WHITE PAPER

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Can Wearable Video Enhance Decision Making in USAR and CBRNE Settings?

Authors	Donal Morris (RedZinc) Jo Kramer-Johansen (Oslo University Hospital) Andreas Gustavsen (Oslo University Hospital) Lalit Saini (RedZinc) Jeanne Caffrey (RedZinc) Subhajit Ghosh (RedZinc)

Table of Contents

1 LIST OF ABBREVIATIONS

USAR	Urban Search and Rescue
CBRNE	Chemical Biological Radiological Nuclear and high yield Explosives
POV	Point of view
GPS	Global Positioning System
GBR	Guaranteed Bit Rate
HAZMAT	Hazardous Material
VHF	Very High Frequency
IP	Internet Protocol
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
HTTPS	Hypertext Transfer Protocol Secure
TURN	Traversal Using Relays around NAT
DNS	Domain Name System
USB	Universal Serial Bus
TETRA	Terrestrial Trunked Radio
VINNI	Verticals Innovation Infrastructure

2 EXECUTIVE SUMMARY

Video is being increasingly used in different types of scenarios for situational awareness and improved decision making. Oslo University Hospital collaborated with wearable video solutions provider, RedZinc Services, *to evaluate if wearable video could help improve decision making in Urban Search and Rescue (USAR) and Chemical Biological Radiological Nuclear and high yield Explosives (CBRNE) settings*. RedZinc provides BlueEye Handsfree wearable video solution, which consists of a lightweight camera integrated with a cloud-based video platform. The solution transmits real-time POV (point of view) video from camera wearer to remote location(s) which can be accessed via BlueEye hot desk.

This report outlines USAR and CBRNE processes, BlueEye technology, pilot details and outcomes. The two-day pilot including 12 runs suggested that wearable video improved situational awareness of the remote commanders and helped them to immerse themselves into the situation. The remote commanders were able to instruct and guide the in-field searchers and technicians, resulting in enhanced decision making and increased team confidence.

We define success as to whether the wearable video solution has potential to improve situational awareness of the incident commanders. The pilot was a success given the feedback from the incident commanders about the potential for future use in USAR and CBNRE scenarios:

"The use of video is the future. I was able to comprehend the situation from home"

-Incident Commander, Oslo University Hospital

3 INTRODUCTION

3.1 Motivation for pilot

RedZinc conducted a pilot with Oslo University Hospital in June 2021 with an **aim to evaluate if wearable video could improve the decision making and improve outcomes in Urban Search and Rescue (USAR) and Chemical Biological Radiological Nuclear and high yield Explosives (CBRNE) use cases.** Oslo University Hospital team organized and conducted the pilots in the university.

RedZinc defines wearable video as a type of wearable technology. While wearable technology includes electronic devices that consumers can wear, like smartwatches and smart glasses, and are designed to collect users' personal health data (Phaneuf, 2019), wearable video is defined as a wearable camera integrated with software that captures live video and relays it to remote location(s) for real-time oversight, assessment, support, and training purposes.

3.2 Background

Urban Search and Rescue (USAR) is the process of location, extrication and medical stabilization of victims trapped in an urban area due to natural disasters or other reasons. CBRNE operations include recognizing and mitigating attacks from the Chemical, Biological, Radiological, Nuclear and Explosives (CBRNE) weapons. In both the cases, time is of the essence and the decision making needs to be precise and quick to contain loss and save lives.

The USAR and CBRNE operations can be enhanced with more 'eyes on the field' for supervision, support, and expert opinion. But the critical nature of these operations and the associated costs prohibit many people on the field. This is where wearable video solutions set in allowing the 'in-field' personnel to relay real-time video to remote location(s) for supervision, support, and expert opinion. The mobile nature of these solutions allows the field personnel to carry them to the most critical situations, and the wearable nature ensures that the personnel can focus on the procedure without having to worry about carrying the camera.

The hypothesis is that wearable video solutions can support USAR operations at the extrication and medical stabilization stages as the searchers can send real-time video to remote commanders or experts during extrication phase and receive advice and guidance. During the medical stabilization stage, the real-time video can be sent to the remote medical experts to get instructions on primary patient treatment at scene and routing decisions. The process also results in quick and effective triage at scene having a direct impact on the patient outcomes.

In the case of CBRNE operations, the technicians can relay real-time video of what they see to remote expert(s) and receive instant support and guidance improving the chances of successful operation.

