's Secure Digital (SD) card because of its large size. This data is important to get to responders within the 12-hour decision cycle, so that it can be assessed it and re-deployed, if required.

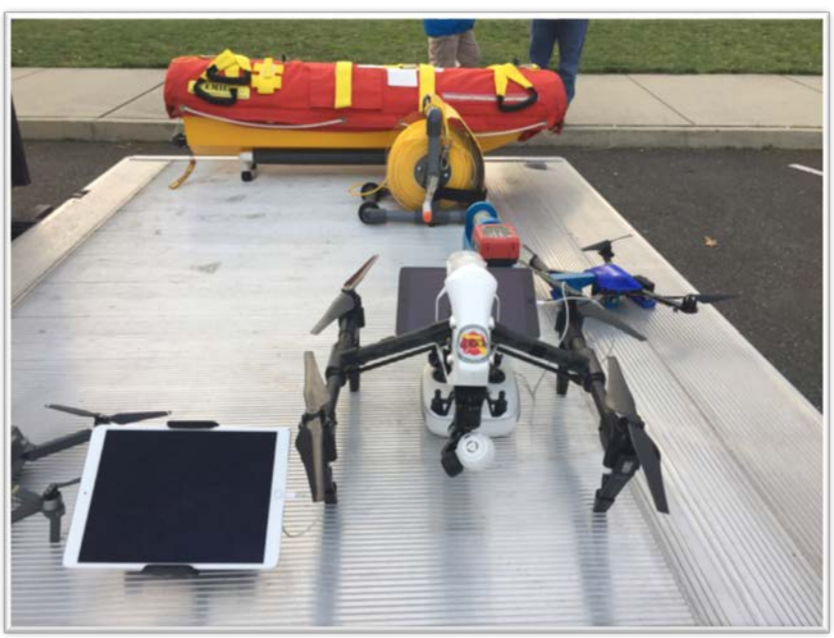

Figure 23. *Several UAS devices connected to solar panels for recharging in the foreground, with a UMV (EMILY) in background.*

The preparation of map products from the high-resolution imagery captured by UASs typically supports the recovery / mitigation phases after the initial response period of a disaster, generally 48-72 hours after the event. However, during a significant geologic event like a lahar flow, these map products would be needed as soon as possible. The production of map products typically requires large computer processing power, often accomplished by cloud-processing the data. An example of this is the orhtomosaic map of the Nooksack River produced by the CAUSE V UAV team in Figure 23.

Figure 24. *Sample orthomosaic map product of the Nooksack River captured by the UAV Team.*

Overall Use of Technology

During the course of the experiment, the participants were exposed to many different applications and technology. It was identified that there were some challenges with the technology, which were resolved on an ongoing basis as the experiment continued. However, the use of the technology helped identify different types of information and data requirements that needed to be distributed and shared among organizations during an emergency. *Table 7* below lists some of the strengths and areas for improvement of the technology and applications based on the participants' experience during CAUSE V.

Table 7: *Strengths and Areas for Improvement in the use of the CAUSE V Technology.*

Strengths
• The shared maps, COP and Operation Dashboards provided a wealth of information that is not typically available through the current methods of information sharing.
• Incident logs on ArcGIS Online were determined to be a valuable tool for sharing planning information and developing cross-border SA. This feature allowed for real-time data exchange between the EOCs involved with the event.
• The wireless networks supported the real-time data transfer from the field to decision makers. Photos, video, voice communications, mapping data and low-resolution drone footage were all easily uploaded from the field and transferred instantly to the participants located at the EOCs and shared among all participating organizations.
• It was recognized that in the event of an emergency when traditional communications are unreliable, the use of a wireless, prioritized Public Safety Network would be necessary to maintain communications. The tests performed during CAUSE V demonstrated how prioritized access to a network could function and highlighted its ability to maintain communications with the field and between responding organizations in cross-border communities in the event of an emergency.
• The emerging technology allowed for organizations to track and control resources and personnel. It was identified that these types of applications would be quite beneficial for resource management in real-world events.
• The use of the various applications supported partnerships and agreements between the participating organizations. Organizations were able to identify available resources and request material and personnel from available mutual aid partners. The technology also supported information sharing among multiple levels of government, supporting the PNEMA processes.
• To support the use of a wireless broadband network among First Responders, FirstNet has developed an online application store available only to Public Safety users. This store has applications available to support secure and standardized data communications in the field [31].
Areas for Improvement
• Company firewalls and security protocols created some access issues for organizations attempting to use ArcGIS Online. These access issues should be identified in advance.
• Some of the mapping products require more details. It was unclear at times to the participants what the various layers signified and what sort of information they could gain by viewing that layer.
• It was identified that it would be beneficial to have access to an application that let each organization pre-define their EEIs and would then be used to help populate the relevant data sets and map layers. This would support information sharing by ensuring organizations are receiving the most relevant information.
• The standardization of symbology in the applications is an important consideration when attempting to create a COP for organizations located in different jurisdictions, as well as for cross-border partners to ensure accurate and consistent information is communicated.
• Consolidating many of the applications and tools into a single application with an effective filter would support the integration of relevant information, the identification of actionable intelligence and would reduce the time required for learning new applications.
• The quick deployment of a prioritized public safety network would be the greatest improvement to ensure it is effectively used by Public Safety users. Having a small, deployable package that can be set up in a short time frame and in a remote location would be ideal for its implementation into real-world operations.

Experiment design and conduct

General

Information from the participants regarding the success of the experiment, the tools utilized to support a cross-border response and the overall design, development, planning and conduct of the experiment was collected following the experiment. Overall, the participants found that the preparation and execution of the experiment was a success.

Participants did note a few areas for improvement for the general design and conduct of the experiment. Additional exposure for the participants to the field personnel who were involved in specific testing of wireless networks would have supported the participants' overall awareness of the technology demonstrations, their importance and may have improved their involvement in the emergency operations. It should be noted that some participating organizations did not have the opportunity to develop an understanding about how the technology and subsequent information exchange introduced during CAUSE V could be coordinated within the NIMS. Finally, a more centralized structure for participant locations would have provided readily accessible support in the event of technology accessibility issues or failure. This design would also facilitate experiment control and evaluation.

Training

The introduction and use of several different types of technologies and applications warranted significant training for the participants. The EDT arranged several training sessions to help familiarize the participants with the technology and applications, however, additional training sessions could have been used to ensure all participants were fully aware of all the capabilities of the technology. Additionally, the trainings and dry runs could have provided a better summary of the processes for the conduct of the experiment to prepare participants for these activities. Testing and familiarization with the technology and the applications including training on all the available tools and clarity on how to use them would have benefited the participants.

It was determined that the hands-on training session that took place prior to the experiment were imperative to provide an opportunity for participants to become familiar with the scenario, experiment plan and emerging technology. It is suggested that in similar future experiments, this training session should become a part of the overall experiment schedule, so organizations can ensure they have available resources to attend as part of their experiment conduct.

