CPNI
Centre for the Protection of National Infrastructure

UNMANNED AERIAL VEHICLES – FOR USE WITH PROTECTIVE SECURITY CCTV

A GUIDANCE DOCUMENT

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Introduction

The aim of this document is to provide guidance to a Critical National Infrastructure (CNI) site on the potential use of Unmanned Aerial Vehicles (UAV) as a host for CCTV and their use as a protective security tool. This document covers the following areas:

- CCTV principles
- Mobile cameras
- UAV flying
- Technical considerations

Principles

CCTV on a CNI site should be installed to achieve the following aims:

1) **Detection** of a security incident
2) **Verification** of a security alarm
3) **Tracking** of a security incident
4) **Support** of a response to a security incident

When designing a CCTV implementation for a CNI site, the above aims should be addressed in the given priority order.

Detection

CCTV should be designed and implemented to provide or support detection. If a security incident is not detected, there can be no verification nor response to that incident. CCTV systems should be designed to give detection as their primary role before any other task is considered.

Verification

Once the CCTV system has been optimised to provide detection of an incident, the system should be able to provide a secondary role such as verification of a security alarm or potential detection incident. Both detection and verification using CCTV can be achieved using the same methodology. This should be achieved by providing a 'complete ring of coverage' around the asset or perimeter of the asset to be protected. To achieve this, fixed cameras (as they provide maximum situational awareness for the security force) should be configured in a heel-to-toe set-up with Rotakin at a minimum of 10% screen height. Pan, Tilt, Zoom (PTZ) or moveable cameras should only be used to support the fixed CCTV. Cameras should be fixed at a consistent height and angle to assist with situational awareness.

Integration

When used for Detection and Verification, CCTV should be carefully integrated into the control room to enable the security force to quickly identify:

1) 'what' the camera is looking at – any **assets** and expected **behaviours** within the scene
2) 'where' the camera is looking – the physical **location** of the camera view

This will usually be provided by integration with a Security Management System (SMS) complete with digitised mapping software.

Only once a site has an effective CCTV scheme to provide Detection and Verification, should it move on to the design of a system to supplement with a tracking ability. A tracking ability should always be considered as an addition to Detection and Verification.

Any security threat to a site must first be Detected and Verified. CCTV adds a great force multiplier in these situations. Once these have been achieved the tracking of an intruder along with a response from the security force can be managed via a security officer on the ground. A site can choose to add an additional CCTV tracking capability if it wishes to actively manage an incident from the control room. Tracking can logically only occur once the incident has been Detected and Verified. The security officer will need good situational awareness to enable them to meaningfully track and respond to an intruder or security incident.

Tracking

Tracking is a very dynamic task, especially during a high stress security incident, and is best achieved by the use of PTZ cameras. These cameras should be integrated into the SMS, along with direction indicators to show staff in the control room which direction the cameras are facing. Care needs to be taken to ensure that situational awareness is maintained at all levels of zoom as visually distinguishing site features may not be visible in a very close up image.

Tracking is particularly difficult when a PTZ camera is used to track a person of interest across an area not covered by the fixed cameras as many of the site markers familiar to a CCTV operator may be missing.

To undertake site-wide tracking a number of cameras will be required to provide full coverage of the site. Increasing the number of cameras (particularly if they are PTZs) increases the complexity of the CCTV operators tasking. This can lead to a lack of situational awareness and confusion. To counteract this clear mapping systems must be employed and a well-trained security officer deployed. To reduce the complexity for the control room staff the number of cameras should be minimised. The best way to achieve this is to mount the tracking cameras high above the site.

Implementation

The simplest way to increase the height of a tracking camera above the site is to increase the height of the pole on which the camera is mounted. Care should be taken to provide a suitable stable pole to reduce camera sway. If this is not possible a stabilised camera mount should be used. The location of the camera will therefore remain constant, which is best to enable the control room staff to carry out their job of Verifying and Tracking an intrusion across site.

If a pole-mounted camera does not provide enough height an aerial vehicle could be considered. Working with an aerial platform is more difficult than working with PTZ cameras in a tracking scenario. If aerial platforms are to be considered they should be located in a fixed position (such as aerial balloons) to enable the control room staff to maintain situational awareness.