4 BLUEEYE TECHNOLOGY

BlueEye Handsfree is a *wearable camera integrated with the BlueEye Cloud-based video platform for relaying live video to remote location(s) while performing an action*. It is an integrated solution (see Figure 1) comprising:

1. BlueEye wearable handsfree camera,
2. BlueEye app on smartphone for mobile connection and,
3. Cloud-based BlueEye video platform based on dedicated secure servers to access live video remotely.

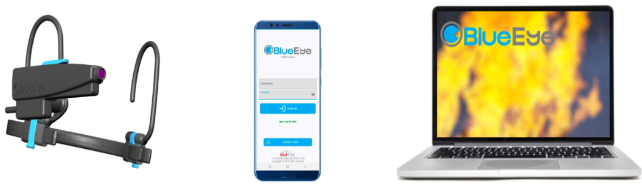

Figure 1 BlueEye camera with 5G smartphone and BlueEye hot desk

The wearable camera captures live video with the camera wearer's point-of-view and sends it to cloud-based BlueEye hot desk for remote access.

The BlueEye Handsfree is perfect for urban search and rescue operations. The searcher wears the lightweight camera near their temple (see Figure 2) and connects it with a 5G smartphone for mobile communication. The BlueEye app in the smartphone allows the searcher to relay live video to a remote scene commander. The remote commander logs in to the secure BlueEye web application to access the real-time video from the searcher's POV (Point of view). This allows the remote commander to immerse themselves in the situation and command the on-field searcher for quicker and more efficient decision-making. Similarly, the real-time, point-of-view video can also be accessed by a remote medical expert to support the first responder with primary treatment of a victim.

Figure 2 BlueEye headband camera on a manikin

The main objective is to emphasize on **remote reality** which is different from augmented reality. With remote reality the specialist receives real-time, point-of-view video and audio from the colleague at the scene, who is wearing small headset camera. A wireless, cloud-based platform is used for sending the video and the audio. With real-time information, the specialist can provide the expertise needed for the task at hand. Augmented reality would work in this scenario, but the bulk of information provided to the rescuer or colleague at the scene could distract them from completing the task. See Table 1 below for a comparison of remote reality vs augmented reality.

Table 1 Comparison of remote reality versus augmented reality

Remote Reality using BlueEye wearable video	Augmented Reality using Smart Glasses
Designed for 'You See What I see' video applications	Designed for Augmented Reality, Virtual Reality, Mixed Reality applications
Focused on relaying real-time video to the remote party	Focused on providing local immersive experience
Focused on immersive experience for the remote user	Focused on immersive experience for the local user
Simple design with low electronic component count	Complex design with high electronic component count
Low heat generated on head of user. No hotspot effect	High heat generated on head of user. High hotspot effect due to the high component headcount
No battery required – derives power from the smartphone	Needs a battery on the head
No eyeline distraction, suitable for busy environments	Require eyeline monitor which can be distracting. suitable for controlled environments
Rotatable camera to adjust point-of-view	N.A.
Meant for longer usage, no ophthalmic effects	Not meant for longer usage, may have ophthalmic effects
Compatible with glasses/ lenses	Not compatible with glasses/lenses
Economic	Expensive
Suitable for IP54 moisture and dust ingress protection for challenging environments	Difficult to protect against water and dust ingress protection because of the high component count
Physically robust design which can accommodate knocks	Difficult to make a physically robust design because of high electronic component count, display stalk and batter

BlueEye camera headset

BlueEye Handsfree solution has an ergonomic and lightweight camera which sits near the wearer's eyes to capture real-time video with the wearer's point-of-view. This ensures that the remote expert can see the procedure and emergency through the on-field personnel's eyes. While RedZinc is continuously working to upgrade the camera, some of the main features of the current camera headset are

a) 2 Mega Pixel camera
b) Wide-angel and narrow-angel options
c) **Rotatable camera** to adjust view
d) Multiple **body docking** options
e) Supports glasses, masks and vizors
f) **Sturdy** make suitable for rough and busy environments

BlueEye app features

BlueEye app currently offers following features for camera user to control video transmission

a. **Start/ Stop streaming** to start and stop video streaming
b. **Screenshot option** allows to take screenshots from BlueEye camera or smartphone camera
c. **Video features** allow to set appropriate video quality as per the room settings
d. **Video controls** to mute microphone or pause video transmission
e. **Call Attention button** to notify the hot desk user about immediate attention needed

BlueEye hot desk features

BlueEye hot desk which is used by the remote expert/commander to access live video has following features

a. **Access streaming** from different BlueEye cameras
b. **Take screenshot** from BlueEye camera
c. **Access GPS location** details of the camera user
d. **Mute audio** transmission from hot desk
e. **Mute audio** transmission from BlueEye camera

