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UAS for Public Safety: Active Threat Recognition

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Unmanned Aircraft Systems (UAS), commonly referred to as drones, are used for military intelligence, surveillance, and reconnaissance and extended for civil aerial photography and videography for cinema, construction, and agricultural jobs. Similarly, drone usage has utility for public safety entities; however, it must provide a value proposition to the resource-constrained agency as better, faster, and cheaper than existing tools to become integrated. Thermal infrared sensors were only available to military and manned aviation law enforcement units in the past. Recently, the cost of thermal infrared sensors has decreased and ushered in a new capability of an affordable dual sensor, electro-optical thermal infrared cameras. Additionally, research in wildlife monitoring has suggested that near-infrared (NIR) sensors could also be used to detect differences between a target and its background (Hewitt, 2021).

The Center for Homeland Defense and Security (2019) has compiled data on active threat events since before the Columbine High School shooting in 1999; however, the number of active threat events has continuously increased annually since 2010. As depicted in Table 1, there have been 306 active threat events between 2000 and 2018. Linger (2018) determined that 90% of shootings were over before law enforcement arrived at the scene. Assaults are not always limited to firearms (Sylvester, 2018). Also, first responder tactics would limit the response to "surround and contain" until Special Weapons and Tactics Teams (SWAT) arrived on the scene (Blair et al., 2013).

Table 1

Active Threat Descriptive Statistics Related to Schools from 2000 to 2018

School Shooting Data 2000-2018	
Event	Number Incidents
Total # of Events	306
# Killed (including Perp)	235
# Killed on Campus (excluding Perp)	150
# Killed off Campus	11
# Injured	241
# Killed by Police	2
In school Building	166

Note. Data is compiled by the Crime Prevention Research Center (2019, 2021).

Niedzielski et al. (2018) determined that finding a human-sized subject in a search and rescue mission took an average of 31 minutes. Even though an active threat scene may vary in size, a smaller, more confined scene such as a school may still be difficult for law enforcement to determine which individual is the actual threat in a crowd of many people. Using UAS technology to detect which individual and type of weapon used can provide information to the first response to increase the speed of response from the first-on-scene rather than waiting for SWAT if the type of weapon was known.

Review of Relevant Literature

Active Threat Response

Responding to active threats was not a new phenomenon for public safety entities within the United States. On May 18, 1927, in Bath, Michigan, a disgruntled farmer planned to kill as many students as possible at the Bath Consolidated School (Hoelscher, 2009). An explosion occurred at the north end of the school complex. Thirty-six students and two teachers were killed (Hoelscher, 2009). An investigation revealed approximately 500 pounds of dynamite set underneath the south side of the school, which did not detonate (Hoelscher, 2009). This was the largest school mass casualty event in the United States (Hoelscher, 2009).

Approximately 72 years later, at Columbine High School in Littleton, Colorado, two students planted a propane tank with explosives in the high school cafeteria (Lee-Collins, 2007). When the explosives failed to detonate, the students engaged their peers with semi-automatic rifles and handguns. According to Lee-Collins (2007), the assault lasted five hours, killing 12 students, one teacher, and the two active threat students themselves. The incident took several hours before police determined it was safe enough to move into the school to assist the wounded, many of which could not be saved (Lee-Collins, 2007).

Ultimately, police administrators had to analyze and develop new policies to address active shooter incident responses (Lee-Collins, 2007). Educational institutions were considered soft targets and highly susceptible to active shooter attacks (Duque, 2021). School grounds had limited security and concentrated areas of unarmed people, making them high-value targets. According to Duque (2021), “the threshold opportunity for active shooters also may involve the passive and unprepared nature of their targets that are often located in specific, enclosed geographies, mainly schools and places of commerce. Due to the lack of organizational preparedness, along with delayed police response, unarmed fellow students or co-workers were literally ‘sitting ducks’” (p. 10).

IACP Policy

The International Association of Chiefs of Police (IACP) was created in 1863 and was one of the most influential and professional associations for law enforcement leadership. IACP consists of more than 31,000 members spread across 165 countries globally (IACP, 2018). The IACP was acknowledged as an organizational leader in global policing issues, and its mission was to increase policing professionalism through considerate, advanced policing leadership styles and policy implementation. The four central underpinning tenets of the IACP Foundation include advocacy, research, outreach, and education (IACP, 2018).