Participating organizations

The experiment was a true cross-border event with numerous organizations participating from both sides of the border. The relationships developed and nurtured between the organizations during this experiment have improved informal communications and coordination and have exposed the need for more official communication channels. Overall, most participants (67 percent) considered the technology implemented in CAUSE V had a positive effect on cross-border information sharing.

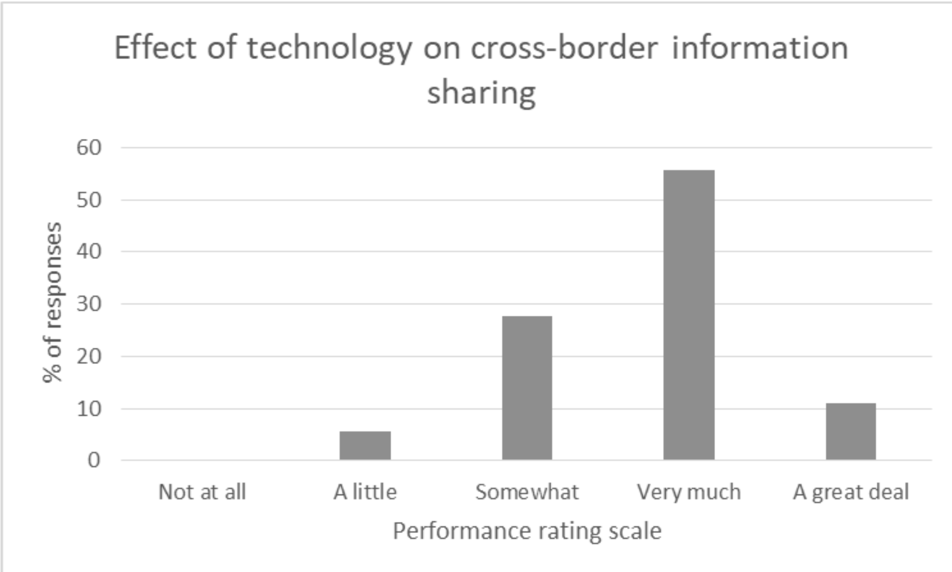

Figure 25. *Participant feedback on effect of technology.*

Not all of the relevant organizations who would be considered and involved in a response to this type of emergency actively participated in the experiment and some organizations were communicating with organizations that they would not typically in real-world events. Additional industry and CI partners, broader representation from the First Nation / Native American tribal community, and first responders would have helped maximize the effectiveness of the experiment in terms of testing the technology to support communications, interoperability and information sharing. The involvement of more first responders and their deployment into the field would have increased the sense of realism and ability for CBSA and U.S CBP, as well as for local EOCs, to play at an operational level.

Within the participating organizations, some of the expected personnel were also not playing. This detracted from the realism of the scenario.

In order to resolve concerns of not having adequate participation, or the required participating organizations being unavailable due to training constraints or similar, it was suggested that in the future, a more rigorous process be implemented for identifying key experiment locations and partners. A survey, or similar, can be distributed to possible participants prior to the location selection in order to determine potential level of effort, scheduling conflicts, current technology usage and available resources. Identifying these requirements prior to the selection process will ensure the required resources are available and willing to participate for the length of the experiment process, maximizing the output for all involved organizations.

Experiment tools

The use of digital volunteers in emergency operations was proven to be quite valuable throughout the conduct of this experiment. Some of the tools used to simulate social media communications in an emergency could be modified to improve the realism and to obtain more valuable data. Assigning geographic locations to simulated social media posts and advancing the search mechanisms provided could aid the digital volunteers to maximize their effectiveness while participating in the experiment. Additionally, timings on social media posts reflected the time zones where they were created, not the one they were received, causing confusion among the digital volunteers.

Technology

Following the completion of the experiment there were still reservations regarding the implementation of some of these technologies in real-world operations. While participants see an advantage in implementing these technologies to promote inter-agency communications and support real-time feedback with field operators, they recognize that there are still hurdles to overcome. Privacy and security issues as a result of widened information sharing and the inability to maintain a capacity for training and experience due to infrequent use, are examples of some of these potential gaps.

Next steps

The use of exercises and experiments, such as the CAUSE experiment series, with the active involvement of provincial / state and federal representatives can help familiarize organizations with official channels of communication, such as those described in PNEMA. Frequent performance of these types of activities will ensure organizations become more familiar with these official procedures and will ensure organizations are ready to leverage them in the event of an emergency.

Implementation of these technologies within day-to-day operations would result in a larger number of trained operators, capable of using the technology during an emergency. Events such as the CAUSE experiment series can also support training and the implementation of corresponding policies and procedures to new technology and applications. Support from federal and provincial partners can assist in the transition of the technology by providing guidance on implementing protocols, training on the technology and official messaging.

Summary and Recommendations

Summary

Experiment Outcomes

The CAUSE V experiment provided an opportunity for emergency responders to test various technologies and applications in an effort to support the planning, response and recovery of a simulated emergency. The results of the evaluation process supported the conclusion that the technology and applications tested allow for information to be effectively exchanged among cross-border partners to support emergency operations and enhance the reach, range and quality of this information exchange.

The EOCs were able to leverage the wireless networks and populate a COP in order to enhance decision making and to share and receive information from multiple responding agencies. The COP and related applications allowed for information to be shared among all participating organizations in a timely and effective manner. While current processes only support traditional methods of communication, these applications and technology allowed for real-time sharing of data. However, it was recognized that modifications are required to the COP application to support the manipulation and filtering of data to meet the specific information requirements of each responding organization. The participants identified the value in the deployment of the prioritized wireless network in a real-world emergency to support continuous communications among emergency officials when traditional infrastructure is affected or the bandwidth is saturated with additional users.

The use of robots in the field to collect images and mapping data reinforced the response of the participating organizations and was demonstrated to be especially beneficial for the infrastructure partners. The experiment also provided an opportunity to explore the use of both aerial and submersible robots to support search and rescue operations. While the ability to relay this information in near-real time from the field to the EOCs through the use of the wireless networks was one of the successes of the experiment; the issues of limited service areas and bandwidth identified by the operators are important real-world considerations and point to the need for further work.

The involvement of trained digital volunteers through an organized VOST was shown to be a success, not only in the context of the experiment, but in real-world situations as well. Since the conclusion of the experiment, the digital volunteers have had two opportunities to activate in response to real-world events [32]. The inclusion of digital volunteers in the experiment allowed emergency managers to monitor the needs of the public, identify situations where life-saving support was required and amplify and / or release official messaging. It was identified that the role of the VOST in support of emergency operations needs to be further defined, as well as the responsibilities within the EOCs for the implementation and control of this group. Investigation as to how reports become actionable, and the feedback process between the EOC and digital volunteers is also required. Additional coordination among the Cascadia VOST members would enhance the social media monitoring products and may increase their efficiency, by minimizing the duplication of work.