4.1 Benefits of BlueEye wearable video solution

The benefits of using BlueEye wearable video solution for the scene commander and the search and rescue crew are the following:

- *Supports quicker and more efficient decision-making*
- *Facilitates command from the remote experienced scene commander to the in-field searcher*
- *Accelerates victim treatment*
- *Facilitates multiple eyes looking at the situation, resulting in improved outcomes*
- *Eliminates the need for travel by the remote commander saving crucial time for support*
- *Supports incident management, control, and oversight, improving safety and helping to get everybody – crew and victim – safely out of the situation*

BlueEye Handsfree supports **one-way video** from the in-field personnel to the remote expert/ commander while facilitating **two-way audio** communications between the two. One-way video ensures that the personnel can focus on the task at hand, while two-way audio ensures that an effective communication exists between both resulting in efficient coordination.

BlueEye Handsfree has been designed after a long Research & Development phase, using the inputs from different projects and pilots. The solution has been developed specifically for the busy environments keeping ease-of-use and security at the centre of the design. The wearable video solution supports public and private (4G/5G) for video transmission.

Apart from the USAR and CBRNE applications, BlueEye Handsfree also has applications in paramedic support, virtual ward rounds, remote doctor support, community nurses support, medical/ nursing education, and many others (see Figure 3). BlueEye Handsfree offers multiple advantages such as

a) Expedite patient treatment
b) Effective triage
c) Improved routing decisions
d) Enhanced operational efficiencies
e) Improved patient outcomes
f) Reduced carbon footprint