The IACP sets the "Gold Standard" for police policy on a national and international scale. One of the most challenging calls a police officer must respond to while on patrol duty is the active threat call. According to the IACP (2018), "An active shooter is an incident in which one or more armed persons have used, or are reasonably likely to use, deadly force in an ongoing manner, and where persons have been injured, killed, or are under imminent threat of death or serious bodily harm by such persons" (p. 3). Many police departments operate with one police officer to a patrol vehicle, making responding to these incidents even more difficult.

The Columbine school shooting provided many valuable lessons to police administrators on responding to active shooter incidents more effectively to reduce the number of victims (Collins, 2007). When the Columbine incident occurred, it was common practice for police officers to establish a perimeter and wait for SWAT personnel, who possessed more training on making entry into a structure containing the active threat situation.

After the Columbine shooting, numerous institutions reviewed law enforcement response policies to active threats. They realized that responding officers need to direct entry into the active threat incident and neutralize the shooter as quickly as possible to save the greatest number of lives (Collins, 2007). The IACP concurred that a specific high-risk incident such as an active threat was dynamic and dangerous for both the responding lifesaving units and potential victims inside. Waiting for SWAT personnel to arrive may be counterproductive to the primary mission of all first responders (IACP, 2018).

With the development and increasing occurrences of active threat incidents, law enforcement response has advanced beyond establishing a perimeter and waiting for specialized personnel like SWAT to respond to the scene to act instead (IACP, 2018). The IACP recommends on-scene officers to determine if immediate action is needed to stop an active threat currently taking place or is about to take place (IACP, 2018). According to the IACP,

> The concept of immediate action reflects a change in operational philosophy related to stopping a deadly force threat. These strategies may save lives, but they should not be considered as a full replacement for the traditional time-talk-tactics protocols that have served law enforcement well for many years. In most critical incidents, patrol officers will determine that requesting tactical assistance is appropriate. In other cases, they will find it reasonable and necessary to use their enhanced skills, training, and equipment to take immediate action to "protect lives." (IACP, 2018, p. 3)

This paradigm shift in active threat response required specialized training and new equipment for the first responders who initially arrived on the scene and decided to immediately enter the active shooter scene to stop the threat (IACP, 2018). Ultimately, the new policy and response technique required the patrolling officer to perform SWAT-like actions to enter and neutralize the deadly threat immediately. The new policy required continuous training, equipment, and funding (Reeping, 2019). Many smaller agencies did not have the budget to train their officers to reach proficient standards properly. The training needed to be as realistic as possible and take place in common areas where active shooter incidents would generally occur, such as malls, churches, schools, and other open venues, providing a soft target for a motivated, active threat (Reeping, 2019). It was imperative that training highlighted the sole responsibility of the police officer to neutralize the threat as opposed to rendering trauma care, extracting victims, and performing other first responder actions that would be inherent for officers to do (IACP, 2018).

The joint training was also recommended for all responding agencies, including Unmanned Aircraft System (UAS) units responding to any active threat scene to ensure proper use of best practices and standard operating procedures. As with any critical incident, the flow of actionable intelligence to those deploying vital and limited resources was vital to the efficacy of the mission. According to Reeping (2019),

> As mass shootings continue to persist; however, planned, and efficient rapid response, which also includes multiple, coordinated medical and law enforcement sectors, is also a key approach to minimizing the death and disability that an active shooter inflicts. By using new and coordinated trainings, drills, and technologies, the public, educators, law enforcement, EMS, and medical professionals can feel more confident and better respond to these tragic events. (p. 310)

A unified command post and practices needed to be established through properly vetted policies and memorandums of understanding (MOUs) before the active threat situation to ensure proper communication is accomplished.