Although mutual aid between the participating organizations was considered at all stages of the emergency, due to experiment constraints and relevant organizations being unable to participate, the ability to fully test resource planning tools such as the MARP, or the EMAC Operating System for enabling requests of cross-border mutual aid was not possible. As such, the consideration of PNEMA was restricted to discussions and the provision of mutual aid was not actively tested. Although

participants are aware of PNEMA and its capability to support cross-border mutual aid, challenges in its use were identified including timely response and potential associated costs.

Finally, the experiment facilitated the real-life movement of resources and personnel across the Canada-U.S. border at two separate POEs. The use of the technology and associated wireless networks allowed for customs and border agents to be notified directly when cross-border movement of an emergency vehicle / resource was imminent. First responders were able to maintain seamless communications with the border agencies on both sides of the border, as well as all involved EOCs and remaining field personnel. This allowed for notifications of the dedicated lane, or changes in traffic flow and real-time updates as the situation progressed. The use of the vehicle tracking system also allowed multiple participating organizations to track and monitor the resources as they crossed the border and deployed to their final destinations.

Technical Innovations

The CAUSE V Experiment provided a low-risk environment for participants from neighboring communities along the BC – WA border to test new technology with the goal of improving overall communication and coordination through information sharing. A summary of the notable technical achievements that were part of this demonstration is included below.

- **Wireless Networks-** The LTE technology used for public safety broadband networks has the ability to operate in co-channel interference environments, albeit at less than maximum capacity. The technology demonstrations involving congestion-based session persistence, where a user in a fixed location covered by two networks could toggle from one network to another under congested conditions, is considered to be a first of its kind. Such a feature could contribute to achieving a high level of wireless performance in co-channel border regions.

- **Robots-** Three teams of UAS and UMV operators streamed videos to the participating EOCs over the experimental wireless network, captured imagery for orthomosaic maps and conducted water-based search and rescue missions.

- **Sensor Integration**- Integration of vibration and water sensors, leveraging the wireless network to provide real-time access to environmental data provided by a broadband-enabled Internet of Things (IoT).

- **Spatial-Temporal Information Products**- Time-based lahar map supported planning efforts. The use of the animated time lapse of the lahar flow provided the Williams staff with the means to determine the window of time required to turn off valves and divert inventory in their pipeline.

- **Field Reporting**- Successfully tracked locations of deployed personnel using Drakontas DragonForce and tested sending field reports using Esri-based digital reporting tools (Survey123). This was the first CAUSE experiment to successfully combine data, applications and wireless networks.

- **System Integration –** Bidirectional information sharing between two different platforms (ArcGIS Online and Drakontas DragonForce) was achieved by integrating the systems using an open REST API.

- **Vehicle and Personnel Tracking**- Tracked location of vehicles and personnel in real-time and superimposed that information on existing maps and dashboards at multiple EOCs and within applications available to the field teams.

- **Social Media Monitoring**- CAUSE V spurred the creation of the Cascadia VOST, facilitating social media for emergency management training for members from the U.S and Canadian digital volunteer teams. The VOST operated during CAUSE V, monitoring social media content and producing listening reports and identifying actionable social media posts using standardized web-based forms and have been activated for real-world emergencies since the conclusion of the experiment.

- **COP Improvements-** The COP leveraged by participants during the experiment included live updates from many different sources on both sides of the border, as well as authoritative hazard data about the volcanic scenario. The COP included new features that have never been tested before during the CAUSE series, including the 'Virtual CAUSE' (vCAUSE) widget that lets users add web maps into their operating picture from trusted information providers.

While participants agreed that the technology and applications introduced in CAUSE V supported cross-border information sharing, data exchange and SA, ultimately to support the planning, response and recovery from a Mt. Baker hazard scenario, remaining gaps and challenges associated with this technology were identified. Potential recommendations as to how to improve the effectiveness of the technology and applications during a cross-border response can be found in the following section.

Recommendations

People Focused

Recommendation 1: Additional training is required to familiarize users with any new technology being considered for adoption, especially with regard to a cross-border disaster event. The 'just-in-time' training provided prior to the experiment was identified as critical, although was insufficient to meet the requirements of the experiment. Modifications to the format of the experiment may be warranted. By allowing an initial day of 'free play', followed by the actual experiment, participants would be able to familiarize themselves with the technology and applications within the simulated environment. As well, the participants would gain knowledge about all the capabilities of the technology that will be explored during the experiment, prior to its use. This awareness would enable evaluators to focus more heavily on the impact of the technology during emergency operations without the bias associated with learning to use the applications. In addition to training for the experiment, a training program for this technology and applications would need to be considered prior to its implementation in any real-world operations.

Recommendation 2: Introducing the technology into everyday use is identified as an effective way to ensure the availability, capability and training for the technology and applications in emergency situations. Technology often gets introduced solely for emergency operations and users are unfamiliar with these systems, as they do not get used during daily operations. This minimizes their effectiveness and may prevent its use altogether during emergencies. By ensuring EOC staff have the ability to use some of this technology on a day-to-day basis, it would minimize the need for additional training on emergency-specific technology and would allow users to gain full functionality of the technology prior to an emergency.

Recommendation 3: Find additional opportunities for training and exercising the new Cascadia VOST, as well as the integration of social media information products into operations within the EOC. CAUSE V served as a primary opportunity to fully explore these concepts for the communities involved with the experiment, and VOST teams will benefit from continued engagements.

Recommendation 4: Although the Cascadia VOST teams were successful in working independently from Whatcom County, WA and Langley, BC, there was little cooperation between the two groups. It is recommended that the Cascadia VOST identify methods they can more easily share information, coordinate their response to joint events and support the other region during emergencies on one side of the border. The use of supplementary applications, such as team collaboration tools may be explored to effectively delegate tasks and manage resources.

Technology Focused

Recommendation 1: New strategies should be considered for dealing with the processor and bandwidth intensive challenge(s) posed by large volumes of data produced by robots and other sensors. One solution is edge computing, in other words, moving the processing of data closer to the 'edge' of the network and closer to the source of the data, rather than leveraging the cloud for processing.

Additionally, data can be optimized based on its intended use. For example, streaming imagery from a UAS to the EOC to provide an initial view of a disaster scene may be compressed significantly, whereas imagery being used to identify structural defects in a bridge may require the highest resolution imagery available.

Recommendation 2: Sign-in issues with ArcGIS Online-based tools were observed, including with the COP and Operations Dashboard, for users accessing the platform through the NISC Member Portal. This necessitates an investigation into more robust and user-friendly methods that can be used to authenticate participants. A more basic approach, such as the generation of a secure, reusable user token that can be applied when logging into the Member Portal, may prove to be more reliable and less susceptible to browser compatibility problems.

Recommendation 3: The list of visible layers contained within the SA information products such as the COP and Operations Dashboards, needs to be fine-tuned to match the needs of the participant that is using the application. The sheer volume of available layers made it difficult for users to focus on the specific data that would assist them. One solution would be to continue to use one overall list of layers, but then create various web map "Views" that service specific needs, such as one for Digital Volunteers, another for EM Directors, a third for border personnel, etc.