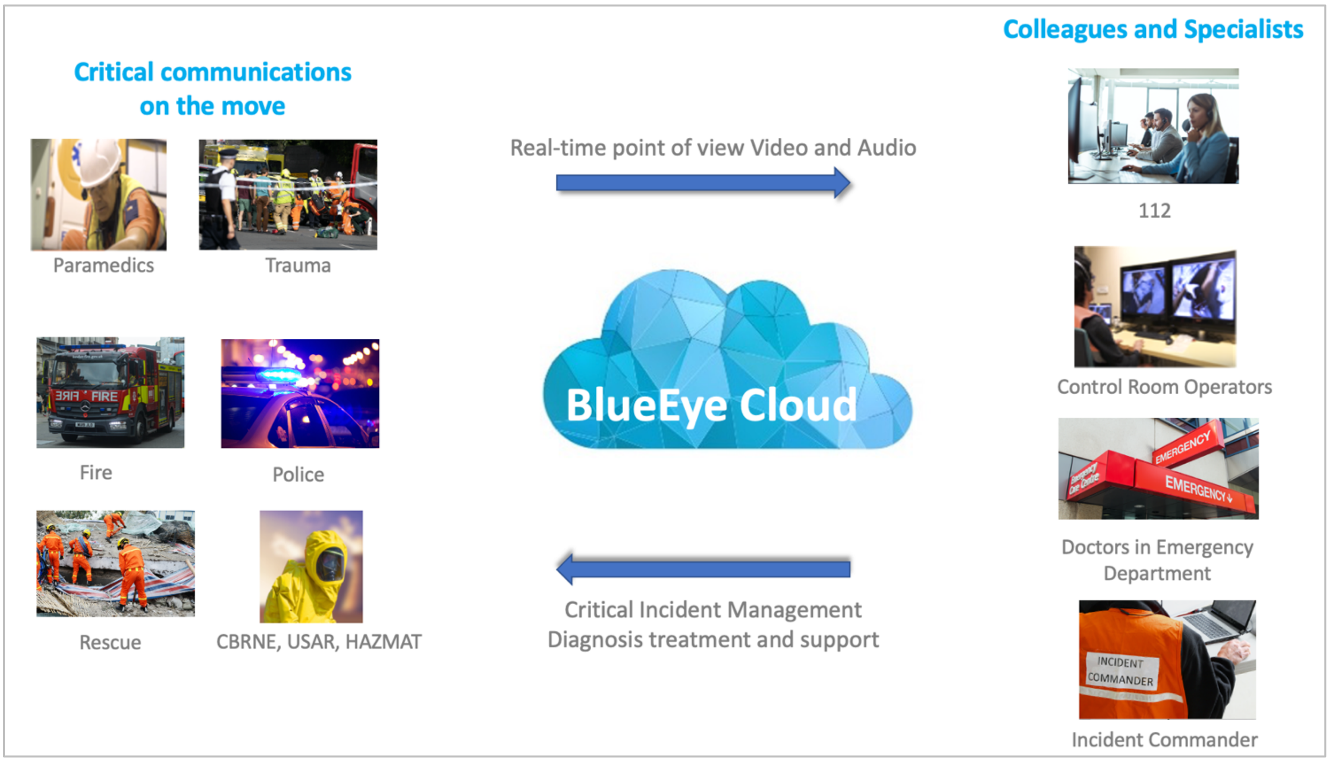

Figure 3 BlueEye Handsfree usage scenarios

4.2 5G for Telemedicine

For several reasons, 5G creates an opportunity to improve telemedicine. Firstly, whereas 4G has reached the network capacity of quick data transfer because of radio limits, 5G uses higher radio frequencies and more bandwidth to transfer more data at faster speeds, with reduced congestion and lower latency. Since 5G uses higher bandwidth, it provides better picture quality, a necessary requirement for telemedicine. Secondly, 5G supports slicing which means that a single network connection is divided into multiple distinct virtual connections that can be used for different types of traffic. This means that a healthcare organization can obtain a network slice with a private address, which in turn can enable enhanced security (i.e., private Internet for healthcare organizations).

In addition, GBR (Guaranteed Bit Rate) can be used to give a guarantee to the emergency video by allocating resource blocks. Thirdly, 5G provides campus support. This means that a 5G network can be deployed privately inside a hospital environment (i.e., NPN – Non Public Network). Fourthly, 5G provides enhanced resource allocation through network slicing. This is like a private 'bus lane' for medical traffic which can be used for emergency and other medical applications (see Figure 4).

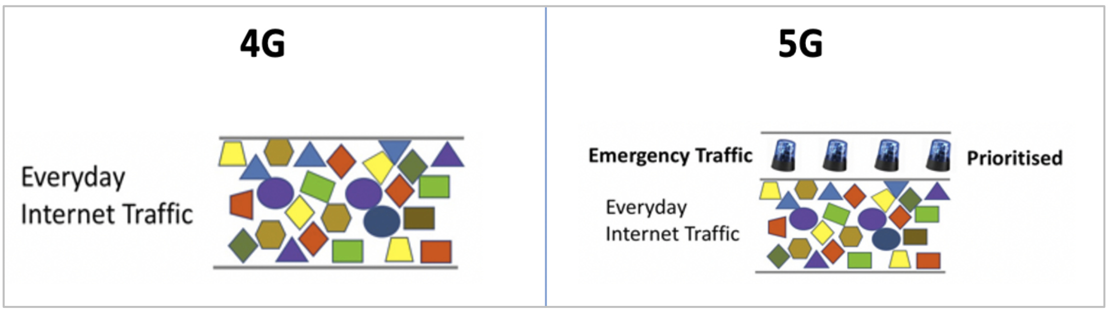

Figure 4 Prioritisation with 5G

5 PILOT

5.1 Setup

An Urban Search and Rescue (USAR) person wears the BlueEye camera and clips a smartphone on his/her clothes. In a CBRNE situation (e.g., Chlorine, chemicals, or Ebola), the camera is worn under a HAZMAT (Hazardous Material) suit. In a USAR scenario, the camera can be attached to the helmet. The incident commander has a continuous video feed of the scenario and obtains a higher situational awareness. The incident commander has continuous audio feed, and this has an advantage over legacy push to talk from VHF radio or TETRA/P25.

Oslo University Hospital team conducted application testing over a period of two days in June 2021 as part of a training event. Two scenarios, one with a focus on CBRNE and one on USAR, were played out.

The participants on each day were divided into two groups of five persons. Each group participated two times in each scenario and then switched. There were two persons in a group and one remote incident commander per group. A total of 12 different runs were conducted over the two days. The video was used in 11 runs, giving a total of 11 valid runs. There was no video in the final scenario for operational reasons. The video feed was transmitted to two persons working as incident commanders sitting at home. After the first scenario, they were asked to describe the incident. They were able to describe it accurately. Figure 5 and Figure 6 give an impression of the training for the USAR scenarios. In this setting the camera was added to the gear as shown in Figure 7.