UAS Capabilities for Public Safety

UAS capabilities for public safety organizations regarding active threat scenarios (Lord, 2017) are a recent addition to legacy operational capabilities that have been tried and tested and include SWAT, long-range listening devices, communication tapping, and optical reconnaissance. Available UAS can range from palm-sized devices to suitcase-sized devices with significant loiter capability for extended active threat scenarios. Platforms are evolving to suit a wide range of capabilities to conduct intelligence gathering, surveillance, and reconnaissance, in any light condition (Whitlock & Timberg, 2014). Some provide the all-weather capability. Politically there have been efforts to prohibit capable Chinese drone

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systems because of information security concerns (IANS, 2021; Liang, 2021). Some departments ignore this potential threat, while other agencies abide by it. This has forced US and western companies to possible voids in this area. The use of UAS for active threat scenarios provides persistent intelligence gathering.

Long Term Surveillance

While the federal government has successfully utilized manned aircraft in extended surveillance operations, an active threat scenario with a long-term need for UAS exists in specific VTOL fixed-wing platforms with electro-optical/ infrared (EO/IR) sensors. Tactics in this regard enable standoff capability and long duration. Tethered multicopter systems (ELISTAIR, n.d.) can possess nearly indefinite station times, with limited maneuverability. A Teledyne Skyranger (Teledyne FLIR, n.d.a) can tether or execute persistence through platform rotation without loss of sensor feed.

Short Term Surveillance

Multicopter platforms have significantly improved in the last ten years, whereby high-resolution thermal and electro-optic capabilities seemingly update every six months. The systems have become lighter and more compact. Also, improvements in battery technology have extended station time to nearly 60 minutes in some cases. The benefit of smaller systems that are only capable of short-term surveillance is their sizes enhance maneuverability, allowing them to get closer to the threat and gather intelligence.

Tactical Application

The intelligence gathering, surveillance, and reconnaissance capabilities add tremendously to law enforcement's preparation for an active threat breach. Multicopter platforms are utilized in various profiles, from perching to maneuvering for best observation capability and out of the aural range of the active threat. Advancements in tactical applications now enable microdrones to become surgical with their maneuverability in palm-sized platforms (Teledyne FLIR, n.d.b). These systems are quiet and maneuverable in tight spaces. Other platforms can breach windows in flight for interior surveillance and intelligence gathering.

Sensor Technology

As has been learned by decades of drone use in combat, the sensor is the primary tool on any UAS. Therefore, this technology generally leads to decision-making in the acquisition process. In the early days of available sensors, many with the capability needed were cost-prohibitive to most municipal law enforcement organizations. Advancements in this area have extended options with lighter-weight multifunctional electro-optical/infrared (EO/IR) sensors (DJI, n.d.). A few years ago, the standard was an electro-optic sensor with 30X optical zoom and a wholly separate infrared sensor with digital zoom only. These are combined into one sensor with optical zoom and laser ranging.

Safety Enhancement

Preventing loss of life is a prime consideration in applying the UAS in active threat situations. The use of UAS has become an exceptional tool for collecting information. The availability of real-time intelligence enables rapid tactical planning for breaching plans that maximize effectiveness and reduce collateral damage or law enforcement casualties. Surveilling a standoff scenario with enhanced sensors provides similar benefits. Tactical applications may at times become necessary based on the active threat scenario and, while potentially risky, can significantly improve an operation from reconnaissance and surveillance application (PR Newswire, 2018).

UAS Limitations for Public Safety

The use of UAS in support of public safety spans many mission sets, each with associated requirements. Every mission requires a specific set of drone capabilities: mapping an accident scene, providing night surveillance, or identifying a potential threat (Stampa et al., 2021). The operational environment and mission requirements may limit the UAS's capability to provide the required data. The environmental challenges may include maintaining visual line-of-sight, limited lighting (artificial and natural), signal transmission/reception, Global Navigation Satellite Systems (GNSS) reception, narrow passageways, precipitation, and mechanical turbulence (Chu et al., 2021).

