

# Gaps in Public-Safety Cameras:

How dust, rain, snow, and shadows impact public safety video

By Margaret H. Pinson

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A video is not always an accurate representation of what a first responder sees at an incident. New research suggests that first responders would benefit from a camera that removes airborne obscurants and shadows before the video is compressed. Current public-safety cameras' faithful reproduction of rain, falling snow, dust, and shadows hinders our understanding of the situation. First responders need new technologies better serve them by better reproducing the subjects of interest.

In a project sponsored by the Public Safety Communications Research Program (PSCR), the Institute for Telecommunication Sciences (ITS) explored how first responders use images, videos, and camera systems in general, along with the quality problems they encounter. ITS then applied its expertise in video quality assessment to describe specific ways that public-safety image and video applications could be made easier to use and more effective.

## What's the Problem?

Entertainment cameras used for cinema and television dominate the camera industry at the high end, and smartphones dominate the consumer market. Video surveillance units, in-vehicle cameras, and body cameras repurpose these same camera components for public-safety applications. This creates unintended problems.

Videographers are artists. They arrange the camera, lights, and scenery until the view through the lens matches their artistic vision. The camera strives to accurately reproduce that artistic vision. If the weather is bad or the lighting is poor, the videographer waits for better weather or deploys lights to create a better video.

Video surveillance units, in-vehicle cameras, and body cameras operate independently, without the aid of a videographer. Inclement weather and uneven lighting can obscure the scene, making it difficult to identify people and observe events. The camera tries to reproduce the inclement weather and uneven lighting because that is how entertainment cameras are designed.

It is difficult to obtain video footage that can be used to research public-safety problems because of licensing and litigation concerns. ITS began addressing this issue more than a decade ago by filming training exercises and staged scenarios. ITS has provided free access to these first responder videos royalty free for research and development purposes through the Consumer Digital Video Library (CDVL). Clips referenced in this article are from the CDVL collection.

## Battling the Elements

First responders do not have the luxury of waiting for good weather. Their cameras must function despite inclement weather and other airborne obscurants—rain, snowflakes, dust, and smoke.

Cameras have difficulty “seeing” past airborne dust particles. The 2010 Mock Prison Riot allowed ITS to film some of their scenarios. Many scenarios included practice rounds that temporarily filled the air with dust. A few seconds later, the dust settled, and the video revealed distant figures. During the actual incident, visibility was not limited to the few feet shown in the picture on the left.



Light reflects off the dust and smoke. The camera cannot record distant people and objects until the smoke clears

Many Mock Prison Riot scenarios were conducted in a cell block. Dust diffused and hung in the air, causing beams of light to cover the video. New practice rounds formed large cloud patterns that obscured the participants. To the camera, these large shapes are important. Details behind the smoke were lost. The black-uniformed officers blurred together into barely distinguishable black blobs.

Video quality plummets when snow or rain is present. Snowflakes change position each video frame and reflect light. They obscure targets of interest farther away and create complex patterns that the camera thinks are important.

Compression exacerbates the problem. Compressing high definition (HD) video for transmission at 1 Megabit per second (Mbps) makes it impossible to detect whether vehicles have license plates. In good weather, the license plates are easy to read. Video surveillance units, in-vehicle cameras, and body cameras experience video quality problems during bad weather because they use bitrates close to 1 Mbps.

## Light and Shadow

Videographers deploy professional lighting to create an aesthetically desirable pattern of light and shadows. Video surveillance units, in-vehicle cameras, and body cameras must accept whatever light is available. Consequently, deep shadows that hinder the understanding of the situation.

At night, streetlamps and headlights illuminate the landscape unevenly. When a person walks from the unlit night into the illumination of a streetlight, their appearance changes dramatically. Cameras on the market optimize either the brightly lit areas or the unlit areas. They cannot optimize both at the same time.

In 2010, ITS simulated and filmed common paramedic responses in a variety of indoor and outdoor settings. Sunlight created strong shadows, so the patients were well illuminated or shaded by the paramedics. Their wounds and skin tones were well reproduced in full sunlight, but obscured and difficult to determine when shaded.