This type of role-based solution would also streamline the user experience for responders in the field, providing them with only access to the products/tools they require for their role. This would also prove to be beneficial from a privacy aspect, to ensure information layers are limited to certain organizations based on their restriction privileges.

Recommendation 4: The mapping applications require readily accessible legends and scales so that emergency operators are able to quickly view and fully understand the information that they are

seeing. The standardization of symbology would be considered useful for implementation, especially within the context of a multi-agency cross-border response.

Recommendation 5: Canada and the U.S. should consider adding the ability for the LTE technology to operate in co-channel interference environments, albeit at less than maximum capacity, when implementing their public safety broadband RAN networks in the border regions.

Process Focused

Recommendation 1: Regarding the development of future experiments, and more generally when applying any new processes and technologies to an organizational system, there needs to be a thorough assessment to determine how it will fit into the relevant incident management structure within the applicable region (e.g., NIMS, Incident Command System). The output of this assessment will help define any specific criteria or requirements that are necessary for implementing the processes or technologies into emergency operations.

Recommendation 2: The experiment identified the need to further define the relationship between the VOST and the command structure involved in an emergency response. Also, it is important to establish clear communication between the VOST and the coordinating unit (e.g., PIO or Operations Unit) in the local command structure.

In addition, the experiment pointed to the need to close the feedback loop for information shared by the VOST. While digital volunteers were providing actionable reports to the EOC, they received no follow-up communications with respect to the results of these reports. This was especially troubling in instances where the reports were based on immediate life-saving requirements. This could be addressed by instituting a process for the PIO / Operations Unit to identify whether follow-up has been completed related to any actionable information provided and implementing a mechanism to share this information with the VOST. A text field, or similar, within the VOST reports where the actioned information could be captured, may be a way to address this requirement.

Recommendation 3: There is a need for more frequent testing of binational Mutual Aid agreements, such as PNEMA, to familiarize all levels of government on the existing policies and procedures related to these mutual aid compacts. This would allow for more training within the official channels of communication and may be an opportunity to identify ways to improve the efficiency of these processes. Providing additional familiarization with the activation processes and communication channels associated with PNEMA as part of this testing is also recommended.

Recommendation 4: An update of the Mt. Baker Coordination Plan that includes defining what personnel, resources, and essential information is required for each of the phases (i.e., planning, response and recovery) of a Mt. Baker event. Active cross-border working groups already exist in Whatcom County and neighboring BC to address this requirement.

Conclusion

The CAUSE V evaluation process identified benefits in leveraging wireless networks, digital volunteers, robots, resource tracking and COP applications to support cross-border communications and information sharing in response to a simulated emergency in the Pacific Northwest. The evaluation considered the specific CAUSE V objectives as well as the overall CAUSE experiment series objectives. While the technology and applications introduced in this experiment support cross-border data transfer, SA and continuous communications with multiple agencies, recommendations in the associated processes, technology and applicable resources were identified.

Prior to the conduct of the experiment, the EDT identified numerous pre-existing working groups that served to address some of the challenges in responding to an emergency within the border communities. An extensive network of pre-existing relationships between applicable EOCs and related agencies supported cross-border communications through traditional means. However, it was identified that the effectiveness and reliability of the existing emergency cross-border communications could be enhanced by combining formal communication channels and non-traditional communication methods that support real-time transfer and data shareing.

The planning and development process of CAUSE V also proved quite beneficial to emergency planning and preparation within this cross-border community. The development of the Cascadia VOST, with members from Canada and the U.S supported the response within the context of the experiment and has proved successful in real-world emergency operations. Additionally, a review of the Mt. Baker coordination plan identified gaps and challenges, warranting further review.

Opportunities for training and familiarization with the technology were identified as being key requirements for its integration into real-world emergency operations. Additional modifications to the technology and applications to support its ease of use and efficiency by operators were identified. Modifications to processes related to cross-border information sharing were also identified in order to close all communications loops.

Overall, the findings from CAUSE V suggest that the interoperable technologies and applications introduced during this experiment can be used to improve current cross-border communications and information sharing and to minimize some of the existing operational gaps. While modifications to the associated processes and technology may be required, these tools were effective in increasing the reach, range and depth of the information being shared with all responding organizations.

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Appendix 1 - Experiment Schedule

Date	Time	Activity
Nov 14th	08:30	Set-up
	10:00	Training at Abbotsford City Hall
	12:00	Lunch
	13:00	Training at Whatcom Unified Emergency Coordination Center (UECC)
Nov 15th	08:00	Registration / Morning briefing
	08:30	StartEx / Planning phase
	09:30	Local level guided discussion regarding Mt. Baker emergency plans
	11:00	Flood response phase
	12:00	Lunch
	14:30	Mt. Baker emissions phase
	16:30	EndEx
	16:45	End of debrief
Nov 16th	08:00	Registration / Morning briefing
	08:30	StartEx / Lahar response phase
	12:00	Lunch
	13:00	Lahar recovery phase
	15:00	Local level guided discussion regarding Mt. Baker recovery plans
	16:30	EndEx
	16:45	End of debrief
Nov 17th	09:00	AAR begins
	12:00	AAR ends

Appendix 2 - Wireless Users

No	Wireless Users	Device Type	Designator	Location
1	CBSA Douglas Port of Entry	Modem/Laptop	LT1/M1	Fixed
2	DHS CBP Peace Arch Port of Entry	Modem/Laptop	LT3/M3	Fixed
3	CBSA Huntingdon Port of Entry	Modem/Laptop	LT2/M2	Fixed
4	DHS CBP Sumas Port of Entry	Modem/Laptop	LT4/M4	Fixed
5	Abbotsford Fire Vehicle	Modem/Laptop	LT7/M7	Mobile
6	Langley Vehicle	Modem/Laptop	LT8/M8	Mobile
7	Semiahmoo First Nation Vehicle	Modem/Laptop	LT9/M9	Mobile
8	City of Bellingham Sheriff Vehicle	Modem/Laptop	LT10/M10	Mobile
9	Commercial User 1 - Langley	Smartphone	SONIM 1	Mobile
10	Commercial User 1 - Abbotsford	Smartphone	SONIM 2	Mobile
11	Public Safety User 1 - Whatcom County	Smartphone	SONIM 3	Mobile
12	Public Safety User 2 - Abbotsford	Smartphone	SONIM 4	Mobile
13	Public Safety User 3 - CBSA Douglas	Smartphone	Bittium Eng1	Mobile
14	Public Safety User 4 - Semiahmoo	Smartphone	Bittium Eng2	Mobile
15	Public Safety User 5 - Langley	Smartphone	Bittium Original	Mobile
16	Public Safety User 6 - CBSA Huntingdon	Smartphone	Bittium TEMS	Mobile
17	Whatcom County EOC	Laptop	LT5	Fixed
18	City of Abbotsford EOC	Laptop	LT6	Fixed
19	Sensor Platform 1	Modem/Laptop	LT11/M11	Fixed
20	Sensor Platform 2	Modem/Laptop	LT12/M12	Fixed
21	TAMU Drone/Robot Platform	Modem	M13	Mobile

Appendix 3 - Experiment Capability Needs

The capability needs identified below do not represent all the capabilities that would be required to plan for, respond, or recover from a volcanic incident, but rather the specific capabilities that were considered for the experiment. These were developed by the experiment design team following the initial planning conference to guide the design of the experiment.