Many situations in public safety application require the UAS to fly into areas that the operator may not observe. Regulatory compliance aside, flying the aircraft beyond visual line of sight (BVLOS) creates challenges for maintaining situational awareness (SA) and ensuring signal transmission. The main challenge caused by maneuvering the aircraft using only the onboard camera is losing SA on objects and obstacles outside of the camera field of view (FOV). This, when combined with tight quarters, can result in the aircraft impacting undesired objects. While flying through the first-person view (FPV) is the preferred method for drone racing, the slow-moving and often stationary movement in a public safety environment can degrade SA quickly. Another challenge with flying BVLOS is maintaining radio communication with the aircraft. Since most aircraft utilize the electromagnetic spectrum's Industrial, Scientific, and Medical (ISM) bands, electronic and mechanical interference is often encountered, which further reduces SA. Electronic interference may occur due to civilian Wi-Fi systems, cell phones, or intentional jamming. Mechanical interference can occur when the aircraft is behind walls or terrain, which restricts the signal between the aircraft and operator.

Whether natural or artificial, environmental lighting may restrict the area serviced by the sUAS. An infrared camera may be the only appropriate sensor for areas that lack natural lighting (e.g., building interior with no lighting, outside at night). However, most environments offer either low light or artificial lighting.

Some light is desired not only for main sensor operation but also for the functionality of aircraft-mounted anti-collision systems. Several aircraft explicitly used for public safety have a self-illumination capability, which can offset some lighting challenges. Regardless of the situation, lighting should be a primary concern when flying at night or entering any structure. Another issue with flying inside a structure is Global Navigation Satellite System (GNSS) reception.

Proper GNSS reception is desired in most situations. Although some aircraft are designed to navigate in close quarters without GNSS, most aircraft rely on GNSS to maintain their position. Whether or not the aircraft can maintain GNSS reception is dependent on several variables. However, any overhead structure can reduce or eliminate GNSS reception and must be considered before the flight. Understanding the aircraft's position keeping sensors is essential to safe flight in these situations. As discussed earlier, collision avoidance and station keeping sensors may not be effective in low-light conditions. When these environmental challenges are combined with operations inside tight quarters, impact with the structure is likely.

Precipitation and turbulence are other environmental factors limiting an aircraft's ability to perform a successful mission. Moisture can cause issues with aircraft electronics and sensors. Each aircraft's capability to fly in precipitation varies and must be considered in flight planning. An often-forgotten impact of precipitation is the effect on the primary sensor. Moisture can cause blurred images, completely distort the image of an infrared sensor, and possibly migrate behind the lens causing sensor failure. Considerations should also include the effect of wind or mechanically produced turbulence. Flights near or in structures are susceptible to rapid changes in airflow, making aircraft control difficult.

The limitations discussed can be overcome by technology and proper flight planning and consideration of risk from the operation. However, completing a successful flight may not be possible when several of these limitations are combined. A cost-benefit analysis should occur before flights with multiple confounding factors. Of particular importance is understanding the aircraft systems and training in a representative environment before a time-critical situation.

Methods

The purpose of this research project was to determine what UAS sensor requirements were needed to recognize an active threat in a crowd of people. The approach involved collecting a series of images of a simulated active threat from different distances from RGB or NIR cameras mounted on UAS. For this research, RGB images were defined as capable of sensing red, green, and blue wavelengths of light from 350nm to 700nm. NIR images could sense only near-infrared wavelengths of light, which are not visible to the human eye at 850nm. A calibration panel with known light reflectance in red, green, red-edge, and near-infrared wavelengths calibrated the image sensor to a known value.

Two research questions were investigated. These questions were:

(1) What was the likelihood of recognizing an active threat in a group of people?
(2) What differences, if any, are there between a RGB or NIR camera mounted on a UAS for recognizing the type of weapon used by an active threat?

Researchers operated multiple UAS equipped with RGB and NIR cameras to answer these questions. A camera angle of 45 degrees was used at different distances to provide variation of likely conditions that public safety officials may operate a UAS. The angle provides a reasonable balance between overhead and oblique angles to determine what type of weapon an active threat was holding between a knife, pistol, rifle, shotgun, a shovel, or no weapon at all.

UAS Image Collection

Data was collected using a DJI Mavic Enterprise Dual (M2ED) equipped with a full spectrum converted camera. The full spectrum conversion was performed by Kolari Vision, which enabled the camera sensor's sensitivity from ultraviolet through near-infrared wavelengths of light (Kolari Vision, 2021). The process involved removing the embedded IR-cut filter, which blocked NIR wavelengths of light. A hot mirror filter was then used over the sensor to capture RGB imagery, or a NIR cut filter at 850nm with a halfwidth of 50nm was used to capture the NIR imagery. Table 2 depicts the UAS configuration and sensor specifications.