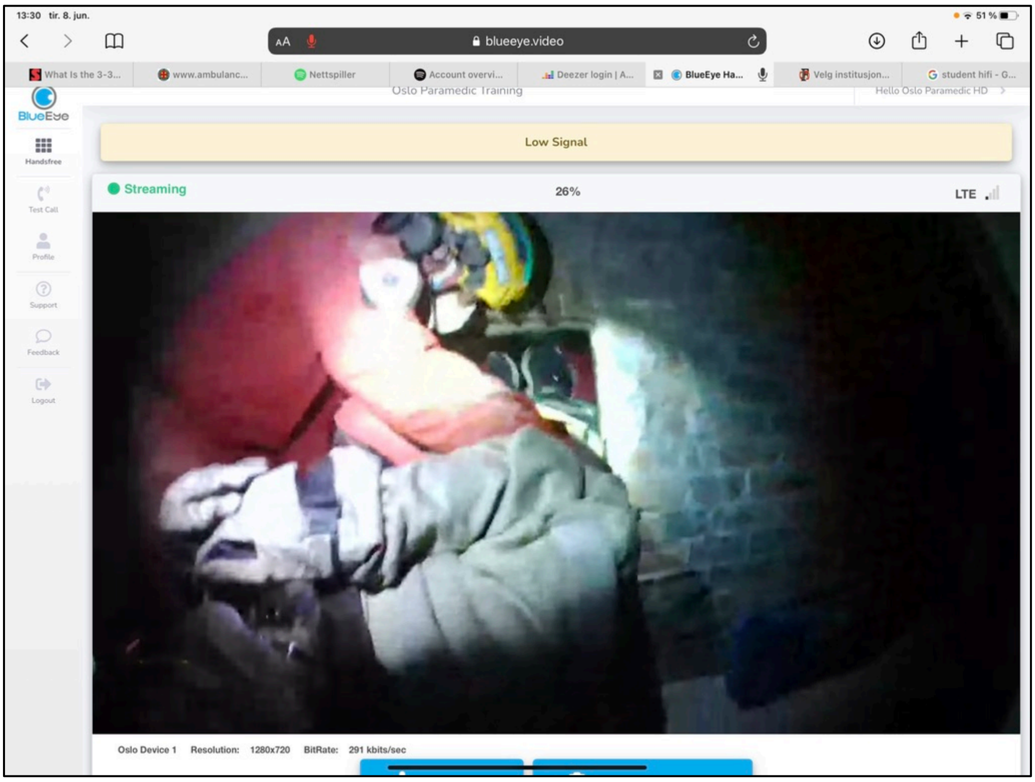

Figure 5 Screenshot of BlueEye video captured during USAR training (photo: Andreas Gustavsen)

Figure 6 USAR environment (photo: Espen Munthe-Kaas)

Figure 7 USAR suit with BlueEye camera installed (photo: Andreas Gustavsen)

5.2 User application architecture

The paramedics (specially trained in USAR and CBRNE) connected the BlueEye Handsfree camera with the smartphone and started video streaming using BlueEye app in the smartphone. The remote incident commander logged in to BlueEye hot desk to access the real-time point-of-view video. The user application architecture for BlueEye video streaming is given in Figure 8.