Situational Awareness

SA1. Visualize the location of regional threats and hazards and critical infrastructure.
SA2. Monitor real-time data from sensors in the incident scene and surrounding area (e.g., stream gauges, seismic sensors, etc.).
SA3. Obtain critical information about the extent/perimeter of the incident
SA4. Model and/or predict future characteristics of the incident
SA5. Visualize information shared by first responders in the field in a common operating picture.
SA6. Access real-time / near-real time photos or videos pertinent to the incident scene.
SA7. Geolocate responders and emergency vehicles on the incident scene.
SA8. Identify other pertinent information to the incident scene and add it to the common operating picture.

Communications and Information Sharing

CIS1. Monitor social media during an incident to inform operations and investigations.
CIS2. Maintain resilient communications systems in urban and rural areas.
CIS3. Issue clear alerts and warnings to the public before, during, and after incidents.
CIS4. Communicate with affected civilians and casualties on the incident scene.
CIS5. Share information in real time among services and agencies.
CIS6. Ingest, assess, and manage data from multiple sources.
CIS7. Disseminate clear direction and tasking to responders on the incident scene, regardless of agency or service.
CIS8. Access data and information (e.g. voice, text, images, video) on the incident scene, including from overhead aircraft/UASs/robots.

Logistics and Resource Management

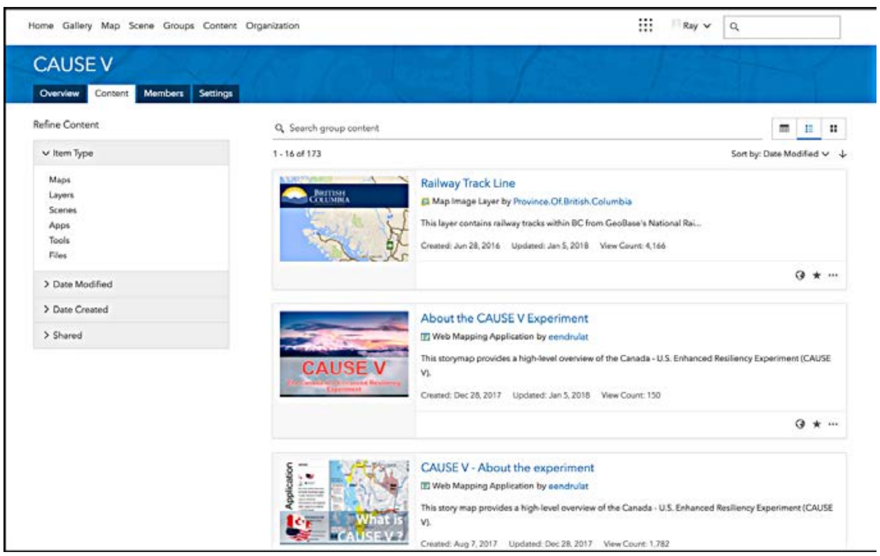
LRM1. Pre-plan resource requirements and mutual aid agreements.
LRM2. Coordinate resources needs across agencies and services.
LRM3. Manage mutual aid resources on the incident scene.
LRM4. Identify, acquire, and track resources sufficient for the size and scope of response activities.
LRM5. Apply the "whole of community planning" concept to resource planning by engaging local, state/province, federal, and private sector partners.

Risk Assessment and Planning

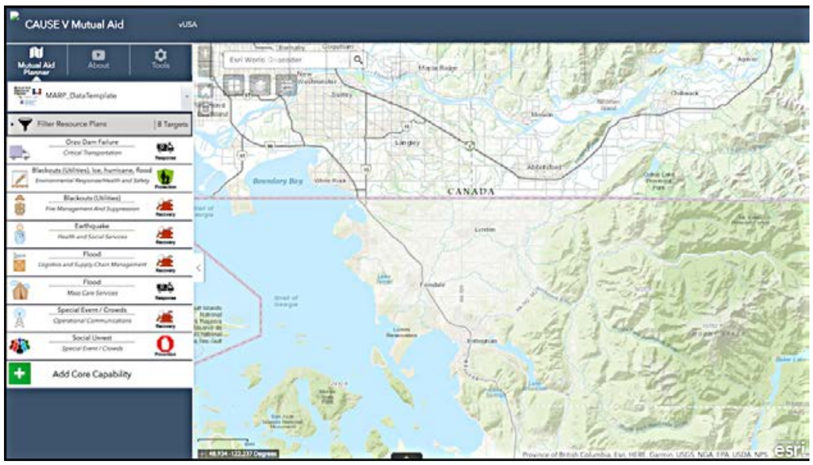
RAP1. Conduct standardized cross-border assessments of threats, hazards, and risks related to a volcanic hazard.
RAP2. Develop plans based on threat, hazard, and risk assessments, including the development of pre-scripted mission assignments.

Appendix 4 - Technology Used During Experiment

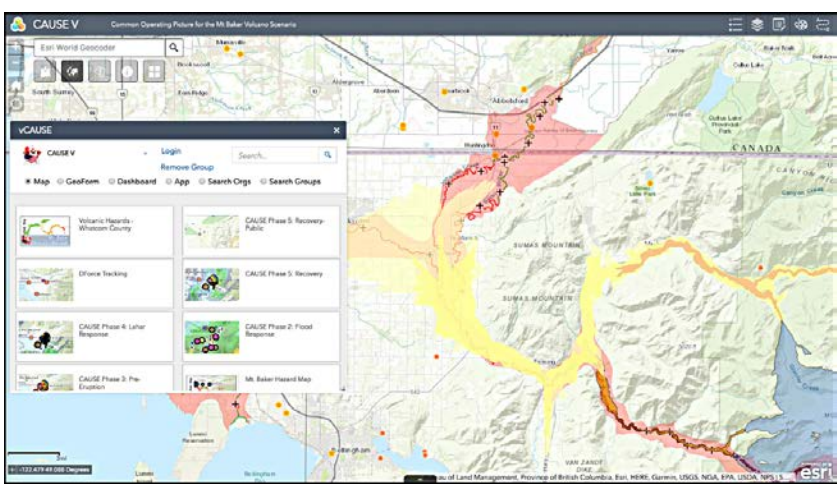
ArcGIS Online	
Owner	Esri
Intended Use	Development of information products, sharing of cross-border content in CAUSE V Group. Supports Web maps, GeoForms, Operations Dashboards, Story Maps, Map Viewers and Web Application Templates.
Users	All