Table 2

UAS Configurations Used for Active Shooter Research

Aircraft	Sensor Configuration	Sensor Specifications
DJI Mavic Enterprise Dual with Full-Spectrum Converted Camera 	Full-spectrum camera with Hot Mirror filter	Type: 1/2.3" CMOS Lens: HFOV 85° Resolution: 4000 x 3000 pixels Wavelength frequency: 350nm-750nm
	Full-spectrum camera with NIR cut filter	Type: 1/2.3" CMOS Lens: HFOV 85° Resolution: 4000 x 3000 pixels Wavelength frequency: 850nm

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A small group of four people was located within a staged scene in southwestern Arizona. The subjects wore dark cotton-synthetic blended upper clothing. One person in the group held a weapon. Only one weapon at a time was used. Individuals in the scene remained in the same position between each sensor type and slant range distances collected to minimize variation between distances; however, they moved places between weapons and sensor filter changes.

Slant distances, or the direct line of sight distance between the active threat and UAS camera, of 25, 50, 75, and 100 feet were used to vary the images' resolution. Finally, a camera depression angle of 45 degrees was used to provide a consistent perspective in the obliqueness of viewing angles between image sets. The differences in camera configuration, slant distances, and weapon type were compared to determine how reliably a weapon could be detected. This approach aimed to recommend a best practice between these parameters to public safety officials using UAS technology in real-world active shooter response situations.

Survey Data Preparation

A total of 48 images were collected between RGB and NIR sensor, a knife, pistol, rifle, shotgun, shovel, or no weapon at all, and 25-, 50-, 75-, and 100-feet slant range, respectively. The sensor settings were set to auto shutter speed and ISO. The images were organized by weapon type, camera type, and slant distance. Because the M2ED could not change the camera white balance to compensate for the NIR filter, the NIR images were converted to grayscale. The RGB images were captured in auto white balance, and no color changes were made. The focus plane was set to the second individual from the right. All images were cropped to 100% from the center of the images containing the group of people and bound to the same image size of 1500 x 1200 pixels at 240 pixels per inch. The resulting image size was six and a quarter inches by five inches. All images had a button indicating “I don’t see a weapon in this image” to enable a selectable portion of the image if a participant could not detect a weapon in the image.

At the beginning of the survey, participants were shown isolated images of the weapons they may see during the survey, as depicted in Figure 1.

Figure 1
Examples of Weapons Shown to Participants at the Beginning of the Survey in RGB

Using the click map feature on the popular online survey tool SurveyMonkey (SurveyMonkey, 2021). The location on the image where the participant clicked was recorded when they submitted their answer. The participant could change their click location as many times as they liked until they submitted their answers; the initial click location was not recorded. Each participant was given the option to select if they did not see a weapon in the image. A box was provided in the lower-left corner of each image (see Figures 2 and 3) should a participant not see a weapon in the image.

Each image in the survey was followed by a multiple-choice question asking the participant to select the type of weapon that they had seen in the previous image. The options for the multiple-choice questions were as follows: a knife, pistol, rifle, shotgun, shovel, or no weapon at all.