Any moveable aerial vehicle will need integration in an SMS mapping system. This will enable the control room staff to determine the aerial vehicle's position and, therefore, what the tracking camera is looking at and where. This will add substantial additional cost and complexity to the overall security solution.

When considering cameras types and placement, the following options are available:

Camera	Situational Awareness	Pros / Cons
• Fixed location • Fixed cameras	✓ Best situational awareness	✓ Provides uninterrupted 'ring of detection'
• Fixed location • Moveable cameras (PTZ)	– Decreased situational awareness	✓ Provides flexibility ✓ Provides tracking ! To maintain 'ring of detection' must be supplement to fixed cameras
• Moveable location (Aerial) • Moveable cameras (PTZ)	× Very difficult to maintain situational awareness	✓ Provides most flexibility × Minimal detection capability

Mobile CCTV – Ground and aerial based platforms

It is worth considering both types of camera (ground and aerial based) to understand the effects these may have on an operator in a control room, or an operator using them to guide ground forces to an incident while in the field. Using mobile CCTV platforms, especially airborne, is likely to create a significant workload for the operator. Workload is widely accepted as the amount of information a person, in this case an operator, needs to handle, interpret and act on through various channels at any one time. Informal control room studies carried out by CPNI during 2013/14 suggest that operators are already likely to be overloaded by their current CCTV control room setup. This includes the outputs from the cameras themselves, as well as other inputs and outputs from the control room that operators must attend to.

Temporary cameras

In some circumstances, for example at protests and major sporting events, temporary cameras are installed and their images are fed back into a control room. Such cameras can be vehicle mounted, or simply be part of a concrete structure base with a camera pole embedded into them. Operators often have difficultly integrating new images from temporary cameras into their understanding of an environment. When new additional cameras are installed, it takes a fair amount of time for the operator to confidently select that image and integrate these into their 'mental model' of the environment. Temporary ground based cameras may increase the workload of the operator considerably. However, the location will be fixed at the time of monitoring, and will have been determined for strategic purposes known to the operator.

An operator with new camera views can become overloaded and unable to integrate these new views into their mental model of their environment. This can result in the operator ignoring either the new or existing camera images. During temporary events it is usual, when deploying additional cameras, to deploy additional staff with the sole responsibility to monitor these cameras.

Aerial platforms

Cameras mounted on UAV's (including quadcopters) in the first instance appear to be a good idea, providing a cheap and easily obtainable aerial perspective of a site or location. Essentially, this type of equipment can be operated in two modes:

- they can record to an on-board memory card image of the site returned to the operator and the images can be transferred for later use as needed. These provide a challenge to the operator in control of the craft. Like any radio controlled device when the craft is flying towards the operator the controls are reversed, meaning that operators may require considerable practice to acclimatise to this perspective and keep the craft stable and airborne.
- they can provide a 'first person view' (FPV). In this the camera provides an image as if the operator were flying the craft, which is then streamed back to the operator via a radio link (such as Wi-Fi). It is often argued that FPV provides the same flight experience as if the person was actually flying the craft and will allow even a novice operator to gain a simple view of a site.

However, it is likely that operating such equipment using FPV is a little more complex, as different types of images can be generated that afford very different information to the operator.

Images can be presented in an 'oblique view' of the ground and generate a view of the landscape stretching away from the viewer. Images can be presented as 'vertical' images showing the view directly under the drone or craft, and typically does not have a view of the horizon. In some cases operators can switch between views, but this may lead to loss of spatial awareness. In aviation knowledge and sight of the horizon is vital to pilots when flying an aircraft.

Some FPV imagery is indeed impressive with stabilised cameras delivering good quality High Definition (HD) images, sweeping panoramas, and almost film-like quality action. However, it is important to think what is the role of a CCTV operator and system, and the nature of the task of that operator?

Human factors

In other CCTV guides produced by CPNI, a model of a typical CCTV operator's actions is introduced. This model briefly describes the actions of a CCTV operator as needing to be able to:

- **See** – to gain knowledge of the world
- **Decide** – to become aware of what is going on in the world outside the control room, and use that knowledge to make a decision
- **Act** – take actions and gain feedback

These activities allow the operator to gain spatial and situational awareness of the environment. Situational awareness is based on the experience of the locations that are viewed and this is mediated by maps, existing photographs and plans of the site and communications from colleagues. When compared to a fixed camera, a camera mounted on a UAV is likely to have degraded situational and spatial awareness. When an image from a static camera is presented to the operator, they know which camera is generating this image (by its camera number or map location), relevant contextual information (such as which way is north), and which camera needs to be selected next if there is a need to track a suspect. In contrast, with a mobile platform the operator has to understand the direction of travel, which way the image is orientated, and its relative position to themselves and to the target to be tracked. A camera mounted on a pole is also of a known height so the operator can gain immediate knowledge of perspective and distance of any threat; this is not the case with a camera of variable height mounted on an aerial platform.