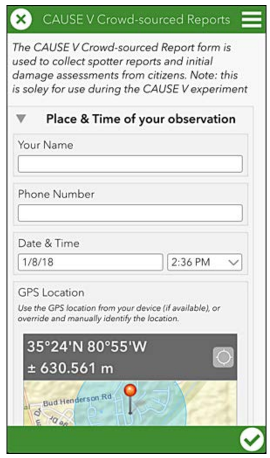
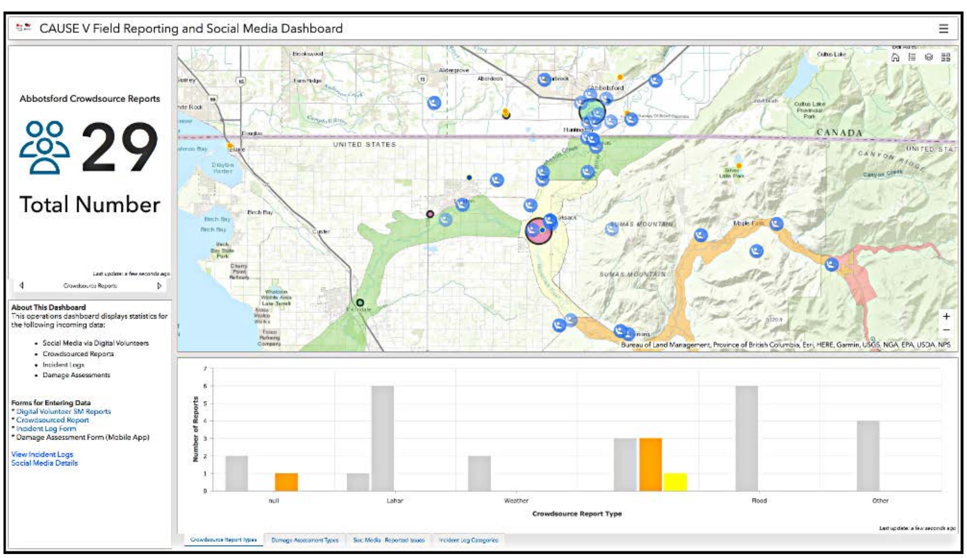
Mutual Aid Resource Planner (MARP)	
Owner	National Information Sharing Consortium (NISC), transitioned from U.S. Department of Homeland Security (DHS) Science and Technology Directorate (S&T)
Intended Use	The Resource Planning Application enables planners to identify hazard-specific capabilities, estimate the type and number of resources (personnel and equipment) required to mitigate the hazard, and identify partner agencies to fill resource gaps. The Resource Planning Application is based on an ArcGIS JavaScript Web Application Builder Template.
Sub-technology	ArcGIS Online
Users	Whatcom County, Emergency Management BC, State of WA



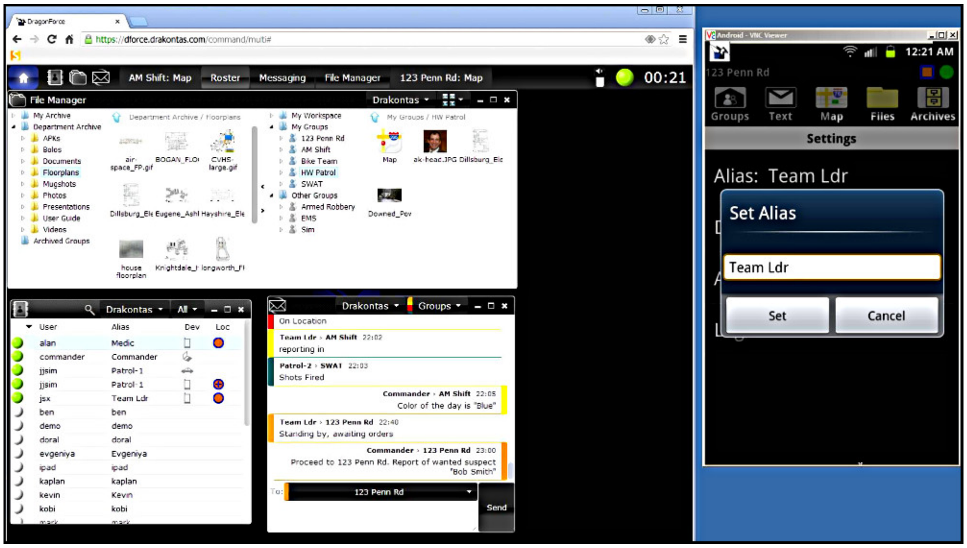
CAUSE V Map Viewer	
Owner	National Information Sharing Consortium (NISC)
Intended Use	The CAUSE V Map Viewer is a configured application built using Esri's Web AppBuilder. The application contained the Virtual CAUSE (vCAUSE) widget, which allows users to easily view map data that is shared through the CAUSE V ArcGIS Online group and acts as a jump-off point to access GeoForms and Operations Dashboards.
Sub-technology	ArcGIS Online (Web AppBuilder platform)
Users	All



Survey123

Owner	Esri
Intended Use	Survey123 provides an easy to use data entry form, which also enables capturing the geographic location associated with the record. Includes the following four Surveys: Lahar Hazard Pre-Assessment Form, CERT Damage Assessment, Digital Volunteer- Social Media GeoForms.
Sub-technology	ArcGIS Online
Users	CERT members, Digital volunteers, Whatcom County Interns
	
Operations Dashboard	
Owner	Esri
Intended Use	The Operations Dashboards were configured to allow users to monitor real-time events, operational status, and other reports. The dashboards are configured with multiple widgets (e.g., bar charts, summary lists), which represent the status of key data layers.
Sub-technology	ArcGIS Online
Users	All
	
DragonForce	

Owner	Drakontas
Intended Use	DragonForce is a situational awareness tool designed for tactical field operations. Enables location tracking, sharing reports from field to team members and EOC.
Users	All