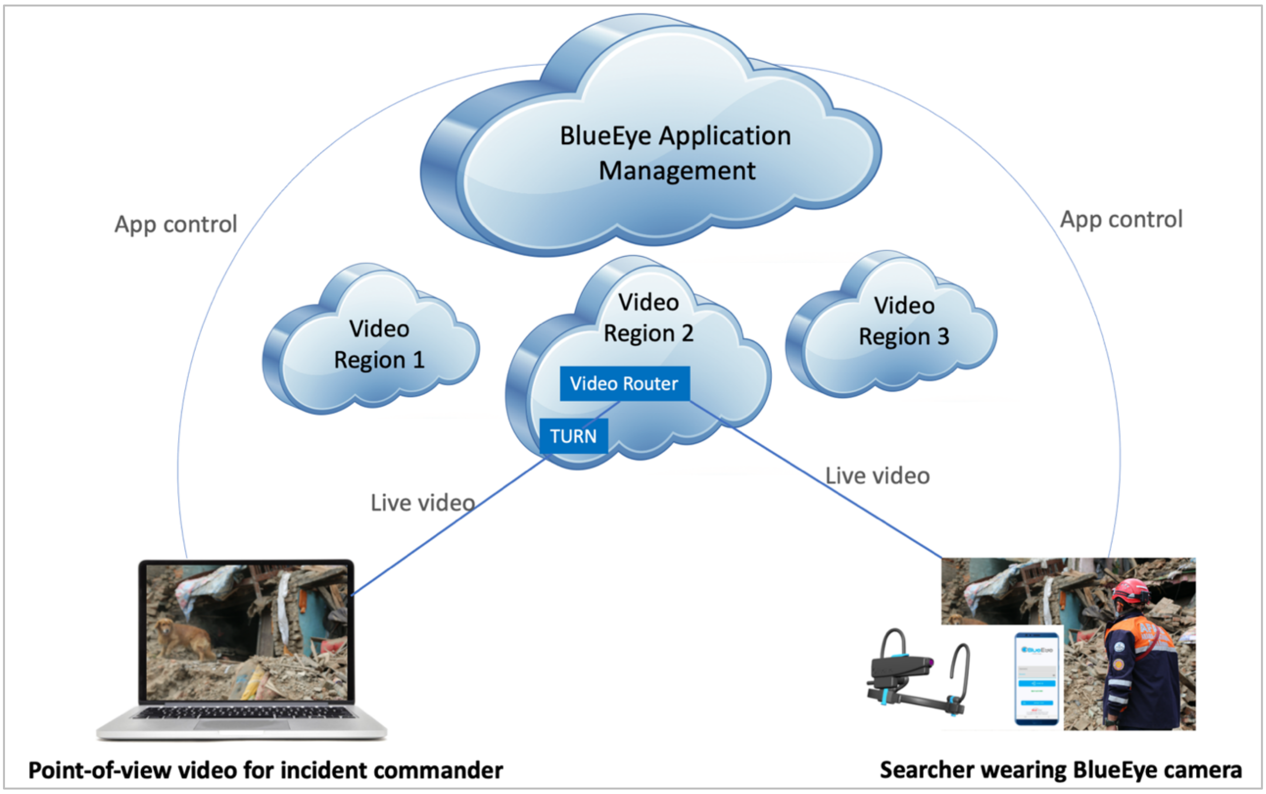

Figure 8 User application architecture for BlueEye video streaming

Table 2 IP and port configuration for RedZinc's video streaming

Domain	***.blueeye.video**
IP	*.blueeye.video
In bound ports	Application traffic and video From 443/TCP (HTTPS) FROM ANY IP *.blueeye.video to ANY port (reply on same connection, using TURN) Domain name service 53 (DNS) TCP/UDP
Out bound ports	ANY port to *.blueeye.video IP 443/TCP (using TURN)
The way it works is that BlueEye opens a random port locally on the app to connect to port 443 on the server. It never uses port 443 on the app itself so it needs to communicate to and from server port 443 to any local random port.	

5.3 Hardware components

The hardware components used for both the use cases are described below.

User equipment at the side of the Incident Commander

- Laptop with Wi-Fi support

User equipment at the side of the paramedic

- BlueEye camera headset
- Smartphone Samsung S20 with USB 3.0 interface

Internet Services

- Ericsson 4G Radio
- Nokia 4G Radio

5.4 Software components

The software components used are the following:

- Android application to connect with video servers (Figure 9).
- Custom management services in the Cloud.
- While most of the Cloud services remained in the Cloud, media relays were installed in the testbed to make the flow compatible with the BlueEye Cameras and the smartphones, without delaying experimentation.
- BlueEye hot desk (Figure 10).

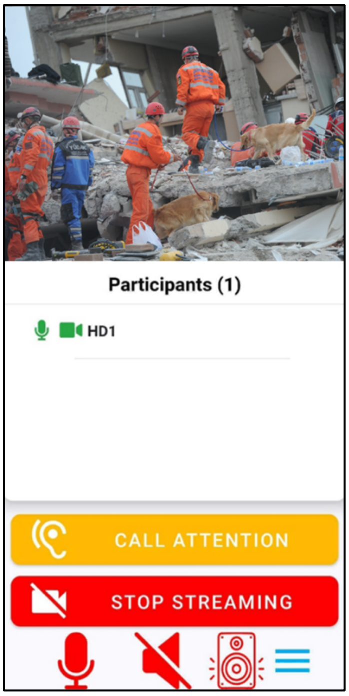

Figure 9 BlueEye mobile app – Used by USAR searcher to send real-time POV video to BlueEye hot desk