Overall, what might appear a simple image generated in FPV from an aerial perspective in reality is likely to lack much of the information needed by a CCTV operator.

There is already difficulty and discrepancy in information flows between ground-based security officers (who have a horizontal view of a situation) and a CCTV operator who has a bird's eye view, looking down on a situation from above. Understanding the interactions and differences in information between these different views is crucial to maximising the effectiveness of CCTV. Further complication is created by the addition of any aerial platform, be it a 'simple' moveable overhead image or a more complex FPV.

UAV flying

It is often argued that there is a similarity between flying a commercial UAV and a military aircraft that is controlled remotely. However military operators flying these are typically experienced pilots, dedicated to the specific role and the information they receive is more detailed than just an FPV of the scene. Like other pilots, remote military aircraft operators have other metrics available to them, such as height, precise location, and an artificial horizon device. These all aid the operator in providing spatial awareness of the overall environment and the aircraft's relative position and direction.

Flying a UAV is a more complex task for an operator than controlling a fixed or PTZ camera, with the operator having to maintain and monitor a remote aircraft's position even before any manoeuvres take place. CCTV operators are already likely to be dealing with a large amount of information, and adding an intricate task such as maintaining, monitoring and manoeuvring a remote aircraft may create an excessive workload.

If a UAV is to be actively flown, either in line of sight or via FPV, it is likely that this will be a dedicated role, requiring either another security officer, or re-deploying a security officer from another task. This dedicated member of the security team will need to be trained in UAV flight, constantly maintain their skill and conduct first line maintenance on the UAV (battery charging and cleaning lenses).

If UAVs are difficult to fly either via line of sight or FPV another mode of operation may be to deploy a UAV under autopilot mode. UAVs often have GPS functionality which will allow them to operate in one of two modes:

1) deploy from a set place, fly a pre-determined route and return to their 'home' location.
2) take off, hover over a pre-programed location and return to their 'home' location.

The advantage of using these modes is that the workload on the security force is reduced as the need to have a 'pilot' is minimised (a member of the security force will still need to launch and monitor the UAV during flight). During either of these modes, the operator will still be presented with an unfamiliar image and each mode will provide additional unique requirements. Under mode 1 the CCTV operator will need to establish where the UAV is in its pre-determined tour, this will probably take some form of electronic map/tracking system and integration into existing mapping systems - adding additional cost and complexity to the CCTV system. Mode 2 is the easiest method to deploy a UAV for monitoring purposes however the location(s) need to be pre-programmed into the UAV and selected during an incident. If the location of the incident is not pre-programmed into the UAV the security guard force is unlikely to have time during the incident to complete this task, thus limiting its usefulness.

Technical considerations

Extra care and attention should be taken over the link relaying the CCTV images to the operator. The usual method of relaying images from a UAV is via either Bluetooth or Wi-Fi. These are fairly insecure protocols to intercept and thought should be given to the risk of CCTV images being intercepted during an incident, either by the media or adversaries. CPNI suggests that wireless communications are not used for security related CCTV. If they have to be used then they should be limited to a maximum protection level of BASE. Where Wi-Fi is used it should be implemented with WPA2 encryption.

Whenever a wireless technology is used thought should always be given to a jamming attack. This attack vector is twofold when using UAVs. Firstly the CCTV images are susceptible to jamming and secondly the UAV controls themselves can be jammed. If the CCTV images were to be jammed this would simply remove any benefit afforded by the UAV-hosted CCTV. If the UAV's controls were to be jammed this would potentially cause a hazard, both on site and external to the site.

Any UAV will require both first and second line maintenance and budget should be allowed for this:

- first line maintenance – battery charging/changing, lens cleaning and memory download. This may well occur during an incident as average UAV flight times are approximately. 20minutes to one hour
- second line maintenance – propeller replacement, motor replacement/greasing, battery replacement.