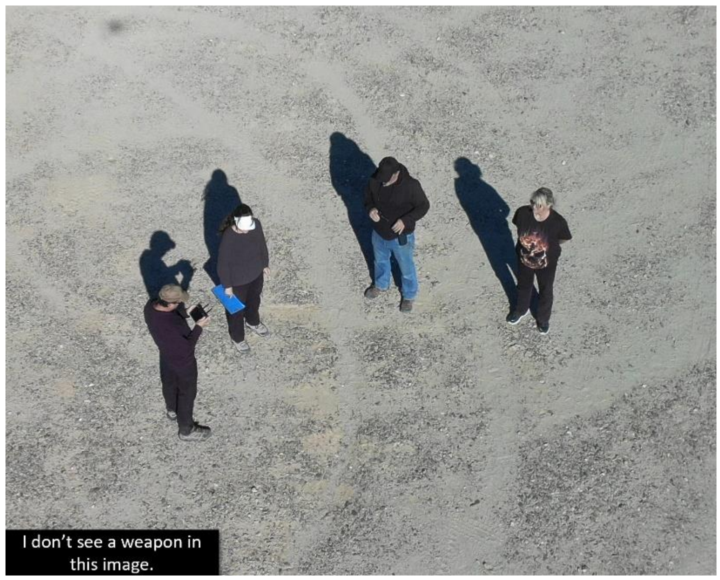
To measure the accuracy of participants' clicks, the click location was compared to the weapon's location in the image. The weapon's location in the image was obtained using an open-source graphical image annotation tool, LabelImg (GitHub, 2021), to create a bounding box around the weapon in the image. Each bounding box contained the pixel coordinates for each corner of the box around the weapon. The participant's click location was obtained by exporting survey results from SurveyMonkey to a Comma Separated Value (CSV) file that contained the pixel location of each participant's click for each image in the survey.

A Python script was written to calculate the accuracy of each click (Github, 2022). If the participant clicked within the pixel range of the bounding box, the result was labeled as a true positive. If the participant clicked outside the bounding box, the result was labeled as a false positive. A false positive click indicates that the participant's click was around the weapon but not on the weapon, i.e., the participant clicked on the arm of the individual holding the weapon. If the user was outside the acceptable false positive range, the result was labeled as a false negative. If the user selected no weapon when there was a weapon in the image, the result was labeled as a false positive.

Figure 2

Image Screenshot of NIR Image of an Active Threat Holding a Pistol from a Slant Range of 25 Feet

Figure 3
Image Screenshot of RGB Image of an Active Threat Holding a Pistol from a Slant Range of 25 Feet



Treatment of Participant Response Data

A convenience sample of 102 survey participants were asked to participate via SurveyMonkey. The participants were recruited from constituents of the Airborne Public Safety Association (APSA) and DRONERESPONDERS. Participants were presented with images of weapons to familiarize them with the type of weapons used in this research. The 48 images were presented to each participant in random order. Participants were asked to click on the image portion where they thought a weapon was located. If the participant did not detect a weapon in the image, they were asked to click on the button titled "I don't see a weapon in this image" instead. A follow-up multiple-choice question was then asked for the participant to select the weapon detected as either a knife, pistol, rifle, shotgun, shovel, or no weapon at all from a list. Both responses for each image for each participant were collected and analyzed.

As shown in Table 3, a response from each participant's selection on each image was collected as true positive, false positive, true negative, or false negative, depending on the location and presence of a weapon in each image.

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Table 3

True/False Positive or True/ False Negative Condition Based on the Presence of a Weapon in an Image and Participant Response

Weapon Present	Clicked on Weapon	Clicked off Weapon (TOP) or on Button (Bottom)
Weapon Present	True Positive	False Negative
Weapon Not Present	False Positive	True Negative

For images containing a weapon, was correctly within the bounding box and the survey participant indicated the correct weapon type, the observation was counted as a "True Positive." If the click was in the wrong location on the image or the participant guessed the wrong weapon type, the observation was counted as a "False Positive." If the click was in the wrong location or the participant guessed the wrong weapon type from the available radio button options, the observation was counted as a "False Positive."

For the images without any weapons: if the participant clicked anywhere on the image except the "I don't see a weapon in this image" button, the observation was counted as a "False Negative", regardless of the weapon type indicated. If the participant clicked on the button "I don't see a weapon in this image," the observation was counted as a "True Negative."

A true positive rate (TPR), as depicted in equation 1, showed the observation rate of correctly detecting a weapon when one was present in the image. The calculation was a function of true positive responses (*Tp*) by the total true positives (*Tp*) and false negative (*Fn*) responses. The sum of the TPR was compared by sensor type and 1) wither slant range distance or 2) weapon type to determine if these factors affected the rate of detecting the weapons by the survey participants under the respective condition.

$$\text{TPR} = \frac{Tp}{Tp + Fn} \quad (1)$$

Results

A true positive rate (TPR) was used to measure the percentage of correctly detecting a knife, pistol, rifle, shotgun, or shovel when one was presented in an image. Not all the images shown to the participants contained a weapon. The TPR was determined, by image containing a weapon, after dividing the number of true positive responses by the total of true positive and false negative responses made by participants in the survey. An overall comparison of TPR by sensor type was shown in Table 4.