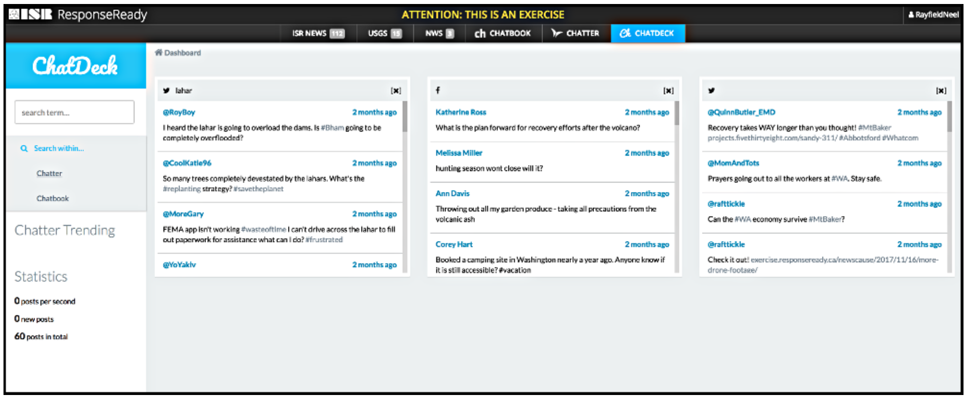


Incident Action Plan

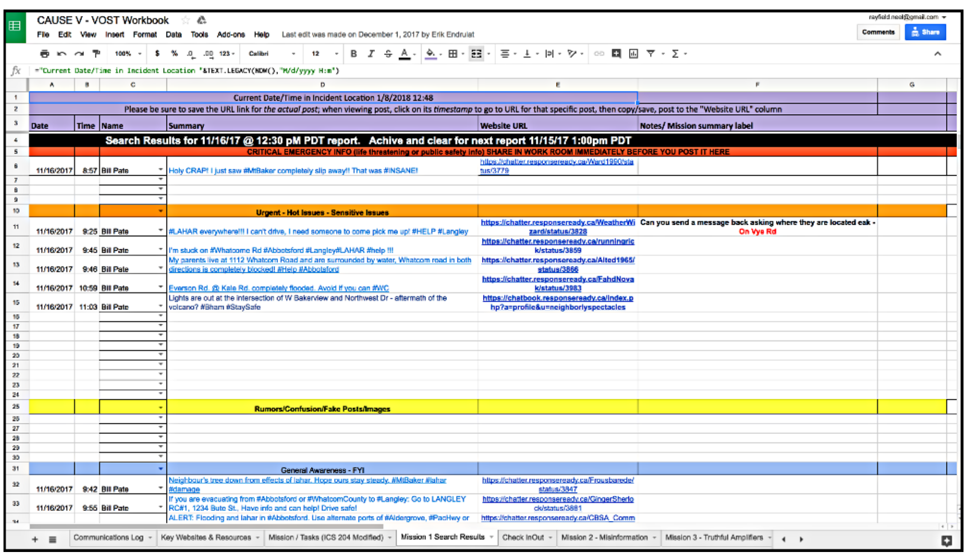
Owner	The Response Group
Intended Use	Incident Action Plan is a NIMS compliant tool for incident management built around the Incident Command Structure (ICS).
Users	Whatcom County

Excon/Response Ready

Owner	International Safety Research
Intended Use	ExCon is a collection of websites and tools that provide a secure, immersive experience for participants to simulate the news and social media experience during an emergency.
Users	All, mainly digital volunteers



Google Docs	
Owner	Google
Intended Use	Google Docs is a free, web-based software, which allows users to create and edit files online while collaborating in real-time.
Users	Digital volunteers



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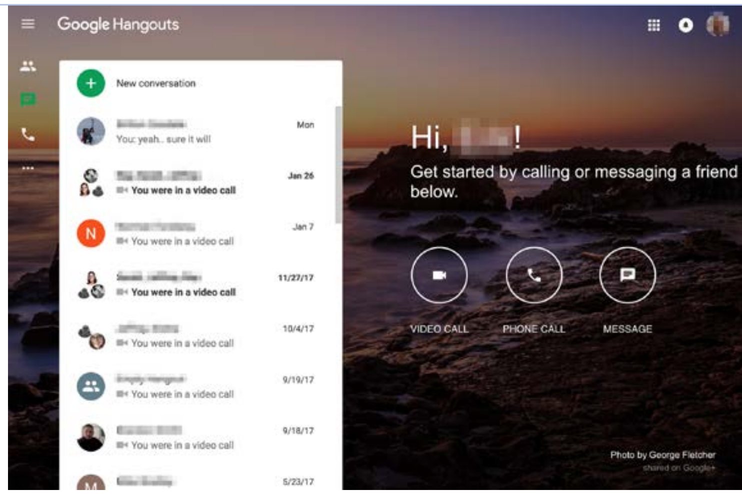
Google Hangouts

Owner	Google
Intended Use	Google Hangouts is a free Voice Over Internet Protocol (VoIP) application Used to message contacts, start free video or voice calls, and hop on a conversation with one person or a group.
Users	EOC representatives, field deployed personnel



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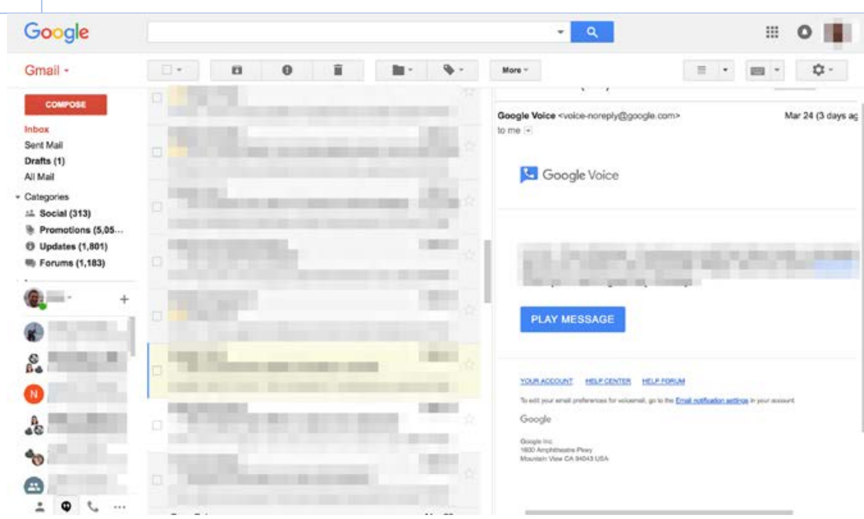
Gmail	
Owner	Google
Intended Use	Web-based email accounts were provided to experiment participants. Participants could email one another or anyone outside of the experiment.
Users	EOC representatives, field deployed personnel



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VLC / MX Player	
Owner	VideoLAN / J2 Interactive
Intended Use	VLC and MX player media players are free and open source cross-platform multimedia players that play most multimedia files as well as discs, devices, and network streaming protocols. In this experiment, VLC was used on Windows computers while the MX player was used on Band 14 Android smartphones.
Users	Field deployed personnel
Wowza	
Owner	Wowza Media Systems
Intended Use	Wowza is the video server for the VLC and MX Player video players.
Users	Field deployed personnel
Internet of Things Sensor Gateways	
Owner	ServerCheck
Intended Use	Internet of Things (IoT) sensors were connected to the wireless LTE networks and monitored vibration/shock (G force), water level and temperature. The information was logged and made available through a web portal or through email alerts. These sensors were also geo tagged, with links to the web portal available on DragonForce.
Users	All
IP Cameras	
Owner	Panasonic
Intended Use	IP cameras were installed at both CBSA border crossing stations in order to provide real-time video feeds from the field. For security reasons, the real-time video feeds were simulated and did not actually monitor the border crossing, but the simulated content being displayed by the cameras still changed as the scenario progressed.
Users	All
Virtual Private Networking	
Owner	Cisco, ShrewSoft
Intended Use	The Virtual Private Networking (VPN) Client software allowed a secure connection to another network over the Internet. This was required for the EOCs that, while wireless participants in the experiment, did not use LTE wireless devices. As a result, VPNs were required to view the live camera and video feeds available in the experiment, with unique credentials for authentication assigned to both EOCs.
Users	EOC representatives