High dynamic range (HDR) cameras will not necessarily solve this problem. HDR cameras capture more shades of light and shadow in a single image, but they still assume that shadows have value and should be reproduced. Basically, HDR cameras are better from an aesthetic standpoint. They cannot compensate for the absence of flood lights or a well-lit environment—but perhaps future HDR cameras will.



Uneven lighting and unplanned shadows hide people and obscure injuries. First responders often cannot fix these lighting problems. An intelligent camera could remove these shadows.

Deep shadows create areas with similar shades. Cameras have difficulty distinguishing between similar shades. The camera maximizes the contrast of light and dark areas. When a fire marshal documents the char and ash after a fire, too much of the picture is simply black. This makes it difficult for a fire marshal to figure out where the fire started and how it spread. The same problem occurs when filming scratches on light skin, bruises on dark skin, or adjacent officers wearing identical uniforms.



Less realistic pictures might help the fire marshal figure out where the fire started and how it progressed.

## Law Enforcement Dichotomy

The needs of law enforcement and the courts add an extra layer of complexity. Specifically, real-time situational awareness needs differ from evidentiary needs.

Consider high-end cameras designed for optimal nighttime performance. Some of these cameras see better at night than people do. Thus, the videos depict events differently than how practitioners saw those events as they occurred.

Let us say an officer on the night shift responds to a report of a person with a gun. The officer sees a woman, who turns around and has what looks like a gun. The officer shoots and kills her. The officer's bodycam clearly shows the woman holding a hose, so the bodycam evidence clearly conflicts with what the officer saw. This discrepancy is difficult to explain, because of the common misconception that video cannot lie.

This causes a dichotomy. The enhanced nighttime view of events is highly desirable for real time remote viewing and computer vision. For evidence purpose, videos need to show only what an officer could see; that is, the camera should emulate the human visual system.

This same dichotomy will apply to future cameras that remove snow, rain, dust, and shadows. On top of this, contemporary cameras respond poorly to snow, rain, dust, and deep shadow. As the photos demonstrate, the video may show much less than an officer could actually see.

## Technical Solutions

Video cameras cannot remove snow, rain, dust, and shadows. The development of cameras that could perform this process would better serve the needs of public safety, the courts, and the many businesses operating video surveillance units.

Ideally, the camera would record two videos. The first would match human perception as closely as possible. The second would enhance the visibility of objects and events by removing snow, rain, dust, and shadows. It might even augment the video with information from outside the visible spectrum, such as infrared video, ultrasound sensor data, and laser sensor data. The two videos would serve different purposes: realistic evidence versus situational awareness.

Similarly, camera systems that produce enhanced nighttime video would be more useful to first responders if they also produced a second video that matched human perception. A viable alternative for enhanced nighttime cameras would be a post-processing filter that shows what the officer saw. However, rain, snow, dust, and shadows must be removed within the camera, before the video is first compressed. After that, the video quality has already dropped and information has been lost.

Two components are missing. The first component is algorithms that can split a video into two streams: an overlay showing the obscurants, and everything else such as distant objects, people, and the landscape. The second component is a video encoder that records both the original video and the obscurant-removed video without doubling the bitrate. The resulting cameras would benefit first responders by allowing greater visibility.

## More Information

This article summarizes information extracted from interviews with more than 100 people from different U.S. public-safety agencies. The goal is to identify and encourage new camera technologies that better meet first responder needs. Initial results are reported in NTIA Technical Memo TM-17-524, Margaret H. Pinson, *Technology Gaps in First Responder Cameras* (May 2017, [www.its.bldrdoc.gov/publications/3171.aspx](http://www.its.bldrdoc.gov/publications/3171.aspx)).

The Public Safety Communications Research (PSCR) is investing millions of dollars through 2022 to advance critical research and development (R&D) in public safety communications. Sign up at [www.pscr.gov](http://www.pscr.gov) to receive important updates about the prize challenge programs and how you can get involved.

*Images are taken from the Consumer Digital Video Library (CDVL). First responder videos are available royalty free for research and development purposes from [www.cdvl.org](http://www.cdvl.org).*

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