Table 4

True Positive Rate by Sensor Type

Sensor Type	TPR
RGB	0.67
NIR	0.79

The data suggests that survey participants could correctly detect all the weapons in images containing the weapons at a 12% greater rate with the NIR sensor than with the RGB sensor.

A TPR comparison between the RGB and NIR sensor types and weapon types were depicted in Table 5. Differences were observed between weapon types. Larger weapons, such as the rifle and shotgun, were more frequently correctly detected (18% and 12% respectively) with the NIR sensor than the RGB sensor. The differences we not just observed with the large weapons. The most considerable difference in TPR between NIR and RGB sensors and the weapon type was the pistol. The pistol was detected at a much higher rate in NIR (73%) than the RGB sensor (40%). The pistol had an increased probability of detection by 33% when using the NIR sensor.

Table 5

True Positive Rate by Weapon and Sensor Type

Weapon Type	TPR (RGB Sensor)	TPR (NIR Sensor)
Knife	0.52	0.62
Pistol	0.40	0.73
Rifle	0.76	0.94
Shotgun	0.80	0.92
Shovel	0.87	0.71

A TPR comparison between the RGB and NIR sensor type and slant range distance was depicted in Table 6. Differences were also observed between distances. Although participants showed variability in detecting each weapon by type correctly, all weapons combined had a higher accurate detection rate at closer ranges than farther away. The highest TPR rate occurred at a 25-foot slant range distance. The lowest rate of accurate detectability occurred at the 100-foot slant range distance. The closed distance of 25 feet showed a 42% increase in participants' ability to correctly determine the weapon type compared to the 100-foot slant range distance.

Table 6

True Positive Rate by Slant Range Distance and Sensor Type

Slant Range Distance	TPR (RGB Sensor)	TPR (NIR Sensor)
25 Feet	0.91	0.97
50 Feet	0.79	0.91
75 Feet	0.55	0.71
100 Feet	0.44	0.55

Conclusions

TPR ratios were calculated from 102 participants, responding to 48 randomly presented images containing a small group of people holding a weapon to simulate an active threat condition. In some images, there was no weapon shown to participants. The results indicated that a UAS equipped with a NIR camera sensor had a 12% greater accurate detection rate with all weapons combined; however, there was variability in some of the weapons. The likelihood of recognizing an active threat in a group of people was increased with a UAS equipped with a NIR sensor.

For example, the pistol had a 42% increase in detection accuracy using the NIR sensor compared to the RGB sensor. The simulated active threat who was holding the pistol was color masking the weapon, whereas the black pistol was masked by a background of a black hooded sweatshirt. However, in the NIR imagery, the sweatshirt reflected NIR light, appearing white. Still, the pistol did not reflect any NIR light, appearing black. This difference created a contrast between the pistol and the sweatshirt, improving the TPR rate. Color masking conditions may represent an actual active threat situation that public safety officials may find. Therefore, using a NIR sensor-equipped UAS when observing an active threat situation may help public safety officials determine the type of weapon, if one is present.

It was noted that the shovel had a lower TPR rate of accurate detection in NIR compared to the RGB image sensor. For most of the field-collected data, the UAS captured imagery perpendicular to the simulated active threat holding a weapon; however, during the shovel data collection for the NIR sensor images, the UAS was not perpendicular to the simulated active threat person. An oblique observation angle between the UAS and an active threat could reduce the detection rate in a real-world situation. Public safety officials may directly influence the detection rate by positioning the UAS perpendicular to the active threat, if possible.

The slant range distance influenced the TPR rate of participants' ability to detect a weapon in an image accurately. Closer slant range distances of 25 and 50 feet had a much higher TPR rate than the further distances of 75 and 100 feet in this study. These results indicate that a public safety official flying a UAS to detect an active threat in a real-world situation could have a better chance of detection at flying a maximum slant range distance of 50 feet.

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