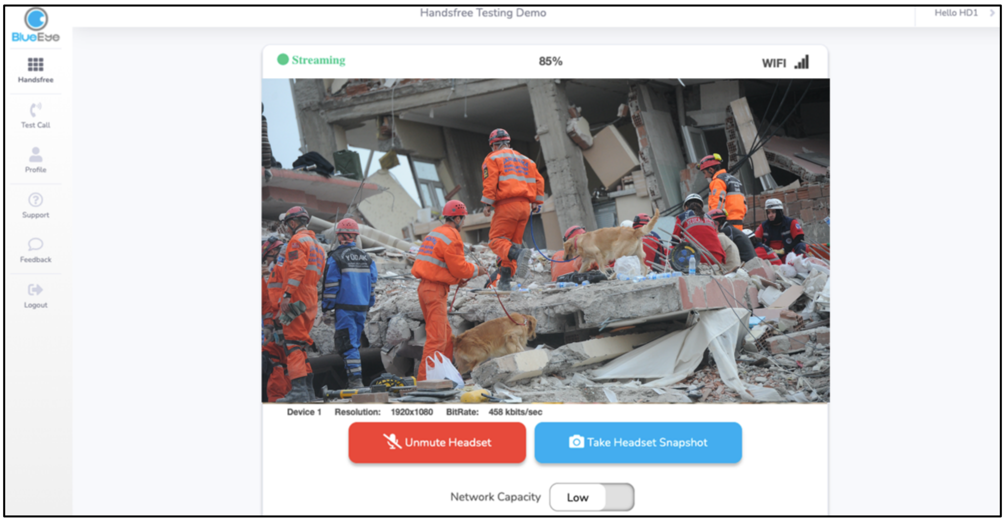

Figure 10 BlueEye hot desk – Used by USAR incident commander to access real-time POV video

6 RESULTS

6.1 Intermediate results

The sound was transmitted from operator to hot desk by use of the phone. Communication from hot desk to operator was through traditional TETRA (Terrestrial Trunked Radio) radio.

On the first day, the operator of the BlueEye solution was not the person closest to the patient. This created some disturbance in the dynamics when the operator was asked to get closer to the patient, especially in the USAR setting, where two persons had to change position inside a tight space. Therefore on the second day, in this setting, the operator closest to the patient was using the camera instead. However, this could not be done for the HAZMAT setting, because it was not possible to safely integrate the camera and the phone into the HAZMAT suit. The camera was sticking out between the hood and the gas mask, but this left a small opening. The camera operator was therefore told to hold a distance to the zone containing hazardous material. A HAZMAT suit is protected gear as shown in Figure 11 and Figure 12.

Figure 9 HAZMAT suit (photo: Espen Munthe-Kaas)

Figure 10 Different type HAZMAT suit used by Oslo Ambulance Service, not in scenarios (photo: Lars Bryhn, Nyland/Spotnews.no)

6.2 Software Challenges

Some of the challenges with software during the pilot were

- Several issues occurred with transmission of the video feeds. On a few occasions, the picture went black or white and it was not possible to fix this by logging out on the hot desk side.
- The sound was missing for no apparent reason in 3 scenarios.
- It was possible for multiple users to login to the same account at the hot desk side, confusing identify and resource allocation.
- When the hot desk was connected to two devices, switching between them was difficult. When switching, snapshots taken were lost, unless they were intentionally downloaded.

These issues were addressed in the next version of BlueEye software and were resolved. The details are summarized in the next paragraph.

Initially, when the video screen went black or white, no relevant error or warning message showed up. RedZinc has now implemented error messages that show the reason for not receiving video on the hot desk. A "Network Capacity" switch has been added on the hot desk to make *sure that video streaming happens even at low network signals. A brightness profile feature has been added to the app to make sure that the app could stream video in dark surroundings. For sound issues, an audio toggle switch has been added to the app so that the audio can be switched from smartphones to earphones. A sound notification in the app has been added in case the headset camera unplugs or there is a loose connection between the smartphone and the headset camera. A new feature is in development that will make sure that the call will not close in case the camera disconnects.*

6.3 Hardware Challenges

Several issues were identified with the hardware:

- The cable got disconnected from the smartphone during two runs. Because of the phone being placed under the protection suit, it was not possible to reconnect, and the run was played without further use of video (note that the run was not stopped because of training reasons).
- The phone went into standby mode during three scenarios, probably because its screen was touched unintentionally.
- Because of the helmet, it was difficult to adjust the camera headset. Therefore, it would help if the camera is mounted on the helmet.
- The setup was not compatible with the use of the HAZMAT protection suit.

RedZinc is developing better smartphone covers with a strong connection anchor to make sure that the camera does not disconnect from the smartphone even if it is placed under a protective suit. The standby mode issue by has been addressed by making changes to the app. If the app is closed mistakenly or the screen is touched, the app will still continue streaming for two minutes. Therefore, the app has to be opened within two minutes in order to continue the streaming. There is a new feature in the engineering pipeline to put the app into permanent standby keep alive mode. RedZinc is working on a new design to make the camera compatible with the HAZMAT suit.

6.4 Operating Procedure

Several issues were identified related to the standard operating procedure:

- Insecurity was created amongst cooperating agencies (fire department and ambulance services) because they didn't know if they could talk freely (user remark). We need to clarify our intentions when working with others not involved in the project.
- When the paramedic stopped streaming video, the sound was still transmitting. This may be seen as problematic in terms of patient confidentiality.