Appendix 5 - UAV/UAS Missions

Real Date	Summary	Content	Assets	Real Time	Mission
Day 1 (15 Nov)					
15-Nov-17	Deploy assets to PSBN Bubble	Relocate all assets to Howard Bowen Park in Sumas for briefing and deployment prior to StartEx.	All	07:30	Pack up and deploy all assets, teams and mobile units from Whatcom County Unified Emergency Coordination Centre in Bellingham, WA.
				08:30	Arrive with all assets, teams and mobile units to Howard Bowen Park in Sumas, WA. Begin set-up and staging requirements in the area. Prepare for StartEx at 08:30.
15-Nov-17	UAV tasked with mapping Sumas River	Gathering Map data in preparation for day 2.	UAV Team 1	09:00	Deploy from Howard Bowen Park.
				09:15	Starting at Front Street in Sumas, collect and collate mapping data for as much of the Sumas river as possible moving south away from the Canada-U.S border.
				11:15	Return to base camp in the Howard Bowen Park and upload mapping data collected thus far.
				13:00	Return to last mapped location from the morning session.
				13:30	Continue mapping the Sumas river moving south.
				15:30	Return to temporary base camp at Drayton Harbor in Blaine and upload all collected mapping data.
15-Nov-17	UAV tasked with mapping North Fork Nooksack	Gathering map data in prep for day 2.	UAV Team 2	09:00	Deploy from Howard Bowen Park in Sumas.
				09:45	Starting in Deming, collect and collate mapping data for as much of the North Fork Nooksack as possible, moving westward away from Mt Baker.
				11:15	Return to base camp in the Howard Bowen Park and upload mapping data collected thus far.
15 Nov 17	Request for UAV team to conduct inspection flights at Mt. Baker ski resort	Mt Baker ski resort is looking to engage UAV team to conduct inspections of the resorts	UAV Team 3	09:00	Deploy from Howard Bowen Park in Sumas
				10:30	Once arrived to Bagley Lakes Loop, begin an inspection of the mountain including identifying potential hazards and checking for stability of the terrain.

Real Date	Summary	Content	Assets	Real Time	Mission
		property looking at: stability of slopes, looking for cracks/crevasses, looking for steam vents, identifying hazardous areas.		14:00	Return to temporary base camp at Drayton Harbor in Blaine and upload all collected imagery.
15-Nov-17	Movement of Assets to Blaine	Relocate relevant assets to Semiahmoo Park in Blaine for afternoon deployments.	UMV Team 1 UAV Team 2	12:00	Pack up and deploy all mobile units and UAV Team 2 and UMV Team 1 from Howard Bowen Park in Sumas, WA.
				13:00	Arrive with assets, teams and mobile units to Semiahmoo Park in Blaine, WA. Begin set-up and staging requirements in the area.
15-Nov-17	Request for UAV/UMV support in response to a downed plane in Drayton harbour	A small aircraft has come down in Drayton Harbour southwest of Blaine. UAV and UMV support and oversight is required.	UMV Team 1 UAV Team 2	14:00	Deploy 1 UMV and 1 UAV to support the response to a downed plane in Drayton Harbour off Semiahmoo Park.
				14:15	Conduct marine and aerial reconnaissance, collecting video data and imagery for uploading.
15-Nov-17	ENDEX	All teams will upload their collected data, pack up and return to Whatcom County Unified Emergency Coordination Centre in Bellingham, WA.	All	16:30	All teams will upload their collected data, pack up and return to Whatcom County Unified Emergency Coordination Centre in Bellingham, WA.
DAY 2 (16 Nov)					
16-Nov-17	Deploy assets to PSBN Bubble	Relocate all assets to Howard Bowen Park in Sumas for briefing and deployment prior to StartEx.	All	07:30	Pack up and deploy all assets, teams and mobile units from Whatcom County Unified Emergency Coordination Centre in Bellingham, WA.
				08:30	Arrive with all assets, teams and mobile units to Howard Bowen Park in Sumas, WA. Begin set-up and staging requirements in the area. Prepare for StartEx at 08:30.
16-Nov-17				09:00	Deploy from Howard Bowen Park in Sumas.

Real Date	Summary	Content	Assets	Real Time	Mission
	UAV Flight to track the progression of the lahar	UAVs monitor the location of the lahar, and impacts of current damage areas.	UAV Team 1	09:45	Starting at Nugents Corner in Everson, fly routes upriver along North Fork Nooksack River to collect video / imagery of the extent of the simulated lahar through Whatcom County.
				11:45	Return to base camp in the Howard Bowen Park and upload all collected imagery and videos.
16-Nov-17	UAVs requested to conduct overflights of remotely located residential homes to search for stranded citizens	UAVs conduct flights in remote areas to determine if any residents are stranded and require assistance.	UAV Team 2	09:00	Deploy from Howard Bowen Park in Sumas.
				09:45	Starting at coordinates (48.901701, -121.987776) "Cornell Creek Rd", collect imagery and video of notional secluded homes in the area. There is a trail leading to an opening for launching the UAV.
				11:30	Return to base camp in the Howard Bowen Park and upload all collected imagery and videos.
16-Nov-17	UAV Flight to Inspect Williams Pipeline valve station in Deming	Williams Pipeline is requesting aerial inspection of their pipeline and valve station located to the East of Deming.	UAV Team 3	09:00	Deploy from Howard Bowen Park in Sumas.
				09:45	Starting at coordinates 48.808583, -122.191833, east of Deming, perform an inspection of the Williams Pipeline valve.
				11:30	Return to base camp in the Howard Bowen Park and upload all collected imagery and videos.
16-Nov-17	Swift Water Rescue UMV	Kids in the river in Sumas have fallen into swift moving flood waters. An adult nearby jumped into the water to rescue the children and now requires rescue. UMV dispatched to support the swift water rescue.	UMV Team 1	11:15	Deploy from Howard Bowen Park in Sumas.
				12:00	Arrive to Silver Lake Park and conduct marine reconnaissance and simulated rescue, collecting video data and imagery for uploading.
				15:00	Return to base camp in the Howard Bowen Park and upload all collected imagery and videos.
16-Nov-17	UAV flights to gather information regarding the extent of lahar	Abbotsford Fire requests UAV flight to identify the leading edge of the lahar flow.	UAV Team 1	13:00	Deploy from Howard Bowen Park in Sumas.
				13:30	Arrive to the village of Nooksack and conduct flights along the Sumas River to collect video of notional leading edge of the Lahar. Collect mapping data/video of Sumas river.

Real Date	Summary	Content	Assets	Real Time	Mission
	damage on the Sumas River			15:30	Return to base camp in the Howard Bowen Park and upload all collected imagery and videos.
16-Nov-17	Contingency	Flexible timing to allow for additional missions, as required.	UAV Team 2, UAV Team 3	12:00	Available time to support uncompleted previous missions or perform ad hoc missions, as required.
16-Nov-17	ENDEX	All teams will upload their collected data, pack up and return to Whatcom County Unified Emergency Coordination Centre in Bellingham, WA.	All	16:30	All teams will upload their collected data, pack up and return to Whatcom County Unified Emergency Coordination Centre in Bellingham, WA.