RedZinc has addressed the sound issues mentioned above. The mute feature has been made more robust. Upon closing the app, both the video and the audio transmission stops. For privacy, we have added an audio toggle switch in the app with which the audio can be switched from the smartphone speaker to the earphones.

6.5 Suggestions

Suggestions from Oslo Ambulance Service:

- Probably, the best solution for fixing the camera is by using Velcro (also known as "hook & loop" it is a fastening technique comprising two matching flexible strips). In this way, the camera can be remounted if it falls off during work. If it were fixated by screws instead, this would be more difficult. During USAR operations, a camera that were fitted rigidly could lead to the operator being stuck in debris.

- Avoid that a single user account can be used to login from different hot desks. Make it possible for only one hot desk to log in per username.
- Make a software key lock that allows the BlueEye app on the phone to transmit while appearing to be in standby mode.
- Make a better connection, using an anchor or similar, between cable and phone, so that it doesn't get disconnected inadvertently.
- Make a phone holder that turns the backside of the phone outwards. This helps to protect the phone, since the scenarios involve crawling into tight spaces, while the phone is hanging on the chest part of the suit. Also, inadvertent touching of the screen can be avoided this way.
- Sound transmitted from the hot desk should be "off" by default, to prevent noise disturbing the crew.

Based on the above suggestions, RedZinc has introduced a camera which can be fixated on the helmet using Velcro as shown in Figure 13.

Figure 11 BlueEye camera fixated on helmet using Velcro

RedZinc engineering team is developing a feature that will allow BlueEye app to transmit video in standby mode. The RedZinc team will also introduce different smartphone cases with strong connection anchors.

6.6 User Experience

Despite a few challenges encountered during the pilot, the overall feedback on using BlueEye Handsfree wearable video for CBRNE and USAR cases was positive.

Real-time video from the field allowed the remote incident commanders to immerse themselves in the situation and enabled them to guide the in-field searcher.

The remote commanders appreciated the video quality that they received via BlueEye Handsfree solution and rated the video quality as 'good'. The Smartphone battery was good as it supported one full day of training. The solution also worked well in dark rooms in combination with helmet mounted lights.

The following observations were made regarding batter life and video quality:

- The battery was sufficient for one day of training.
- The camera in combination with a positive pressure suit was a success (This suit was not included in the scenarios but tested under other circumstances). The picture inside the biological suit was received by hot desk as good quality. There was a fear that the picture would get distorted, but this was not the case. **Communication was eased with the use of camera.**
- The camera increased the confidence of the team and incident commander.

"Good picture quality. The picture was very good with no other particular issues"
-Incident Commander

7 CONCLUSION

The purpose of the pilots were to establish if the wearable video for USAR and CBRNE can potentially give benefits. **The pilot validated the hypothesis that wearable video solutions can support USAR operations at the extrication and medical stabilization stages as the searchers can send real-time video to remote commanders or experts during extrication phase and receive advice and guidance.**

Real-time video with paramedic POV (point of view) allowed the remote commander to immerse themselves in the situation. The real-time video also enhanced the situational awareness of the remote commander and allowed them to optimally assess the situation. At the same time, the use of real-time video in critical use cases in USAR and CBRNE increased the confidence of all the participants i.e. searchers, technicians and the commanders.

During the pilot, several challenges were encountered related to the software, hardware and operating procedure, which have been addressed by RedZinc.

The pilot was a success given the feedback from the incident commanders:

"This is perfect for achieving situational awareness"

"Showing the picture to the fire brigade and police will help us work better together"

The next step plans comprise two activities:

- Firstly, to conduct a controlled experiment, involving several scenarios, in which the effectiveness and efficiency of the legacy method is compared to those of the newly proposed method. The legacy method involves the incident commander managing a check list via audio only. The proposed approach involves abovementioned immersive approach with wearable video (and audio). The application-level KPIs to be assessed in the comparison are time to completion and procedure error minimization.
- Secondly, to conduct the network (quantitative) tests.

Current experiments have been done by using 4G on Telenor's commercial network in Oslo. Migration to use the 5G-VINNI (Verticals Innovation Infrastructure) platform instead, as used for the other OUS-based experiments, has been planned. It is however uncertain whether this is feasible due to limited device support on the 5G-VINNI RAN. Commercial 5G is being rolled out in Oslo, and is considered for further experiments, however losing the possibility of tailoring the slice definitions and setup.

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